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The impact of exchange rate fluctuations on markups – firm-level evidence for Switzerland*

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Abstract

This paper estimates the impact of exchange rate fluctuations on markups. Firm-level markups are estimated for a comprehensive panel of Swiss manufacturing firms for the period 2012-2017 using a production-function approach. The pass-through of the exchange rate is then estimated using an event-study design exploiting the large, sudden and persistent appreciation of the Swiss franc against the euro in January 2015. The results show that following an appreciation, Swiss manufacturing firms adjust their markup very heterogeneously. Large firms, especially those that invoice in foreign currency or are highly profitable, substantially decrease their markup. Owing to their sheer size, large firms shape the aggregate response. In contrast, the average firm does not respond significantly. This suggests that smaller firms, which are in the majority, are either unable or unwilling to absorb exchange rate movements by adjusting their markup.

JEL classification: D22, D24, F12, F14, F41, F23, L11
Keywords: Markup, exchange rate, pass-through, firm-level data.

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1 Introduction

Exchange rate fluctuations can affect both the price firms pay for imported inputs and the prices they charge for their finished products. While firms often have little influence on the price of their imported inputs, they can actively adjust output prices by varying their markup. By gaining insight into the magnitude and timing of the pass-through of exchange rate fluctuations into markups, policymakers can better understand firms' pricing strategies. This helps to assess the impact of an exchange rate shock on firms' prices and ultimately on overall sales and profits. For a small open economy such as Switzerland with a flexible exchange rate, where exports account for two-thirds and imports for half of total GDP, this is particularly relevant.

My paper estimates the impact of exchange rate fluctuations on firm-level markups for the Swiss manufacturing sector. A distinctive feature is that it examines firm-level data to better understand the heterogeneity that underlies the aggregate pass-through. The analysis shows that firms' markup adjustment differs strongly across firms. Some firms are much more willing and able than others to absorb exchange rate movements by adjusting their markup. Examining how the markup response differs across firms thus provides a differentiated understanding of the price-setting strategies of different types of firms.

There is a large literature on the incomplete pass-through of the exchange rate into prices (see, for example, Krugman (1986), Atkeson and Burstein (2008), Gopinath et al. (2010) or Amiti et al. (2014)). The transmission is complicated by the fact that exchange rate changes can affect both costs and demand and affects both exporting and import-competing firms. In addition, the impact is related to whether cross-border prices are set in the producer or local currency. In the short run, cost changes caused by exchange rate fluctuations are typically exogenous to firms. The key element with which firms can adjust their prices in response to changes in the exchange rate is the markup. Nonetheless, the transmission of exchange rate shocks into markups is an issue that has not yet been fully resolved in the empirical literature, primarily because markups are not directly observable and the data needed to estimate them are often not available. Empirical work on the pass-through of exchange rate movements into markups is therefore sparse.[1] One of the few exceptions is the work of Caselli et al. (2017), who analyse the response of markups to exchange rate shocks at the firm-product level depending on productivity.

In my analysis, markups are estimated using a large panel of firm-level data on Swiss manufacturing firms that includes detailed information on expenditures and revenue. The data cover the 2012-2017 period. With this data set, firm characteristics, such as profitability and productivity, are also estimated. Moreover, the panel is merged with firm-level export

[1] Markups are defined as the upcharge over firms' marginal costs. Some authors such as Amiti et al. (2019) or Kaufmann and Renkin (2018) use microdata to calculate markup proxies based on the sum of variable costs over sales or production. However, these proxies reflect the average markup rather than the markup at the margin.

and import data, making it possible to include the invoicing currency of firms in the analysis. These different firm characteristics are used to estimate the heterogeneity of the response: In addition to the average pass-through, I can also estimate to what extent the pass-through depends on five firm-specific features: size, level of markup, share of sales invoiced in EUR, profitability and productivity.

Methodologically, this paper builds on the work of De Loecker and Warzynski (2012), who developed a framework with which firm-level markups can be estimated using input and output data. The markup is defined as the output elasticity of labour divided by the share of labour income in revenue. An advantage of this production function approach is that it allows for the measurement of firm-level markups without having to make any assumptions on the demand function or the competitive environment.

The pass-through of the exchange rate into markups is estimated using an event-study design, exploiting the large, sudden and persistent appreciation of the CHF against the EUR on 15 January 2015. After 15 January 2015, the EUR/CHF exchange rate[2] stabilised relatively rapidly and remained in a quite narrow band until mid-2017. Swiss manufacturing firms are particularly vulnerable to large movements of the EUR/CHF exchange rate because the euro area is their main trading partner. Kaufmann and Renkin (2018) and Bonadio et al. (2020) provide strong evidence that the appreciation in January 2015 was unexpected by firms, financial markets and economists alike and thus constituted a true 'shock' to the economy. This makes is possible, in contrast to many other pass-through studies, to clearly identify a causal effect of the exchange rate shock on markups.[3]

Three firm-specific control variables are considered to capture factors that might affect markups independently from the exchange rate. The variable designed to control for changes in prices of intermediate goods in foreign currency proves to be of particular relevance, while the variables constructed to control for changes in demand and changes in the USD/CHF exchange rate are not significant.

The results show that the mean firm does not significantly adjust its markup in response to an exchange rate shock. Thus, the mean response is compatible with models that assume monopolistic competition and constant elasticity of substitution with a constant markup-pricing rule. However, this is only part of the story: the results also provide strong evidence that the response is very heterogeneous across different types of firms. While smaller firms leave their markup unchanged, large firms are estimated to transmit 40% of a change in the exchange rate into their markup. Moreover, for large firms that are also highly profitable,

[2]The EUR/CHF exchange rate is defined as the number of Swiss francs (CHF) to be paid for one euro (EUR)

[3]Various aspects of the exogenous EUR/CHF exchange rate shock of 15 January 2015 have already been analysed in the literature. Bonadio et al. (2020) estimate the speed of the response of prices in the days following the shock. Kaufmann and Renkin (2018) estimate the pass-through into import and export prices depending on the invoicing currency with monthly data for the period Q1 2015 to Q3 2016. Auer et al. (2021) estimate the sensitivity of import prices and import shares of consumer goods in the aftermath of the shock.

the markup adjustment increases to nearly 80% and is practically complete if the large firms invoice a large share of their sales in EUR. Although smaller firms are in the majority and determine the mean response, large firms shape the aggregate response owing to their sheer size.

My results are consistent with the findings of Amiti et al. (2019), who demonstrate that for larger firms it is optimal to price to market by varying their markup to keep prices in foreign currency stable. In contrast, smaller firms tend to apply a constant markup-pricing rule. The results of this paper are also in line with the findings of Gilchrist et al. (2018), who show that firms with unhampered access to external finance, i.e., mostly larger firms, have a strong incentive to lower their markup to preserve their market share, while firms with limited access to external finance, i.e., smaller firms, tend to leave their markup stable to preserve internal liquidity.

The remainder of the paper is structured as follows. The next section reviews the five firm-specific differentiating features that enter the estimation. Section 3 discusses the input data and the method used to estimate firm-level markups. Furthermore, some stylised facts about the estimated markups are shown. Section 4 describes the empirical model and the computation of the additional variables that enter the model. Section 5 presents the results. Section 6 concludes the paper.

2 Literature review

This work is embedded in a vast literature on the incomplete pass-through of exchange rate shocks into export quantities or into international prices.[4] The increasing availability of data sets containing firm-level balance sheet data and firm- or product-level price and volumes data has enabled a growing literature seeking to explain the heterogeneous response of prices to exchange rate fluctuations depending on firm-level characteristics. One differentiating feature that has received special attention is the share of sales invoiced in foreign currency. Further features, such as size and productivity, have shown to be theoretically associated with varying levels of exchange rate pass-through into prices or markups.

One of the drawbacks of these studies is that they mostly cover only one characteristic determining the impact of exchange rate changes on markups at a time. In contrast, my analysis covers five main characteristics within a consistent framework, i.e., in terms of the dataset and the estimation method.

In the following, the five firm-level features used in this analysis (size, level of firm markup, invoicing currency, profitability and productivity) are discussed.

The first firm-level differentiating feature is size. Because of their economic weight, the response of large firms plays a predominant role in determining the aggregate pass-through.

[4] See, for example, Amiti et al. (2019), Burstein and Gopinath (2014) or Corsetti and Dedola (2005), just to name a few.

Theoretically, the impact of size could go in both directions. On the one hand, if one assumes that larger firms have a larger market share, size could be related to higher pricing power and lower markup adjustment. The literature, however, emphasises however the opposite effect. One rationale is offered by Amiti et al. (2019), who find that there exists a substantial heterogeneity in markup elasticities depending on firm size. Small firms exhibit no strategic complementarities in price setting and complete cost pass-through. In contrast, larger firms face strong strategic complementarities and choose to keep prices stable by varying their markup. An alternative line of argument is that large firms often have an unimpeded access to external finance[5] that, according to Gilchrist et al. (2018), allows them to adjust their markup more flexibly than smaller firms.[6]

The second differentiating feature is the level of markup. The models developed by Burstein and Gopinath (2014) and Atkeson and Burstein (2008) show that because firms with a high market share have a low price elasticity of demand, they are able to charge a higher markup and choose to keep their prices and quantities stable by varying it. This implies that markup and markup elasticity co-move positively. Intuitively, only firms with high a markup have scope to decrease their markup. Thus, the level of markups preceding the exchange rate shock is set to be a decisive factor influencing the elasticity of markups.

A further factor is the invoicing currency. Older empirical work by Gagnon and Knetter (1995) shows that, for the international automobile industry, variations in the pass-through of exchange rate fluctuations into sale prices can be traced back to the invoicing currency. In their seminal work, Gopinath et al. (2010) and Amiti et al. (2020) develop a model of endogenous currency choice in which it is optimal for exporting firms facing strong strategic complementarities to leave their prices in foreign markets stable because of price-setting rigidities. Such firms prefer to bear the currency-related variation in domestic-currency revenue to keep their prices and volumes in foreign markets stable. They invoice in the customer's currency and exhibit a high markup elasticity.

The fourth feature relates to firms' profitability. High-profit firms are likely to be in better financial health and have more leeway to vary their markup. In contrast, as shown by de Almeida (2015), firms in a tight financial position refrain from decreasing their prices in a crisis to maintain short-term profits even at the expense of future market shares. Heterogeneity in the profitability of firms may therefore have an impact on the heterogeneity

[5] As shown by Gertler and Gilchrist (1994), access to external finance is strongly linked to size because of the costs of asymmetric information. Because information on large firms is much more available and less costly, large firms have easier and cheaper access to external finance.

[6] The authors show with their two-country model that when hit by adverse shocks, firms in countries with unhampered access to external finance have a strong incentive to lower their markup to preserve or even increase their market share. In contrast, limited access to external finance acts as a major friction, which can lead firms to leave their markup stable or even raise them to preserve internal liquidity even at the cost of losing market share. Montero and Urtasun (2021) confirm these findings in an empirical study using Spanish manufacturing data on markups during the Great Recession (2008-2012). Furthermore, Dai et al. (2021) show that the exchange rate pass-through into domestic prices is affected by the degree to which a firm can access external finance.

of the pass-through of an exchange rate shock into markups.

The fifth feature is productivity. Using French firm-level data, Berman et al. (2012) provide strong evidence that highly productive exporting firms adjust their unit value in domestic currency much more strongly than low-productivity firms. Accordingly, highly productive firms price more to market by absorbing changes in the exchange rate in their markup, while their export volumes are less sensitive. They explain this mechanism with the monopolistic competition theory of Melitz and Ottaviano (2008), which holds that the price elasticity of demand increases with price. As high-productivity firms are low-price firms, they face less elastic demand. Consequently, highly productive firms price more to market by absorbing changes in the exchange rate in their markup, while their export volumes are less sensitive.[7] According to these findings, the level of firms' productivity is therefore predicted to affect the pass-through of exchange rate shocks into markups. A number of studies have confirmed these results, such as Berthou et al. (2015) who use cross-country and cross-sector data provided by the Competitiveness Research Network (CompNet) or Li et al. (2015) using Chinese firm-level data. Caselli et al. (2017) show with Mexican data that in response to a change in the real exchange rate, markup and producer prices react more pronouncedly for products with higher productivity.

In the literature, the relationship between these five distinguishing features is ambiguous. For example, Melitz and Ottaviano (2008) argue that competition forces the least productive firms to exit the market and reallocates market share towards more productive, larger, exporting firms, which have a lower markup. In contrast, Bellone et al. (2016) propose a model with a quality-enhancing channel, in which markups are increasing in productivity, and export intensity.[8]

In addition to this ambiguity, some of the mechanisms described above may not be orthogonal to each other. This empirical analysis estimates the impact of the five distinguishing features on markup pass-through separately. Combined regressions are run to test if the features are orthogonal to each other. The results in Table 4 in Section 5 show that the response to an unexpected appreciation increases if large firms also invoice

[7] A further mechanism that links productivity and markup elasticity runs through distribution costs. Products closer to the firm's core competency have a higher productivity and relatively lower prices. For lower price goods, distribution costs account for a larger fraction of total costs. As distribution costs are not affected by changes in the exchange rate (as they are paid in local currency), the sale prices of such goods experience a larger increase in markup following a depreciation than goods with lower productivity, high prices and a smaller share of distribution costs. Caselli et al. (2017) show that in response to a change in the real exchange rate, markup and producer prices react more pronouncedly for products with higher productivity, a consequence of local distribution costs.

[8] These findings are in line with the model developed by Atkeson and Burstein (2008). They show that markups are inherently correlated with the level of productivity. If a firm becomes more productive and can decrease its costs relative to other firms, it will decrease its prices to gain market share. The firm will decrease its prices less than the decrease in costs and thereby increase its markup. Accordingly, markup is increasing in productivity. A positive relationship between markups and productivity is also a key element of more recent literature, such as Autor et al. (2020), who focus on the rise of 'superstar firms' and show that large firms have a high markup and are more productive.

in foreign currency or are highly profitable. In contrast, the response of large firms hardly increases if they are also highly productive or have a high markup. This indicates that that size, productivity and the level of markups are not independent of one another. This is not surprising because most large firms in the sample are also highly productive and often have a high markup (see Table 8 in the Appendix).

3 Measurement of markups and data

Markups for the Swiss manufacturing sector are estimated per firm and per year. In the following, the methodology and data employed to estimate firm-level markups are described. Descriptive statistics are shown in Section 3.3.

3.1 Measurement of firm-level markups

The estimation methodology applied in this paper closely follows the so-called 'production function approach' described in De Loecker and Warzynski (2012), who extended the model originally proposed by Hall et al. (1986).[9] A brief description of the production function approach is provided in Section A in the Appendix. This approach assumes that firms minimize costs and are price takers in input markets. Taking labour as the variable input, markups are defined as the output elasticity of labour multiplied by the inverse of the labour share in total revenue:

$$\mathcal{M}_{it} = \theta_{it}^{L} S_{it}^{L^{-1}}$$

Using the output elasticity of labour and the labour expenditure share in revenue to derive markups assumes that the Swiss labour market is very flexible. Although, in international comparison, the Swiss labour market is ranked as one of the most flexible, with relatively few regulations regarding the hiring and laying off of staff (Di Tella and MacCulloch, 2005),[10] this assumption may not fully hold. However, this issue is attenuated by the fact that we employ annual data.

While the labour share can be taken directly from the firm data, the output elasticity of labour has to be estimated by means of a production function. Productivity is controlled for in the production function to resolve the simultaneity problem, which arises because productivity affects the amount of input, which flows into production. It is assumed that production follows a second-order translog production function. This makes it possible to

[9] The methodology developed by De Loecker and Warzynski (2012) and the increasing availability of balance sheet data has enabled new empirical analysis on firm-level markups, such as Meier and Reinelt (2022) on the response of markup dispersion to monetary policy, Caselli et al. (2017), who estimate the impact of changes in the exchange rate depending of productivity, or Bellone et al. (2016), who analyse the relationship between markups and productivity.

[10] Most labour contracts in Switzerland have a mutual notice period of two to three months. An employer may terminate the employment of an employee with a notice period of two (three) months if the employee has been employed in the company for less (more) than 10 years.

estimate an output elasticity that varies between firms. The production function is estimated by NACE 2-digit subsector and by year.

Markups are computed using variables that relate to the firm as a whole. Therefore, the estimated markup is a firm average, covering all products and activities a firm produces and sells in a given year.[11]

3.2 Raw Data

The two main data sets used in this paper are data on expenditures and revenue, which are used to estimate the markups, and goods import and export data, which are used to define the export intensity of a firm and compute the firm-level control variables. Both data sets are matched at the firm level. As the import and export data only comprise goods, the analysis has been restrained to the manufacturing sector because this is the sector in which goods play a predominant role, in contrast to the service sector.

Annual markups are estimated for the manufacturing sector for the period 2012-2017 using a large panel of firm-level balance sheet and income statement data (value added statistics) provided by the Swiss Federal Statistical Office (SFSO).[12] The data set contains the required variables to estimate firm-level markups: revenue, intermediate goods, labour costs and the capital stock. The data set comprises $10,158$ observations from $2,462$ firms. It is an unbalanced panel; that is, not every firm is observed for all years. The sample is a comprehensive draw from the population of Swiss manufacturing firms, including all sub-industries of the manufacturing sector (see Table 6 in the Appendix). However, while it includes many of the large and medium-sized firms, the data do not cover the full universe of firms of the small and very small firms, which are underrepresented.

The variables entering the estimation of the firm-level output elasticity of labour are defined in physical terms. Labour is measured by full-time employment and therefore does not need to be deflated. The data set does not contain information on firm-level output, only nominal revenue. Nominal revenue is therefore deflated with the respective subsector NACE 2-digit deflators from the national accounts (SFSO). The need to proxy for firm-level sale prices with industry-level price deflators is a problem faced by many researchers. In the literature, there

[11] Firms produce a variety of goods and services and sell them to a variety of customers, which are active in a variety of markets (e.g. domestic versus foreign markets). A firm typically charges different markups on its various products and in the various markets in which the products are sold. Firm-level markups estimated with the production approach therefore reflect the average markup across all the products a firm sells.

[12] The sample is not representative because it over samples large firms. This is because the sample is used to project aggregate GDP, for which large firms' statistics have a higher information content. The sampling frame is broken down by industries, respectively by sectors (primary strata) on the basis of the 2-digit NOGA classification (NOGA is the Swiss industry classification, similar to NACE) and size classes on the basis of the number of employees (secondary strata). This stratification allows the SFSO to build the most homogeneous subpopulations possible, in terms of economic activity and size. A size limit is set for each economic sector, above which all companies are surveyed. In the remaining strata, simple random samples are drawn. The sample size is set such that total gross production and total full-time equivalents at the 2-digit NOGA can be estimated with a coefficient of variation of 2.5%. See BFS (2020) for details.

is some controversy in about the potential bias in markups brought around by neglecting sale prices variation across firms of a given subsector.

To circumvent this omitted firm-level price variation, the methodology of De Loecker and Warzynski (2012), which is used in this paper, employs an adjustment using the firm-level residuals of the production function to capture the unobserved price differences across firms within sub-sectors. De Loecker and Warzynski (2012) argue that with this adjustment, any bias due to the omission of firm-level price variation only leads to a downward shift in the *level* of the estimated markups (see also Klette and Griliches (1996)) but does not affect the *evolution* of the markup estimates. Bond et al. (2021), however, claim that beyond the downward bias, the informative value of the estimated markups may also be weakened. In their empirical work, De Ridder et al. (2022) refute this. While they confirm the downward bias in revenue-based markups, they find that revenue-based markups follow a similar evolution over time as quantity-based markups.[13] This suggests that markups estimated with sub-sector deflated revenue are suited for the analysis in this paper because it focuses on the evolution of markups following an exchange rate shock.

Firm-level customs data is also supplied by the SFSO. These data contain information on the amount of exports and imports by firm, in CHF including a breakdown by region and invoicing currency. Customs data are used to define an export-intensity dummy, which is used to estimate the heterogeneity of the exchange rate pass-through depending on firms' exposure to the EUR/CHR exchange rate (see details in Section 4.3). Furthermore, these data are used to compute three firm-level control variables: The regional breakdown of imports is used to construct a firm-level intermediate input price index in foreign currency. The regional breakdown of exports is used to build a proxy for firms' foreign demand. The currency breakdown is used to calculate a proxy for firms' exposure to the USD/CHF exchange rate (details in Section 4.4).

Export and import data that can be linked to firm-level balance sheet data are only available for the years 2016 and 2017. In the absence of a better alternative, it is therefore assumed that the average export and import shares of 2016-2017 are constant over the whole estimation period. Eventual shifts in export and import weights due to the exchange rate shock are not considered. However, as described in Section B.2 in the Appendix, the impact on the estimated pass-through is probably small.[14]

[13] De Ridder et al. (2022) are able to conduct such an analysis because they dispose of a unique database of French manufacturing firms containing not only firm balance sheet and income statements but also data on firm revenues and sale quantities, which they use to calculate firm-level product prices.

[14] For further details and sample statistics on the raw data, see Section 3.2 in the Appendix.

3.3 Descriptive statistics

Table 1 lists the means, medians, weighted means[15] and the standard deviations of the estimated markups for the whole sample and by sub-sector. The mean markup over all observations is 1.26, meaning that firms set their sale price equal to their marginal cost plus an upcharge of 26% of the marginal cost. The median is lower, at 1.13%. The weighted mean amounts to 1.81% and is thus more than 40% above the mean. This means that larger firms tend to have a higher markup. The standard deviation of the sub-sector means is only 0.17, indicating that the between-sector heterogeneity is quite low. In contrast, the heterogeneity within firms of the same sub-sector is much higher, in particular for the sub-sectors 'IT and watches', 'Pharmaceuticals' and 'Chemicals'.[16] The distribution between firms is particularly large in the pharmaceutical sector. In this sub-sector, the difference between the median and the weighted mean is especially large, indicating that this sub-sector is composed of few very large firms with a high markup and many smaller firms with a low markup. The high within-sub-sector and low between-sub-sector heterogeneity makes the sub-sector perspective not particularly informative. A more interesting desegregation is by size. Figure 1 shows the distribution of markups for different size classes. This figure clearly shows that larger firms tend to have a larger markup, although here too, the dispersion is large.[17]

The revenue of the fifth largest firms in the sample amounts to 81% of total revenue. Because of their economic weight, the development of large firms' markups plays a predominant role in the aggregate development. Figure 2 depicts the development of the weighted mean (solid line) and the unweighted mean (dashed line) of markups between 2012 and 2017. A striking feature of this figure is that the weighted mean, which is representative of the aggregate of firms, is markedly higher than the unweighted mean, which reflects the development of the average firm. Furthermore, this figure also shows that the weighted mean developed very differently to the unweighted mean in the aftermath of the exchange rate shock. The vertical line separates the pre-shock phase (2012-2014) and the post-shock phase (2015-2017). While the unweighted mean markup increased slightly in 2015, the weighted mean decreased by 6.3%. This indicates that large firms were a driving force behind the aggregate squeeze in markups following the appreciation.

[15] Markups are weighted by their size, which is measured by their revenue. The aggregate markup is computed using a two-step aggregation procedure. First, a weighted mean is constructed at the sub-sector level using firm-level data. Second, the sub-sector weighted means are aggregated using sub-sector weights derived from the production data from the national accounts. (see B.4 for details on the aggregation method).

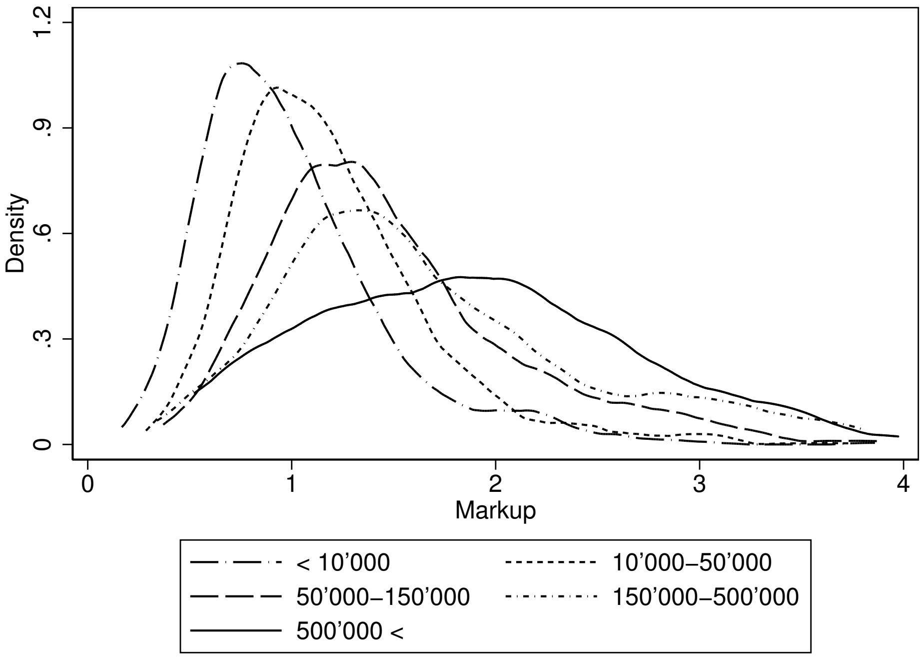
[16] This is in line with the findings of Baqaee and Farhi (2020), who find for the US that the dispersion of markups is higher across firms within a sector than across sectors.

[17] Figure 1 shows that a non-negligible share of firms are estimated to have a less than unit markup. This feature is not uncommon and has been analysed and explained in the literature. An important finding is that the use of revenue-based markup estimates, as in this paper, tends to bias the level of markups downwards, compared to quantity-based markups estimates. See Appendix C.1 for more details.

Table 1: Descriptive statistics for Swiss markups 2012-2017

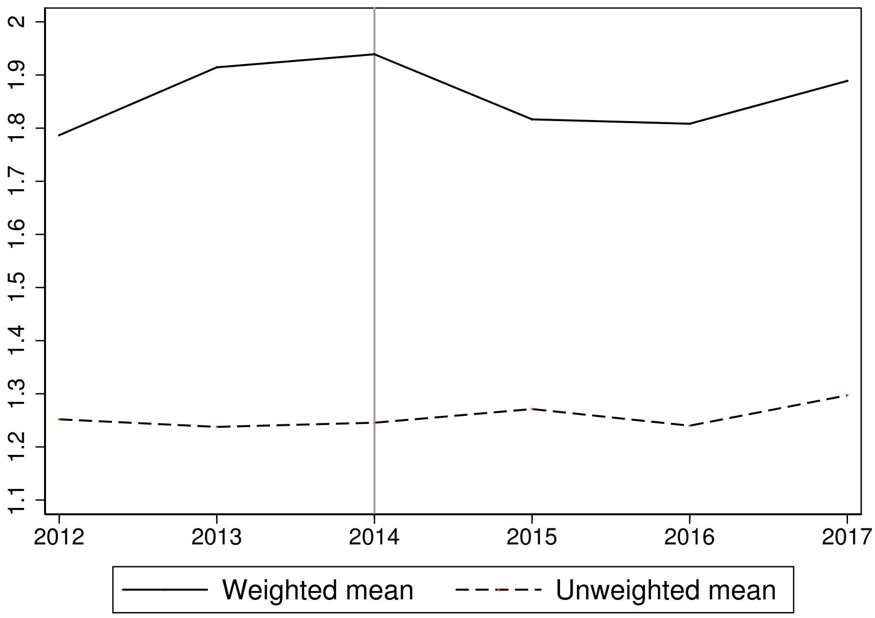
	median	mean	weighted mean	stdev
Whole sample				
	1.13	1.26	1.81	0.66
Within sub − sectors				
Food, Tobacco	1.19	1.32	1.77	0.65
Textiles	1.42	1.49	1.85	0.58
Wood	1.1	1.29	1.54	0.54
Paper	1.23	1.31	1.60	0.51
Print	1.19	1.2	1.30	0.31
Chemicals	1.03	1.25	1.62	0.82
Pharmaceuticals	0.71	0.95	2.05	0.87
Plastics	1.08	1.19	1.38	0.5
Glass	0.92	1.08	1.28	0.6
Basic metals	1.06	1.3	1.90	0.69
Metal products	1.08	1.13	1.23	0.35
IT Watches	1.42	1.63	2.46	0.97
Electrical	0.93	1	1.14	0.52
Machines	1.15	1.24	1.54	0.52
Vehicles	1.07	1.14	1.38	0.51
Furniture	0.89	0.94	1.01	0.28
Other	1.03	1.13	1.42	0.51
Between sub − sectors				
	median of medians	mean of means	mean of weighted mean	stdev of means
	1.08	1.21	1.56	0.17

Figure 1: Distribution of markups by size group



Notes: This figure shows the kernel density estimates for five size groups, where size is defined by firms' mean annual revenue in CHF, for manufacturing firms between 2012 and 2017.

Figure 2: Markups, mean and weighted mean



Notes: This figure shows the annual arithmetic mean of the weighted and unweighted markups for Swiss manufacturing firms between 2012 and 2017. Markups are weighted by their size, which is measured by their revenue. See B.4 for the aggregation method.

4 Empirical strategy

The pass-through of an exchange rate shock into firm-level markups is estimated based on an event-study design. In this section, the identification and estimation strategy is described. Furthermore, the firm-specific feature dummies, which are used to estimate the heterogeneity of pass-through, and the control variables, which enter the estimation, are listed.

4.1 Identification of the shock

The analysis exploits the large, sudden and persistent appreciation of the Swiss franc against the euro on 15 January 2015, when the Swiss franc appreciated by nearly 15% against the euro. Following this sharp appreciation, the exchange rate stabilised relatively rapidly and remained in a quite narrow bound until mid-2017. In annual terms, the Swiss franc appreciated by 12.1% in 2015. In 2017, the Swiss franc was still 8.5% stronger than before the shock. The exchange rate shock of 2015 was very relevant for Swiss firms because Switzerland is a small open economy with exports and imports of goods amounting to approximately one-third of total GDP. Moreover, interdependencies along the production chains are especially intense with the euro area, its main trading partner.

A key point, however, is that the drop was not only large and economically relevant but that this unparalleled event provides a singular context that can be used to lay down an identification strategy to estimate the exchange rate pass-through. First, the shock was exogenous. Second, in its aftermath, the new exchange rate level was seen to be persistent. Third, the shock occurred in a period of relative stability. Factors that potentially may have affect markups independently from the exchange rate, such as changes in commodity prices, are controlled for.

There is clear evidence that the sudden appreciation of the Swiss franc on 15 January 2015 was exogenous to firms' pricing decisions at the time. Kaufmann and Renkin (2018) attest that the shock was generated by the policy decision of the Swiss National Bank (SNB) and was completely unexpected by professional forecasters up to the moment it occurred. Bonadio et al. (2020) analyse the EUR/CHF forward rates and conclude that financial market participants had also not anticipated the shock. Indeed, during the three years preceding the exchange rate shock of January 2015, fluctuations in the EUR/CHF exchange rate were very moderate due to the exchange rate floor policy conducted by the SNB, which was put in place on 6 September 2011. The long period of exchange rate stability came to a sudden end on 15 January 2015, when the SNB made the announcement that it would terminate its minimum exchange rate policy. The Swiss franc appreciated immediately against the euro. The exchange rate shock in 2015 being independent of firms' pricing decisions makes it possible to identify a causal effect between the exchange rate and markups.

Furthermore, Kaufmann and Renkin (2018) show that the appreciation was perceived by firms to be permanent.[18] This is a decisive point because it lays the ground for firms to adjust their prices. Moreover, Kaufmann and Renkin (2018) analyse the economic environment before and after the shock and attest that, apart from the exchange rate shock, most other macroeconomic factors developed quite steadily during that period.

4.2 Empirical model

The impact of the exchange rate shock is estimated following the methodology used by Kaufmann and Renkin (2018) in which time dummies capture the effect of the shock:

$$\mu_{it} = \alpha_i + \sum_{year \neq 2014} \gamma_{year} D_t^{year} + \beta X_{it} + \epsilon_{it} \tag{1}$$

The dependent variable μ_{it} is the log-markup of firm i in year t. The time dummies D_t^{year} are equal to one in the corresponding year, zero otherwise. The time dummy for the year before the shock D_t^{2014} is omitted. The response is therefore normalised to zero in the year preceding the shock. The impact of the exchange rate on markups is measured by the dummy coefficients, γ_{year}, which can be interpreted as the response of markups relative to the year before the shock. A control function, X_{it}, has been introduced into the model to capture factors that potentially may affect markups independently of the exchange rate. It contains three control variables: a firm-level intermediate input price index in foreign currency, a firm-specific demand index in foreign currency and a firm-specific exchange rate variable to control for potential changes in other currencies than that in which the shock occurred. The regression is estimated with firm fixed effects.

As markups are estimated with firm-level data on expenditures and revenue, the coefficients of the dummy variables reflect the estimated response of the realised markups. If prices are sticky, the realised markups may, however, not correspond to the desired markups. Frictions in price setting could cause markups not to react as strongly or as quickly as desired by the firm.[19] Thus, price stickiness, which is not controlled for in Equation (1), may lead to a lower pass-through than what would be optimal for firms, at least in the first year after the

[18]The authors analyse the individual responses of the KOF Consensus Forecast, a survey that contains the exchange rate forecasts of 20 economists. According to this survey, the 12-month forecasts of the EUR/CHF exchange rate declined directly after the exchange rate shock of January 2015 and remained stable over the following years. Kaufmann and Renkin (2018) find further evidence that firms perceived the shock to be permanent in the development of the applications to the Swiss short-time work scheme. The short-time work scheme is a governmental program designed to give firms financial support in bridging temporary reductions of working hours. The applications for short-time work increased little following the shock of January 2015, indicating that a large majority of firms did not expect the appreciation to be temporary.

[19]Amiti et al. (2020) discuss the divergence between the desired and realised price and find that the loss that arises because of price stickiness drives firms' choice of invoicing currency.

shock (2015).[20] However, in the analysed sample, the impact of price stickiness may actually be small because the exchange rate shock of January 2015 was extraordinarily large, and according to Alvarez et al. (2017), the response of prices to an exchange rate shock depends on the size of the shock.

To be able to assign the estimated results to the exchange rate shock of January 2015, the coefficients of the time dummies preceding the event, γ_{2012} and γ_{2013}, should not be significantly different to zero given that during this period the EUR/CHF exchange rate was more or less flat. The dummy coefficients for 2015-2017 can be interpreted as the cumulated change in markups resulting from the exchange rate shock of January 2015.

The heterogeneity across firms is introduced into the model by means of dummy variables representing each of the five firm-level features described in Section 2. Equation (2) is enhanced with such a firm-specific feature dummy variable $D_i^{Feature}$. The marginal impact of a single firm-specific feature on the pass-through of the exchange rate into markups is measured by the coefficients of the interaction term of the time dummies with a given feature dummy ψ_{year}. The feature dummy itself is absorbed by the firm fixed effects:

$$\mu_{it} = \alpha_i + \sum_{year \neq 2014} \gamma_{year} D_t^{year} + \sum_{year \neq 2014} \psi_{year} D_t^{year} D_i^{Feature} + \beta X_{it} + \epsilon_{it} \tag{2}$$

In a further step, the model is extended to estimate the simultaneous impact of two feature dummies. With these combined estimates, one can test whether the various features are independent of one another and therefore whether they have an amplifying impact on the pass-through. Given the economic importance of large firms, the size dummy D_i^{Size} is included in all regressions, and the interaction terms of the other features are added in turn:

$$\begin{aligned} \mu_{it} = {} & \alpha_i + \sum_{year \neq 2014} \gamma_{year} D_t^{year} + \sum_{year \neq 2014} \psi_{year} D_t^{year} D_i^{Size} \\ & + \sum_{year \neq 2014} \phi_{year} D_t^{year} D_i^{Feature} + \sum_{year \neq 2014} \chi_{year} D_t^{year} D_i^{Size} D_i^{Feature} \\ & + \beta X_{it} + \epsilon_{it} \end{aligned} \tag{3}$$

The difference between the sum of the estimates of ψ_{year}, ϕ_{year} and χ_{year} from Equation (3) and ψ_{year} from Equation (2) provides evidence of whether the additional feature has an amplifying effect on the pass-through.

[20] Kaufmann (2009) calculates the frequency of price changes and the number of quarters between price adjustments using price quotes of the products underlying the Swiss consumer price index between 2000 and 2005. According to his results, prices of industrial goods sold at the consumer level in Switzerland are on average adjusted every 4.5 quarters.

4.3 Firm-specific feature-dummies

For each of the five firm-level features, a firm-specific dummy is constructed. These feature dummies are set to equal 1 for those firms in the upper fifth quintile of the distribution. Otherwise, they take value 0. Therefore, the coefficients of the feature dummies in Equations (2) and (3) measure the marginal impact of the highest 20%of firms.

Size: Because of their economic weight, the response of large firms plays a predominant role in aggregate pass-through. Size is measured by firms' average revenue in the years before the shock (2012-2014). It is assumed that large firms are more willing and able to lower their markup and will therefore have a higher markup elasticity than smaller firms.

Level of markup: The markup dummy is constructed with firms' average markup in the years preceding the exchange rate shock (2012-2014). Firms with a higher markup are assumed to have more scope to decrease their markup.

Invoicing in EUR: Firms that choose to invoice a large share of their sales in EUR can be expected to keep their prices in EUR stable by varying their markup. The share of sales invoiced in EUR is calculated by firms' exports invoiced in EUR divided by their total revenue, whereby revenue and exports are measured in CHF.[21]

Profitability: High-profit firms are likely to be in better financial health and have more leeway to vary their markup. Profitability is proxied by earnings before interest rates and taxes (EBIT) per unit revenue in the year preceding the shock.

Productivity: In the production function used to estimate firm-level markups, total factor productivity (TFP) has been controlled for, as it could potentially impact markups and bias the markup estimates. This makes it possible to use TFP as a differentiating feature. TFP is derived from a firm-level production function estimated with the methodology developed by Wooldridge (2009). Firms' average TFP in the years preceding the shock is used.

Most large firms in our data set are also highly productive firms (93.5%) and often have a high markup (40.5%), indicating that these three features (size, productivity and level of markup) are not independent of one another. In contrast, only 29.1% of large firms are also highly profitable, and only 13.3% of large firms invoice a high share of their sales in EUR (see Table 8 in the Appendix).

4.4 Control variables

Although most macroeconomic factors, beside the EUR/CHF exchange rate, developed quite steadily before and after the exchange rate shock of 2015, variables that may have influenced markups should enter the control function. Three control variables have been constructed to

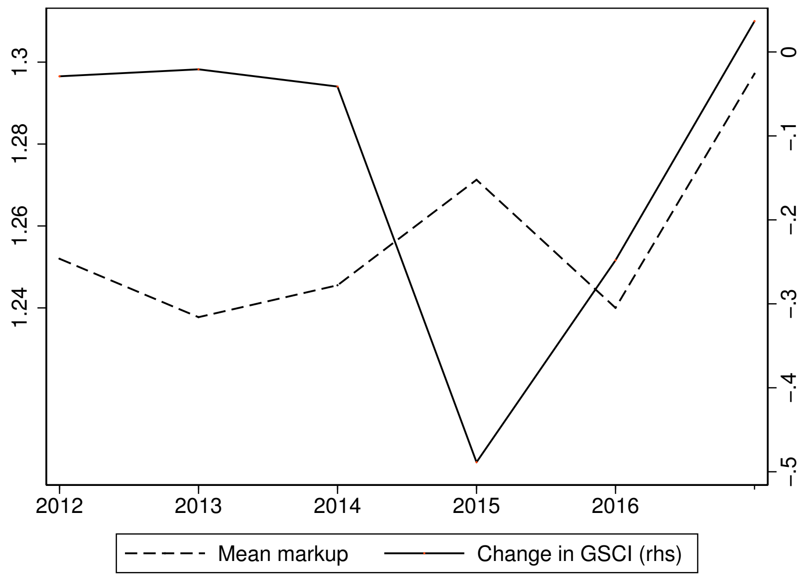
[21] In Section D.5 in the Appendix, a robustness test is conducted, in which the share of revenue invoiced in EUR is replaced by the share of revenue stemming from exports to the euro area. The response to the exchange rate shock is similar because 87.3% of the firms with a high share invoiced EUR also belong to the upper fifth of firms ranked by their share of revenue stemming from exports to the euro area.

prevent biased estimates.[22]

First, an intermediate input price index in foreign currency is built to control for changes in commodity prices. As shown in Figure 3, the mean markup (dashed line) was quite stable, at approximately 1.21%, between 2012 and 2014. In 2015, however, it increased by 2.4%. This increase is at first glance surprising given that the sharp appreciation of the Swiss franc presumably put pressure on sale prices and hence on markups. The rise in the average markup in 2015 is an indication that an additional factor may have had a counterbalancing impact on firms' markups.

The solid line in Figure 3 depicts the annual change in the Goldman Sachs Commodity Index (GSCI) denoted in USD. In 2015, the GSCI dropped by 38.7%. In 2016 it fell by a further 22%. In 2017, it was more or less flat. The sharp drop in commodity prices in 2015 presumably led to a decrease in firms' costs for intermediate inputs, which may have led to a rise in markups, despite the negative impact of the appreciation. To correctly assess the impact of the appreciation on markups, one has to control for this effect.

Figure 3: Markups and the change in material prices in foreign currency



Notes: The solid line shows the annual mean of the firm-specific markups. The solid line shows the annual change in the Goldmann Sachs commodity index in USD.

In the pass-through regression, one only wants to control for the worldwide drop in costs for intermediate inputs without considering the decrease in import prices stemming from the appreciation of the Swiss franc. To do so, a firm-specific intermediate input price index, $Price^{Interm}_{i,t}$, is constructed for each firm i and year t, excluding the impact of the appreciation:

[22] A detailed description on how the three control variables are constructed is provided in Appendix B.3

$$Price_{i,t}^{Interm} = \sum_c PPI_{c,t}^{For} Share_{c,i}^{Imp} + PPI_t^{Dom} Share_i^{Dom}$$

The index consists of two terms. The first term reflects the cost of intermediate inputs that are directly imported by the firms. It is a weighted average of foreign producer prices, $PPI_{c,t}^{For}$, which are indexed at 100 in 2014. The weights, $Share_{c,i}^{Imp}$, are the firm-specific share of imported intermediate goods from a given country or region c. The foreign producer prices are denominated in the respective foreign currency. This ensures that the decrease in import prices stemming from the appreciation is not considered. The second term PPI_t^{Dom} proxies for the firm-specific cost of intermediate goods including energy bought on the domestic market excluding the impact of the appreciation. $\sum_c Share_{c,i}^{Imp} + Share_i^{Dom}$ equals one. The intermediate input price enters the control function as the cumulated change relative to 2014.[23]

Biased estimates may also come from a change in demand that by affecting market conditions could lead to an adjustment in markups as described in Goldfajn and Werlang (2000). As domestic demand is endogenous to the exchange rate, a firm-level control variable based on foreign demand in foreign currency is constructed to proxy for a demand shift. Furthermore, changes in the USD/CHF exchange rate may have an impact on markups, although data show that the average firm trades over 90% of its imports or exports in Swiss francs or in euros. Therefore, in addition to the firm-specific intermediate input price index, a firm-specific foreign demand index and a firm-weighted USD/CHF index also enter the control function.

5 Response of markups to changes in the exchange rate

In this section, the estimates of the pass-through of the exchange rate shock of January 2015 into markups are reported. First, the overall response estimated with Equation (1) is shown in Table 2. For all specifications, the estimated dummy coefficients γ_{2012} and γ_{2013} are not significantly different from zero, as expected given that during the period preceding the shock, the EUR/CHF exchange rate was more or less flat.

The dummy coefficients for the years following the shock can be interpreted as the cumulated change in markups resulting from the exchange rate shock of January 2015. Specification (1) lists the coefficients when no control variables are included in the estimate. The coefficients reflect what is shown in Figure 3: markups increased in 2015 and again in 2017. The coefficients are highly significant.

In specification (2), which includes the three control variables, the coefficients of the dummy variables for the two years following the shock, 2015 and 2016, are negative but

[23] The unweighted mean of markups (depicted in Figure 3) increased by 2.1% in 2015. If one deduces the estimated effect of intermediate input prices, the unweighted mean increases only very slightly in 2015, by 0.6%.

Table 2: Response of markups to the exchange rate

	(1)	(2)	(3)
Response of markups relative to 2014			
γ_{2012}	0.004	0.001	0.001
	(0.006)	(0.006)	(0.006)
γ_{2013}	-0.006	-0.004	-0.004
	(0.004)	(0.005)	(0.005)
γ_{2015}	0.019***	-0.007	-0.007
	(0.006)	(0.015)	(0.015)
γ_{2016}	0.017**	-0.019	-0.021
	(0.007)	(0.022)	(0.022)
γ_{2017}	0.042***	0.021	0.019
	(0.008)	(0.016)	(0.016)
$\beta^{MaterialPrice}$		-1.407**	-1.396**
		(0.687)	(0.708)
$\beta^{ForeignDemand}$		-0.104	
		(0.327)	
$\beta^{USDindex}$		-0.028	
		(0.032)	
Observations	10158	10099	10099
Firm FE	yes	yes	yes

Notes: Estimated response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014. The p-values are denoted as ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$. Heteroskedasticity- and autocorrelation-consistent standard errors in parentheses.

not significant. This indicates that, after having controlled for other influences, on average, firms did not respond to the exchange rate shock of January 2015 by increasing their markup. However, they did not significantly decrease them either. The only control variable that plays a significant role is the firm-specific material price index, which has a negative sign indicating that material prices are negatively correlated with markups, as expected. The coefficient of the foreign demand index is not significant, confirming the assumption presented in Kaufmann and Renkin (2018) that most macroeconomic factors, other than the EUR/CHF exchange rate, developed steadily before and after the exchange rate shock of 2015 and therefore had no significant impact on the development of prices and markups. The coefficient of the firm-specific US dollar index is not significant either. This is not very surprising given the small amount of goods traded in US dollars.[24] In specification (3) the insignificant control variables are dropped from the regression without changing the results.

These first results show that on average firms did not respond to the exchange rate shock of January 2015 by significantly decreasing their markup.[25] In the next step, the impact of each of the five firm-level features are estimated using Equation (2). In Panel 1) of Table 3, the response of the exchange rate shock measured by the sum of the coefficients of the time dummy, γ_{year}, and the interaction term, ψ_{year}, is shown for each type of firm. Panel 2) reports the total implied exchange rate elasticity in the year of the shock, i.e., in 2015, and in the year after the shock, i.e., in 2016. The implied elasticities are computed by dividing the marginal response in 2015 and 2016 relative to 2014 by the change in EUR/CHF exchange rate in 2015 and 2016 relative to 2014. Figure 4 replicates the results graphically.

Table 3: Response of markups to the exchange rate shock depending on the five firm-level features

	(1) large firms	(2) high markup	(3) high EUR share	(4) high profitability	(5) high productivity
Panel 1) Total response of markups relative to 2014					
$\gamma_{2012} + \psi_{2012}$	-0.000	0.004	0.006	0.002	-0.010
$\gamma_{2013} + \psi_{2013}$	-0.003	0.004	0.007	-0.009	-0.016
$\gamma_{2015} + \psi_{2015}$	-0.053***	-0.042**	-0.040*	-0.027	-0.064***
$\gamma_{2016} + \psi_{2016}$	-0.048*	-0.072***	-0.039	-0.051*	-0.062**
$\gamma_{2017} + \psi_{2017}$	-0.003	-0.033	0.006	-0.011	-0.020
Panel 2) Total implied exchange rate elasticity					
2015	0.413	0.327	0.309	0.209	0.501
2016	0.448	0.666	0.362	0.471	0.576

Notes: Panel 1) on the top shows the estimated average response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014, depending on five firm-level features, measured as the sum of the coefficients γ_{year} and ψ_{year}. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variances and covariances of the coefficients γ_{year} and ψ_{year}. Panel 2) reports the total implied exchange rate elasticity in 2015 (2016), which is computed by dividing the total response in 2015 (2016) relative to 2014 by the change in EUR/CHF exchange rate in 2015 (2016) relative to 2014. Table 15 in the Appendix, reports the full results of Equation (2).

[24] see Table 7 in the Appendix.

[25] These results contrast with those found by Caselli et al. (2017) who estimate with Mexican data that a depreciation led to a significant increase of markups across all firms, albeit with quite a low elasticity of only 0.06.

Specification (1) lists the estimates for the 20% largest firms. In the year of the shock, in 2015, large firms decreased their markup by 5.3% and left them more or less at that level in the following year. Given that the exchange rate decreased by over 12% in 2015, the implied exchange rate elasticity amounts to 41%, as shown in Panel 2). In the following year, the implied elasticity increases to 45%. The pass-through of all firms compared to that of large firms reflects what is shown in Figure 2: While the mean markup, which is driven by a large number of smaller firms, remained practically unchanged, the weighted mean, which is driven by the response of large firms, decreased markedly. Thus, the response of the average firm confirms models that assume a constant markup-pricing rule. In contrast, large firms react to an adverse exchange rate shock by notably decreasing their markup and thereby shape the aggregate response. These results are consistent with the findings of Amiti et al. (2019), who show that large firms exhibit strong strategic complementarities.[26]

Specification (2) depicts the response of firms with a high markup preceding the shock. The implied pass-through elasticity is 33% in the year of the shock and is at its highest in the following year the shock, at 67%.

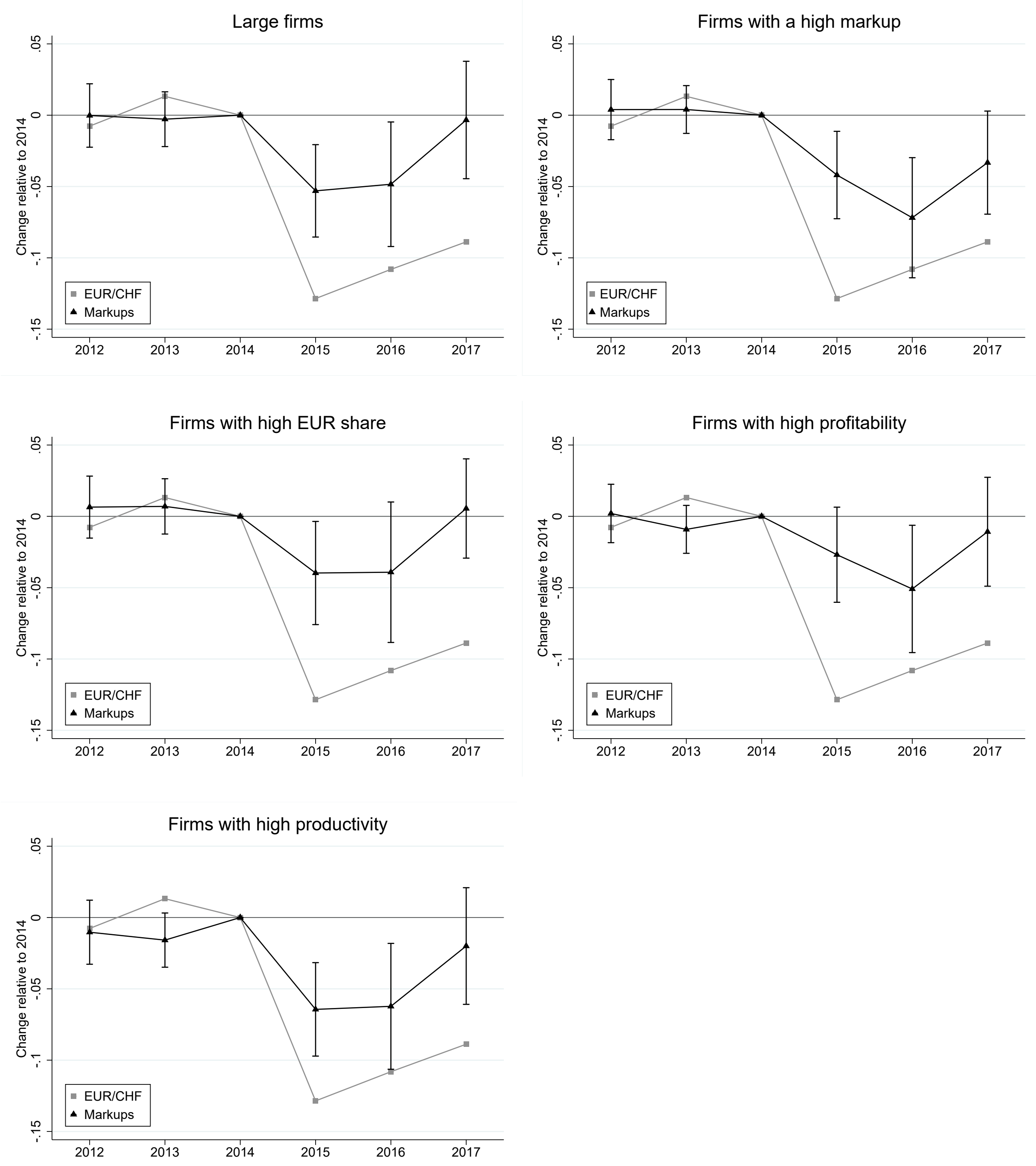
Firms with a high share of sales invoiced in EUR decreased their markup by 4.0% in the year of the shock. In the following years, the shock had no significant impact. The exchange rate elasticity is 31%. At first glance, this elasticity may seem to be low. Indeed, according to theory on invoicing currency (e.g., Gopinath et al. (2010)), firms that prefer to export in foreign currency choose to do so because they strive to keep prices in the foreign currency stable by varying their markup. Kaufmann and Renkin (2018) provide empirical evidence that CHF prices of exported products invoiced in EUR responded strongly to the exchange rate shock. However, while firms invoicing in EUR tend to keep their *prices* in EUR stable by reducing their prices in CHF, they do not necessarily have to adjust their *markup* by the same amount because many exporting firms are also importers. The appreciation of the EUR/CHF exchange led to a decrease in the marginal costs of importers, partly offsetting the negative impact stemming from reduced sale prices. This mechanism acts as a sort of ‘natural hedging’. Amiti et al. (2014) show that this channel can play a large role because large exporters tend to be large importers. Swiss data confirm this: The upper fifth of firms invoicing in EUR import on average 40% of their intermediate goods in EUR.[27]

Specification (4) shows that highly profitable firms do not significant vary their markup in the year of the shock. However, in the following year, the pass-through elasticity reaches

[26] That large firms lower their markup to preserve their market share is also consistent with the findings of Hanslin Grossmann et al. (2016), who find that Switzerland’s overall export volumes are relatively insensitive to changes in the exchange rate. This overall weak response of volumes is driven by the low sensitivity of the export sectors chemicals, pharmaceuticals and watches. As show in Table 6, these are the sectors with the largest mean firm size.

[27] Furthermore, one must keep in mind that many firms in the upper fifth of the distribution do not invoice all their sales in EUR. Some of their products are sold abroad in another currency unaffected by the EUR/CHF appreciation or to the domestic market, which may be affected by the exchange rate through import competition, albeit to a lesser extent.

Figure 4: Response of markups to the exchange rate shock depending on the five firm-level features



Notes: The black lines show estimates of the average response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014, depending on the five firm-level features, measured as the sum of the coefficients γ^{year} and ψ^{year}. The vertical bars denote the 90% confidence intervals, which are derived from the variances and covariances of the estimated coefficients γ^{year} and ψ^{year}. The grey line is the change in the EUR/CHF exchange rate relative to 2014.

47%. This suggests that firms in a healthy financial condition have more leeway to actively adjust their markup, in contrast to firms in a tight financial position, which refrain from decreasing their prices in a crisis to maintain short-term profits even at the expense of future market shares. However, the adjustment proceeds slowly. Finally, highly productive firms have a pass-through elasticity in the year of the shock of 50%, which increases to 58% in the following year.

As described in Section 2, the relationship between the firm-specific features is not clear cut in the literature. Combined regressions are run to estimate whether being large, invoicing strongly in EUR, being high profitability, highly productive or having a high markup are different facets of the same feature or if these features have an independent, mutually amplifying impact on the pass-through. Given the economic importance of large firms, the size dummy is fixed in all regressions, and the interaction terms of the other features are added in turn.

Table 4 lists the responses of the combined regressions. The response of large firms with a high markup is shown in Column (1). The implied exchange rate elasticity is estimated at 42% in the year of the shock and 71% in the following year. Panel 3) shows that the increase compared to the average high-markup firm is small. The estimates in Column (4) show that the elasticity of large firms with high productivity also remains practically unchanged compared to the average highly productive firm. This indicates that these three features (size, markup level and productivity) are not orthogonal to each other. While there are rationales for each of these three mechanisms, it is not possible with the data set to distinguish which of the three features is the cause of the pass-through.

In contrast, Panel (3) shows that the implied markup elasticity increases strongly if large firms invoice a large share of their sales in EUR or if they are highly profitable. This is shown in Columns (2) and (3). Column (2) shows that for large firms that invoice a large share of their sales in EUR the implied exchange rate elasticity increases to nearly 90% in the year of the shock and close to 1 in the following year. This means that such firms practically completely adjust their markup, in favour of stable sale prices in foreign currency. Panel 3) shows that the elasticity is more than twice as high as that of the average firm with a large share of sales invoiced in EUR. The implied markup elasticity of large and highly profitable firms, shown in Column (3), is approximately 60% in the year of the shock and increases to nearly 80% in the year after, up by approximately 35% compared to the average high-profitability firm.[28]

According to these results, large firms, which either invoice a high share of their sales in EUR or are highly profitable, adjust their markup substantially. However, how relevant

[28]While the point estimates in Table 4 indicate that the pass-through is very high for large firms when they invoice a large share of their sales in EUR or when they are highly profitable, Figure 5 shows that the dispersion of the response is however quite large and that the responses of the combined channels are not statistically different from the responses of single pass-through channels.

Table 4: Response of markups to the exchange rate shock for large firms combined with another firm-level feature

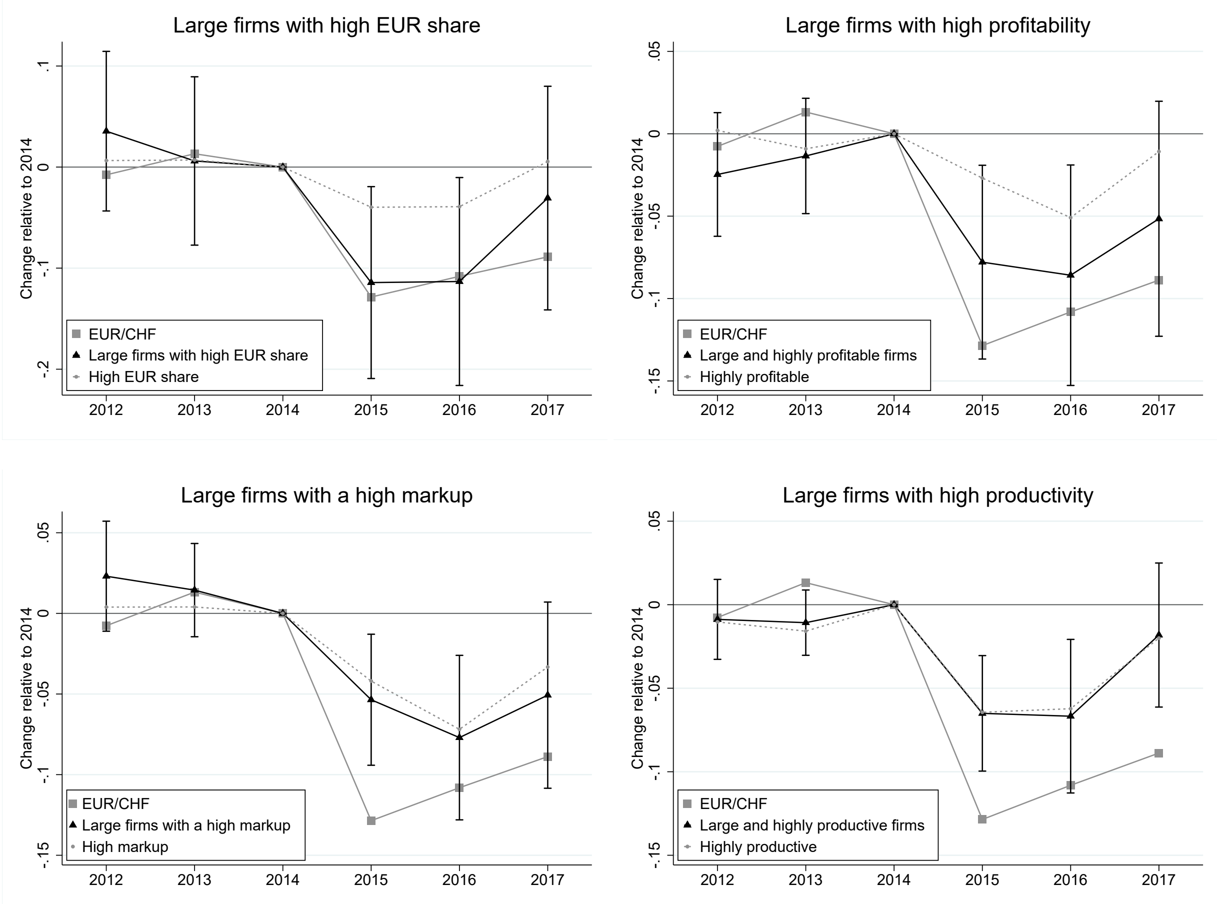
	(1) large and high markup	(2) large and high EUR share	(3) large and high profitability	(4) large and high productivity
Panel 1) Total response of markups relative to 2014				
$(\gamma+\psi+\phi+\chi)_{2012}$	0.023	0.036	-0.025	-0.009
$(\gamma+\psi+\phi+\chi)_{2013}$	0.014	0.006	-0.013	-0.011
$(\gamma+\psi+\phi+\chi)_{2015}$	-0.054**	-0.114**	-0.78**	-0.065***
$(\gamma+\psi+\phi+\chi)_{2016}$	-0.077**	-0.113*	-0.86**	-0.067**
$(\gamma+\psi+\phi+\chi)_{2017}$	-0.051	-0.031	-0.052	-0.018
Panel 2) Total implied exchange rate elasticity				
2015	0.417	0.889	0.606	0.506
2016	0.713	1.047	0.794	0.617
Panel 3) Difference in elasticity compared to that of a single channel				
2015	0.090	0.580	0.397	0.005
2016	0.047	0.685	0.323	0.041

Notes: Panel 1) on the top shows the estimated average response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014, for large firms with a further firm-level feature. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variances and covariances of the coefficients γ_{year},ψ_{year},ϕ_{year},χ_{year}. Panel 2) reports the total implied exchange rate elasticity in 2015 (2016), which is computed by dividing the total response in 2015 (2016) relative to 2014 by the change in EUR/CHF exchange rate 2015 (2016) relative to 2014. Panel 3) reports the increase in implied elasticity between a single channel and the combined channels. Table 16 in the Appendix reports the full results of Equation (3).

are such firms for the whole economy? Large firms are defined as the 20% largest firms in terms of revenue. 7.6% of all firms in the sample, i.e., over one-third of large firms, either invoice a high share of their sales in EUR or are highly profitable. Their aggregated revenue amounts nearly to half of total revenue, 48% (see Table 8 in Section C.2 in the Appendix). This indicates that the response of such firms is economically relevant.

Thus, while smaller firms are in the majority and shape the mean response, large firms with an unhampered pass-through have a strong influence on the aggregate development

Figure 5: Response of markups to the exchange rate shock for large firms combined with another firm-level feature



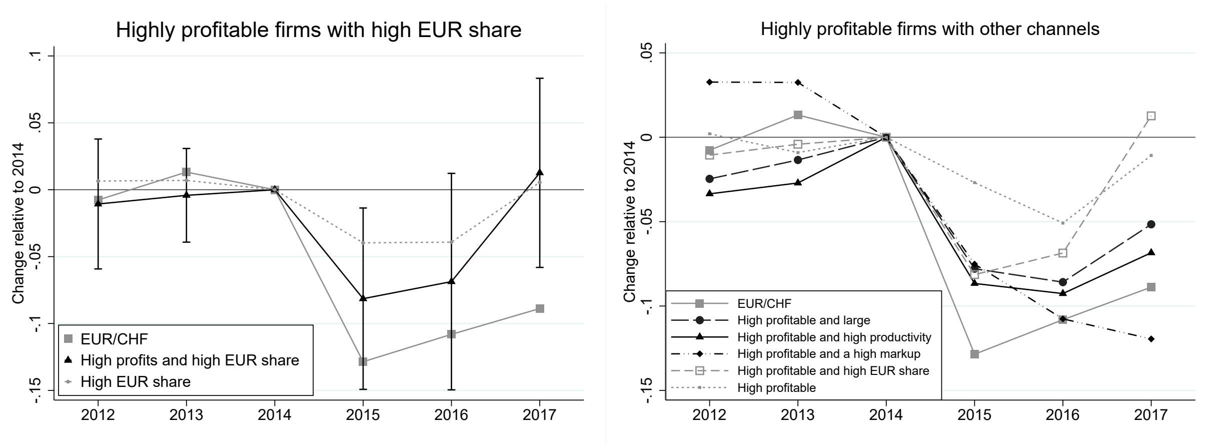
Notes: The black lines show estimates of the combined response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014, measured as the sum of γ_{year},ψ_{year},ϕ_{year} and χ_{year}. The vertical bars denote the 90% confidence intervals, which are derived from the variances and covariances of the estimated coefficients. The grey line is the change in the EUR/CHF exchange rate relative to 2014. The dotted grey lines are the estimates of the single channel.

of markups.[29] These findings are in line with Gabaix (2011), who with respect to aggregate growth, shows that the development of the largest firms has a substantial impact on aggregate variation.

For completeness, the combined responses of highly profitable firms are shown in Figure 6. The chart on the left depicts the response of highly profitable and firms invoicing strongly in EUR. The chart on the right shows the response with the other features.

[29]Section C.3 in the Appendix compares the development of markups of the large firms with the rest of the sample and shows the estimated response of small firms, firms invoicing in domestic currency and low-profit firms. The estimated coefficients confirm that firms subject to strong frictions tend to leave their markup stable or even raise them in a crisis to preserve internal liquidity even at the cost of losing market share.

Figure 6: Response of markups to the exchange rate shock for highly profitable firms combined with another firm-level feature



Notes: The black lines show estimates of the combined response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014, measured as the sum of γ_{year},ψ_{year},ϕ_{year} and χ_{year}. The vertical bars denote the 90% confidence intervals, which are derived from the variances and covariances of the estimated coefficients. The grey line is the change in the EUR/CHF exchange rate relative to 2014. The dotted grey lines are the estimates of the single channel.

The robustness of the results is tested using several variations of the baseline specification. These robustness tests are reported in Appendix D. First, the sample is reduced to firms having at least one observation in the period before and at least one observation in the period after the shock, i.e., firms that only have observations in the post-shock period are dropped. Second, probability weights are calculated using the number of firms in the true universe and the number of firms in the survey sample. With these weights, the impact of the sampling bias is tested. In a third test, sector-time effects are added to the regression. Fourth, the baseline regression is estimated with clustered standard errors based on full-time-employment, revenue and sector cells. Fifth, a robustness test is conducted in which firms are classified by their sales share stemming from sales to the euro area instead as their share of sales invoiced in EUR. The results of these tests show that the baseline estimates remain robust to changes in specification.

In summary, the empirical results show that markups respond very heterogeneously to an exchange rate shock depending on firm-specific characteristics. Large firms invoicing in EUR and large, highly profitable firms strongly adjust their markup following an exchange rate shock. It is, however, not possible to distinguish whether this is because large firms are also highly productive or have a high markup. In contrast, the average firm does not respond significantly to a change in the exchange rate implying that smaller firms, which account for the lion's share of firms, are not willing or not able to vary their markup following an exchange rate shock.

6 Conclusions

This paper documents the pass-through of an adverse exchange rate shock to firm-level markups. In particular, the heterogeneity of the response is analysed using five firm-specific characteristics: size, invoicing currency, profitability, productivity and the level of markup. Markups are estimated using firm-level data from balance sheets and income statements of Swiss manufacturing firms for the period 2012-2017 following the production approach described in De Loecker and Warzynski (2012). The data are matched with firm-level export and import statistics, making it possible to include the invoicing currency of firms in the analysis. In addition to the data, a key ingredient in the analysis is the exchange rate shock of 15 January 2015, which provides a perfect setting to estimate the causal impact of an exchange rate shock on firms' markups.

The results provide strong evidence that the response is very heterogenous across the different types of firms. While smaller firms leave their markup unchanged, the elasticity of large firms is estimated to be approximately 40%. Moreover, the combined regressions show that if large firms are also highly profitable, the markup pass-through increases to nearly 80% and is practically complete if large firms also invoice a large share of their sales in EUR. These results suggest that large firms exhibit strong strategic complementarities and are capable of unconstrained markup adjustment. Smaller firms, in contrast, are less able to adjust their markup, for example because they have to preserve internal liquidity even at the cost of losing market share. Although such firms are in the majority, large firms with an unhampered pass-through have a strong influence on aggregate development owing to their sheer size.

The combined regressions for highly productive firms or firms with a high markup show that the response is not amplified if they are also large. This indicates that these three features are not independent of each other. With the data set, it is however not possible to distinguish which of the three features (size, productivity or high markup level) is the cause of the pass-through

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Appendix to "The impact of exchange rate fluctuations on markups"

A Estimating Markups

In monopolistic competition, the demand curve for a product is not perfectly elastic, and the profit-maximizing firm has market power and is able to influence the price of its products. The firm's marginal revenue curve is downward sloping and lies under the average revenue curve. The firm will set its output at the point where its marginal revenue equals its marginal costs. The price at which this output quantity is sold (i.e., the average revenue) is above the firm's marginal costs. The markup, defined as the wedge between sale prices and marginal costs of production, is greater than one.

As markups are not directly observable, they have to be estimated. In this paper, markups are estimated with the production approach developed by De Loecker and Warzynski (2012), which relies on the idea that under any form of imperfect competition, price does not equal the marginal cost of production, and output elasticity does not equal its expenditure share. Markups are defined as the output elasticity of a variable input divided by the input share of this input and this ratio is larger than one when a firm has a certain degree of market power. With this method, it is possible to estimate firm-level markups without any detailed price data and without having to define any form of price competition among firms. Two assumptions, however, have to be made. First, it is assumed that an input of production can be adjusted without friction, and second, it is assumed that firms optimise their production by minimizing their costs.

Following De Loecker and Warzynski (2012), labour is the variable input. Firms' output, Q_{it}, is produced using capital, K_{it}, labour, L_{it}, and intermediate inputs, M_{it}, given firms' productivity level, ω_{it}. Applying cost minimization conditions, firms optimize their output with the following Lagrangian function:

$$L(K_{it}, L_{it}, M_{it}, \lambda_{it}) = r_{it}K_{it} + w_{it}L_{it} + P_{it}^{M}M_{it} + \lambda_{it}(Q_{it} - f(K_{it}, L_{it}, M_{it}, \omega_{it}) \tag{4}$$

where r_{it}, w_{it} and P_{it}^{M} are the rental rate of capital, the wage rate and the price of intermediate goods, respectively. The first-order conditions for the variable input labour can be rearranged to:

$$\lambda_{,t}\frac{\partial f(K_{it}, L_{it}, M_{it}, \omega_{it})L_{it}}{\delta L_{it}Q_{it}} = \frac{w_{it}L_{it}}{Q_{it}} \tag{5}$$

λ_{it} is the cost of producing one more unit of Q_{it}, i.e., the marginal cost of production for a given level of output. In the context of imperfect competition, firms can generate a markup and set their price higher than their marginal costs. In this case, $\lambda_{it} = \frac{P_{it}}{\mathcal{M}_{it}}$, and the markup, $\mathcal{M}_{it}$, is greater than one.

The second term on the left-hand side of Equation (5) is the output elasticity of labour. Denominating the output elasticity of labour as θ_{it}^{L} and rearranging terms, markups can therefore be defined as the output elasticity of labour multiplied by the inverse of the labour share in total revenue, S_{it}^L:

$$\mathcal{M}_{it} = \theta_{it}^L \frac{P_{it}Q_{it}}{w_{it}L_{it}} = \theta_{it}^L {S_{it}^L}^{-1} \tag{6}$$

While the labour share can be taken directly from the firm data, the output elasticity has to be estimated by means of a production function. To do so, the method described in De Loecker and Warzynski (2012) is followed closely. A key issue is the simultaneity problem, which arises because TFP affects input amounts, which flows into production: Firms set their optimal level of labour, capital and material inputs depending on their level of TFP, which they themselves know although it is unobservable to the statistician. A productivity shock potentially influences the optimal amount of input factors and lead to a bias in the estimated markup. Thus, in the production function, one has to control for productivity. This is done by using material inputs, which are used to proxy for the unobserved TFP.[30] Furthermore, the exchange rate enters the regression to control for the impact of changes in the exchange rate, the focus of this paper. The estimation is done using standard GMM techniques and a translog production function, by NACE 2-digit subsector, by year. This enables to estimate individual firm-level output elasticities, making it possible to capture the heterogeneous factor input intensity between firms.

B Data description

B.1 Input data for the estimation of markups

The labour share, S_{it}^L, is computed in nominal terms as the wage sum divided by revenue, whereby both variables are taken directly from firms' income statements. The variables entering the estimation of the firm-level output elasticity of labour, θ_{it}^L, are defined in physical terms. Labour is measured by full-time-equivalent employment and therefore does not need to be deflated. In the data set, revenue and intermediate goods are however only available in nominal terms and are deflated with the respective subsector NACE 2-digit deflators from the national accounts.[31] As the reference dates of balance sheet variables, such as the capital stock, are set at the end of the reporting period, these variables are taken from the data set in $t-1$. Therefore, k_{it} is the capital stock reported at the end of the previous reporting period. The capital stock is deflated with the capital stock deflator taken from the national accounts.

Table 5 lists the definition and the source of the variables used for the estimation of the markups.

[30] The method developed in De Loecker and Warzynski (2012), with which productivity is controlled for, relates to previous work done by various authors such as Hall et al. (1986), Olley and Pakes (1992), Levinsohn and Petrin (2003), Ackerberg et al. (2006) and Wooldridge (2009).

[31] See the discussion in Section 3.2

Table 5: Definitions and sources of input variables

	Definition	Source
Variables used for the calculation of the labour share		
$P_{it}Q_{it}$	Revenue (nominal)	Value-added statistics
$w_{it}L_{it}$	Wage sum (nominal)	Value-added statistics
Variables used for the estimation of labour output elasticity		
Y_{it}	Sales, nominal revenue, deflated with the sub-sector production deflator	Value-added statistics, national accounts
K_{it}	Capital stock of the previous year, deflated with the capital stock deflator	Value-added statistics, national accounts
L_{it}	Employment, full-time equivalent	Value-added statistics
M_{it}	Material expenditure, deflated by the sub-sector intermediate goods' deflator	Value-added statistics, national accounts

Notes: The value-added statistics and data from the national accounts are provided by the SFSO. The wage sum is the sum of wages, expenditures for temporary work and ancillary wage costs.

Table 6 lists some sample statistics of the value-added statistics data set by sub-sector. The number of observations per sub-sector and their share are listed in the first two columns. In the third column, the number of firms by sub-sector are shown. In the last two columns, the average revenues per sub-sector are listed. The average revenue varies strongly between the sub-sectors, and the differences between the mean and the median are very large. This reflects the high heterogeneity throughout the Swiss manufacturing sector.

Table 6: Sample statistics by sub-sector, 2012-2017

	Observations		*Firms*	*Revenue*	
	number	share in %	number	mean	median
Food, Tobacco	1162	11.4	311	98227	26606
Textiles	395	3.9	100	21871	10866
Wood	316	3.1	93	28508	15829
Paper	265	2.6	59	45577	19018
Print	322	3.2	87	23998	14280
Chemicals	608	6.0	147	129313	36693
Pharmaceuticals	368	3.6	81	943894	50428
Plastics	548	5.4	131	46288	24407
Glass	402	4.0	102	57523	29737
Basic metals	378	3.7	80	55527	14636
Metal products	1095	10.8	256	35123	21714
IT Watches	1305	12.8	287	174298	38447
Electrical	456	4.5	111	124630	53925
Machines	1630	16.0	380	76631	34904
Vehicles	340	3.3	83	92279	13180
Furniture	261	2.6	70	24289	16856
Other	307	3.0	84	81702	22504
Total	10158		2462	113950	26111

Notes: The sub-sectors are defined according to the NOGA classification as follows (NOGA code in parentheses): Food, Tobacco: Manufacture of food products, beverages, tobacco products (10-12). Textiles: Manufacture of textiles, wearing apparel, leather products (13-15). Wood: Manufacture of wood products except furniture (16). Paper: Manufacture of paper and paper products (17). Print: Printing and reproduction of recorded media (18). Chemicals: Manufacture of chemicals, coke and refined petroleum products (19-20). Pharmaceuticals: Manufacture of pharmaceutical products (21). Plastics: Manufacture of rubber and plastic products (22). Glass: Manufacture of other non-metallic mineral products (23). Basic metals: Manufacture of basic metals (24). Metal products: Manufacture of fabricated metal products, except machinery and equipment (25). IT Watches: Manufacture of computer, electronic and optical products, including watches (26). Electrical: Manufacture of electrical equipment (27). Machines: Manufacture of machinery and equipment n.e.c. and repair and installation of machinery and equipment (28+33). Vehicles: Manufacture of motor vehicles and other transport equipment (29-30). Furniture: Manufacture of furniture (31). Other: Other manufacturing (33).

B.2 Export and import data

Export and import data are used to compute firms' share of sales invoiced in EUR as well as firms' import shares that are used to construct the firm-specific intermediate input price index and firms' export shares to construct the firm-specific foreign demand index. As firm-level export and import data only exist from 2016 onward, the matching of the export and import data with the income-statement data is only possible for 2016 and 2017. For these two years, the two data sets are merged, and firms' share of sales invoiced in EUR is computed as an average over both years.

The export and import data set covers the full population of firms, which exported or imported goods in 2016 or 2017. Hence, firms, which are in the income statement data set in 2016 and 2017 but not in the export and import data set, are defined to have a share of sales invoiced in EUR of zero and no imports of intermediate goods.

A first problem may arise because the assumption that the share of sales invoiced in EUR is constant throughout the estimation period may be wrong, failing to capture eventual shifts in weights due to the exchange rate shock. This may be a problem for two reasons: First, if the shifts were heterogeneous across firms, some firms could be classified incorrectly as having one of the 20% highest share of sales invoiced in EUR in the years preceding the shock. However, while this may occur for a few firms at the margin, one can assume that the bulk of firms with a high share of sales invoiced in EUR in the period preceding the shock were also those with a high share following the shock. Therefore, one can assume that the impact on the estimated pass-through is small and not biased in a given direction. The literature justifies this assumption. Amiti et al. (2014), who measure the pass-through of an exchange rate shock into sale prices with Belgian data, confirm that import shares invoiced in a given currency prove to be very persistent over time, even following a sharp exchange rate shock. Actually, although they could use a time-variant measure of import share in their baseline specification, they replace it with a time-invariant measure arguing that in this way the measurement error can be reduced while their results are little affected by this choice.[32] Second, the import shares used to weight the foreign PPI in the firm-specific material cost index may not be correct in the years before 2016. However, as material prices were more or less flat in the years preceding the exchange rate shock (see Figure 3), a bias in the weights in the years before the shock probably have only a minor impact on computed material cost index.

A second problem refers to the sample of firms. The value-added data set, with which markups are estimated, is an unbalanced panel and a comprehensive draw from the whole population. The SFSO collects data for all large firms on an annual basis. Smaller firms, however, are subject to a gradual turnover. Every year the SFSO replaces some of them with firms from the same industry and similar characteristics. For the years 2012-2015, all firms that are not in the income statement data set in 2016 or 2017, are dropped because it is not possible to compute their share invoiced in EUR. In 2015, 2552 firms of total 11,761 firms were dropped because they were not in the sample in 2016 or 2017. While the number of observations remains high, the draw tends however to be tilted towards larger firms between 2012 and 2015.

[32] Furthermore, the Swiss export data used by Auer et al. (2019), which stretches from 2013 to 2015, show that, at least at the aggregate level, the shares of exports invoiced in CHF, EUR or USD were exceptionally stable before and after the EUR/CHF shock.

B.3 Control variables

B.3.1 Firm-specific intermediate input price index

The firm-specific intermediate input price index, which excludes the impact of the appreciation of the Swiss franc against the euro (see Section 4.4) is constructed as follows:

$$Price_{i,t}^{Interm} = \sum_c PPI_{c,t}^{For} Share_{c,i}^{Imp} + PPI_t^{Dom} Share_i^{Dom}$$

The foreign producer price indices, $PPI_{c,t}^{For}$, are taken for five regions: the euro area, non-euro European countries, USA, China and the rest of the world. $PPI_{c,t}^{For}$ is denominated in the respective foreign currency. The producer price index of the non-euro European countries is a weighted average of the country-level producer prices, whereby the country weights are the respective GDP shares. The producer price index for the rest of the world is constructed in the same manner and contains the producer price indices of four countries: Russia, Brazil, India and Japan.[33]

The second term proxies for the firm-specific cost of intermediate goods and energy goods bought on the domestic market. There exists a sub-index of the Swiss producer price index for both categories. PPI_t^M is constructed as a weighted average of the Swiss producer price indices for intermediate goods, PPI_t^{Interm}, and energy, PPI_t^{Engy}. The weights $weight_t^{Interm}$ and $weight_t^{Engy}$ are taken from the Swiss PPI index. PPI_t^{Engy} is multiplied by 18.4%, the share of total energy purchased by the manufacturing sector:[34]

$$PPI_t^M = PPI_t^{Interm} \frac{weight_t^{Interm}}{weight_t^{Interm} + weight_t^{Engy} * 0.18} + PPI_t^{Engy} \frac{weight_t^{Engy} * 0.18}{weight_t^{Interm} + weight_t^{Engy} * 0.18}$$

A substantial part of the goods included PPI_t^M have been imported, for example oil or gas, and bought from a domestic intermediary. To extract the variation in the EUR/CHF exchange rate that is contained in this domestic intermediate goods index, its quarter-on-quarter change is regressed against the quarter-on-quarter change in the EUR/CHF exchange rate. The variation in the domestic intermediate goods index that can be explained by the variation in the EUR/CHF exchange rate is then deduced from PPI_t^M, leaving us with PPI_t^{Dom}, which is used as a proxy for the price of intermediate goods, which firms have bought on the domestic market, in the definition above.

The intermediate goods price index enters the control function, X_{it} in Equation (2) as the cumulated change relative to 2014.

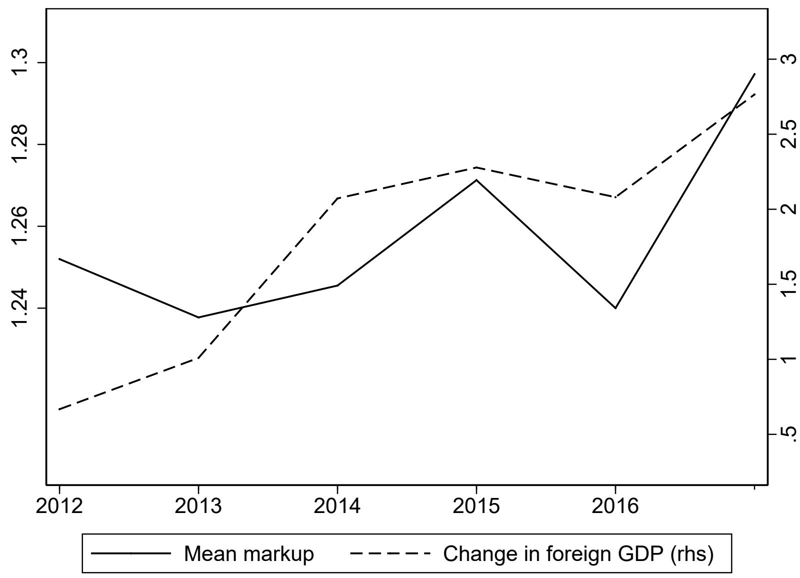
[33] All PPI data is provided by Datastream

[34] https://www.bfe.admin.ch/bfe/de/home/versorgung/statistik-und-geodaten/energiestatistiken/gesamtenergiestatistik.html

B.3.2 Firm-specific foreign demand index

Shifts in demand could affect market conditions and change firms' scope to adjust prices. Goldfajn and Werlang (2000) show that in a boom, firms find it easier to increase sale prices, while in recessions, some firms tend to decrease prices. As domestic demand is endogenous to the exchange rate, foreign demand in foreign currency is taken to proxy for a demand shift. This is possible because Switzerland is a small open economy, highly dependent on foreign growth dynamics but having only a minor influence on them. Figure 7 depicts the mean markup over time (solid line) together with the growth in Swiss export-weighted foreign GDP (dashed line).

FIGURE 7: MARKUPS AND THE CHANGE IN FOREIGN DEMAND



Notes: The solid line shows the annual mean of the firm-specific markups. The dashed line shows the annual the change in the Swiss export weighted foreign GDP.

A control variable for firm-specific foreign demand is constructed, in which foreign GDP in USD is weighted by the firm-specific export share to that region:

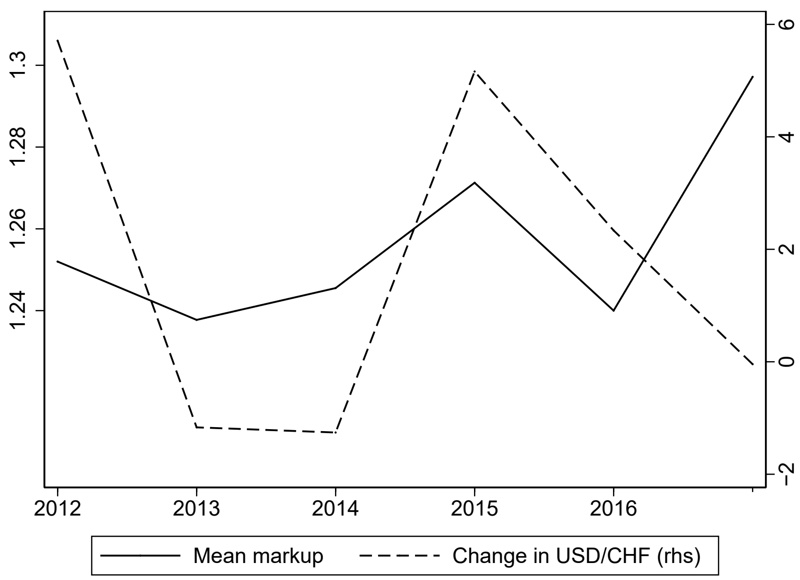
$$Demand_{i,t}^{Foreign} = \sum_c GDP_{c,t}^{USD} Share_{i,c}^{Exp}$$

The denomination in a common foreign currency ensure that, first, that the appreciation is extracted from the control variable and, second, that the contributions from each region can be added up. The export regions are the European countries, USA and China. Foreign demand enters the control function, X_{it}, as the cumulated change relative to 2014.

B.3.3 Firm-specific US dollar index

Although the US dollar is not a very important invoicing currency for Swiss firms, it may have had an impact on markups. Indeed, between 2012 and 2017, the USD/CHF exchange rate was not completely flat. In particular, in 2015, the USD appreciated against the CHF, leading to more favourable exchange rate conditions for firms exporting in US dollars and adverse conditions for firms importing in US dollars, as show in Figure 8.

FIGURE 8: MARKUPS AND THE CHANGE IN FOREIGN DEMAND



Notes: The solid line shows the annual mean of the firm-specific markups. The dashed line shows the annual the change in the USD/CHF exchange rate.

To control for this effect, a USD/CHF exchange index rate based on the firm-specific share of exports and imports in US dollars and defined as the change against 2014 has been introduced in the control function.

$$\Delta USD_{i,t} = \Delta USD/CHF_t Share_i^{Exp-USD} - \Delta USD/CHF_t Share_i^{Imp-USD}$$

However, as shown in Table 7, the US dollar is not a very relevant invoicing currency for the Swiss manufacturing sector. In the data sample used in this paper, the average share of exports in US dollars was only 4.4% over all firms. The share of imports in US dollars was on average 7.7%. In contrast, the share of exports in euros was on average 41.9% and that of imports was 81.4%. The figures on the right-hand side of the table show the average export and import shares not by firm but over all exports and imports respectively. These figures suggest that larger firms tend to trade more intensely in US dollars and less in euros than smaller firms.

Table 7: Share of exports and imports by currency, in %

	Average of firms' export shares	Average of firms' import shares	Share of all exports	Share of all imports
CHF invoiced	52.5	8.9	34.4	9.4
EUR invoiced	41.9	81.4	34.8	60.2
USD invoiced	4.4	7.7	10.9	17.1
ROW invoiced	1.2	2.0	19.8	13.3

Notes: Shares of exports by currency in total exports and shares of imports by currency in total, 2016-17, in the manufacturing sector.

B.4 Computation of weighted mean

Larger firms are well covered in firm-level data sets such as that used in this paper. Typically, over the course of time, firm coverage increases, and the share of small firms increases. As explained in Bajgar et al. (2019), the incomplete coverage of small firms and the shift over time can lead to biased aggregations. Using unbiased sub-sector weights from the national accounts in a two-step aggregation procedure helps mitigate this bias: First, a weighted mean is constructed at the sub-sector level, $\mathcal{M}_{jt} = \sum \mathcal{M}_{it} \frac{Revit}{Rev_{jt}}$. Rev_{it} is the revenue of firm i operating in sector j and $Revjt$ is the total revenue of sector j. Rev_{it} and Rev_{jt} are taken from the firm-level data. Second, the sub-sector weighted means are aggregated using sub-sector weights derived from the production data from the national accounts, $\mathcal{M}_t = \sum \mathcal{M}_{jt} \frac{Prod_{jt}}{Prod_t}$, where $Prod_{jt}$ is the nominal gross production of the manufacturing sub-sector j according to national accounts' data and $Prod_t$ is total nominal manufacturing gross production.

C Additional descriptive statistics

C.1 Explaining markups smaller than one

As shown in Figure 1, a surprising number of observations are estimated to have a less-than-unit markup, meaning that in these cases sale prices are lower than marginal costs. This phenomenon is not unique to Swiss data. Caselli et al. (2018), who estimate markups with approximately the same methodology as in this paper, find that in their sample of French manufacturing firms, approximately 14% of firms display less-than-unit markups, many of which for more than one year. Other papers note that this artefact (which they call "markdowns") also occurs in Indian and Mexican data with a fraction of 25% and 45% of observations, respectively. Caselli et al. (2018) show that markdowns can be linked to the irreversibility of investment, which may encourage firms to continue producing even if their prices fall below marginal costs. Young start-ups are a firm type that may often combine large investments and low or no profits. As young start-ups are typically small, this could explain why this phenomenon mostly occurs with small firms.

A further explanation for markups smaller than unit is that the level of the estimated markups in this paper is probably biased downwards because they are estimated with revenue instead of output data. Indeed, De Ridder et al. (2022) demonstrate using data on French manufacturing firms that aggregate quantity-based markups averages approximately 1.5, while aggregate revenue-based estimates lies at 1.1.

Another explanation is that firms may be able to operate for some years with prices being lower than their marginal costs because they are producing in a region where prices are still above their average total costs, i.e., in a region, where firms are making a loss per additional unit but are still making a profit on total production. Data on firms' annual firm total profits are included in the Swiss data set and confirm this hypothesis: 84% of all observations with below-unit markups reveal positive overall profits (earnings after subtracting all production costs, taxes and depreciation). Only 16% of observations with markups below unit report overall losses. This corresponds to 6.3% of all observations in the sample.

C.2 Intersection statistics

In Table 8, the share of large firms and firms invoicing highly in EUR are shown. In addition to the share of observations, the share of total revenue is shown to highlight the relevance of large firms for the total economy.

The upper 20% of large firms account for 81% of total revenue. Firms that adjust their markup substantially, i.e., large firms, which either invoice a high share of their sales in EUR or are highly profitable, account for only 7.6% of all observations in the sample but for 48% of total revenue. Such firms are therefore economically relevant.

Regarding the decomposition of large firms, the table shows that most large firms are also highly productive firms (93.5%) and often have a high markup (40.5%). These large intersections explain why the pass-through elasticity of large firms which are highly productive or have a high markup hardly increases compared to the average pass-through of large firms (see Table 4, panel (3)). In contrast, the intersection of large firms with high profits amounts only to 29.1%, and only 13.3% large firms invoice a high share of their sales in EUR.

The lower part of Table 8 depicts the decomposition firms invoicing highly in EUR. The intersections with the other features are small, at a maximum of 21.8% for firms that are also highly profitable. This reflects the fact that the exporting segment of the Swiss manufacturing sector is very heterogeneous and not dominated by a specific type of firm.

Table 8: Share of large firms and firms highly invoicing in EUR, in %

	Share of observations	Share of revenue
Share of whole sample		
Large	20.0	81.0
Large and high EUR or high profitability	7.6	48.2
Decomposition of large firms		
Large and high EUR	13.3	13.8
Large not high EUR	86.7	86.2
Large and high profitability	29.1	53.2
Large and not high profitability	70.9	46.8
Large and high markup	40.5	61.4
large and not high markup	59.5	38.6
Large and high productivity	93.5	98.7
Large and not high productivity	6.5	1.3
Large and EUR or high profitability	37.9	57.4

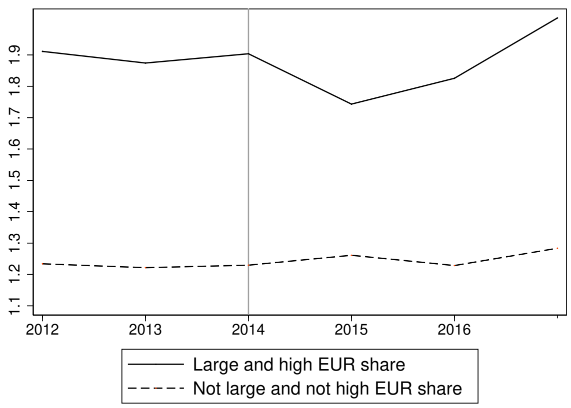
Share of whole sample		
High EUR	20.0	15.5
High EUR and large or high profitability	5.8	12.4
Decomposition of high EUR firms		
High EUR and large	13.3	73.9
High EUR and not large	86.7	26.1
High EUR and high profitability	21.7	56.6
High EUR and not high profitability	78.3	43.4
High EUR and high markup	19.1	56.4
High EUR and not high markup	80.9	43.6
High EUR and high productivity	13.6	74.1
High EUR and not high productivity	86.4	25.9
High EUR and large or high profitability	30.4	79.2

Notes: The shares are shown for the year 2014. The firms in the upper fifth of the distribution are labelled "Large" when ranked by size, "high EUR" when ranked by share of sales invoiced in EUR, "high profitability" when ranked by profitability, "high markup" when ranked by level of markup, and "high productivity" when ranked by TFP. The labels labelled with "not" contain the firms in the lower 80% of the distribution.

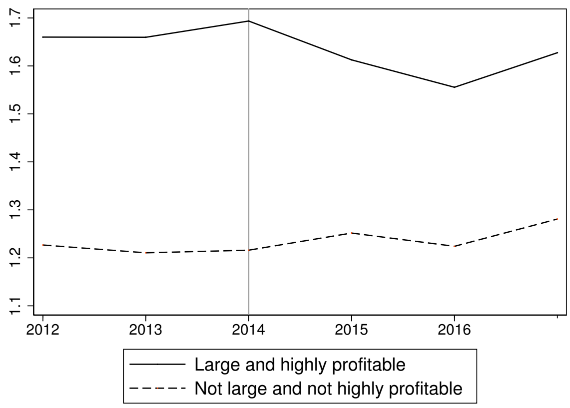
C.3 Markups of large and non-large firms

Figure 9 displays the annual development of the unweighted mean markup of large firms that invoice a high share of their sales in EUR (left chart, solid line) and are highly profitable (right chart, solid line). For comparison, the mean markup of the rest of the sample (dashed line) is shown. The mean markup of the large firms which strongly invoice in EUR and the large and profitable firms is clearly higher than that of the rest of the sample. Moreover, such firms reacted to the exchange rate shock by strongly decreasing their markup.

FIGURE 9: UNWEIGHTED MEAN MARKUP OF LARGE FIRMS THAT HIGHLY INVOICE IN EUR OR ARE HIGHLY PROFITABLE



(a) Large and high EUR share



(b) Large and highly profitable

In Table 9, the response of markups to the exchange rate shock for the fifth smallest firms, for the firms with the fifth lowest share invoiced in EUR and for the fifth lowest profitability are shown. For 2015, the signs of the coefficients are in four of five cases positive. However, none of them is significantly different form zero. These estimates indicate that firms subject to strong frictions tend to leave their markup stable or even raise them in a crisis to preserve internal liquidity even at the cost of losing market share. These results confirm the findings of Gilchrist et al. (2018).

Table 9: Response of markups of small firms, firms with small EUR share and low-profitability firms

	(1) small firms	(2) low EUR share	(3) low EBIT	(4) small and low EUR	(5) small and low EBIT
Panel 1) Total response of markups relative to 2014					
2012	-0.025	-0.002	0.007	-0.044	-0.019
2013	-0.005	-0.009	-0.008	-0.003	-0.020
2015	0.013	-0.003	0.015	0.008	0.035
2016	-0.023	-0.019	0.004	-0.018	0.014
2017	0.006	0.019	0.055	-0.015	0.016

Notes: The results in this table are for the lowest fifth of the distribution for size, share invoiced in EUR and profitability. The p-values are based on heteroskedasticity- and autocorrelation-consistent standard errors and denoted as ***$p < 0.01$, **$p < 0.05$, and *$p < 0.1$.

D Robustness tests

D.1 Sample reduced to firms having observations before and after the shock

As described in Section B.2, the data set is an unbalanced panel, meaning that not every firm is observed for all years. The following table shows the response of markups using a reduced sub-sample of firms, which have at least one observation in the period before and at least one observation in the period after the shock, i.e., firms that only have observations in the post-shock period have been dropped. In all, 11.7% of the observations included in the baseline regressions have been dropped from the sample. A comparison with the figures in the last column of Table 2 and the corresponding columns of Table 3 and Table 4 shows that the exclusion has little impact on the level of the coefficients. In contrast to the baseline estimates, however, the coefficients of specification (2) and (4) are not significant in 2016.

Table 10: Response of markups using a sample only including firms with at least one observation before and after the shock

	(1) all firms	(2) large firms	(3) high EUR share	(4) high EBIT	(5) large and high EUR share	(6) large and high EBIT
Panel 1) Total response of markups relative to 2014						
2012	0.004	0.001	0.007	0.004	0.036	-0.023
2013	-0.003	-0.003	0.007	-0.009	0.007	-0.014
2015	-0.004	-0.050**	-0.038*	-0.023	-0.112*	-0.75**
2016	-0.016	-0.044	-0.043	-0.046*	-0.110*	-0.82*
2017	0.024	-0.000	0.012	-0.008	-0.029	-0.049
Panel 2) Total implied exchange rate elasticity						
2015		0.386	0.297	0.183	0.276	0.583
2016		0.405	0.617	0.426	0.393	0.754
Observations	8914	8914	8914	8914	8914	8914

Notes: The results in this table are based on a sample only including firms that have at least one observation in the years before the shock and one observation in the years following the shock. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variance-covariance matrices.

D.2 Estimation including sector-time effects

Table 11 shows the response of markups estimated with a regression including sector-time effects. The pattern of the estimated responses is similar to that of the baseline. The coefficients are, however, somewhat lower. The implied elasticity of large firms with a high share of sales invoiced in EUR in 2015 was 78% and that of large and profitable firms was 46%. In the baseline specification, the estimated elasticities are 89% and 61%, respectively. These results indicate that the baseline results include a small effect due to time-variant, sector-specific factors. The reason is, however, not clear. The lower response may be due to sector-specific issues, which were independent of changes in the exchange rate. They could, however, simply indicate that certain sectors reacted to the exchange rate shock in 2015 and 2016 more strongly than others because of factors other than firm size, share invoiced in EUR and profitability.

Table 11: Response of markups including sector-time effects

	(1) all firms	(2) large firms	(3) high EUR share	(4) high profit.	(5) large and high EUR share	(6) large and high EBIT
Panel 1) Total response of markups relative to 2014						
2012	0.028**	0.018	0.022	0.026	0.014	-0.018
2013	0.005	0.002	0.007	-0.003	-0.011	-0.019
2015	0.001	-0.043***	-0.024	-0.016	-0.100**	-0.059**
2016	-0.016	-0.037**	-0.022	-0.040**	-0.89**	-0.055
2017	0.000	-0.008	-0.016	-0.020	-0.038	-0.025
Panel 2) Total implied exchange rate elasticity						
2015		0.336	0.184	0.122	0.779	0.456
2016		0.343	0.203	0.373	0.825	0.506

Notes: The results in this table are estimated with sector-time effects included in the regressions. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variance-covariance matrices.

D.3 Clustered standard errors

In the baseline specification, standard errors are clustered at the firm level because many firms are observed over several periods. An alternative clustering has been tested: In Table 12, standard errors are clustered by revenue size because this is a key level of treatment in this analysis. The revenue size cells are additionally subdivided by sector-groups as firms of the same sub-sector group may be related to each other and by full-time-employment groups as firms of a given sub-sector are sampled based on their number of employees (see Footnote 11). For most specifications, the significance of the response remains the same as in the baseline estimation, except for large firms in 2016, specification (2), and firms with a high share of sales invoiced in EUR in both 2015 and 2016, specification (3). The response of large and firms with a high share of sales invoiced in EUR is however just as significant as in the baseline estimation.

Table 12: Estimates of clustered standard errors based on full-time-employment, revenue and sector cells

	(1) all firms	(2) large firms	(3) high EUR share	(4) high EBIT	(5) large and high EUR share	(6) large and high EBIT
Panel 1) Total response of markups relative to 2014						
2012	0.001	-0.000	0.006	0.002	0.036	-0.025
2013	-0.004	-0.003	0.007	-0.009	0.006	-0.013
2015	-0.007	-0.053**	-0.040	-0.027	-0.114**	-0.078*
2016	-0.021	-0.048	-0.039	-0.051*	-0.113*	-0.086*
2017	0.000	-0.003	0.006	-0.011	-0.031	-0.052
Panel 2) Total implied exchange rate elasticity						
2015		0.413	0.309	0.209	0.889	0.606
2016		0.448	0.362	0.471	1.047	0.794

Notes: The estimates in this table are estimated clustered by full-time-employment, revenue and sector. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variance-covariance matrices.

D.4 Sampling bias

As described in Section 3.2, the draw of the value-added data set is tilted towards larger firms. For five full-time-employment size classes, weights have been calculated using the number of firms in the true universe and the number of firms in the survey sample.[35] With these weights, it is possible to test how strongly the estimated coefficients are biased due to the sampling bias.

Table 13 shows that the pattern of the estimated responses is similar to that of the baseline. However, as smaller firms, which tend to react less to an exchange rate shock have a higher weight, the estimated coefficients are somewhat lower and the standard errors somewhat higher. The implied elasticity of large and firms with a high share of sales invoiced in EUR in 2015 was 85% and that of large and profitable firms was 62%. In the baseline specification the estimated elasticities are 90% and 65%, respectively. These results show that the bias due to the sampling bias exists but is not very large.

Table 13: Response of markups using a weighted estimation to correct for sampling bias

	(1) all firms	(2) large firms	(3) high EUR share	(4) high EBIT	(5) large and high EUR share	(6) large and high EBIT
Panel 1) Total response of markups relative to 2014						
2012	0.005	0.001	0.012	0.005	0.036	-0.025
2013	-0.005	-0.002	0.007	-0.011	0.009	-0.015
2015	-0.004	-0.047**	-0.029	-0.027	-0.109**	-0.073***
2016	-0.011	-0.038	0.020	-0.040	-0.103	-0.078**
2017	-0.027*	0.004	0.020	-0.005	-0.027	-0.044
Panel 2) Total implied exchange rate elasticity						
2015		0.364	0.225	0.207	0.848	0.571
2016		0.355	0.201	0.366	0.949	0.718

Notes: This table shows estimated coefficients corrected for sampling bias. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variance-covariance matrices.

[35] This information is only available for 2019 and 2020. Given that the SFSO has not changed its sampling frame recently, it is assumed that the average weights of 2019-2020 were valid in 2012-2017.

D.5 Exports to euro area

In the baseline specification firms are classified as having a high share invoiced EUR if they belong to the upper fifth of firms having the highest share of revenue invoiced in EUR. One could however argue that all exports to the euro area are influenced by a change in the exchange rate, independent on the invoicing currency. Table 14 lists the estimated coefficients for the upper fifth of firms ranked by their share of revenue stemming from exports to the euro area.

The response with one interaction term, specification (1), is very similar to the baseline response. The estimated coefficients of the combined regression, specification (2), are somewhat higher, especially for the second year after the shock (2016). The results are similar because 87.3% of the firms with a high share invoiced EUR also belong to the upper fifth of firms ranked by their share of revenue stemming from exports to the euro area.

Table 14: Response of markups depending on their export share to the euro area

	(1) high export share to euro area	(2) large and high export share to euro area
Panel 1) Total response of markups relative to 2014		
2012	0.001	0.021
2013	-0.001	0.011
2015	-0.042*	-0.134**
2016	-0.045	-0.175***
2017	0.001	-0.061
Panel 2) Total implied exchange rate elasticity		
2015	0.324	1.045
2016	0.415	1.619

Notes: This table lists the response of the exchange rate shock of January 2015 into markups for export-intensive firms, whereby firms are classified by their export share to the euro area. The p-values denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$ are derived from the heteroskedasticity- and autocorrelation-consistent variance-covariance matrices.

E Full estimate results

Table 15 and Table 16 list the estimated coefficients of Equation (2) and Equation (3), respectively.

Table 15: Coefficients of Equation (2)

	large firms	high markup	high export share	high EBIT	high productivity
γ_{2012}	0.001	0.001	-0.001	0.001	0.004
	(0.006)	(0.006)	(0.007)	(0.007)	(0.006)
γ_{2013}	-0.005	-0.006	-0.006	-0.003	-0.002
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
γ_{2015}	0.006	0.007	-0.004	-0.002	0.009
	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)
γ_{2016}	-0.010	0.000	-0.023	-0.012	-0.006
	(0.022)	(0.022)	(0.023)	(0.022)	(0.022)
γ_{2017}	0.026*	0.037**	0.018	0.027*	0.030*
	(0.016)	(0.016)	(0.018)	(0.016)	(0.016)
ψ_{201}	-0.002	0.002	0.007	0.001	-0.014
	(0.015)	(0.014)	(0.015)	(0.014)	(0.015)
ψ_{2013}	0.002	0.010	0.013	-0.006	-0.014
	(0.013)	(0.011)	(0.013)	(0.011)	(0.013)
ψ_{2015}	-0.059***	-0.049***	-0.036**	-0.025	-0.073***
	(0.015)	(0.012)	(0.015)	(0.015)	(0.015)
ψ_{2016}	-0.039**	-0.072***	-0.017	-0.039**	-0.056***
	(0.018)	(0.015)	(0.018)	(0.019)	(0.018)
ψ_{2017}	-0.030	-0.070***	-0.012	-0.038*	-0.050**
	(0.022)	(0.019)	(0.020)	(0.021)	(0.022)
$\beta_{MaterialPrice}$	-1.302*	-1.157	-1.572**	-1.359*	-1.299*
	(0.706)	(0.718)	(0.775)	(0.720)	(0.708)
Constant	0.102***	0.102***	0.103***	0.102***	0.102***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Observations	10099	10099	10099	10099	10099
Fixed effects	yes	yes	yes	yes	yes

Notes: Estimated response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014. The p-values are denoted as $^{***}p < 0.01$, $^{**}p < 0.05$, and $^{*}p < 0.1$. Heteroskedasticity- and autocorrelation-consistent standard errors standard errors in parentheses.

Table 16: Coefficients of Equation (3)

	(1) large and high markup	(2) large and high export share	(3) large and high EBIT	(4) large and high productivity
γ_{2012}	0.005	0.001	-0.001	0.004
	(0.007)	(0.007)	(0.007)	(0.006)
γ_{2013}	-0.005	-0.008	-0.004	-0.002
	(0.006)	(0.006)	(0.006)	(0.005)
γ_{2015}	0.018	0.011	0.009	0.009
	(0.015)	(0.016)	(0.016)	(0.015)
γ_{2016}	0.006	-0.013	-0.004	-0.009
	(0.022)	(0.024)	(0.022)	(0.022)
γ_{2017}	0.039**	0.025	0.031*	0.029*
	(0.016)	(0.018)	(0.016)	(0.016)
ψ_{2012}	-0.016	0.002	0.014	-0.046
	(0.017)	(0.015)	(0.016)	(0.036)
ψ_{2013}	-0.001	0.015	-0.005	-0.102**
	(0.014)	(0.013)	(0.013)	(0.042)
ψ_{2015}	-0.050***	-0.039**		-0.069***
	(0.014)	(0.015)		(0.019)
ψ_{2016}	-0.073***	-0.013	-0.028	-0.005
	(0.017)	(0.018)	(0.019)	(0.034)
ψ_{2017}	-0.061***	-0.013	-0.023	-0.077
	(0.021)	(0.020)	(0.022)	(0.049)
γ_{2012}	-0.023	-0.006	0.010	0.006
	(0.018)	(0.016)	(0.018)	(0.039)
γ_{2013}	-0.014	0.005	0.005	0.004
	(0.017)	(0.014)	(0.015)	(0.059)
γ_{2015}	-0.068***	-0.060***	-0.051***	-0.010
	(0.018)	(0.015)	(0.015)	(0.030)
γ_{2016}	-0.030	-0.033*	-0.028	0.081**
	(0.023)	(0.019)	(0.020)	(0.040)
γ_{2017}	-0.013	-0.029	-0.013	0.026
	(0.027)	(0.024)	(0.025)	(0.049)
χ_{2012}	0.057*	0.040	-0.048	0.028
	(0.031)	(0.053)	(0.032)	(0.055)
χ_{2013}	0.033	-0.006	-0.010	0.089
	(0.028)	(0.056)	(0.030)	(0.074)
χ_{2015}	0.046*	-0.026	-0.024	0.005
	(0.028)	(0.059)	(0.038)	(0.038)
χ_{2016}	0.019	-0.054	-0.026	-0.134**
	(0.034)	(0.062)	(0.043)	(0.055)
χ_{2017}	-0.016	-0.013	-0.046	0.004
	(0.044)	(0.072)	(0.051)	(0.070)
$\beta_{MaterialPrice}$	-1.114	-1.489*	-1.266*	-1.326*
	(0.718)	(0.774)	(0.720)	(0.710)
Constant	0.102***	0.103***	0.102***	0.102***
	(0.004)	(0.004)	(0.004)	(0.004)
Observations	10099	10099	10099	10099
Fixed effects	yes	yes	yes	yes

Notes: Estimated response of log-markups to the exchange rate shock of 15 January 2015, relative to 2014. The p-values are denoted as $***p < 0.01$, $**p < 0.05$, and $*p < 0.1$. Heteroskedasticity- and autocorrelation-consistent standard errors standard errors in parentheses.

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BANCA NAZIUNALA SVIZRA
SWISS NATIONAL BANK