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THE SKILL-BIASED EFFECTS OF EXCHANGE RATE FLUCTUATIONS*

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This article examines the linkages between real exchange rate movements and firms' skill demand. Augmenting the model of Campa and Goldberg (2001) with heterogeneous labour, we show that exchange rate movements may affect unskilled workers differently than skilled workers because they change the relative price of imported inputs. Using panel data on Swiss manufacturers covering the period 1998–2012, we find that an appreciation increases high-skilled and reduces low-skilled employment in most firms. We present evidence consistent with our model that the skill-biased effects of exchange rates arise because unskilled labour is more substitutable with imported inputs than skilled labour.

A growing literature demonstrates that the effects of movements in real exchange rates on overall employment and wages are very heterogeneous across industries and firms (Campa and Goldberg, 2001; Klein *et al.*, 2003; Moser *et al.*, 2010; Nucci and Pozzolo, 2010, 2014). Much less is known about the heterogeneity of the exchange rate effects on employment and wages of workers with different skill levels within firms. Are high-skilled workers less exposed to exchange rate shocks than low-skilled workers? Does the relatively low responsiveness of total employment to real exchange rate movements established in previous firm-level studies hide the fact that exchange rates change firms' skill composition? To understand if and to what extent such distributional effects of exchange rate fluctuations exist is relevant not just for the individual worker. If an exchange rate appreciation mainly lowers employment of low-skilled workers with poor prospects of finding new jobs, the welfare consequences and the associated costs for social security systems may be more substantial than if skilled workers are dismissed.

This article examines the linkages between movements in the real exchange rate and skill-specific employment. We augment the model of Campa and Goldberg (2001) by incorporating heterogeneous labour and by introducing the possibility that unskilled workers and imported inputs are closer substitutes than skilled workers and imported inputs. This is a relevant extension since there is ample evidence that foreign input factors such as imported capital and imported intermediate inputs may complement high-skilled labour while potentially substituting low-skilled labour (Krusell *et al.*, 2000;

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Crinò, 2009; Burstein *et al.*, 2013; Hummels *et al.*, 2014). Our model implies that if imported inputs and unskilled labour are gross substitutes, an appreciation of the exchange rate leads to an increase in firms' skill intensity because it lowers the relative price of imported inputs.

Our empirical analysis studies the skill bias in the effects of exchange rate shocks in Swiss manufacturing firms. We rely on panel data based on the KOF innovation surveys covering the period 1998–2012. We capture exchange rate effects on firms' skill structure of employment by analysing whether firms that differ in their pre-existing degree of exchange rate exposure display systematic differences in adjusting their skill structure when affected by an exogenous exchange rate shock. The empirical strategy closely follows previous studies examining the effects of exchange rates on employment and wages in industries and firms. The most prominent paper is Campa and Goldberg (2001), who analyse the effects of real exchange rates on changes in net employment and wages in the US manufacturing sector using panel data on 20 two-digit industries from 1972 to 1995.[1] They find an average real wage elasticity to a permanent depreciation of the US Dollar of 0.06, while employment elasticities are close to zero. Nucci and Pozzolo (2010, 2014) extend their analysis using micro data of Italian manufacturers. They document that exchange rates have a considerable impact on wages, employment and hours worked by affecting firms' revenues and costs. But the overall elasticities of these outcomes to exchange rates are rather small for the average firm because the revenue and cost-side effects tend to offset each other. To the best of our knowledge, there is no study that focuses on how exchange rates affect workers with different skills.[2]

Analysing the case of Switzerland appears particularly interesting for two reasons. First, Switzerland is a small open economy with exports amounting to 52% of GDP in 2012. The average Swiss manufacturing firm therefore depends heavily on exports and, hence, is prone to movements in real exchange rates. Second, the Swiss franc acts as a safe haven currency. In periods of economic turmoil and increased uncertainty in financial markets, the Swiss currency can be subject to substantial movements which can be regarded as exogenous shocks to manufacturing firms. The exchange rate shocks are illustrated in Figure 1, which depicts the evolution of trade-weighted real effective exchange rates for Switzerland, the Euro area, the UK and the US. The Figure shows the strong and eventually fast appreciation of the Swiss franc relative to the currencies of Switzerland's main trading partners in the course of the sovereign debt crisis in the EU from 2009 onward. To prevent a further appreciation of the currency, the Swiss National Bank (SNB) introduced a ceiling on the EUR/CHF exchange rate in September 2011 that it entertained until January 2015.

[1] Other important earlier contributions on the relationship between exchange rates and employment are Revenga (1992) Burgess and Knetter (1998) and Gourinchas (1999).

[2] The studies of Campa and Goldberg (2001) and Nucci and Pozzolo (2010) both present regressions in which they interact the employment elasticity of the exchange rate with the initial share of non-college or blue-collar workers, respectively. In both cases, these worker characteristics have a quantitatively meaningful influence on the magnitude of the employment response to exchange rate movements. Yet, neither study examines this issue in more detail.

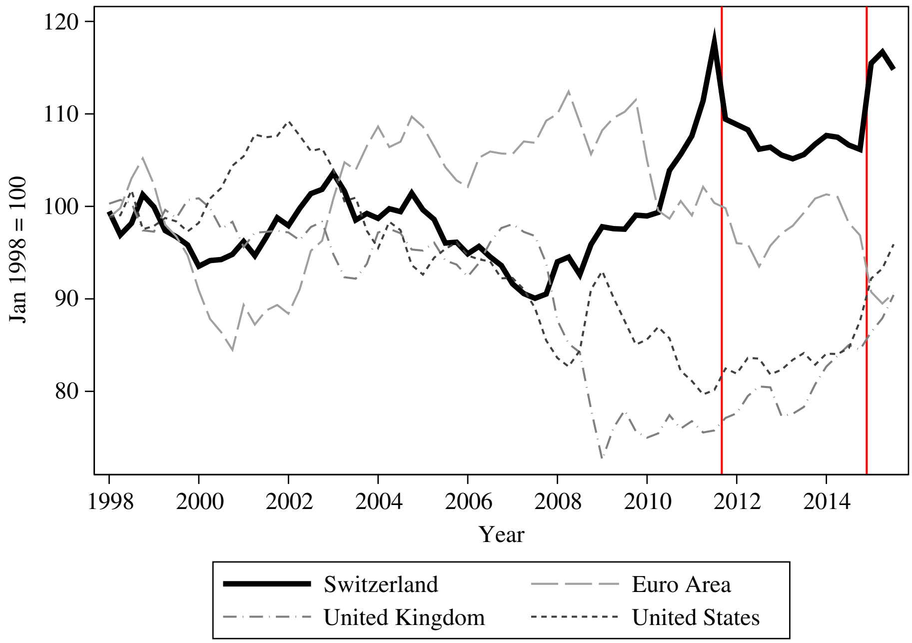

Fig. 1. *Trade-weighted Real Effective Exchange Rates for Selected Currency Areas*
Notes. The vertical lines mark the period during which the SNB entertained a ceiling on the Swiss franc relative to the Euro.
Source. BIS, 'broad' indices.

Our empirical results suggest that small effects of exchange rate movements on total employment in surviving manufacturing firms mask considerable differences in the effects on the employment of different types of workers. As implied by our simple theoretical model, we find that high-skilled workers clearly benefit from cheaper imported intermediate inputs as a result of an exchange rate appreciation, while low-skilled workers do not. On the other hand, changes in firms' revenues caused by exchange rate movements affect workers of different skill groups symmetrically. We present empirical evidence consistent with our model that the skill-specific effect on labour demand is driven by the larger substitutability between less-skilled workers and imported inputs. We also discuss the empirical relevance of two alternative mechanisms that may explain why exchange rate movements have asymmetric effects on workers with different skills: skill-specific adjustment costs and changes in firms' price competitiveness caused by exchange rates. Finally, in contrast to the firm-level analysis, we find no robust evidence for a skill bias in an industry-level analysis. This may be partially explained by the fact that the relative demand for skills on the industry level is affected by between-firm reallocation of resources which counteract the within-firm adjustments in the skill mix.

The remainder of this paper is organised as follows. In Section 1, we present a theoretical model to study the impact of exchange rates on firms' skill demand. Section 2 describes our econometric framework. Section 3 explains the data and presents descriptive statistics and Section 4 contains the results of our empirical analysis. Finally, Section 5 contains some concluding remarks.

1. Theoretical Background

1.1. *The Model*

To motivate our empirical analysis, this Section presents a straightforward modification of the model of Campa and Goldberg (2001) that incorporates heterogeneous labour and allows for effects of exchange rates on skill demand. In contrast to Campa and Goldberg (2001) and consistent with our empirical analysis, we abstract from adjustment costs and focus on the long-run labour demand of firms. To keep mathematical expressions as tractable as possible, we assume that firms produce final output using three inputs only: skilled labour (H), unskilled labour (U) and imported non-labour inputs (Z^*).[3] The factor prices associated with these input factors are wages of skilled workers (w^H), wages of unskilled workers (w^U) and the price of imported inputs in domestic currency (s^*/e), where e is the exchange rate expressed as the number of foreign currency units per unit of domestic currency. Firms operate in monopolistically competitive markets and maximise profits by choosing production for the domestic market (q), foreign markets (q^*) and their factor inputs, employing the following nested production function:

$$Q(H, U, Z^*) = q + q^* = H^\alpha \times [(\theta_1 U^\rho + \theta_2 Z^{*\rho})^{1/\rho}]^{(1-\alpha)}. \tag{1}$$

Under this production technology, the elasticity of substitution between imported inputs and unskilled labour ($\sigma = 1/(1-\rho) > 0$) is generally different from the elasticity of substitution between imported inputs and skilled labour. If $\sigma > 1$, imported inputs and unskilled labour are gross substitutes. A similar production function has recently been used by Hummels *et al.* (2014) to study the wage effects of offshoring.[4]

In Section B.1 of the online Appendix B, we show that unconditional log labour demand for skilled workers in this model can be expressed as:

$$\begin{aligned}\ln(H) = \ln\Bigg[&\frac{p^*(q^*, e)}{e}(1+\eta^{*-1})\chi + p(q, e)(1+\eta^{-1})(1-\chi)\\ &- w^U \frac{\theta_1(1-\alpha)}{\theta_1 + \theta_2\phi(e)^{\sigma-1}}\left(\frac{\partial Q}{\partial U}\right)^{-1} - \frac{s^*}{e}\frac{\theta_2(1-\alpha)}{\theta_1+\theta_2\phi(e)^{\sigma-1}}\left(\frac{\partial Q}{\partial Z^*}\right)^{-1}\Bigg]\\ &+ \ln(Q) - \ln(w^H).\end{aligned} \tag{2}$$

The terms in large brackets constitute the three channels of how exchange rates affect firms' labour demand highlighted by Campa and Goldberg (2001). The first term illustrates that exchange rates affect labour demand through firms' degree of export orientation. An appreciation (i.e. an increase in e) decreases labour demand because the firms' products become more expensive relative to the products of their foreign competitors in the export markets. This effect is more pronounced, the greater their

[3] Note that an extension which adds domestic non-labour inputs does not change the implications of the model.

[4] Because foreign non-labour inputs comprise imported capital goods, there also exists a close correspondence between the production function used here and the production functions employed to study capital-skill complementarity (Krusell *et al.*, 2000).

export share in total sales (χ) and the higher firms' price elasticity of foreign demand (η^*).[5] An appreciation also lowers labour demand because it raises the extent to which firms face import competition from foreign competitors in the domestic market. Equation (2) shows that the exposure of workers to this effect is determined by the domestic sales share $(1 - \chi)$ and by the price elasticity of domestic demand with respect to e, denoted η. The domestic pass-through elasticity, in turn, is proportional to the degree of an industry's import penetration *IP* (Campa and Goldberg, 2001). The last term in the brackets captures that an appreciation reduces production costs through cheaper imported inputs. The term $\theta_2(1 - \alpha)/(\theta_1 + \theta_2)$ reflects the cost share of foreign inputs and $\phi(e) = \theta_2 w^U/(\theta_1 s^*/e)$ is a weighted factor price ratio described below. If a firm has a high share of foreign inputs in total variable inputs (i.e. $\theta_2(1 - \alpha)/(\theta_1 + \theta_2)$ is large), it is hedged against fluctuations in the exchange rate, attenuating the effects of an appreciation on firms' demand for labour. This natural hedging of firms against exchange rate movements is an important factor in explaining low aggregate exchange rate effects on a range of economic outcomes (Amiti *et al.*, 2014).

1.2. *Exchange Rates and Skill Demand*

The transmission of exchange rate shocks to skill-specific labour demand is related to changes in the input mix caused by changes in relative factor prices. This channel enters the model through a factor price ratio that is increasing in the exchange rate: $\phi(e)$. The intuition is simple: an appreciation lowers the relative price of imported inputs and therefore induces firms to use relatively more of these inputs. This has two implications. First, an appreciation affects the skill intensity of firms – an effect that is captured by $\phi(e)$ in (2). If $\sigma > 1$, an appreciation lowers the demand for unskilled workers relative to the demand for skilled workers. The expression shows that the magnitude of this effect depends on the wage costs for unskilled workers w^U and the share of unskilled workers in total variable costs. Second, the substitution between imported inputs and unskilled labour magnifies the natural hedging of firms against appreciations through the cost side. The higher σ, the more responsive are costs of imported inputs, and thus total costs, to exchange rates. This effect reduces the sensitivity of labour demand to e independent of workers' skills.[6]

The model is closed with a labour supply schedule and by re-expressing the third term on the right-hand side of (2) in terms of the share of imported inputs in total costs (as explained in Section B.1 of the online Appendix B). The resulting expressions for equilibrium log employment of skilled workers (B.13) and unskilled workers (B.14) suggest a common reduced-form regression model of the form:

[5] If firms have a high price-setting power, they tend to pass-through the exchange rate shock to foreign-currency prices, which attenuates the labour demand effect of exchange rates. This result mirrors the general importance of the firms' mark-up power in mediating the impacts of exchange rate movements on individual firms (Berman *et al.*, 2012).

[6] The effect, captured by the second $\phi(e)$ in (2), is thus present in the optimal input demand for H and U (cf. the log labour demand for U given by (B.14)).

$$\ln_{S=H,U}(S) = \alpha_{0,S} + \left\{\gamma_{0,S} - \gamma_{1,S}\chi - \gamma_{2,S}[IP \times (1-\chi)] + \gamma_{3,S}\frac{\theta_2(1-\alpha)}{\theta_1+\theta_2}\right\}e + \theta_{S1}\ln(y) + \theta_{S2}\ln(y^*), \quad (3)$$

where y and y^* reflect the demand situation in the domestic and foreign market, respectively.

According to our theoretical model, the effects of exchange rates on firms' revenues affect skilled and unskilled workers symmetrically. In fact, under the assumption that the labour supply elasticity with respect to the wage (a_1) is the same for skilled and unskilled workers, our model predicts that both the coefficient on the export share χ and the coefficient on the import penetration ratio multiplied by the domestic sales share $IP \times (1-\chi)$ should be identical for both skill groups in the reduced form regression above (i.e. $\gamma_{1,U} = \gamma_{1,H}$ and $\gamma_{2,U} = \gamma_{2,H}$). In contrast, the model predicts skill-biased effects of exchange rates if imported inputs are closer substitutes for unskilled workers than for skilled workers. This is arguably the empirically relevant case. First, because offshoring is most likely to happen for intermediate inputs that are standardised and require little coordination, an exchange rate appreciation is likely to lead to offshoring of tasks usually done by low-skilled workers. At the same time, more offshoring activities might require more managerial resources, thus raising the demand for skilled workers (Hijzen *et al.*, 2005; Biscourp and Kramarz, 2007; Crinò, 2009; Becker *et al.*, 2013; Hummels *et al.*, 2014). Second, in the presence of capital-skill complementarity, an appreciation of the currency may also increase the relative demand for skills by lowering the price of imported capital goods (Krusell *et al.*, 2000; Eaton and Kortum, 2001; Burstein *et al.*, 2013). Given these examples, we expect skill-biased effects of exchange rates mirrored in the coefficient on the imported inputs share in total variable costs (i.e., $\gamma_{3,H} > \gamma_{3,U}$).

2. Econometric Approach

Our empirical framework is organised in a panel structure where firm $i = 1, \ldots, N$ is the cross-section unit which belongs to some industry $j \in J$. Firm i is observed repeatedly during T_i time periods, where subscript i indicates that the panel is unbalanced. Following the reasoning in the last Section, we specify the following equation for the long-run labour demand of firms:

$$\begin{aligned}\Delta y_{ijt} = {} & \alpha_0 + \alpha_1 \Delta R^X_{jt} XS_{ij,t-1} + \alpha_2 XS_{ij,t-1} + \alpha_3 \Delta R^I_{jt} IS_{ij,t-1} + \alpha_4 IS_{ij,t-1} \\ & + \alpha_5 \Delta R^{Imp}_{jt}(1 - XS_{ij,t-1}) \times IP_j + \alpha_6(1 - XS_{ij,t-1}) \times IP_j \\ & + \boldsymbol{X}_{ijt}\boldsymbol{\beta} + \boldsymbol{\theta}_{jt} + u_{ijt}. \end{aligned} \quad (4)$$

The dependent variable of interest, Δy_{ijt}, refers to the change in the firm's (log) number of employees, or a component thereof. The model (4) is specified in first differences such that firm fixed effects in the level of the outcome are accounted for. It contains a vector of industry-period fixed effects $(\boldsymbol{\theta}_{jt})$ that capture shocks common to all firms in industry j such as changes in industry-specific prices and demand and industry-specific trends in employment growth. The idiosyncratic error term u_{ijt} is assumed to be strictly exogenous with respect to the covariates.

The explanatory variables of main interest are the (log) changes in different real effective exchange rates (REER), each denoted by ΔR_{jt}. As indicated by subscript j, we allow REER to be industry-specific. We use three different exchange rates: R_{jt}^{X} is an export-weighted, R_{jt}^{I} an imported-inputs-weighted, and R_{jt}^{Imp} an import-weighted REER of industry j (see the next Section for more details on the construction of these exchange rates).[7] Following previous papers in the literature, we decompose monthly exchange rates into a permanent and transitory component and only use the permanent component of the exchange rate in the estimation. The rationale for doing this is that firms are unlikely to change their employment level in response to temporary fluctuations in exchange rates (Campa and Goldberg, 2001; Nucci and Pozzolo, 2010).[8]

Fluctuations in real exchange rates affect employment in the firms through the three channels highlighted in Section 1. The impact on revenues in export markets is captured by the interaction between the export REER (R_{jt}^{X}) and $XS_{ij,t-1} \in [0, 1]$, the lagged share of annual revenues attributable to exports. The second channel – the impact of exchange rate movements on domestic sales of import-competing firms – is captured by an interaction between the import exchange rate R_{jt}^{Imp} and the import penetration ratio IP_j multiplied with the lagged share of domestic sales of the firm (i.e. $(1 - XS_{ij,t-1}) \times IP_j \in [0, 1]$). The term captures that the competitive pressures caused by an appreciation on domestic sales of firms are higher, the higher the domestic sales share and the higher the degree of competition from foreign suppliers. Finally, the cost-side effect of exchange rate movements is incorporated by an interaction between the imported-inputs exchange rate R_{jt}^{I} and $IS_{ij,t-1}$, the lagged share of imported intermediate input costs in overall variable input costs. As in Moser *et al.* (2010), the shares are lagged one period to mitigate issues of simultaneity in the specification. The direct effects of the share variables are also included in the model.

The model (4) exploits both cross-sectional variation and time variation to estimate the effect of exchange rates on employment. In particular, the effect is identified from differences in firms' pre-existing exposure to exchange rate movements (through differences in $XS_{ij,t-1}$, $IS_{ij,t-1}$ and $(1 - XS_{ij,t-1}) \times IP_j$), and from changes in the movements of the industry-specific real exchange rates (R_{jt}^{X}, R_{jt}^{I} and R_{jt}^{Imp}). The latter arise because exporting and import-competing industries can differ substantially in their mix of trading partner countries such that movements in a specific bilateral exchange rate have an asymmetric impact on domestic firms operating in different industries.

The inclusion of industry-period effects ($\boldsymbol{\theta}_{jt}$) implies that our coefficients of interests are identified from pre-existing firm-specific differences in exposure to a common

[7] Note that the main effects of the exchange rates (i.e. R_{jt}^{X}, R_{jt}^{I}, and R_{jt}^{Imp}) are absorbed by the industry-period effects.

[8] We decompose the original real monthly exchange rates into a permanent and transitory component using the Beveridge and Nelson (1981) decomposition, as in Campa and Goldberg (2001) and Nucci and Pozzolo (2010). We employ an AR model with a lag length of 24 months. It is worth pointing out that the results differ little between the actual exchange rates and their permanent components.

industry-specific exchange rate shock. The fixed effects also address two potential endogeneity concerns that may arise although exchange rate movements can be assumed to be exogenous to individual firms. First, the industry-period effects account for the possibility that industry-specific exogenous shocks (e.g. technology shocks) simultaneously affect skill-specific employment and industry-specific real exchange-rates through changes in firms' prices. Second, movements in the Swiss franc could be related to changes in international demand because the Swiss franc is a safe haven currency. The industry-period fixed effects $\boldsymbol{\theta}_{jt}$ thus control for the potential correlation between changes in industry-specific exchange rates and changes in industry-specific (foreign) demand.

Finally, to ensure that the industry-specific exchange rate changes are indeed orthogonal to firms' expectations in period $t-1$ and to increase the precision of the estimates, we add a vector of controls, $\boldsymbol{X}_{ijt}$. It comprises three variables firms' demand situations in $t-1$: two predetermined variables accounting for firms' past and expected demand in period $t-1$ and the beginning-of-period price-over-cost margin (Mark-up $t-1$) which accounts for firms' initial profitability.

3. Data

We draw on a range of sources to construct the data set for our empirical analysis. The main source is the innovation surveys of the KOF Swiss Economic Institute. These surveys were conducted among Swiss companies in 1999, 2002, 2005, 2008, 2011 and 2013 but the quantitative data refer to the year before the survey. Our sample thus covers the period 1998–2012. All surveys are based on a representative sample of the manufacturing industry, construction and business services sector in Switzerland and are disproportionately stratified with respect to firm size and two-digit industry affiliation.[9] Since there is a substantial time lag between the surveys, only about 50% of the firms responded to two successive surveys such that the panel is highly unbalanced. Because industry-specific exchange rates can only be constructed for tradable industries, the empirical analysis is restricted to firms in the manufacturing sector.

The firm-level data provide information on the main variables considered in this article, i.e. total employment, the skill structure of firms' labour force and export shares. The data set thus allows us to estimate the elasticities of skill-specific employment to exchange rate movements on the firm level. Moreover, we can analyse how the potential skill bias in the effect of exchange rate fluctuations emerges. A disadvantage of the data set is that we do not directly observe the share of imported intermediate inputs in total intermediate inputs, which we therefore impute using industry-level input–output tables.[10]

[9] The raw data contain answers for 2,172, 2,586, 2,555, 2,141, 2,363 and 2,034 firms respectively, representing an average response rate of 34.7%. The survey questionnaires can be downloaded from www.kof.ethz.ch/en/surveys.

[10] We multiply the import share in intermediate inputs on the industry-level with the firm-level share of intermediate inputs in total variable costs to obtain a measure of IS_{ijt}. The industry-level data is based on the Swiss input–output table from 2001 available from the OECD STAN database. This approach is also used by Fauceglia *et al.* (2014) to study the natural hedging of Swiss firms against exchange rate fluctuations.

The export and import REER used in the analysis are specific to each NACE two-digit industry. The imported inputs REER is less disaggregated and is specific to 10 different composite two-digit industries. All exchange rates are weighted averages of the nine most important bilateral real exchange rates for Switzerland.[11] For the imported inputs REER R^I_{jt}, the currencies are weighted according to the industry-specific geographic composition of Swiss imported inputs. The export REER, R^X_{jt}, is 'double-weighted', i.e. the weights not only take into account the composition of destination countries of industry *j*'s exports but also the fact that movements in the bilateral exchange rate affect the competitiveness of Swiss exporters relative to those from the trading partners in the (eight) other export markets in which they compete. Finally, the import exchange rate, R^{Imp}_{jt}, is weighted according to the geographical composition of imports to Switzerland of the products sold by industry *j*. We refer to Section B.2 in online Appendix B for more details on the construction of the industry-specific REER and the sources of the trade data required for these calculations, and to the Appendix A for detailed information on data sources and the construction of all the variables used in the analysis.

Table 1 provides summary statistics on outcomes and covariates in our firm-level data set. The average number of full-time equivalent workers is around 180 but there is a large amount of variability. The firm size distribution is heavily skewed to the right, with many small firms and few very large firms. When breaking down employment into education groups, we notice a large amount of heterogeneity, especially for highly educated workers. The average export share is 38%. The 1st and 3rd quartiles imply

Table 1
Descriptive Statistics

	Mean	SD	Q25	Median	Q75
FTE employees	182.4	605.4	25.0	75.0	170.0
High-skilled (tertiary education)	44.9	317.8	2.9	9.1	29.3
Medium-skilled (secondary education)	72.9	224.3	9.8	28.1	70.4
Low-skilled (primary education)	52.2	104.6	6.5	22.0	59.7
Annual average wage (in 1000 CHF)	88.4	31.0	71.8	85.8	101.0
Double-export-weighted REER (ΔR^X_{jt}, growth)	0.022	0.071	−0.020	0.031	0.071
Imported inputs-weighted REER (ΔR^I_{jt}, growth)	0.025	0.078	0.005	0.036	0.068
Import-weighted REER (ΔR^{Imp}_{jt}, growth)	0.027	0.076	−0.031	0.034	0.079
Export share in sales ($XS_{ij,t-1}$)	0.382	0.368	0.010	0.265	0.760
Imported inputs in var. costs ($IS_{ij,t-1}$)	0.142	0.055	0.106	0.138	0.177
Import penetration exposure ($(1 - XS_{ij,t-1}) \times IP_j$)	0.156	0.122	0.062	0.132	0.210
Mark-up ($t-1$)	0.237	0.140	0.140	0.220	0.310
Past demand ($t-1$)	0.080	1.033	−1.104	−0.149	0.806
Expected demand ($t-1$)	0.084	0.969	−0.157	−0.157	0.980

Notes. The sample contains all observations of the firms in the estimation sample. Growth rates refer to changes between cross-section periods.

[11] The real exchange rates are provided by the SNB and are constructed using consumer price indices (CPI). Using producer price (PPI) or wholesale price indices (WPI) would be conceptually preferable, since they reflect prices of traded goods more appropriately. However, different countries have different methods and baskets to construct PPIs and WPIs. Using the more homogeneous CPIs to construct trade-weighted exchange rates thus remains standard.

that at the lower tail, almost 25% of firms are non-exporters, while at the upper tail, 25% of firms earn more than 76% of their revenue in exports. The average growth rates in the exchange rates are around 2.5% but they exhibit a substantial amount of variation, especially over time.[12]

4. Empirical Results

4.1. *The Skill-biased Effects of Exchange Rate Movements*

The first column of Table 2 presents the results when estimating our baseline regression model on the log change in the number of full-time equivalent (FTE) employees on the level of the firm. The standard errors are clustered on the industry (j) level to take into account that our variables of interest – the industry-specific exchange rates – vary only at the level of each industry.[13] At the bottom of the Table, we present the 'export-side elasticity' $\bar{\varepsilon}_{R^X} = \alpha_1 \times XS^{med}_{ij,t-1}$ and 'imported inputs elasticity' $\bar{\varepsilon}_{R^I} = \alpha_3 \times IS^{med}_{ij,t-1}$, i.e., the elasticity of the outcome variable with respect to the export and imported inputs REER respectively, evaluated at the sample median of the corresponding share variable. Our discussion mainly focuses on the effects of REER movements that result from these two channels. The reason is that the effect of import competition as measured by the import REER (R^{Imp}_{jt}) is imprecisely estimated and not statistically significant.[14]

The baseline regression in the first column confirms the finding of previous papers that exchange rate effects on firms depend strongly on the characteristics of firms. The regression shows that the higher the firms' initial export share, the more negative is the effect of an appreciation of the export REER on employment. The coefficient in the first column implies that a 10% appreciation of the export REER reduces FTE employment in firms with median export share (i.e. $XS_{ij,t-1} = 26.5\%$) by $\bar{\varepsilon}_{R^X} = 2.45\%$. The coefficients on the cost-side effect of REER movements (i.e. the coefficient on $\Delta R_{jt} \times IS_{ij,t-1}$) is also statistically and economically significant. It implies that the positive effect of an appreciation on employment through reduced costs of imported inputs may effectively offset the negative effect through depressed export revenues. All else equal, a 10% appreciation of the imported inputs REER increases FTE employment by 4.8% in the median firm with an imported inputs share in total costs of 13.8%. The coefficient capturing the effects of exchange rates on import competition is not statistically significant. It is worth noting that the estimated exchange rate elasticities in column 1 are remarkably similar to those estimated by Nucci and Pozzolo (2010) for Italian manufacturing firms.

[12] A decomposition of the overall variance into components due to between variation and within variation shows that the between-firm variation in the growth of the export, imported inputs and import REER (i.e. ΔR^E_{jt}, ΔR^I_{jt} and ΔR^{Imp}_{jt}) accounts for 27%, 27% and 29% of total variation, respectively.

[13] An alternative would be to cluster standard errors at the level of the individual firm. This approach is followed in the working paper version of this article (Kaiser and Siegenthaler, 2015) and it generally yields slightly larger standard errors.

[14] Potential reasons for this are that the impact of exchange rate movements on import competition are absorbed by the industry-period effects or the fact that our import penetration ratio (IP_j) is not time-varying, potentially leading to measurement error.

Table 2

Firm-level Effects of Exchange Rates on FTE Employment and Average Wages

Variables	(1) $\Delta\ln(E)$	(2) $\Delta\ln(H)$	(3) $\Delta\ln(U)$	(4) $\Delta\ln[H/(H+U)]$	(5) $\Delta\ln(w)$
$\Delta R^X_{jt} \times XS_{ij,t-1}$	−0.925**	−1.020	−1.391***	−0.150	0.480
	(0.341)	(0.814)	(0.388)	(0.811)	(0.371)
$\Delta R^I_{jt} \times IS_{ij,t-1}$	3.483**	11.965***	0.733	10.082***	3.836
	(1.668)	(2.513)	(1.832)	(2.206)	(2.622)
$\Delta R^{Imp}_{jt} \times (1 - XS_{ij,t-1}) \times IP_j$	−0.437	0.750	−1.271	0.820	−0.148
	(1.203)	(1.847)	(0.977)	(2.199)	(1.509)
$XS_{ij,t-1}$	−0.018	−0.036	0.022	−0.017	−0.104***
	(0.047)	(0.073)	(0.061)	(0.056)	(0.028)
$IS_{ij,t-1}$	0.161	−0.070	0.327*	−0.289	1.026***
	(0.098)	(0.452)	(0.181)	(0.469)	(0.227)
$(1 - XS_{ij,t-1}) \times IP_j$	−0.093	−0.307	0.025	−0.214	−0.187*
	(0.114)	(0.193)	(0.137)	(0.186)	(0.102)
Mark-up $(t-1)$	0.123**	0.169	0.140**	0.006	0.399***
	(0.049)	(0.126)	(0.052)	(0.104)	(0.089)
Expected demand $(t-1)$	0.038***	0.043**	0.031***	0.006	−0.002
	(0.007)	(0.017)	(0.007)	(0.016)	(0.009)
Past demand $(t-1)$	0.030***	0.045***	0.035***	0.010	−0.007
	(0.007)	(0.015)	(0.009)	(0.014)	(0.009)
Observations	2,496	2,109	2,109	2,109	1,897
$\bar{\varepsilon}_{R^X}$	−0.245***	−0.306	−0.417***	−0.045	0.149
	(0.090)	(0.244)	(0.116)	(0.243)	(0.115)
$\bar{\varepsilon}_{R^I}$	0.480**	1.665***	0.102	1.403***	0.535
	(0.230)	(0.350)	(0.255)	(0.307)	(0.366)
Industry-period effects	Yes	Yes	Yes	Yes	Yes

Notes. ***p < 0.01, **p < 0.05, *p < 0.1. Cluster-robust standard errors in parentheses. Regression constant included but omitted from the regression output.

The main argument of this article is that a small effect on total employment may mask that workers with different skills are exposed differently to exchange rate shocks. Columns 2 and 3 in Table 2 thus present estimates of the baseline model separately for two groups: high-skilled workers and medium/low-skilled workers. Workers are assigned to these two groups based on their highest educational attainment.[15] The results suggest that there is a skill bias in the effects of exchange rate movements. Column 2 shows that high-skilled workers are not statistically significantly affected by the effects of exchange rate movements on exporting or import-competing firms. However, high-skilled workers clearly benefit from reduced costs of imported intermediate inputs if exchange rates appreciate. Taking the point estimates of all three exchange rate interactions at face value, a real appreciation of 1% in all three exchange rates actually increases FTE employment of high-skilled workers in most surviving firms in the sample. On the other hand, an appreciation of exchange rates appears to reduce FTE employment of low and medium-skilled workers in most surviving firms. Contrary to high-skilled workers, their export-side elasticity is highly

[15] Low-skilled workers are apprentices and workers who have not attained a secondary school degree. Medium-skilled workers are workers whose highest degree is an apprenticeship. High-skilled workers have a post-secondary degree.

statistically significant. Moreover, low and medium-skilled workers do not appear to benefit from reduced costs of intermediate inputs. In fact, Table B2 in online Appendix B shows that the imported inputs elasticity increases monotonically with the skill level of workers when we run separate regressions for high, medium, and low-skilled workers as well as apprentices.

From the results discussed so far, we cannot directly infer whether the differences in the exchange rate elasticities between skill groups are statistically significant. A simple way to test the difference in the elasticities between worker groups is to use the log change in the high-skilled share in total FTE employment as outcome, as done in column 4 of Table 2. A positive elasticity of the exchange rates in this regression implies an increase in the skill intensity of production. The regression confirms that the skill-biased effects of exchange rate movements arise because skilled and unskilled workers are affected differently by exchange rate-induced changes in the costs of imported intermediate inputs, consistent with our theoretical model. The model also predicts that skilled and unskilled workers are equally affected by the revenue-side and import competition effects of exchange rates. The results in column 4 show that these predictions of the model are also not at odds with the empirical results.

Column 5 of Table 2 shows the regression results when the outcome is the average wage per FTE worker in the firm. The responsiveness of average wages to exchange rates appears very limited. This is consistent with previous studies that indicate that wages in Switzerland are surprisingly rigid despite the relatively flexible labour market (Fehr and Goette, 2005). Since our data do not provide average wages by skill group on the firm level, we analyse the impact of exchange rates on relative wages by skill group when discussing our industry-level regressions in subsection 4.4.

4.2. *Robustness of the Main Results*

Table 3 contains several robustness tests of the estimates based on the change in the log employment share of high-skilled workers ($\Delta \ln [H/(H+U)]$), which allows direct assessment of whether the effects of exchange rates are statistically different for high-skilled *versus* low/medium-skilled workers.[16] In the first column in Table 3, the sample is not restricted to the firms in which we observe non-zero employment of both low and medium-skilled workers, which leads to a small increase in the number of observations. The regression in the second column excludes the control variables. The results suggest that real exchange rate shocks between $t-1$ and t are orthogonal to the firm-level demand situation in $t-1$ (conditional on the industry-period fixed effects). The regression in column 3 augments the baseline model with a full set of canton-period fixed effects and additionally adds industry-period effects specified on the three-digit level. While the coefficients of the variables of interest do not change noticeably, they are slightly less precisely estimated. Since the regression accounts for canton-period

[16] In Table B3 in online Appendix B, we also present the results when running the regressions in columns 2, 3, and 4 of Table 3 on employment of high and medium/low-skilled workers separately.

Table 3

Main Robustness Checks

Variables	(1) OLS $\Delta\ln[H/(H+U)]$	(2) OLS $\Delta\ln[H/(H+U)]$	(3) OLS $\Delta\ln[H/(H+U)]$	(4) Sys GMM $\ln[H/(H+U)]$ one-step	(5) Sys GMM $\ln[H/(H+U)]$ two-step	(6) Sys GMM $\ln[H/(H+U)]$ one-step
$\Delta R^X_{jt} \times XS_{ij,t-1}$	−0.120	−0.110	−0.196	−0.503	−0.743	−1.334
	(0.756)	(0.743)	(0.866)	(0.861)	(1.047)	(1.216)
$\Delta R^I_{jt} \times IS_{ij,t-1}$	12.363***	12.442***	12.295***	10.915***	12.159***	12.829***
	(3.298)	(3.328)	(4.273)	(4.180)	(4.328)	(4.183)
$\Delta R^{Imp}_{jt} \times (1 - XS_{ij,t-1}) \times IP_j$	1.176	1.246	0.989	−2.794	−1.966	−2.548
	(2.263)	(2.232)	(2.517)	(2.295)	(2.930)	(2.908)
$XS_{ij,t-1}$	−0.021	−0.017	−0.046	0.363	0.381	0.324
	(0.053)	(0.049)	(0.065)	(0.401)	(0.484)	(0.342)
$IS_{ij,t-1}$	−0.276	−0.290	−0.425	−0.292	−0.408	−2.213
	(0.449)	(0.419)	(0.559)	(1.123)	(1.206)	(1.351)
$(1 - XS_{ij,t-1}) \times IP_j$	−0.224	−0.221	−0.242	0.318	0.909	0.078
	(0.182)	(0.182)	(0.201)	(1.142)	(1.327)	(0.873)
Mark-up $(t-1)$	0.031		0.008	−0.010	−0.059	−0.039
	(0.101)		(0.129)	(0.237)	(0.237)	(0.239)
Expected demand $(t-1)$	0.002		0.005	0.019	0.020	−0.016
	(0.016)		(0.020)	(0.026)	(0.028)	(0.031)
Past demand $(t-1)$	0.011		0.008	−0.049**	−0.049**	−0.016
	(0.014)		(0.014)	(0.024)	(0.022)	(0.026)
$y_{ij,t-1}$				0.268***	0.253***	0.340***
				(0.059)	(0.065)	(0.103)
$y_{ij,t-2}$						0.126*
						(0.071)

Table 3

(*Continued*)

Variables	(1) OLS $\Delta\ln[H/(H+U)]$	(2) OLS $\Delta\ln[H/(H+U)]$	(3) OLS $\Delta\ln[H/(H+U)]$	(4) Sys GMM $\ln[H/(H+U)]$ one-step	(5) Sys GMM $\ln[H/(H+U)]$ two-step	(6) Sys GMM $\ln[H/(H+U)]$ one-step
Observations	2,140	2,140	2,125	2,140	2,140	983
$\bar{\varepsilon}_{R^X}$	−0.036	−0.033	−0.059	−0.151	−0.223	−0.414
	(0.227)	(0.223)	(0.260)	(0.258)	(0.314)	(0.377)
$\bar{\varepsilon}_{R^I}$	1.719***	1.730***	1.709***	1.518***	1.691***	1.777***
	(0.459)	(0.463)	(0.594)	(0.581)	(0.602)	(0.580)
Industry–period effects	Yes	Yes	No	Yes	Yes	Yes
Canton–period effects	No	No	Yes	No	No	No
Three-digit industry-period effects	No	No	Yes	No	No	No
Number of firms				1,161	1,161	550
Number of instruments				238	238	192
p-value Hansen J test				0.767	0.767	0.297
p-value AR(2) test				0.965	0.898	0.990

Notes. ***p < 0.01, **p < 0.05, *p < 0.1. Cluster-robust standard errors in parentheses. In the GMM regressions, the lagged dependent variable is instrumented using all available lags in the first-differenced and the level equation. The following variables are treated predetermined but not strictly exogenous: $XS_{ij,t-1}$, $IS_{ij,t-1}$, $(1 - XS_{ij,t-1}) \times IP_j$, expected demand $(t-1)$, past demand $(t-1)$, mark-up $(t-1)$. regression constant included but omitted from the regression output.

effects, it shows that our results are not driven by simultaneous changes in cantonal policies or possible region-specific labour supply shocks caused by exchange rate fluctuations.[17]

In columns 4–6, we estimate the model in levels rather than first differences by shifting the lagged dependent variable to the right-hand side of the estimation equation. Since OLS is inconsistent in this case, we estimate the dynamic employment model by employing the System GMM estimator developed by Arellano and Bover (1995) and Blundell and Bond (1998). We treat the following variables as pre-determined: $XS_{ij,t-1}$, $IS_{ij,t-1}$, $(1 - XS_{ij,t-1}) \times IP_j$, expected demand $(t-1)$, past demand $(t-1)$, and the mark-up $(t-1)$.[18] We use all available instruments in the first-differenced and in the level equation but the results are robust to restricting the instrument set to, for instance, the first available lag only. At the bottom of the Table, we examine the validity of the specification by conducting a Hansen test of the overidentifying restrictions and the Arellano–Bond test for second-order serial correlation of residuals in the first-differenced equation. The results from one-step and two-step system GMM estimation in columns 4 and 5 are very similar to the corresponding OLS results in first differences. In column 6, we augment the specification with the second lag of the dependent variable $y_{ij,t-2}$ to assess whether adjustments in the skill intensity extend over a period of six rather than three years. Only firms which are observed during four consecutive survey periods can be used for this estimation. While the second lag of the dependent variable is marginally statistically significant, it does not influence the estimated exchange rate elasticities in any relevant way.

Tables B4–B8 in online Appendix B provide further robustness checks. Table B4 analyses whether our results depend on the use of time-varying weights when computing REER and on the use of time-varying share variables (i.e., $XS_{ij,t-1}$, $IS_{ij,t-1}$, $(1 - XS_{ij,t-1}) \times IP_j$). To this end, industry-specific REERs are computed using time-invariant pre-sample trade weights (termed $\Delta R_{jt}^{\bar{X}}$, $\Delta R_{jt}^{\bar{I}}$ and $\Delta R_{jt}^{\overline{Imp}}$).[19] These exchange rates are then interacted with the corresponding shares in the first period that a firm participates in the survey (t_0). The results using these re-specified variables are very similar to our baseline results.

Table B5 provides an analysis of the influence of outliers on the results by winsorising the outcome distribution.[20] The Table shows that our results are not driven by outliers with very high absolute period-to-period changes in the outcomes.

[17] REER movements could affect labour supply of immigrants. Even more likely, exchange rates movements could affect the labour supply of cross-border workers because they influence cross-border workers' nominal wage but not their costs of living. Our framework is not suited for directly examining this potential impact of exchange rate movements on Swiss firms. The reason is that our coefficients are identified from pre-existing firm-level differences in the exposure to exchange rates. Potential labour supply effects of exchange rates, however, are a regional phenomenon and are likely to similarly affect firms with different REER exposure located in the same labour market region.

[18] The reason is that unobserved shocks to the skill intensity of firms may impact these firm-specific variables in future periods.

[19] The weights reflect the average geographic composition of Swiss exports and imports in the 1996–8 period and the geographic composition of imported intermediate inputs of 2001.

[20] We apply a 98% winsorisation to the first-differenced data, i.e. we set all period-to-period changes in outcomes above the 99th percentile to the 99th percentile and set all changes below the 1st percentile to the 1st percentile.

Table B6 presents estimation results based on economy-wide (t-specific) REER measures computed by averaging all period-to-period industry-specific REER over all firms in the estimation sample (termed $\Delta\bar{R}_t^X$, $\Delta\bar{R}_t^I$, $\Delta\bar{R}_t^{Imp}$). The regression further analyses concerns regarding the presence of unobserved industry-specific shocks that simultaneously affect industry-specific exchange rates and firms' employment, e.g. through changes in prices. The estimated exchange rate elasticities are almost unchanged when employing t instead of jt-specific REER. This finding suggests that the potential endogeneity arising from the industry-specific component in our exchange rate variables is not a concern.

Table B7 tests the sensitivity of our results to individually missing observations and potential non-random panel attrition. We do this by means of t-tests on two selection indicators that are added to our baseline specification.[21] If these variables were statistically significant, it would question the validity of the central assumption of the unbalanced panel case that observations are missing at random. The coefficients of these variables are insignificant in all cases. To further explore the issue of non-random attrition, we also estimate a two-step Heckman sample selection model (see Wooldridge, 2010, Chapter 19.9.3, for details). In the first step, a probit model for the probability of inclusion in the sample is estimated separately for each period. In the second step, the inverse Mills ratios interacted with the corresponding period dummies are added to the outcome model.[22] The results are shown in Table B8. The joint test of the selection variables at the bottom of the Table is only significant in column 3 (on a 5% level). Comparing the exchange rate elasticities to those in the baseline specification in Table 2, we find that results are remarkably similar. Overall, these robustness checks support the view that our results are not driven by non-random panel attrition.

4.3. *Is the Skill Bias Driven by Factor Substitution?*

The results in the last Section suggest that exchange rate fluctuations trigger changes in the skill structure of employment within firms. This effect appears to originate from the changes in the price of imported inputs caused by exchange rates. The pattern of the coefficients is consistent with our model, which postulates that exchange rates change relative factor prices and induce firms to adjust their input mix.

However, exchange rates could affect firms' skill intensity through at least two alternative channels. First, in the short run, skill-specific adjustment costs of labour demand to exchange rate shocks may matter if firms face skill-specific hiring and firing costs (Hamermesh, 1993; Blatter *et al.*, 2012).[23] However, since our analysis focuses on

[21] The first of the added variables, denoted $missing_{i,t-1}$ indicates whether a firm observed in period t is included in the sample in the previous period. The second variable, denoted $missing_{i,t+1}$,indicates whether a firm is in the sample in the following period. Wooldridge (2010, Chapter 19.9.2) provides a description of this test, which can be applied in a fixed effects or first difference specification as long as there are more than two time periods.

[22] We use the same covariates in the first-step equation such that the coefficients on the additional variables in the second-step are identified from the nonlinearity of the inverse Mills ratio.

[23] In flexible labour markets, adjustment costs (i.e. hiring and firing costs) are likely to increase with skills. On the one hand, skilled workers generally possess more firm-specific human capital, rendering them more costly to replace. On the other hand, expected search costs are generally higher for more demanding positions, particularly in a labour market characterised by shortages of skilled workers as in Switzerland (Hamermesh, 1993; Blatter *et al.*, 2012).

changes in employment over three-year periods, skill-specific adjustments costs are unlikely to account for our results.

A second alternative channel is that exchange rates affect firms' skill intensity by changing their price competitiveness. Such an effect could have several sources. First, the higher competition caused by an appreciation may incentivise firms to increase their innovation efforts which is likely to raise their skill demand (Aghion *et al.*, 2005; Lu and Ng, 2013). Second, if the within-firm skill intensity varies across products, changes in the product mix or quality upgrading caused by higher competition might increase firms' skill intensity of production (Chatterjee *et al.*, 2013; Lu and Ng, 2013). Third, higher competition may induce firms to update their capital faster, which would increase firms' skill intensity if capital and skill are complementary (Guadalupe, 2007; Ekholm *et al.*, 2012; Lu and Ng, 2013). However, it appears unlikely that innovation efforts, technology upgrading or product mix adjustments as a result of competition alone would generate the coefficient pattern found in the regressions. Arguably, effects of exchange rates on the firms' skill intensity operating through higher competition would be reflected in skill-biased exchange rate effects through the two revenue-side channels. Nevertheless, we cannot rule out that competition effects partially explain the skill bias of exchange rate movements operating through the input cost channel presented in the last sections. For instance, due to the high intra-industry correlation between import penetration and imported input use (Campa and Goldberg, 2001) and our relatively crude measurement of import penetration, the coefficient on the cost channel may partly pick up the effects of higher import competition on domestic firms.

To provide further evidence that factor substitution is important in accounting for the skill-biased effects of exchange rates through the cost channel as postulated by our model, we specify a slightly modified version of our baseline model of the high-skilled employment share:

$$\begin{aligned}\Delta\ln(H_{ijt}/E_{ijt}) = {} & \alpha_0 + \alpha_1\Delta R^X_{jt} XS_{ij,t-1} + \alpha_2 XS_{ij,t-1} + \alpha_{3,0}\Delta R^I_{jt} IS_{ij,t-1} + \alpha_{4,0} IS_{ij,t-1} \\ & + \gamma D_{it} + \alpha_{3,1}\Delta R^I_{jt} IS_{ij,t-1} \times D_{it} + \alpha_{4,1} IS_{ij,t-1} \times D_{it} \\ & + \alpha_5 \Delta R^{Imp}_{jt}(1 - XS_{ij,t-1}) \times IP_j + \alpha_6(1 - XS_{ij,t-1}) \times IP_j + \cdots + u_{ijt}. \quad (5)\end{aligned}$$

The only difference between this model and the baseline model is that we interact all variables that capture the cost-side effect of exchange rates on firms with a dummy variable, D_{it}. This allows us to estimate separate elasticities of H/E with respect to the imported inputs REER for firms with $D_{it} = 0$ and $D_{it} = 1$, termed $\varepsilon^{D=0}_{R^I}$ and $\varepsilon^{D=1}_{R^I}$, respectively. A test of the null hypothesis $H_0: \alpha_{3,1} = 0$ reveals whether the two elasticities are statistically significantly different.

Table 4 presents estimated elasticities for different definitions of D_{it}. In the first column, the dummy is equal to one if a firm reports fierce price competition before the exchange rate shock occurred (i.e. in period $t - 1$).[24] The p-value of the test whether $\varepsilon^{D=0}_{R^I} = \varepsilon^{D=1}_{R^I}$ indicates that initial differences in price competition do not significantly influence the imported inputs elasticity of the employment share of

[24] Firms are asked to assess on a five-point Likert scale the intensity of price competition they face. The indicator is set to one if the firm gives at least four points to the survey item.

Table 4
What Drives the Skill Bias of Exchange Rates Through the Cost Channel?

Variables	(1) High price competition ($t-1$)	(2) Foreign owned ($t-1$)	(3) Outsourcing ($t-1$)	(4) Outsourc. production ($t-1$)	(5) Outsourc. complex ($t-1$)	(6) High wage costs in sales ($t-1$)
Observations	2,103	2,127	1,205	1,205	1,205	2,140
$\bar{\varepsilon}_{R^I}^{D=0}$	1.762***	1.643***	1.704***	1.669***	1.902***	1.713***
	(0.498)	(0.535)	(0.693)	(0.691)	(0.521)	(0.568)
$\bar{\varepsilon}_{R^I}^{D=1}$	1.780***	1.984***	2.236***	2.547***	2.139**	2.277***
	(0.506)	(0.462)	(0.524)	(0.530)	(0.944)	(0.476)
p-val $\bar{\varepsilon}_{R^I}^{D=0} = \bar{\varepsilon}_{R^I}^{D=1}$	0.965	0.319	0.265	0.079	0.690	0.024

Notes. ***p < 0.01, **p < 0.05, *p < 0.1. Cluster-robust standard errors in parentheses.

high-skilled workers. The same holds if we use firms' initial mark-up to split the sample (not shown).

Next, we identify firms that may be expected to have a higher propensity to substitute low-skilled labour with foreign inputs in $t-1$. We then examine whether the skill intensity of these firms is more responsive to subsequent exchange rate-induced changes in the costs of intermediate inputs. The first group consists of firms with foreign ownership. Foreign-owned firms can be expected to have a higher probability of substituting to foreign inputs, among other things, because they are by definition multinational firms and because they may have better access to external providers of services, capital and material inputs than do purely domestic firms (Girma and Görg, 2004). Column 2 tests show that the elasticity is higher for foreign-owned firms, but the difference is not statistically significant.

A second such group of firms are those firms that have previously outsourced tasks (Girma and Görg, 2004).[25] We thus compare ε_{R^I} between firms that have and have not outsourced tasks in the past. To this end, we exploit that firms are asked whether they have outsourced R&D, IT, production, production components, or other tasks (such as accounting) in the five years preceding the survey. Firms are not asked whether the outsourcing was to a domestic or a foreign workplace, though, which prevents us from explicitly focusing on international outsourcing. Using the responses to the survey question, we set D_{it} to one if a firm has outsourced one of the five possible tasks in $t-1$ and zero otherwise. The results are shown in column 3. Although ε_{R^I} is higher for firms with experience in outsourcing, the difference is not statistically significant. However, past outsourcing of production-related tasks is associated with a higher sensitivity of the skill intensity to changes in the imported inputs REER (column 4). By contrast, ε_{R^I} does not depend on firms' experience in outsourcing complex tasks (i.e. IT and R&D tasks), as column 5 shows. These results suggest that it is the outsourcing

[25] As Hijzen and Swaim (2010, p. 1019) put it: 'To the extent that setting up an international production network involves a fixed cost, the constant-output elasticity of substitution between workers at home and value-added produced abroad will tend to be greater for firms that are already offshore and have thus established an international production network'.

of tasks performed by low and medium-skilled workers that affects the responsiveness of the skill intensity to shocks in the imported inputs REER. Consistent with this explanation, we show in the working paper version of this article that an appreciation increases outsourcing of production-related tasks, whereas outsourcing of other tasks is unaffected (Kaiser and Siegenthaler, 2015).

A third group of firms with potentially higher willingness to substitute to foreign labour is firms with high labour costs. Saving wage costs is a central determinant of the decision to outsource (Girma and Görg, 2004). In column 6, D_{it} is an indicator for firms in which the ratio of wage costs to sales in $t-1$ exceeds median wage costs to sales ratio over all surveys.[26] In line with our expectations, ε_{R^I} is higher in firms with high initial wage costs, and statistically significantly so.

4.4. *Industry-level Analysis*

Thus far, our theoretical and empirical discussion has focused on exchange rate effects within firms. Yet, these results do not necessarily imply that unskilled workers are more exposed to exchange rate movements on a more aggregate level. Most importantly, our analysis may mask the between-firm reallocation of labour caused by exchange rate swings (Gourinchas, 1999; Klein *et al.*, 2003).

To illustrate the importance of between-firm reallocations in explaining changes in the demand for skills over time, we decompose the period-to-period percentage point change in the high-skilled employment share in manufacturing in our firm panel data set into five components, following Abowd *et al.* (2001): three components that reveal the importance of changes in the high-skilled employment share within continuing firms and the reallocation of market shares between them; and two components related to entry and exit of firms out of the panel (see Section B.3 in online Appendix B for more details).[27] According to the decomposition, the change in the skill intensity within continuing firms accounts for 51% of the total 7.5 percentage point change in the high-skilled employment share in the manufacturing sector over the entire 1998–2012 period. The other half of the change in the share is mostly accounted for by the fact that firms entering the panel have an above-average skill intensity.

The results from the decomposition suggest that understanding the skill-biased effects of exchange rates on the aggregate level involves studying the Melitz (2003)-type between-firm reallocations caused by exchange rate movements. Fung (2008) provides a useful framework to think about the potential mechanisms at work. Her model suggests that between-firm reallocation could both strengthen and weaken the skill bias of exchange rate movements. On the one hand, if exporters are more strongly affected by appreciations than import-competing firms, an appreciation of the REER may decrease the demand for skilled labour by reallocating market shares towards

[26] This specification of D_{it} accounts for the fact that there are substantial between-firm differences in production technologies. Between-firm comparisons of wage costs shares are thus potentially uninformative about the question whether firms perceive their costs to be high.

[27] Hence, the latter not only reflect a systematic relationship between changes in the high-skill share and firm entry and closures, but also any systematic correlation between changes in the aggregate share and the high-skilled employment share of non-responding firms or firms dropping out of the stratified sample.

non-exporting firms. These are usually less skill-intensive. On the other hand, an appreciation increases competition both for exporting and import-competing firms, which may lead to a reallocation of resources from inefficient to efficient firms. The induced increase in exit of inefficient firms could imply that surviving domestic firms gain market shares.

To gain insights into as to how the between-firm reallocation of resources affects the impact of exchange rate shocks on the relative demand for skills, we shift the level of analysis from the firm level to the industry level. The analysis is performed on a slightly unbalanced panel of 91 NACE three-digit industries computed by aggregating data from the bi-annual Swiss wage structure surveys 1998–2010.[28] The broad coverage of this data set ensures that we can reliably estimate employment by skill group in three-digit industries on the national level.[29] It also provides employer-reported, skill-group specific wages of workers. To make our results comparable to the firm-level analysis, we construct an industry-level data set that matches the years to which the data in the innovation surveys refer to.[30] The export share, the share of imported inputs in total variable costs and our measure of import competition exposure are taken from the KOF innovation surveys and has been merged to the two-digit level of the industry classification.[31]

Table 5 presents the results of the industry-level regressions. Observations are weighted by the industry's average FTE employment over the sample period. In contrast to the firm-level analysis, the model does not contain industry-period effects but only period effects because the former would absorb the variables of interest. We thus also include the baseline effects of the exchange rates (i.e. ΔR^{X}_{jt}, ΔR^{I}_{jt} and ΔR^{Imp}_{jt}) in the regressions. To mitigate concerns about the potential endogeneity of industry-specific exchange rates, the regression contains a variable representing the trade-weighted change in real GDP in two-digit industry j's export markets ($\Delta FGDP_{jt}$) and an interaction of this variable with the industry's initial export share. These variables account for the potential correlation between demand-side and industry-specific exchange rate shocks.

The outcome in the first column of the Table is the number of FTE workers. As on the firm level, we find that the negative impact of the export REER on FTE employment increases with the export share of the industry. A high imported inputs share in variable costs reduces the negative employment impact of an appreciation.

[28] The KOF innovation survey is not used here because sample sizes are too small to estimate skill-group specific employment in individual industries reliably, even when aggregating on high levels of the industry classification. Individual observations of large firms have a strong influence on the results in these industries and employment figures by skill-group display substantial period-to-period changes.

[29] The wage structure surveys covers between 15% and 50% of all employees in firms with more than three employees in Switzerland.

[30] The adjustment involves pooling two survey waves of the bi-annual wage structure survey to match the uneven years in which two of the innovation surveys took place. In particular, we compute employment in 2001 by averaging industry-specific employment and wages in 2000 and 2002. The same is done for the year 2007. We delete publicly owned firms and observations with missing information on highest educational attainment.

[31] To have reliable estimates for these exposure variables and to account for the potential endogeneity of the export and import shares on the industry-level, we use time-invariant shares computed by averaging over all firms in the KOF innovation surveys 1996, 1999 and 2002. In fact, however, the results are qualitatively similar when using time-varying weights.

Table 5

Industry-level Effects of Exchange Rates on FTE Employment and Wages

Variables	(1) FE $\Delta\ln(E)$	(2) FE $\Delta\ln(H)$	(3) FE $\Delta\ln(U)$	(4) FE $\Delta\ln[H/(H+U)]$	(5) FE $\Delta\ln(w)$	(6) FE $\Delta\ln(w^H/w^U)$
$\Delta R^X_{jt} \times XS_{j,t_0}$	−3.059***	−2.084**	−3.484***	0.975	−0.080	0.139
	(0.960)	(0.852)	(1.074)	(0.752)	(0.217)	(0.421)
$\Delta R^I_{jt} \times IS_{j,t_0}$	11.818*	9.003**	12.092	−2.815	−0.792	−0.154
	(5.948)	(4.210)	(8.046)	(6.796)	(1.352)	(2.135)
$\Delta R^{Imp}_{jt} \times (1 - XS_{j,t_0}) \times IP_j$	−4.538*	−2.833*	−5.007*	1.705	−0.463	0.477
	(2.331)	(1.569)	(2.809)	(2.105)	(0.508)	(0.883)
ΔR^X_{jt}	1.462	0.773	1.596	−0.689	−0.241	−0.297
	(1.248)	(1.599)	(1.250)	(0.868)	(0.233)	(0.350)
ΔR^{Imp}_{jt}	−1.009	−0.652	−1.326	0.357	0.257	0.148
	(2.491)	(2.925)	(2.563)	(1.360)	(0.508)	(0.884)
ΔR^I_{jt}	−2.937**	−2.460	−2.591**	0.477	0.227	0.471
	(1.162)	(2.334)	(1.206)	(1.822)	(0.425)	(0.871)
$\Delta FGDP_{jt}$	1.848	−1.275	3.661	−3.123	−1.284	1.575
	(6.064)	(6.919)	(4.975)	(2.543)	(1.548)	(2.032)
$\Delta FGDP_{jt} \times XS_{j,t_0}$	2.076	5.727	0.089	3.651*	1.582	−0.467
	(3.998)	(4.620)	(3.375)	(1.904)	(1.074)	(1.289)
Observations	354	354	354	354	354	354
$\bar{\varepsilon}_{R^X}$	0.321	−0.005	0.296	−0.325	−0.271	−0.245
	(1.391)	(1.765)	(1.390)	(0.870)	(0.286)	(0.422)
$\bar{\varepsilon}_{R^I}$	−1.193	−1.132	−0.806	0.062	0.110	0.449
	(1.458)	(2.133)	(1.393)	(1.436)	(0.351)	(0.741)
Period effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes. ***p < 0.01, **p < 0.05, *p < 0.1. Cluster-robust standard errors in parentheses. Observations are weighted using average industry-level FTE employment. Regression constant included but omitted from the regression output. Standard errors clustered on two-digit industry level.

In contrast to the evidence on the firm level, the industry-level regressions also weakly suggest that industries experience a reduction in FTE employment through an increase in import competition. Even though the interaction terms are significant and have the expected sign, the resulting elasticities for the median firm are not statistically significant in all three cases because the main effects of the exchange rates are very imprecisely estimated.

The remaining results in the Table show no statistically significant skill bias of exchange rate movements on the industry level. Most importantly, the export-side elasticity ($\bar{\varepsilon}_{R^X}$) and imported inputs elasticity ($\bar{\varepsilon}_{R^I}$) are far from statistically significant in column 4. Exchange rates also do not affect average wages (column 5) or the industry-level ratio of skilled to unskilled wages (column 6).[32]

There are two reasons why the apparent firm-level skill bias of exchange rates through costs of imported inputs does not arise on the industry level. The first is that industries may be partially shielded from the competitive pressures originating from an appreciation if they heavily rely on imported intermediate inputs that become cheaper. This may result in a muted between-firm reallocation towards efficient firms within

[32] We use a standardised monthly wage measure provided by the LSE to estimate the industry-level wage ratio. Regressions using the ratio of hourly wages yielded similar results.

industries. If efficient firms are more skill intensive, such an effect may counteract the substitution of less skilled workers with imported intermediate inputs within surviving firms.[33]

The other, potentially more relevant reason is related to data and estimation issues. First, the estimates (especially the skill-specific regressions in columns 2–5, less so the results in column 1) lack precision and are quite sensitive to sample and estimation choices. For instance, they depend on the weighting scheme and on the inclusion or exclusion of individual industries. For instance, dropping one outlier industry reverses the negative sign on the coefficient on the cost channel in column 4 (see Table B9 in online Appendix B). Possible reasons for the sensitivity of the skill-specific regressions are measurement error, the absence of the strong appreciation period of the Swiss franc in the data (2010–2) and the potential simultaneity between industry-specific shocks, changes in prices and the industry-specific exchange rates that we cannot address in these regressions by using industry-period fixed effects.

5. Conclusion

This article examines whether exchange rates exhibit a skill bias in their effects on employment. Our theoretical model implies that a skill bias arises through changes in the price of domestic labour relative to foreign-produced inputs if unskilled labour is more substitutable to foreign-produced inputs than skilled labour. In addition, firms' skill composition may also be affected by exchange rate-induced changes in competitive pressure or because of skill-specific adjustment costs.

Our empirical analysis is based on a panel data analysis of Swiss manufacturing firms covering the years 1998–2012, a period characterised by large swings in the real exchange rate of the Swiss franc. Several important findings emerge from our analysis. In a surviving manufacturing firm with average exchange rate exposure, appreciations of the Swiss franc have only small impacts on total FTE employment. This effect on total employment, however, masks considerable heterogeneity in the effects for different types of workers within these firms. In particular, a currency appreciation reduces less-skilled employment and increases high-skilled employment in the average firm. In contrast to high-skilled workers, less-skilled workers do not appear to benefit from lower costs of intermediate inputs. These findings remain robust when different estimation methods and model specifications are used. We present evidence consistent with our model that the higher within-firm exposure of less-skilled workers to movements in the import exchange rate is driven by a higher elasticity of substitution between unskilled workers and imported inputs than between high-skilled workers and imported inputs. Finally, the impact of exchange rate movements on skill demand is not apparent when shifting the level of the analysis to the industry level, which can either be attributed to a between-firm reallocation of resources towards less skill-intensive firms that offset the within-firm increase in the skill intensity, or to the econometric problems associated with the industry-level regressions.

[33] Baggs *et al.* (2009) provide evidence consistent with this argument. They show that firms' sales and, to a lesser extent, firm survival decrease less after an appreciation if firms are less exposed to exchange rate movements due to a higher share of imported intermediate inputs.

Appendix A. Variable Definitions

Table A1

Variable	Definition and measurement	Source(s)	Coverage
Dependent variables			
Employees (E)	FTE employment, ln	KOF IS	1998–2012
Employment high-skilled (H)	Number of FTE high-skilled employees, ln High-skilled are workers with post-secondary education	KOF IS	1998–2012
Employment medium/low-skilled (U)	Number of FTE medium- and low-skilled employees, ln Medium-skilled are workers with a secondary, low-skilled are workers with less than a primary degree (excluding apprentices)	KOF IS	1998–2012
Wages (w)	Average wage per FTE employee, ln Derived from the share of wage costs in total sales, total sales and the number of FTE employees	KOF IS	1998–2012
Independent variables			
$XS_{ij,t-1}$	Share of exports in total sales in period $t-1$	KOF IS	1998–2012
ΔR^X_{jt}	Growth of export real effective exchange rate from t to $t-1$ in two-digit industry (NACE rev. 2) (see Section B.2 in the online Appendix B)	SNB, SFCA, WITS	1998–2012
$IS_{ij,t-1}$	Share of imported inputs in total variable costs in period $t-1$ Imputed imported intermediate inputs as a share of wage costs plus total intermediate inputs. The share of imports in intermediate inputs by industry is derived from the OECD Input–Output Table 2001 for Switzerland (NACE rev. 1.2, 19 industries)	KOF IS, OECD STAN	1998–2012
ΔR^I_{jt}	Growth of imported inputs real effective exchange rate from t to $t-1$ in broad two-digit industries (NACE rev. 1.2, 18 industries) (see Section B.2 in the online Appendix B)	SNB, OECD TiVA	1998–2012
IP_j	Import penetration ratio of industry j in 2001 (NACE rev. 1.2, 19 industries). Import value relative to value of domestic absorption (gross production + Imports − Exports)	OECD TiVA	2001
ΔR^{Imp}_{jt}	Growth of import exchange rate from t to $t-1$ in two-digit industry (NACE rev. 2) (see Section B.2 in the online Appendix B)	SNB, SFCA	1998–2012
$\Delta FGDP_{jt}$	Export-weighted industry-specific growth of GDP in export markets from $t-1$ to t	SFCA, IMF WEO	1998–2012
Expected demand ($t-1$)	Expected development of demand in next three years in $t-1$ Five-level ordinal variable (level 1: 'strong decrease'; 5: 'strong increase')	KOF IS	1998–2012
Past demand ($t-1$)	Perceived development of demand in past three years in period $t-1$ Five-level ordinal variable (level 1: 'strong decrease'; 5: 'strong increase')	KOF IS	1998–2012
Mark-up ($t-1$)	Price over cost margin in $t-1$	KOF IS	1998–2012
High price competition ($t-1$)	High intensity of price competition in main selling market in period ($t-1$) Dummy variable equal to 1 if perceived price competition in firm's main selling market 'strong' (value of 4) or 'very strong' (value of 5)	KOF IS	1998–2012
Foreign owned ($t-1$)	Dummy indicating foreign ownership of firm in period ($t-1$)	KOF IS	1998–2012

Table A1

(*Continued*)

Variable	Definition and measurement	Source(s)	Coverage
Outsourcing of production $(t-1)$	Firm has outsourced production tasks in the past five years prior to period $(t-1)$. Sum of two binary variables which are 1 if 'intermediate production' or 'final production' were outsourced, respectively, value 0 otherwise	KOF IS	1999, 2005, 2008, and 2011
Outsourcing of complex tasks $(t-1)$	Firm has outsourced complex tasks in the past five years prior to period $(t-1)$ Sum of two binary variables which are 1 if 'R&D' or 'IT-services' were outsourced, value 0 otherwise	KOF IS	1999, 2005, 2008, and 2011
Outsourcing $(t-1)$	Firm has outsourced production or complex tasks in the past five years prior to period $(t-1)$ (see outsourcing of production and outsourcing of complex tasks)	KOF IS	1999, 2005, 2008, and 2011
High wage costs in sales $(t-1)$	Dummy indicating that wage cost share in total sales is above within-firm median in period $t-1$	KOF IS	1998–2012

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Additional Supporting Information may be found in the online version of this article:

Appendix B. Supplementary Information and Results.
Data S1.

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