

Exchange rate risk and the skill composition of labor*

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Abstract

This paper uses matched employer-employee data covering the universe of Swedish private sector firms 1997-2014 to examine links between exchange rate risk and the share of high-skilled workers in firms. We use firm \times export destination and firm \times import origin data to calculate firm-level measures of real effective exchange rates and real exchange rate risk. Our main result is to establish that higher exchange rate risk leads firms to employ a higher share of skilled labor. This finding is consistent with theoretical models that see more flexible work systems that require higher skill levels as a way of responding to higher risk. We further find that “natural hedging,” simultaneously exporting to and importing from the same currency area, serves to limit the effect on skill composition. Regarding first moment effects our findings point in the same direction as an earlier study using data from Switzerland: A depreciation lowers the share of skilled labor.

Keywords: Skill-biased organizational change, exchange rate risk, firm heterogeneity, natural hedging.

JEL: F16; F31; J24.

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1 Introduction

Exchange rate changes have the potential to substantially affect the competitive situation of firms that trade internationally. Large literatures examine links between exchange rates and issues such as prices and price setting currencies (see e.g. Burstein and Gopinath (2014)), investments (see e.g. Goldberg et al. (1993)) and stock market valuation of firms (see e.g. Dominguez and Tesar (2006)). Not only the level of the exchange rate, but also its variability may affect a firm’s decision making. A firm may want to adjust the way it produces to limit harm and possibly take advantage of exchange rate variability. In the present paper we examine whether firms faced with higher exchange rate variability respond by adjusting the skill composition of their labor force. Such a link would not be surprising as we know that over the last few decades many firms have adopted more flexible work practices, which generally require more highly skilled labor (see e.g. Caroli and Van Reenen (2001), Thesmar and Thoenig (2000)). The increasing use of flexible ways of organizing work has in turn been linked to increased uncertainty, albeit on an overarching level (globalization, deregulation and an increasingly complex and fluid environment for firms). By using variation in firm-level risk we want to provide a detailed examination of links between the skill level in a firm and the exchange rate risk that it faces.

We use matched employer-employee data covering the universe of private sector Swedish firms for 1997 to 2014 inclusive to examine the link between exchange rate risk and skill composition at the firm level (we set a lower threshold at 10 employees). As we develop below, the evidence for “skill-biased organizational change” is encompassing but we know much less about its determinants at the firm level and its link to firm-level measures of risk, rather than to broad technological trends. We will use differences in international exposure to generate differential treatment to exchange rate risk for firms. To tease out the effects of risk on skill composition at the firm level we use firm \times country exports and imports. Since firms differ in their international composition of imports and exports this gives us variation in exchange rate risk at the firm level.¹

We find substantial effects: A one standard deviation increase in exchange rate risk is associated with an increase in the share of university educated labor force from 29% to 32%. We find stronger effects of export volatility than of import volatility. This is consistent with substantial sunk costs of accessing foreign customers, which suggest

¹Caggese et al. (2016) use a similar identification strategy, also on Swedish data, to establish that financially constrained firms are more likely to fire workers with low firing costs rather than the workers who can be expected to contribute most to productivity.

that a firm is loath to leave an export market and that it is worth having highly skilled employees to maintain the position in that market. On the import side uncertainty on the cost side might to some degree be handled by shifting to suppliers located in other currency areas.

We further explore the possibility that export and import effects might cancel, as suggested by the logic of natural hedging (see e.g. Allayannis et al. (2001) or Amiti et al. (2014)). Indeed we find that natural hedging, exporting to and importing from the same currency area, moderates the effect of exchange rate changes on skill composition. Volatility on both the import and export side are associated with a higher skill share but the effects partly cancel such that the net effect is lower than the sum of gross effects.

We then proceed to disentangle the within-firm and between-firm effects using a nested random effects model. The data exhibit a nested structure: observations are at the firm-level and firms are nested within industries. We find evidence that export intense firms exhibit a within-firm increase in skill share in response to an increase in exchange rate risk. We relate the within-firm response to the between-firm response where most of the variation in skill levels is situated.

To the best of our knowledge we are the first to examine the links between exchange rate risk and the skill composition of labor. Judging by the title of Kaiser and Siegenthaler (2016): “The skill-biased effect of exchange rate fluctuations” one might expect that their recent article is an exception to this. However, they examine first moment shocks. Using rich data from Switzerland they establish that appreciations of the Swiss franc are associated with a higher share of skilled labor. We find the same pattern for first moment shocks among Swedish firms but add to the literature by also examining the effects of second moment shocks.

We also tie in to a vibrant literature that has examined changes in labor demand across different skill levels. Much of this work documents a polarization of labor markets with increasing relative demand for labor at the top and bottom of the skill distribution, with technological change automating routine tasks and increasing trade as important forces (see e.g. Bekman et al. (1998), Autor and Dorn (2013) or Autor et al. (2013)). Most closely related to us is research on “skill-biased organizational change”: more flexible work systems increasing the relative demand for skilled labor.² Changes in the available technology and the relative supply of labor appear to be contributing to skill-biased organizational change (see e.g. Caroli and Van Reenen (2001)). Skill-biased organizational

²Other related terms are also used, for instance “high-performance work practices” (see e.g. Cappelli and Neumark (2001)) or “flexible work systems” (see e.g. Bauer and Bender (2001)).

change has also been linked to creative destruction (Thesmar and Thoenig (2000)) - a more turbulent environment increases the value of flexible work systems. Related is also Aghion et al. (2017) who show that more decentralized firms showed superior performance during the financial crisis of 2008 and its aftermath.³ Thus, a number of previous articles have linked skill-biased organizational change to broad developments that are believed to be associated with higher uncertainty. Our contribution to this line of inquiry is to link firm-level variation in uncertainty to skill composition.

In the next section we outline the theoretical foundations for the predictions that we take to the data and section three describes the data and the indices that we compute. We discuss the empirical specification in section 4 and then turn to results in section 5. Section 6 concludes.

2 Theoretical predictions

A depreciation of the real exchange rate (RER) tends to both raise export revenue and raise the cost of imported inputs. RER variations may thus translate into profit variations for a firm. The expectation of future variability, what we may term exchange rate risk, may in turn affect the financial and operational policies of firms. If a firm faces credit constraints, convex tax schedules, or is subject to some other mechanism that creates a value of lowering variability, it may aim to limit effects of exchange rate variability on the value of the firm by using financial derivatives to hedge. Many firms do indeed use financial derivatives to manage exchange rate risk (see e.g. Bartram et al. (2011), Allayannis et al. (2012)) but evidence also suggests that substantial exchange rate exposure remains (Guay and Kothari (2003)). A firm may also turn to operational hedging - letting the potential for future variability affect the way it organizes production (see e.g. Friberg (2015) for an overview). In the present article we explore two aspects of operational hedging. First a firm may wish to steer imports to large export markets so as to limit the net exposure to different currencies, a practice that we term “natural hedging”.⁴ Second a firm may strive to organize its production in a different manner if it is faced with higher risk, an issue to which we now turn.

In a seminal contribution Stigler (1939) showed that a firm that faces more variability

³Of some relation is also Kurz and Senses (2016) who link patterns on the volatility on overall employment growth at the firm level to export and import status, finding that on average employment volatility is lower among exporters but higher among importers.

⁴This practice of “natural hedging” may also apply to ownership patterns, owning subsidiaries in large export markets, see Allayannis et al. (2001) for an early examination of this

may want to organize production in a way that sacrifices static efficiency to gain flexibility. While Stigler focused on the curvature of the average cost function (associating a flatter average cost curve with a more flexible firm) a complementary literature notes that uncertainty may have effects on how to delegate authority within firms and how to organize work. A typical result is that higher uncertainty promotes decentralization, see for instance Alonso et al. (2008) for an influential formalization of this idea.⁵ Greater decentralization and more flexible means of operating are generally assumed to require a higher share of skilled labor. Empirical support for that organizational change towards decentralization increases the relative demand for skilled workers comes from e.g. Caroli and Van Reenen (2001). In our data we can't directly observe the flexibility built into an organization but we observe a correlate of a flexible way of organizing work, the share of skilled labor. The first hypotheses that we explore is hence

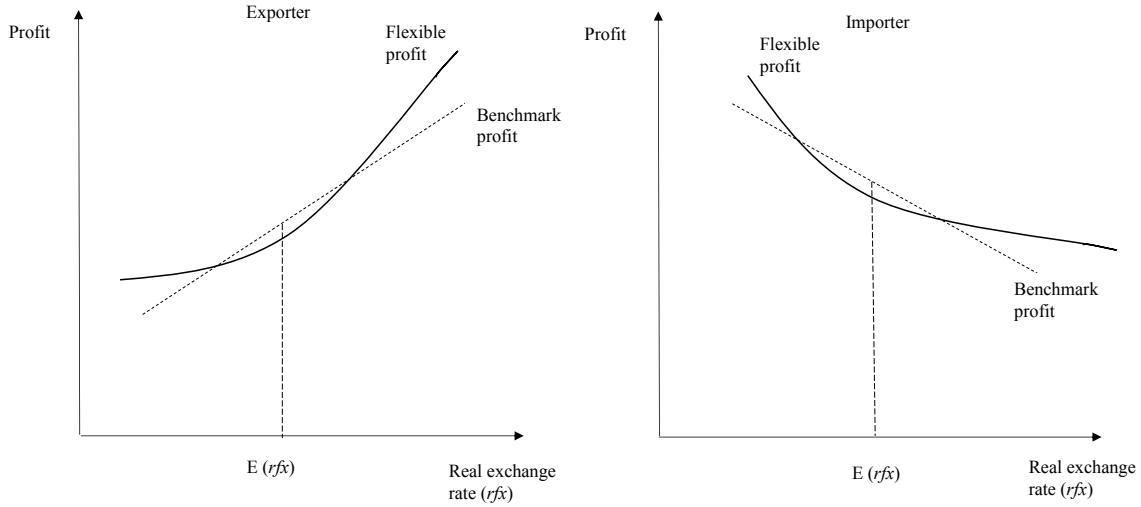
Hypothesis 1 Firms faced with higher exchange rate risk will have a higher proportion of skilled labor than comparable firms which face lower exchange rate risk.

Let us use figure 2 to highlight the intuition. In the left panel we illustrate the situation for an exporter with only domestic costs. Profits increase as the real exchange rate (rfx) depreciates and takes on higher values. As the price of foreign currency goes the competitive position of an exporter improves and foreign currency earnings become more worth when converted into domestic currency. For concreteness consider a benchmark where there is a linear relationship between profit and rfx . Stigler's realization is that if there is substantial risk, e.g. a sufficiently high probability of either high or low exchange rates, then it may optimal for the firm to invest in flexible production. An increased weight in the tails of the exchange rate distribution leads to higher expected profit for the flexible firm. The right hand panel shows the corresponding case for a firm that only sells domestically but uses imported inputs. Here the exchange rate exposure is negative: As the real exchange rate depreciates imports become more expensive and profits decrease. An importer, just as an exporter, can increase expected profits by being more flexible.

In figure 2 we considered a pure exporter and a pure importer. As many firms both import and export, real exchange rate changes will have opposing effects on profits and we expect the net exposure to be what matters for the decision of how flexible to be. For a firm that simultaneously exports to - and imports from - a particular national

⁵The notion that decentralization is a way to manage uncertainty has deep roots in business history and Alfred Sloan's reorganization of General Motors is an iconic example, see e.g. Chandler (1962).

Figure 1: Flexibility and exchange rate risk.



market exposures should partly cancel. Such is the logic behind “natural hedging”, if the domestic currency appreciates vis-à-vis an export market (with a negative effect on profits) this negative effect will be counteracted by a lower price of imports from that same market. Amiti et al. (2014) show that exchange rate pass-through is affected by the net currency exposure, a finding consistent with net exposure to a particular currency being of importance for firm performance.⁶ When examining the data in the light of Hypotheses 1 we therefore first focus on net exposure net exchange rate exposure to a particular currency, which we expect to have a positive effect on the skill level. It may also be of interest to examine the link between skill levels and exchange rate risk on the export and import side separately however. It may be that flexibility mainly comes from the import side, having a high skill level to be able to rapidly shift suppliers or it may be that flexibility mainly comes from the export side. Here the analysis will be rather exploratory and we have no strong prior. We do expect however that firms choose skill level with overall profit in mind (“net effect”) rather than with respect to exports and imports separately which leads us to the following hypothesis.

Hypothesis 2 The effect of exchange rate risk on the export and import side is expected to partly cancel such that the estimated effect of the share of high skilled to net currency exposure is lower than the sum the effects of import and export exposure.

⁶Other related work on net exposure and its link to exchange rate pass-through is found in e.g. Berman et al. (2012) or Ekholm et al. (2012).

Finally, we are also interested in understanding the effect of changes in the real effective exchange rate on the skill share. Kaiser and Siegenthaler (2016) establish that an appreciation of the exporter’s currency is associated with a higher skill share. They extend Campa and Goldberg (2001) and present a stylized model, showing that if imported inputs are closer substitutes for unskilled workers then the prediction is that depreciations should be associated with a falling skill share.

Hypothesis 3 A depreciation of the real effective exchange rate is expected to lower the share of skilled labor.

While the last hypothesis has already been shown to hold for Swiss data it may be of interest to see if the same pattern holds true in Sweden. The two countries share many similarities (open, high-income European countries with floating exchange rates) but a marked difference is that recent Swiss exchange rate history has been shaped by the Swiss franc’s role as a reserve currency with strong appreciations.

3 Data

We use matched employer-employee data on the universe of Swedish firms. Both manufacturing and service firms are included. We limit attention to firms with at least 10 employees. The main source of the data is Sweden’s official statistics agency, Statistics Sweden. The data are yearly and our data cover the period 1997 to 2014 inclusive. We observe firm \times country exports and imports and also use overall sales, employee data and capital from Statistics Sweden. Capital is defined as the sum of machines, inventory and tangible capital. We also observe industry classification at the 5-digit level of the Swedish industry classification (SNI 2007). At the 4-digit level the classification is analogous to NACE Rev 2. The 5-digit level is quite detailed and for instance the 4-digit NACE industry 1711 (manufacture of pulp) is further divided into three 5-digit industries, manufacture of sulphite pulp, of sulphate pulp and of mechanical pulp.

As our main measure of skill level we use the percentage share of the total workforce in a firm that has at least some university education. In robustness exercises we also explore average education level where we make use of that education is observed at four different levels: 0 corresponds to educational attainment of most 9 years (which is the mandatory level in Sweden), 1 for having finished “gymnasium” (additional 3 years of education which may be vocational as well as academic), 2 to at least some university education and 3 to a doctoral degree.

We combine the data from Statistics Sweden with quarterly data on nominal exchange rates and consumer price indices from IMF’s International Financial Statistics. For each trading partner we calculate the real exchange rate, expressed as the real Swedish krona price of foreign currency. A higher value for an exchange rate is thus associated with a real depreciation of the Swedish krona. All real exchange rates are normalized by their mean value and the real exchange rate vis-à-vis country a in year t is denoted by rfx_{at} . As an input for the firm-level measure of risk we also calculate a measure of volatility for each currency - to do so we calculate standard deviations at the quarterly level for a three year rolling window and then take the average in year t for currency area a as a measure of the risk, denoted by σ_{at} .⁷

3.1 Computing firm-level indices of real effective exchange rate levels and volatility

Denote total revenue for a firm in a year by R_t and total cost of goods sold by C_t . Denote the value of exports from firm i to currency area a at time t as X_{iat} and the corresponding value of imports by M_{iat} . We also examine net trade with area a , $X_{iat}-M_{iat}$.⁸ Our measure of exchange rate risk for a firm is the weighted average of standard deviations of the real exchange rate. For export weights wx_{iat-1} we use the average of the share of exports in total revenue to currency area a over the last three years. As discussed further below, when we present the empirical specification, we want the movements in the weights to be generated by changes in exchange rate volatility rather than by simultaneous movements in the weights of an individual market for the firm. Import risk, σ_{it}^M is defined analogously but with weights wm_{iat-1} given by the share in total costs for imports from area a . Net risk finally similarly uses weights that depend on the absolute value of net trade.

⁷We thus follow the practice in much of financial risk modeling of using realized volatility as a measure of risk (see e.g. Andersen et al. (2013) for a survey). With high frequency data, volatility clustering is commonly observed in exchange rates and various GARCH-models are frequently used to model volatility. As our main data is observed only at a yearly frequency we opted for the simpler rolling standard deviation.

⁸We treat each country as a currency area with the exception of the euro area which is treated as a currency area (including Denmark, which has a fixed exchange rate vis-à-vis the euro fixed within a narrow band).

$$\sigma_{it}^X = \frac{1}{3} \underbrace{\sum_{k=1}^3 \sum_{a=1}^A \frac{X_{iat-k}}{R_{iat-k}}}_{w_{iat-1}^X} \times \sigma_{at} \quad (1)$$

$$\sigma_{it}^M = \frac{1}{3} \underbrace{\sum_{k=1}^3 \sum_{a=1}^A \frac{M_{iat-k}}{C_{iat-k}}}_{w_{iat-1}^M} \times \sigma_{at} \quad (2)$$

$$\sigma_{it}^{NET} = \frac{1}{3} \underbrace{\sum_{k=1}^3 \sum_{a=1}^A \frac{|X_{iat-k} - M_{iat-k}|}{R_{iat-k}}}_{w_{iat-1}^{NET}} \times \sigma_{at} \quad (3)$$

Indices of real effective exchange rates RER_{it}^X , RER_{it}^M and RER_{it}^{NET} are defined analogously by simply letting rfx_{at} replace σ_{at} in the equations (3)-(2).

3.2 Summary statistics

Before we proceed with the analysis it may be useful to briefly describe the data and we provide summary statistics in table 1. While we use data from 1997 to 2014 inclusive our use of lagged weights means that the first years are not used in the regressions, only to calculate weights. The summary statistics in table 1 are presented for the data used in the regressions, but there are small differences with respect to the full data.

On average, across these firms and years, 29% of the workforce has a university education but we see that there is substantial variation in this measure across firms. The number of employees also range widely around the average of 122 employees. There is substantial variation in international trading intensity as well. The average export share in revenue is 0.16 and the average import share of costs is 0.19. On average there are about 12,000 firms in the sample in a given year. The average period that a firm is present in the data is somewhat below 11 years, lower than the maximum of 15 and this reflects both movements around the lower cutoff of 10 employees as well as entry and exit. Note that these periods refer to the years for which we estimate regressions, the first two years of the data (1997 and 1998) are used only to construct export and import weights.

Table 1: Summary Statistics - Panel regression sample

	Variable	Mean	Std. Dev.	Min.	Max.	N
Share university	$SKILL_{ist}$	29.129	23.665	0.005	100	128,996
Weight (net) \times S.D. of RER	σ_{ist}^{NET}	0.005	0.008	0	0.116	128,996
Weight (export) \times S.D. of RER	σ_{ist}^X	0.004	0.007	0	0.1	128,996
Weight (import) \times S.D. of RER	σ_{ist}^M	0.005	0.007	0	0.104	128,996
Weight (net) \times RER	RER_{ist}^{NET}	0.199	0.259	0	2.136	128,996
Weight (export) \times RER	RER_{ist}^X	0.157	0.242	0	1.264	128,996
Weight (import) \times RER	RER_{ist}^M	0.189	0.248	0	1.309	128,996
Employees	L_{ist}	122	591	10	39,100	128,996
Capital (million SEK)	K_{ist}	75	728	1	30,902	128,996
Sales (million SEK)	Y_{ist}	272	1872	1	109,856	128,996
Export share of revenue	S_{ist}^X	0.163	0.248	0	1	128,996
Import share of costs	S_{ist}^M	0.194	0.251	0	1	128,996
Number of firms per year		11,904	320	11,282	12,470	128,996
Number of years in panel		10.76	4.195	1	15	128,996

4 Empirical specification

4.1 Firm-level effects within industrial sectors

As a first test, we estimate the effect of net and gross exchange rate risk on a firm's skill composition with the following specifications:

$$\ln(SKILL_{ist}) = \alpha_{n1}\ln(RER_{ist}^{NET}) + \alpha_{n2}\ln(\sigma_{ist}^{NET}) + \gamma_{jt} + \theta_s + \beta_n X_{ist} + \varepsilon_{ist}. \quad (4)$$

$$\ln(SKILL_{ist}) = \alpha_{x1}\ln(RER_{ist}^X) + \alpha_{m1}\ln(RER_{ist}^M) + \alpha_{x2}\ln(\sigma_{ist}^X) + \alpha_{m2}\ln(\sigma_{ist}^M) + \gamma_{jt} + \theta_s + \beta_{xm} X_{ist} + \varepsilon_{ist}. \quad (5)$$

The key variables of interest are the measures of the firm \times year specific real effective exchange rate (RER_{ist}^{NET}) and the firm \times year specific exchange rate volatility (σ_{ist}^{NET}). Both these variables, as well as the dependent variable, the share of workers with at least some university education in firm i in year t , are in natural logarithmic form, which

implies that we can interpret the coefficients α_1 and α_2 as elasticities. In addition we include year \times 2-digit sector fixed effects (γ_{jt}) and 5-digit sector fixed effects (θ_s), where j and s denote the 2 and 5-digit sectors, respectively. X_{it} is a vector of additional controls, including capital and sales for firm i in sector s in year t , both in logarithmic form, $\ln(K_{ist})$ and $\ln(Y_{ist})$ respectively. To control for differences in international exposure we also include the export and import shares of revenue, S_{ist}^X and S_{ist}^M , respectively. The statistical error terms are denoted by ε_{it} and ϵ_{ist}

Our hypotheses imply that we expect higher net exchange rate risk to be associated with higher skill levels (H1: $\alpha_{n2} > 0$) and that a net depreciation lowers the skill level (H3: $\alpha_{n1} < 0$). We further expect the net effect of exchange rate risk to be less than the combined effects of separately estimated import and export risk (H2: $\alpha_{n2} < \alpha_{x2} + \alpha_{m2}$).

Our approach identifies the effect of net risk exposure (σ_{ist}^{NET}) on the level of skill. First of all we assume that exchange rate volatility is exogenous to the firm which is imminently plausible if exchange rate changes are generated by macroeconomic shocks and expectations regarding macroeconomic policies and shocks. We use firm-specific weights to reflect the importance of different currency areas. In principle this might be a concern in that a positive shock in a currency would not only lead to an increase in σ_{ist}^{NET} via the higher standard deviation of the exchange rate but also via the market in question gaining a higher weight. The latter would be endogenous to the firm and thereby a potential source of concern. To circumvent this possible endogeneity we use lagged weights to capture the importance of different markets.

4.2 Decomposing within and between firm-level effects within industrial sectors

In this section, we extend our model to decompose the estimated effects into within and between firm components. Identification in the regressions discussed above is achieved, in part, because some firms face higher exchange rate volatility, and a greater change in the real effective exchange rate, because of the geographic composition of exports and imports. Partly identification is expected to come from differential time series patterns in the development of exchange rate volatility across different exporters and importers, but partly identification is also likely to come from cross-sectional variation within 5-digit industries.

In many applications researchers use fixed effects at the firm level to control for unobserved heterogeneity. A challenge for such an identification strategy in the present

case is that firm skill shares adjust slowly with hiring and firing being associated with substantial costs. Sweden has a high level of protection for permanent employees and in redundancies priority is based on seniority.⁹

The relatively slow within-firm changes in employees presents a challenge for identifying within-firm effects from changes in exchange rate risk exposure. A look at the data confirms this. Much of the variation in firm skill levels is between firms. Across the full sample reported in table 1, within-firm standard deviation in $SKILL_{ist}$ is 33% of the overall standard deviation, whereas between-firm standard deviation is 104% of the overall standard deviation. We therefore collapse the data from annual observations to the average over a four year period. The purpose is that the longer time period between observations will help identify within-firm effects.

We are further interested in decomposing the within and between-firm components of the effect of exchange rates on firm skill level. We therefore deploy a nested random effects model to decompose these components. Following Baltagi (2013) and Snijders (2011), the specification to be estimated is

$$\begin{aligned}
 \ln(SKILL_{isp}) &= \delta_1 \ln(RER_{isp}^{NET}) + \delta_2 \ln(\sigma_{isp}^{NET}) + \delta_3 X_{isp} & (6) \\
 &+ \lambda_1 \overline{\ln(RER_{is}^{NET})} + \lambda_2 \overline{\ln(\sigma_{is}^{NET})} + \lambda_3 \overline{X_{is}} \\
 &+ \varphi_1 \overline{\overline{\ln(RER_s^{NET})}} + \varphi_2 \overline{\overline{\ln(\sigma_s^{NET})}} + \varphi_3 \overline{\overline{X_s}} \\
 &+ u_{isp}.
 \end{aligned}$$

This specification is analogous to the fixed effects specification in equation (4) with the addition of firm level and sector level means, and each observation is the average over a four year period. $\ln(SKILL_{ip})$ is the share of workers in firm i with at least some university education, averaged over a four year period p . There are 4×4 year periods, with the first period covering the years 1999-2002 inclusive and the last period covering the years 2011-2014 inclusive. s denotes 5-digit SNI 2007 sectors. Again the variables of interest are $\ln(RER_{isp}^{NET})$ and $\ln(\sigma_{isp}^{NET})$, which are identical to their counterparts in equation 4, except for being averaged over the period p . $\overline{\ln(RER_{is}^{NET})}$ and $\overline{\ln(\sigma_{is}^{NET})}$ are means by firm and $\overline{\overline{\ln(RER_s^{NET})}}$ and $\overline{\overline{\ln(\sigma_s^{NET})}}$ are means by sector s .

⁹Compared to other OECD countries Sweden's labor market is quite flexible in several dimensions but it is clear that replacing a low skilled worker with a high skilled one would be subject to substantial costs and negotiations. ? provide a comparative overview of Swedish regulations regarding firing and Von Below and Thoursie (2010) a detailed examination of the effect of seniority rules on firms' employment behavior.

Another motivation for applying the nested error component model is econometric. The data exhibits a nested structure: observations are at the firm-level, and firms are grouped by industry. The disturbances in a nested data structure are given by

$$u_{isp} = \lambda_{0is} + \varphi_{0s} + \mu_{isp}, \quad (7)$$

where φ_{0s} denotes the unobserved industry-specific effect s , λ_{0is} denotes the nested effect of the i^{th} firm in sector s , and μ_{isp} denotes the remainder disturbance. φ_{0s} is assumed to be $IID(0, \sigma_\varphi^2)$, λ_{0is} is assumed to be $IID(0, \sigma_\lambda^2)$ and μ_{isp} is assumed to be $IID(0, \sigma_\mu^2)$.

The econometric problem with nested data structures is the potential that individual effects are associated with each nest. There may be firm and industry level effects, but firm-specific effects exclude the possibility of using sector-specific effects, and vice versa. Estimations based on nested data with a non-nested error structure (e.g. fixed effects) can bias standard errors, as discussed by Antweiler (2001), and Baltagi (2013).¹⁰

The usual assumption for random effects applies: random effects are independent of covariates. Firm level and sector level averages of all covariates are therefore included to ensure this assumption holds. The specification can then be written in terms of random effects at the firm-level and at the industry level.

$$\begin{aligned} \ln(SKILL_{isp}) = & \delta_1 \ln(RER_{isp}^{NET}) + \delta_2 \ln(\sigma_{isp}^{NET}) + \delta_3 X_{isp} \quad (8) \\ & + \left(\lambda_{0is} + \lambda_1 \overline{\ln(RER_{is}^{NET})} + \lambda_2 \overline{\ln(\sigma_{is}^{NET})} + \lambda_3 \overline{X_{is}} \right) \\ & + \left(\varphi_{0s} + \varphi_1 \overline{\ln(RER_s^{NET})} + \varphi_2 \overline{\ln(\sigma_s^{NET})} + \varphi_3 \overline{X_s} \right) \\ & + \mu_{isp}. \end{aligned}$$

The first line of the specification captures the within-firm response to changes in $\ln(\sigma_{isp}^{NET})$ and $\ln(RER_{isp}^{NET})$. We check that these within-firm estimates match estimates from the fixed effects specification. The second and third lines of 8 can be interpreted as the firm's random intercept, and the sector's random intercept, respectively.

¹⁰The bias is downwards if the errors are positively correlated.

5 Estimation results on firm skill composition and exchange rate risk

5.1 Within-sector skill level variation across firms

In table 2 we examine the link between net exchange rate risk and the skill share. All specifications use fixed effects at the 5-digit industry level as well as year fixed effects that vary by 2-digit industry level. Standard errors are clustered at the firm level. In column (1) we present results for all firms. We see that higher net exposure to exchange rate variability is associated with a higher skill share, in line with Hypotheses 1. The effect is precisely estimated (statistically significant at the 1% level) and economically significant. The effect might at first blush appear limited: We can interpret the coefficient as an elasticity and an increase in the exchange rate risk by 1% is associated with an increase in the skill share by 0.06%. Note however that there is great variation in the exchange rate risk and the standard deviation of the index (0.008) is greater than the average (0.005). Thus, increasing exchange rate risk by one standard deviation means that we predict that we increase the risk index by 160 % with an associated increase in the share of highly skilled by 9.6% (0.06×160) which implies increasing from a mean of 29 high skilled out of a 100 employees to almost 32 out of 100.

Turning next to the level effect we see that a depreciation of the net real effective exchange rate is associated with a decrease in the skill share, or vice versa, an appreciation is associated with an increased skill share. The effect is statistically significant and of similar magnitude as the effect of risk. In recent work Kaiser and Siegenthaler (2016) claim to be the first to study this issue and, using data from Switzerland, find effects in the same direction: the share of high skilled workers increase as the Swiss franc appreciates.

Table 2: Net (Export-Import) exchange rate risk and the skill level of employees.

VARIABLES	(1) All firms	(2) Traders	(3) No entry exit	(4) 50+ employees	(5) 50- employees	(6) Manufacturing
$\ln(\sigma_{ist}^{NET})$	0.0414*** (0.00603)	0.0179** (0.00740)	0.0363*** (0.00968)	0.0274*** (0.00792)	0.0459*** (0.00797)	0.0549*** (0.00860)
D_{ist}^{neg}	-0.0150 (0.0152)	0.0508** (0.0242)	0.0185 (0.0302)	0.0168 (0.0261)	-0.0237 (0.0183)	-0.0323 (0.0262)
$\ln(RE R_{ist}^{NET})$	-0.0332*** (0.00630)	-0.00302 (0.00819)	-0.0192* (0.0108)	-0.0187** (0.00861)	-0.0387*** (0.00819)	-0.0344*** (0.00915)
$\ln(RE R_{ist}^{NET}) \times D_{ist}^{neg}$	-0.00860*** (0.00271)	0.0125 (0.00880)	-0.00573 (0.00722)	-0.00653 (0.00433)	-0.00894*** (0.00339)	-0.0109* (0.00634)
$\ln(K_{ist})$	-0.0459*** (0.00291)	-0.0505*** (0.00609)	-0.0601*** (0.00671)	-0.0367*** (0.00560)	-0.0468*** (0.00340)	-0.0494*** (0.00556)
$\ln(Y_{ist})$	0.0894*** (0.00464)	0.109*** (0.00949)	0.0838*** (0.0105)	0.115*** (0.00945)	0.108*** (0.00731)	0.0812*** (0.00856)
S_{ist}^X	0.268*** (0.0226)	0.240*** (0.0315)	0.291*** (0.0456)	0.346*** (0.0391)	0.270*** (0.0274)	0.312*** (0.0328)
S_{ist}^M	0.439*** (0.0524)	-0.0540 (0.118)	0.281*** (0.103)	0.544*** (0.0858)	0.398*** (0.0645)	0.182** (0.0840)
Constant	2.068*** (0.0712)	1.705*** (0.139)	2.370*** (0.163)	1.266*** (0.164)	1.821*** (0.124)	2.061*** (0.120)
Observations	114,736	25,242	36,060	37,720	76,393	50,033
(R^2)	0.490	0.437	0.517	0.647	0.442	0.311

Dependent variable: Share of employees in the firm with at least a university (undergraduate) degree.

* p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses, clustered at the firm level.

All specifications include fixed effects at the SNI 5-digit sector.

Let us also comment on the signs of the remaining control variables which are in line with expectations and with influential results in the previous literature. More capital is associated with a lower skill level, indicating that overall capital and high skilled labor are substitutes. This may at first appear surprising as much recent interest regarding labor markets has focused on complementarity between certain forms of capital, such as information technology, and the demand for high skilled labor. Note that such effects would be possible also in our sample but masked by the use of an overall measure of capital. Indeed work by e.g. Michaels et al. (2014) across 11 developed economies indicates that capital in the form of information and communications technology (ICT) is a complement to high skilled labor but that overall (non-ICT) capital rather is a substitute for high skilled labor. Larger sales are associated with a higher skill share, which is in line with expectations and also in line with results in e.g. Michaels et al. (2014).

Further note that it is important to control for export shares in the skill regressions. A number of previous articles have shown that exporting, and the composition of export markets, may matter for the skill composition even if one disregards uncertainty. Bernard and Jensen (1997) provide early evidence for this on U.S. data and Verhoogen (2008) shows a positive relation between exporting and skill intensity among Mexican firms. Using Argentinian data Brambilla et al. (2012) show that exporting to richer countries is associated with higher skill levels but find no such relation for exports to lower and middle income countries. In the Swedish data it is also the case that higher export shares are associated with higher skill level. Again the effect is statistically significant at the 1% level and economically significant. An increase in the export share by 1% is associated with an increase in the share of skilled workers by 0.3%. The point estimate on the import share is also positive, a finding which can be related to a number of papers have examined effects of offshoring (importing intermediate inputs) on wages, frequently finding that importing raises the relative demand for high-skilled workers (see e.g Hummels et al. (2014) who use matched employer-employee data for Denmark or Hummels et al. (2016) for a survey). Similarly, using matched employer-employee data for Sweden 1997-2002 Andersson et al. (2016) find that offshoring of services is associated with a higher demand for high skilled workers (even if they find little or no effect for outsourcing of manufacturing inputs). By and large the sign and significance of the controls are similar across the alternative specifications in columns (1)-(6) and we refrain from further commenting on the controls, finding it reassuring that we see similar patterns for Sweden as has been documented for other countries.

In column (2) we only include observations for firms where exports make up at least

15% of revenue. Both coefficients on exchange rates are somewhat lower but differences are minor. Our baseline regression in column (1) includes also firms that are not present in all periods and thus entry and exit may partly affect results. To explore this further column (3) reports results from a sample of firms present in all periods only. There is considerable entry and exit but comparing results between columns (1) and (3) we note that patterns are quite stable. In column (4) we restrict attention to firms with at least 50 employees and find lower effects of the real effective exchange rate, both in levels and in standard deviations, than in the full population. Roughly the magnitude of coefficients is halved. A large literature documents that larger firms are more likely to use financial derivatives to manage exchange rate risk (see e.g. Allayannis et al. (2012)) and also other ways of managing exchange rate risk are likely to be more accessible for larger firms (for instance switching suppliers or renegotiating terms of a contract) which would imply that they have less need for this kind of flexibility. Results for firms with fewer than 50 employees in column (5) are close to the overall effects reported in column (1), a result that is not surprising given that around two thirds of the sample are such smaller firms. Finally we note that results for manufacturing firms only, reported in column (6) are also well in line with the benchmark results from column (1).

Let us now turn to an examination of possibly differential effects of import and export exposure. In table 3 we present results from regressions with the same specifications as in table 2 but separating effects from exchange rate levels and exchange rate volatility into export and imports. In column (1) we see that both export and import volatility are positively related to the share of high-skilled workers. It is noteworthy that the point estimate for the effects is larger for exports than for imports. If fixed costs of being present on export markets are more important than fixed costs associated with importing, this may offer a partial explanation for the relative magnitude of coefficients. If a firm is locked into serving a specific market it will want to have the flexibility to be able to continue serving it also when the exporter's currency is appreciated or volatile. The existence and importance of sunk costs of exporting are well documented from before (see e.g. Roberts et al. (1997), Bernard and Jensen (2004)) and there is also evidence consistent with sunk costs of importing (e.g. Kasahara and Lapham (2013)). To the extent that it is easier to switch import suppliers we expect sunk costs of importing to be lower than sunk costs of exporting, which could explain the lower coefficients on imports.

Turning then to the effects of a depreciation on skill levels the effects observed regarding net effects for the exchange rate level are also observed for gross effects - a depreciation lowers the share of skilled employees. These patterns are seen for both exports and im-

ports. On the export side a depreciation is associated with a better competitive situation vis-à-vis foreign competitors and the share of high skilled decreases. On the import side a depreciation is associated with rising prices of imported inputs and to the extent that imported inputs are closer substitutes for low skilled workers, the relative share of high skilled workers should be expected to fall.

We note that the magnitude and statistical significance of coefficients are quite robust across the different specifications in columns (2)-(6). It is worth to highlight that both coefficients on both exports and imports are higher for more export intensive firms (exports at least 15% of sales). Combined with the effect that these firms had lower effects of net exposure in table 2 this is suggestive that exposures cancel to a greater extent for firms that export more, an issues that we return to below. As in table 2 a comparison of columns (4) and (5) also show that smaller firms (less than 50 employees) exhibit a greater sensitivity of skill shares to exchange rates. Reassuringly, we also note that the coefficients on the additional controls are quantitatively close to coefficients when we examined net exposure in table 2 and we therefore refrain from repeating the associated discussion.

Table 3: Export and Import risk and the skill level of employees.

VARIABLES	(1) All firms	(2) Traders	(3) No entry exit	(4) 50+ employees	(5) 50- employees	(6) Manufacturing
$\ln(\sigma_{ist}^X)$	0.140*** (0.0151)	0.175*** (0.0324)	0.138*** (0.0260)	0.114*** (0.0234)	0.153*** (0.0189)	0.138*** (0.0240)
$\ln(\sigma_{ist}^M)$	0.0746*** (0.0142)	0.0168 (0.0284)	0.0417 (0.0256)	0.0677*** (0.0217)	0.0667*** (0.0176)	0.0820*** (0.0212)
$\ln(RE R_{ist}^X)$	-0.143*** (0.0149)	-0.172*** (0.0319)	-0.140*** (0.0260)	-0.117*** (0.0230)	-0.154*** (0.0187)	-0.127*** (0.0240)
$\ln(RE R_{ist}^M)$	-0.0683*** (0.0143)	-0.0363 (0.0287)	-0.0309 (0.0259)	-0.0547** (0.0223)	-0.0629*** (0.0175)	-0.0749*** (0.0212)
$\ln(K_{ist})$	-0.0500*** (0.00339)	-0.0511*** (0.00610)	-0.0635*** (0.00686)	-0.0378*** (0.00603)	-0.0519*** (0.00411)	-0.0527*** (0.00605)
$\ln(Y_{ist})$	0.0949*** (0.00536)	0.109*** (0.00950)	0.0865*** (0.0108)	0.112*** (0.0101)	0.124*** (0.00870)	0.0909*** (0.00927)
S_{ist}^X	0.292*** (0.0224)	0.222*** (0.0314)	0.291*** (0.0424)	0.331*** (0.0357)	0.293*** (0.0281)	0.307*** (0.0318)
S_{ist}^M	0.304*** (0.0609)	0.173 (0.121)	0.237** (0.116)	0.403*** (0.0952)	0.233*** (0.0749)	0.0342 (0.0935)
Constant	2.670*** (0.0977)	2.261*** (0.196)	2.903*** (0.199)	1.935*** (0.200)	2.270*** (0.159)	2.578*** (0.158)
Observations	85,900	25,144	32,481	31,739	53,673	41,495
(R^2)	0.479	0.438	0.520	0.636	0.427	0.336

Dependent variable: Share of employees in the firm with at least a university (undergraduate) degree.

* p<0.10, ** p<0.05, *** p<0.01. Standard errors in parentheses, clustered at the firm level.

All specifications include fixed effects at the SNI 5-digit sector

Finally, it is interesting to compare the magnitude of coefficients across the net and gross specifications. Using the estimates for the effect of risk in column (1) of table 3 suggest that the combined effect of a 1% increase in both export and import volatility add up to an elasticity of 0.19 (0.125+0.0677), which is greater than the estimated net effect of 0.0618. The difference of 0.13 is, with a standard error of 0.013 and a z-statistic of 10.04, statistically significant at the 1% level. That the net effect is substantially lower than the sum of gross effects indicates that export and import effects partly net out. Such netting out is far from surprising: to the extent that a firm imports from the same destination that it exports to the competitive situation is likely to be less affected than if it it were a pure importer or pure exporter. The precise effects will clearly depend not only on net trading patterns but also on possible differences in exchange rate pass-through on inputs and output. To the extent that exchange rates affect export revenue and import costs in similar ways it is clear that the net exposure of firm profitability to exchange rates is lowered and thus the incentives to deal with the resulting exposure via a higher skilled (presumably more flexible) work force are lowered. As seen effects do not fully cancel however and, as noted above, the estimated effect of net exposure on skill levels is rather precisely estimated and non-trivial in magnitude.

Similarly for the level effects the sum of import and export exposure, -0.19 (-0.129-0.0616) is greater than the corresponding coefficient on net exposure which is -0.0591. Also for these variables the difference between the sum of gross effects and the net effect is statistically significant at the 1% level.

5.2 Within-firm and between-firm components of skill variation and exchange rate risk

In table 4 we disentangle the within-firm and between-firm effect of net exchange rate risk on skill share. The data for all specifications consists of firm-level observations collapsed to means of 4×4 year periods. All specifications include controls for firm capital $\ln(K_{isp})$, output $\ln(Y_{isp})$, export and import intensity, S_{isp}^x and S_{isp}^m , respectively.

Under column (1), we report the within-firm effect of exchange rate risk on skill share using fixed effects at the firm level. The estimated within-firm effect of increased exchange rate volatility ($\ln(\sigma_{isp}^{NET})$) across all firms is insignificant with a negative estimated elasticity. The estimated within-firm effect of an increase in the exchange rate ($\ln(RER_{isp}^{NET})$) is significant at the 5% level with an estimated elasticity of 0.015.

Table 4: Net (Export-Import) exchange rate risk and the skill level of employees with nested random effects.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Fixed effects		Nested error component				
VARIABLES	All firms	All firms	Exporters	No entry exit	50+ employees	10-49 employees	Manufacturing
$\ln(\sigma_{isp}^{NET})$	-0.011 (0.007)	-0.013 (0.007)*	0.028 (0.014)**	0.004 (0.014)	-0.011 (0.012)	-0.014 (0.009)	-0.004 (0.011)
$\overline{\ln(\sigma_{is}^{NET})}$		0.114 (0.020)***	0.117 (0.042)***	0.207 (0.075)***	0.131 (0.044)***	0.116 (0.022)***	0.171 (0.032)***
$\overline{\overline{\ln(\sigma_s^{NET})}}$		2.032 (0.067)***	1.829 (0.126)***	1.347 (0.157)***	2.022 (0.135)***	2.017 (0.071)***	1.389 (0.112)***
$\ln(REER_{isp}^{NET})$	0.015 (0.007)**	0.017 (0.007)**	-0.025 (0.015)*	0.001 (0.014)	0.018 (0.012)	0.016 (0.009)*	0.004 (0.012)
$\overline{\ln(REER_{is}^{NET})}$		-0.127 (0.020)***	-0.110 (0.043)**	-0.201 (0.076)***	-0.139 (0.043)***	-0.131 (0.022)***	-0.163 (0.033)***
$\overline{\overline{\ln(REER_s^{NET})}}$		-2.161 (0.064)***	-1.903 (0.121)***	-1.474 (0.152)***	-2.159 (0.127)***	-2.147 (0.068)***	-1.453 (0.110)***
Observations	48910	48910	13904	11192	14566	34344	19812
R^2 and \mathcal{L}	0.137	-35447	-8377	-4605	-9458	-26465	-12338
Random part							
Residual σ_μ^2	0.290	0.287 (0.003)***	0.256 (0.004)***	0.249 (0.004)***	0.248 (0.008)***	0.296 (0.002)***	0.283 (0.004)***
Firm σ_λ^2		0.584 (0.008)***	0.506 (0.014)***	0.492 (0.013)***	0.643 (0.016)***	0.560 (0.009)***	0.0517 (0.009)***
Sector σ_φ^2		0.292 (0.013)***	0.258 (0.024)***	0.224 (0.021)***	0.249 (0.025)***	0.299 (0.016)***	0.209 (0.019)***

Dependent variable: Share of employees in the firm with at least a university (undergraduate) degree, every 4 year period p .

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses, clustered at the firm level.

Column (1) report fixed effect estimates for each firm and 4 year period.

Columns (2)-(7) report nested random effects estimations, with random intercepts at the firm and 5-digit sector level.

All specifications include controls for firm capital $\ln(K_{isp})$, output $\ln(Y_{isp})$, export and import intensity S_{isp}^x and S_{isp}^m .

Columns (2)-(7) include meaned controls by firm and by sector.

Under columns (2)-(7), we report the results for the nested error component model in Equation 8, following the same samples reported in Tables 2 and 3, for comparability. Each includes controls for firm capital $\ln(K_{isp})$, output $\ln(Y_{isp})$, export and import intensity S_{isp}^x and S_{isp}^m , as well as the mean by firm and by sector of these respective controls.

Under column (2), the estimated *within-firm* effect of $\ln(\sigma_{isp}^{NET})$ is significant at the 10% level with a negative estimated elasticity of -0.013 . The corresponding estimate for $\ln(RER_{isp}^{NET})$ is significant at the 5% level with a positive estimated elasticity of 0.017 . The within firm estimates obtained from the nested error component model match well with the results reported in column (1).

Column (2) also reports the coefficients on $\overline{\ln(\sigma_{is}^{NET})}$ and $\overline{\overline{\ln(\sigma_s^{NET})}}$, which capture the between-firm and between-sector effects, respectively. The regression includes 48 910 observations, which is fewer observations reported in table 2 column (1) since the data have been collapsed from annual observations to one observation each 4 year period. The estimate on $\overline{\ln(\sigma_{is}^{NET})}$ is significant at the 1% level with a positive estimated elasticity of 0.114 . This estimate captures the difference in slope of the within-firm and between-firm effects. Likewise, the coefficient on $\overline{\overline{\ln(\sigma_s^{NET})}}$ captures the difference in slope of the between-firm and between-sector effects. The estimate is significant at the 1% level with a positive elasticity of 2.032 .

The total between-firm effect is therefore simply the sum of the within-firm and between-firm coefficients, which is $-0.013 + 0.114 = 0.101$ with statistical significance at the 1% level. This confirms that most of the effect reported in table 2 is due to between-firm variation. The estimate suggests that a one standard deviation increase in exchange rate risk index between firms (160% increase) leads to a 16% increase in the share of workers with at least a university degree.

The total between-sector effect is the sum of the within-firm, between-firm and between-sector effects, which is $-0.013 + 0.114 + 2.032 = 2.133$, with a statistical significance at the 1% level. In terms of the results reported in table 2, the between-sector effects are absorbed by the fixed effects.

Under column (3), we restrict the sample to export intensive firms, as defined earlier: firms that derive at least 15 % of their revenue from exports. the estimated within-firm effect of $\ln(\sigma_{isp}^{NET})$ is significant at the 5% level with a positive estimated elasticity of 0.028 . The corresponding estimate for $\ln(RER_{isp}^{NET})$ is significant at the 10% level with a negative estimated elasticity of -0.025 . For export intensive firms, the within-firm effect of $\ln(\sigma_{isp}^{NET})$ is in line with Hypothesis 1, and the within-firm effect of $\ln(RER_{isp}^{NET})$ is

in line with Hypothesis 3. The between-firm and between sector effects of $\ln(\sigma_{isp}^{NET})$ and $\ln(RER_{isp}^{NET})$ are statistically significant and have the expected sign.

Under columns (4)-(7), we report the results where all firm entry and exits are excluded, firms with more than 50 employees, firms with between 10 and 49 employees, and manufacturing firms. The within firms effects of $\ln(\sigma_{isp}^{NET})$ and $\ln(RER_{isp}^{NET})$ are statistically insignificant, and the point estimates largely have the opposite signs from those in Hypothesis 1 and 3. The estimate under column (6) on $\ln(RER_{isp}^{NET})$ is an exception, with a positive estimated coefficient that is statistically significant at the 10% level.

Finally, the estimated variance components are reported under columns (2)-(7). Since it is assumed that each variance component is IID, we can simply add the three variance components to obtain the total variance. Under Column (2), the total variance is 1.163. Most of the variance is from σ_{λ}^2 , the variance across firms. Around 50% of the total variance is between firms, within a sector. Around 25% of the total variance is between sectors. The estimated variances are statistically significant at the 1% level. The pattern is similar across columns (3)-(7).

6 Concluding remarks

This paper has examined the relationship between exposure to exchange rate risk and the skill level of employees at the firm level. Our study contributes to a growing body of research on the operational measures undertaken by firms to manage the risks they face. We find substantial effects on both second moment, and first moment shocks that support the hypotheses we test. Firms that face higher exchange rate risk adjust the skill level of their employees upwards. In contrast, firms that face a currency depreciation (appreciation) lower (raise) the level of skill employed. We also find evidence that firms use operational hedging to manage their exposure to currency risk.

Hiring and firing employees is often associated with significant costs, and we therefore disentangle the within-firm and between-firm effects using a nested random effects model. In such a model the within-firm effect of higher exchange rate risk is positive and significant for relatively export-intensive firms but for other firms the effects are weak and typically not significant. In contrast, between-firm and between-sector effects of exchange rate risk on skill levels are strong and positive across specifications.

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