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 1998–2014 to examine the links between exchange rate risk and the skill composition of labor in firms. We use firm × export destination and firm × import origin data to calculate firm-level measures of real exchange rate risk and real effective exchange rates. Our main result is that firms facing higher exchange rate risk employ a higher share of skilled labor and that the effect is especially marked among trade intensive firms in manufacturing and in firms with fewer than 50 employees. This finding is consistent with theoretical models of flexible work systems that require higher skill levels as a way of responding to higher risk.

Keywords Skill-biased organizational change · Exchange rate risk · Firm heterogeneity

JEL Classification 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 (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. In a seminal contribution (Stigler 1939) showed that a firm that faces more variability may want to organize production in a way that sacrifices static efficiency to gain flexibility. Stigler’s intuition, together with the observation that more flexible work practices generally require more highly skilled labor [see e.g. Caroli and Van Reenen (2001), Thesmar and Thoenig (2000)] motivate our analysis of links between firm specific exchange rate variability and the skill composition of the labor force in these firms.

We use matched employer–employee data covering the universe of private sector Swedish firms for 1998–2014 inclusive. These data are matched to firm-level customs data that include observations on each firm’s imports and exports across currency areas. With this rich data, we derive a risk index that measures each firm’s exposure to exchange rate shocks, which is a function of the firm’s trading activities across currency areas, and the magnitude of the variability of the exchange rate. Firms differ in their international composition of imports and exports and this gives us variation in exchange rate risk at the firm level: the risk index varies between firms and within firms over time. We use this variation to identify the effect of risk on skill composition at the firm level.\(^1\)

As a first test of the relationship between risk and skilled labor, we study firm-level effects within narrowly defined industrial sectors. Effects are positive throughout and non-trivial in magnitude when we consider the full population of firms with at least some international trade in the sample period. We find substantial effects for the tercile of firms with the highest trade share: for these firms, the estimated elasticity of a firm’s currency risk exposure from net trade on the firm’s share of skilled labor is 0.06. For manufacturing firms, the corresponding elasticity is 0.05. Given the variation of our measure of exchange rate risk, this suggests that a firm’s net exchange rate exposure has an important effect on the share of skilled labor employed by these firms. For example, for a given level of trade intensity, a manufacturing firm switching its exports and imports from Germany to the United States faces a 130% increase in exchange rate risk and would employ 7% higher share of labor with post-secondary education.\(^2\)

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1 Caggese et al. (2019) 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.

2 The 130% increase in exchange rate risk is based on the average standard deviation of the real exchange rates in Germany and the U.S., over the years 2000–2014.
Identification of these first estimates relies on variation in the risk index and skill levels between firms as well as within firms over time. However, we observe that most of the variation in risk and skill is between firms, which suggests that the estimated effects are derived mainly from between-firm variation. This evidence is consistent with a view that the decision on what skill level to use, and what currency areas to trade with, are long run in nature with significant sunk costs. Even with a rich set of controls and high-quality register data a causal interpretation of the estimates partly derived from between-firm variation in risk should therefore be undertaken carefully.

We therefore proceed to a specification that relies on within-firm variation in exchange rate risk to identify effects. To account for the time that it can take for firms to adjust their skill composition, given the relatively strong labor protection laws in Sweden, we examine 4-year periods. For the top tercile of trade intensive firms the effects are marked with an estimated elasticity of the share of high-skilled labor with respect to exchange rate risk of 0.07 and the associated increase in exchange rate risk associated with fully switching exports from Germany to the U.S. this would imply an increase in the share of high-skilled by some 9%. For an average firm with around 130 employees this is equivalent to replacing three low-skilled workers with three high-skilled workers. We parse the population into subsamples and find that the effect is particularly strong on the most trade intensive firms with fewer than 50 employees with an estimated elasticity of 0.1, or by some 13% for the thought experiment of fully switching from Germany to the U.S. as a trading partner.

To the best of our knowledge we are the first to examine the links between exchange rate risk and the skill composition of labor. In a related study (Kaiser and Siegenthaler 2016) examine the effect of a first moment exchange rate shock on the composition of skilled labor at the firm. Using rich data from Switzerland they establish that an appreciation of the Swiss franc is associated with a higher share of skilled labor. In contrast, we study skill-biased organizational change under second moment shock. Nonetheless, we also identify the same effect from first moment shocks to Swedish firms.

Our contribution is to establish a distinct effect of exchange rate risk on skill composition. We relate to a large literature that examines links between labor demand and a firm’s international engagement [see e.g. Bandick and Hansson (2009), Grossman (2013), Davidson et al. (2017), Malgouyres and Mayer (2018)]. Although are focus is on the role of risk, our results fit well with this literature. For instance we see that firms with a higher export share are more skill intensive.

In the next section we outline the theoretical foundations for the predicted effects and discuss the related literature. Section 3 describes the data and the risk indices that we compute. We discuss the empirical specification in Sect. 4 and then turn to results in Sect. 5. Section 6 concludes.

### 2 Theoretical foundation

In the introduction we posited that risk creates a value to being flexible, which in turn increases the value of a highly skilled/well educated work force. The reasoning is nontrivial and in the following we lay the theoretical foundation for the mechanism we study and review previous empirical evidence.
A first conceptual issue is that the terms “risk” and “uncertainty” are at times used as distinct concepts in the literature and at times used interchangeably. We will use the term risk and give it a broad interpretation, letting it capture a lack of knowledge of the realizations of future states of the world. This same broad interpretation is manifested for instance in the regulations from the SEC that govern how U.S. firms are to discuss “Risk factors” in Section 1A of their 10-K statements [see e.g. Friberg and Seiler (2017)].

2.1 Flexibility as a way of dealing with exchange rate risk

A depreciation of the real exchange rate tends to both raise export revenue and raise the cost of imported inputs. Exchange rate variations may thus translate into profit variations for a firm. Firms may respond to expectations of such future variability in many ways. For example, investing in state dependent contracts to create an offsetting exposure (e.g. using financial derivatives to hedge some exposure), modifying exposure (for instance engaging in “natural hedging”, trying to match currency inflows and outflows) or building buffers to limit consequences of adverse shocks [for instance precautionary cash holding as in e.g. Bates et al. (2009) or keeping greater inventory]. These methods for managing risk are not mutually exclusive.

In addition to these examples, and in line with the focus of this paper, firms may adapt their degree of flexibility. The strategic management literature highlights the importance of flexibility in adjusting to changing conditions [see e.g. Teece et al. (1997), Sull (2009) or Collins and Hansen (2011)]. Also the economics literature has examined flexibility as a way to respond to risk and the formalization by Stigler (1939), where greater flexibility is associated with a flatter average cost curve, remains a seminal reference. In this formalization flexible firms have a flatter average cost curve allowing them to at a lower cost respond to positive demand

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3 Narrower definitions reserve the term “risk” for situations with known probability distributions and “uncertainty” (e.g. Knightian uncertainty or ambiguity) to capture situations where different agents have different probability distributions or where there is potential for states of the world that were not foreseen by agents [see Gilboa (2009) for a comprehensive treatment]. Exchange rates may be reasonably described by objective probability distributions but the ultimate effect of an exchange rate change on a firm’s value will be operating via many channels, hinging on the behavior of customers, suppliers, regulators which will bring it more into the realm of uncertainty. Matters are further confounded by that in another strand of the literature uncertainty refers to the movement over time of a variable that follows a random walk where shocks follow a known probability distribution [see e.g. Bernanke (1983), Dixit et al. (1994)].

4 It is sometimes asked why a firm would concern itself with risk at all—why not just let diversified owners choose portfolios that suit their risk preferences? A number of reasons have been forwarded for why a firm would manage risk—for instance if a firm faces credit constraints, convex tax schedules, or is subject to some other mechanism that makes the value of the firm a concave function of risk factors which in turn imply that exchange rate risk lowers the value of the firm. 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, see Guay and Kothari (2003).

5 In operations research much work examines links between inventory and risk using “news vendor” models where inventory has to be decided before the realization of demand shocks, see e.g. Arrow et al. (1951) or Eeckhoudt et al. (1995).
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Figure 1 illustrates, in the simplest terms, the intuition for this mechanism but graphing profit functions rather than cost functions. The left panel illustrates the situation for an exporter with only domestic costs. $rf_x$ denotes the real exchange rate in domestic to foreign currency units.

Profits increase as the domestic currency depreciates against the foreign currency. Assume that the exchange rate is stochastic and has an expected value of $E(rf_x)$. Consider first the case of a “benchmark” technology where profits increase linearly with the exchange rate. Assume that this is the production technology that maximizes profits if the exchange were equal to its expected value, $E(rf_x)$. As profits in the benchmark case are linear in the exchange rate, expected profits are unaffected by a mean preserving spread of the exchange rate.

Now consider an alternative technology that has lower profits if the exchange rate has a realization close to the expected value but that has higher profits in the tails of the exchange rate distribution. We may call this a flexible technology—it sacrifices some profits in the case of small shocks for greater profits in the case of either large negative or large positive shocks. As with any convex function its expected value increases if we take a mean preserving spread of the exchange rate.

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.

The right hand panel of Fig. 1 illustrates 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. The two panels highlight that exchange rate risk is likely to operate both as demand and as cost shocks.6

Firms that face sufficiently high risk value flexibility, but what strategies can the firm deploy to operationalize flexibility? We may think of flexibility as the ability to respond quickly or at lower-cost to changes in the state of the world.7 Choosing a production function with higher fixed costs but lower marginal costs as suggested by Stigler (1939) is one way of being flexible but there are a variety of strategies available to the firm that operate through the different components of the profit function: price, demand and costs.

Flexibility through pricing can for example be achieved by greater price discrimination [see e.g. Friberg (2001)] or by lower price adjustment costs. On the demand side, the customer segments that a firm targets, and the degree of product differentiation, can also be related to flexibility [see e.g. Chang and Harrington Jr (1996) for an analysis]. On the cost side, flexibility can be achieved by choosing the appropriate number and location of suppliers of intermediate inputs [a large literature in supply chain management explores this strategy, see e.g. Esmaeilikia et al. (2016) and Antras et al. (2017) for evidence at the source country level] or adjusting capital structure [for instance leasing rather than owning equipment as explored in Gavazza (2011)]. The fact that a firm strives to become more flexible can also affect its demand for labor, an issue that we turn to now.

2.2 Flexibility, decentralization and labor demand

In broad terms, the study of how risks faced by firms affect labor demand has focused on two aspects. The first aspect is the composition of the work force in terms of temporary and permanent workers. In many countries there exist a difference in the labor contracts and hiring/firing costs between regular workers on open-ended contracts and non-regular workers, typically on fixed-term contracts. As the latter have lower hiring/firing costs they can act as a margin of adjustment.8 Holmlund and Storrie (2002) for instance document that temporary workers bore the brunt of the impact of a severe downturn in Sweden in the early 1990s. Of particular interest is also Yokoyama et al. (2018) who show that an appreciation of the Japanese yen is associated with a decrease in non-regular employment whereas there is no statistically significant effect on the number of regular employees. We may think of this first aspect as choosing different labor inputs for a given production function.

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6 This is clear in the case of a firm that both exports and imports but may hold also for firms that are only exporting if input prices are affected by exchange rate changes. To take a simple example, a goldsmith that procures her gold domestically would still experience an effect on her input price as gold is priced on world markets.

7 At a formal level we can think of flexibility as maximizing under fewer constraints (Silberberg 1971).

8 On a related note, differences in employment regulation across countries can affect production patterns as examined in Bergin et al. (2011) who document high volatility of maquiladora production in Mexico or Cuñat and Melitz (2012) who show that production in countries with laxer labor laws is concentrated in more volatile sectors.
The second aspect is the organization of production. An idea with deep roots in the history of strategy is that in volatile and risky environments decision rights should be delegated to those that have the relevant information, termed the “delegation principle” by Milgrom and Roberts (1992). The prediction follows from models built in a principal-agent setting: with asymmetric information the benefits of devolving responsibility to the agent increase when there is more risk or in situations where there is a need for rapid decision making. This benefit is balanced against the cost of coordination across a firm, but a typical outcome is that risk promotes delegation [see e.g. Aghion and Tirole (1997), Alonso et al. (2008) or Aghion et al. (2013) for a survey]. From this perspective Caroli and Van Reenen (2001) highlight the following benefits of decentralization: reduced costs of information transmission, increased reactivity to market changes, reduction in costs of monitoring and potential for increased job satisfaction.

A greater degree of decentralization is likely to affect the type of workers needed and a natural assumption is that decentralized organization requires a higher skill level of workers. There is empirical evidence to support this assumption. Caroli and Van Reenen (2001) for instance show that organizational change in panels of British and French firms are associated with increased relative demand for skilled labor. Acemoglu et al. (2007) report results with the same flavor.

The link between decentralization and increased relative demand for skilled workers is also in line with what several observers have characterized as “skill-biased organizational change”. In the words of Thesmar and Thoenig (2000, p. 1201) “the new organizational paradigm is supposed to achieve greater flexibility, adaptability, and reactivity through decentralized decision making, product-based hierarchy, unwritten rules and multitasking workers.” Other 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)].

Some data sets, such as those used by Caroli and Van Reenen (2001), have classifications of skill level for different positions (such as “skilled manuals” and “unskilled manuals”, something we do do not have in our data set). The skill-level of a worker clearly depends on previous relevant experience and innate ability, but also on the quality of the match. Much of this is hard to observe. However, there should be a positive correlation between skills and education levels, of which we have good measures in our data.11

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9 The discussion on temporary vs. permanent workers could be thought of as choosing \( L_{\text{TEMP}} \) and \( L_{\text{PERM}} \) in the production function \( Y = f(K, L_{\text{TEMP}}, L_{\text{PERM}}) \) in obvious notation. In contrast, reorganizing production is about adjustments to the function \( f \) itself—which in turn will affect labor demand.

10 They use survey data measure organizational change—in the UK for instance measured by managers answering yes to a question if there have been “substantial changes in the work organization or working practices not involving new plant, machinery or equipment”.

11 For instance, on the link between education and delegation (Caroli and Van Reenen 2001), discuss that more educated workers may be expected to raise the ability to handle and communicate rich information, to be less costly to train at performing different tasks and to be more likely to display job satisfaction as more authority is delegated to them.
In our analysis we will thus use the term high-skilled to capture workers with at least some post secondary education and low-skilled to capture those without such education. This is a simplification but corresponds to how the terms high-skilled and low-skilled have been used in the large literature on skill-biased technological change where high-skilled typically is defined as university graduates or those with post secondary education [see e.g. Acemoglu and Autor (2011) or Akerman et al. (2015)].

In sum, the mechanism we study links higher risk to greater flexibility to a greater skill share. The literature on “skill-biased organizational change” provides evidence of the latter link between flexibility and the skill of the workforce. A contribution of our work is to focus on the former link as well: to examine the role of exchange rate risk as a driver for greater flexibility and to establish if this source of risk leads to an increase in the demand for skilled labor.

The discussion above leads us to the following key hypothesis that we explore:

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

Section 4 specifies how we take this prediction to the data. In developing the hypothesis we emphasized the role of skilled labor for flexibility. As discussed above there are many possible ways whereby firms can respond to demand and cost volatility such as holding more cash or restructuring to engage in more price discrimination. Mostly these alternative means have unclear (if any) implications for the relative demand for high-skilled workers but it deserves to be noted that we can’t rule out that some of these other means may have effects that strengthen (or counteract) the mechanism that serves as our motivation.

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 and furthermore limit attention to firms that export or import at least 1 year in the sample. The main source of the data is Sweden’s official statistics agency, Statistics Sweden. The data are yearly and our data cover the period 1997–2014 inclusive. The main regression analysis uses one yearly lag for some independent variables and thereby these regressions rely on data from 1998 to 2014. We observe firm × country exports and imports and also use 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 the 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 measure of skill level we use the percentage share of the total workforce in a firm that has at least some post-secondary education. Sweden has 9 years of
mandatory schooling, followed by secondary education which consists of 2 or 3 years of vocational or academic schooling, which is followed by the majority: 78% of low-skilled workers have completed secondary education.\textsuperscript{12} We refer to those with at most a degree from secondary education as low-skilled. Those with post-high secondary education are counted as high-skilled. This group includes not only those with a bachelor degree or higher, but also those that have studied at least one semester at university or those that have followed post-secondary vocational training. The Swedish classification of educations follows the ISCED 1997 standard from year 2000 onward and individuals with education levels 4, 5 and 6 in this nomenclature are counted as high-skilled. Due to changes in the classifications in year 2000 data from before this are not directly comparable to later data. In the benchmark regressions that use 1998 as their first year this is a limited concern because industry \( \times \) year fixed effects are likely to capture the change (robustness checks for the post-2000 period confirm that this is not important for results). The change in classifications is more of a potential concern in firm fixed regressions and in these we examine the post 2000 period only.

Employees are linked to employers via wage bills in the tax records and there is no direct distinction between permanent (on open-ended contract) and temporary (on fixed-term contract) employees and the latter are therefore included in e.g. our calculated share of high-skilled. Swedish labor laws permit temporary employment for up to 2 years, after which the employment becomes permanent unless there are specific circumstances. Statistics Sweden reports on various issues related to temporary employment in their labor force surveys, which covers a random sample of around 20,000 individuals per month. Based on these surveys around 15% of employment is temporary during our period of study. A little less than a third of temporary employees are substitutes (generous parental leave of more than 1 year per child is one important reason for substitutes) and overall the evidence suggests that temporary employment is used both for reasons of flexibility and as way for employers to screen employees, thus acting as a gateway for permanent employment, see e.g. Berglund et al. (2017) for further analysis.

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 (SEK) price of foreign currency.\textsuperscript{13} A higher value for

\textsuperscript{12} The share of low-skilled workers that have graduated with a secondary schooling degree is computed across all workers in the data from the period 2001–2014. We exclude earlier years to avoid the confounding effects of the new education classification system that was introduced in 2000.

\textsuperscript{13} Unfortunately we do not have access to the currency of invoice for the trade flows in our data but one may wonder if it is not the currency of the invoice, rather than the currency of the trading partner, that matters for risk. A first observation, which mitigates this concern is that Swedish exports are predominantly invoiced and priced in the importer’s currency (Friberg and Wilander 2008) at the same time as Swedish imports are predominantly invoiced in the exporter’s currency (Hopkins 2006). Changes in the bilateral exchange rate then have a direct effect on export revenue and import cost. Second, at longer time horizons, such as the yearly level that our study focuses on, we expect the relative cost level of a country
an exchange rate is thus associated with a real depreciation of the SEK. 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 \( rfx_{at} \). We use \( rfx_{at} \) to calculate a measure of volatility for each currency area against the SEK. To do so we calculate standard deviations at the quarterly level for a 3 year rolling window and then take the average in year \( t \) for currency area \( a \) as a measure of the risk, denoted by \( \sigma_{at} \).\(^{14}\)

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

We construct indices to capture each firm’s exposure to exchange rate risk. Likewise, we derive separate indices to capture each firm’s exposure to changes in the exchange rate level for exports and imports. Denote total revenue for firm \( i \) in year \( t \) by \( R_{it} \) and total cost of goods sold by \( C_{it} \). Denote the value of exports from firm \( i \) to currency area \( a \) in year \( t \) as \( X_{iat} \) and the corresponding value of imports by \( M_{iat} \).\(^{15}\)

Our measure of exchange rate risk for a firm is the weighted average of standard deviations of the real exchange rate. For export and import weights we use the average of the share of exports to (imports from) currency area \( a \) in total revenue (total cost) over the years the firm is observed to be active. The weights are constant over time to ensure that changes to the index are generated by changes in exchange rate volatility rather than by simultaneous changes in the weights. Our main measure of exchange rate risk is hence

\[
\sigma_{it}^G = \sum_{a=1}^{A} (w_{X_{ia}} + w_{M_{ia}}) \times \sigma_{at}
\]  

(1)

where the export and import weights are, respectively

\[
w_{X_{ia}} = \frac{1}{N_i} \sum_{t \in N_i} \frac{X_{iat}}{R_{it}}
\]  

(2)

\[
w_{M_{ia}} = \frac{1}{N_i} \sum_{t \in N_i} \frac{M_{iat}}{C_{it}}
\]  

(3)

Footnote 13 (continued)

(as captured by the real exchange rate) to be more important than the denominational currency of a contract as long as prices are somewhat flexible in the long run.

\(^{14}\) We 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.

\(^{15}\) We treat each country as a currency area with the exception of the euro area which is treated as one currency area (including Denmark, whose exchange rate vis-à-vis the euro is fixed within a narrow band).
and $N_i$ is the number of years the firm is active. We use revenue and costs to normalize weights to reflect that the impact of exchange rates will hinge on whether trade is important to firm profits. Intuitively, we expect a more limited effect if say exports account for 5% of revenue as opposed to a case where exports account for say 60% of revenue. Note that the weights we use are equivalent to a case where we consider the share of a respective market in trade and then multiply with the share of trade in revenue or cost. Exemplifying with exports, and ignoring the time index, export share to market $a$ times the share of exports in total revenue $w_{ia}^X = \frac{X_i, a}{X_i, R_i}$ (where $X_i$ is total exports) clearly is equivalent to the measure we use $w_{ia}^X = \frac{X_i, a}{R_i^i}$.

We also calculate the corresponding indices for the real exchange rate level, considering exports and imports separately:

$$RER_{it}^X = \sum_{a=1}^{A} w_{ia}^X \times R_{fa}$$  \hspace{1cm} (4)

$$RER_{it}^M = \sum_{a=1}^{A} w_{ia}^M \times R_{fa}$$  \hspace{1cm} (5)

Finally, we also examine “net” exchange rate risk: if a firm exports to and imports from the same currency area the exposure may cancel. We discuss the distinction between net and gross exchange rate risk in more detail below. We calculate an index of net exchange rate risk using weights that is a function of the absolute value of the difference between export and import intensity from a currency area $a$.

$$\sigma_{it}^{NET} = \sum_{a=1}^{A} |w_{ia}^X - w_{ia}^M| \times \sigma_{at}$$  \hspace{1cm} (6)

### 3.2 Summary statistics

Before we proceed with the analysis it may be useful to briefly describe the data and we provide summary statistics of the full regression sample in Table 1 Panel A. Identification of the effects relies on firms having some exposure to exchange rate variability. The sample is therefore restricted to include only those firms that engage in some level of international trade.

On average, across these firms and years, 29% of the workforce has post-secondary 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 133 employees. There is large variation in the capital stock around the average of 80 million SEK.

We see that the indices of risk and real effective exchange rates exhibit substantial variation, representing both different trade intensity and differential geographical trading patterns. This is important for identification. The sample contains only firms engaged in international trade and nonetheless, there is substantial variation in the
risk indices. The correlation between risk and real effective exchange rates is $-0.17$ which supports the idea that we will be able to identify the effect of risk separately from first moment movements.\(^{16}\) There is substantial variation in international trading intensity as well.

The average export share in revenue is 0.18 and the average import share of costs is 0.11. 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 around 11 years, lower than the

\(^{16}\) This is the correlation between the first and second moments of the changes in exchange rates across all of Sweden’s trade partners.
maximum of 15 and this reflects both movements around the lower cutoff of 10 employees as well as entry and exit.

In Panel B, we report the descriptive statistics for the tercile of firms that are most trade intensive. Most trade intensive firms defined as the observations in the top tercile in terms of export share + import share ($S_{it}^X + S_{it}^M$). On average, these firms have a higher share of export revenues in total revenue than the full sample of firms, likewise for imports. Some of these most trade intensive firms are exporters with no imports, or importers with no exports (the minimum observations for $S_{it}^X$ and $S_{it}^M$ are zero).

Finally, these firms have on average a higher gross and net exposure to exchange rate risk according to our measures $\sigma_{it}^G$ and $\sigma_{it}^{NET}$. There is substantial variation in risk exposure and educational levels within this sample, which is important for identification of the results.

4 Empirical specification

We use two types of regressions to estimate the relationship between firm-specific exchange rate risk and skill levels. In a first set of regressions we use variation over time and within finely defined sectors to identify the effect. We estimate the effect of exchange rate risk on a firm’s skill composition with the following specification:

$$
\ln(SKILL_{ijst}) = \alpha_0 \ln(\sigma_{it}^G) + \alpha_1 \ln(RER_{it}^X) + \alpha_2 \ln(RER_{it}^M) + \gamma_{jt} + \theta_{s} + \beta X_{it-1} + \varepsilon_{ijst}.
$$

The dependent variable is the natural log of the share of workers with at least some post-secondary education in firm $i$ in two-digit industry $j$ and five-digit industry $s$ in year $t$. We also analyse the level of skilled (unskilled) workers, where the dependent variable is the natural log of the number of workers with at least some (no) post-secondary education in firm, which we denote with $\ln(L_{it}^{HS})$ ($\ln(L_{it}^{LS})$).

The key variable of interest is the measures of the firm $\times$ year specific exchange rate volatility where both gross ($\sigma_{it}^G$) and net volatility ($\sigma_{it}^{NET}$) are explored. Where gross volatility $\sigma_{it}^G$ is examined, it is implicitly assumed that there is scope for risk from both exports and imports to increase the value of flexibility. For example, consider a firm that derives a substantial share of revenue from exports to the U.S., and likewise has a substantial share of U.S. imports in its costs. An increase in SEK-USD exchange rate volatility on its exports might drive a firm to invest in a more flexible production system that allows it to switch across product lines. Likewise, increased volatility of import prices might drive a firm to increase flexibility by investing in production systems that allows it to substitute input suppliers from other currency areas. Currency risk would then increase in both export and import exposure, or gross exposure. Gross exposure will be our benchmark specification.

Alternatively, note that exposure to first moment export and import shocks are likely to partly cancel, i.e. “natural hedging”. A firm’s exposure to an appreciation in the domestic currency is likely to be offset by exporting to, and importing from, the
same currency area. Hence, it could be that export and import sources of risk cancel and that net exposure is what matters from the point of view of the firm. We do not have any prior on whether it is gross or net currency exposure that matters, but we do note that the nature of the shocks and the production technology of the firm play a role. If it is “net” exposure that matters, we would observe a significant effect of net exchange rate risk and we also explore this with a specification identical to Eq. (7) except we replace $\sigma^G_{it}$ with $\sigma^{NET}_{it}$.

As controls we use the natural log of the level of the firm-specific real exchange rate on exports and imports, $RER^X_{it}$ and $RER^M_{it}$ respectively. As all these variables are in natural logarithmic form the coefficients can be interpreted as elasticities. In addition we include year × 2-digit sector fixed effects ($\gamma^j_{jt}$) and 5-digit sector fixed effects ($\gamma^s_{it}$), where $j$ and $s$ denote the 2 and 5-digit sectors, respectively.

$X_{it-1}$ is a vector of additional controls that are lagged 1 year: capital in logarithmic form for firm $i$ in year $t - 1$, and to control for differences in international exposure we also include the lagged export share of revenue and import share of costs, $S^X_{it-1}$ and $S^M_{it-1}$, respectively. The statistical error term is denoted by $\epsilon_{it}$. Equation (7) is estimated using data from 1998–2014 on all Swedish private firms with at least 10 employees and at least some imports and/or exports during the sample period. Observations from 1997 are used as lagged control variables in the first year of the sample.

4.1 Identification: between firm variation

Our key hypothesis is that $\alpha_0 > 0$. Identification of this effect relies on differential time series patterns in the development of exchange rate volatility across different exporters and importers and from cross-sectional variation within 5-digit industries. We assume that exchange rate volatility is exogenous to the firm which is plausible if exchange rate changes are generated by macroeconomic shocks and expectations regarding macroeconomic policies and shocks. We use constant firm-specific weights to reflect the importance of different currency areas. A potential concern is that a positive shock to a currency would not only lead to an increase in $\sigma^G_{it}$ 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 fixed weights (across time) to capture the intensity of a firm’s trade across currency areas.17

Another concern is firm heterogeneity within sectors. We include a rich set of lagged controls with the vector $X_{it-1}$, but cannot observe all the differences between firms. The decision on skill level and what currency area to trade with are long run in nature and probably correlated with a number of unobserved firm characteristics such as leadership and corporate culture. With this approach, we cannot claim that currency risk causes firms to adopt flexible operations with skilled workforce.

17 We have also examined a specification where we use weights based on trade in the last 3 years, and results are largely unaffected.
4.2 Identification: within firm variation

In a second set of regressions we use the variation of risk within-firms to identify effects and use firm fixed effects to control for unobserved heterogeneity. For this part of the analysis, identification is achieved from the differential time series patterns in exchange rate volatility. In our setting, a challenge with this identification strategy 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.\footnote{Compared 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 worker would be subject to substantial costs and negotiations. Von Below and Thoursie (2010) provide a detailed examination of the effect of seniority rules on firms’ employment behavior.}

Another challenge is persistence in the volatility of exchange rates. Markets with volatile exchange rates in the past are likely to have volatile exchange rates in the future. We expect a firm to increase its skill level if volatility increases for these markets. However, if there is a persistence in the relative volatility of an exchange rate, we would expect such firms to start from an already high skill level and the within-firm effect may be quite limited. A look at the data confirms that much of the variation in firm skill levels is between firms. Across the full sample reported in Table 1, within-firm standard deviation in $\text{SKILL}_i$ is 33\% of the overall standard deviation, whereas between-firm standard deviation is 104\% of the overall standard deviation.

Given the persistence of both dependent and explanatory variables we therefore collapse the data from annual observations to averages over 4 year periods. These longer time period between observations helps identify within-firm effects given the potential persistence in measures of skill level and currency risk. Equation (8) describes the within-firm regressions with the longer time period, where $p$ denotes the respective 4 year period, $\kappa_i$ denotes a firm fixed effect and $(\gamma_{jp})$ captures period x 2-digit sector fixed effects:

$$
\ln(\text{SKILL}_{ip}) = \alpha_0 \ln(\sigma_{ip}^{G}) + \alpha_1 \ln(\text{RER}_{ip}^{X}) + \alpha_2 \ln(\text{RER}_{ip}^{M}) + \gamma_{jp} + \kappa_i + \beta X_{ip-1} + \varepsilon_{ip}.
$$

Equation (8)

As noted, educational classifications changed in 2000 which may be a concern in a firm fixed effects regression and the first 4-year period that we use in estimations commences with 2003, previous years being used to generate lags only.\footnote{Estimation results are largely the same using data commencing in 2001 or 2002.}
Table 2 Exchange rate risk and the share of high-skilled employees

| Variables       | (1)          | (2)          | (3)          | (4)          | (5)          |
|-----------------|--------------|--------------|--------------|--------------|--------------|
| $\ln(\sigma^G_{it})$ | 0.0316***    | 0.0236***    | 0.0246***    | 0.0178***    | 0.0136***    |
|                  | (0.00255)    | (0.00461)    | (0.00459)    | (0.00459)    | (0.00287)    |
| $\ln(\sigma^{NET}_{it})$ | 0.0113***    | 0.0119***    | 0.00639**    | 0.00827***   | 0.00285***   |
|                  | (0.00297)    | (0.00297)    | (0.00310)    | (0.00285)    | (0.00285)    |
| $\ln(RER^X_{it})$ | -0.000484    | -0.000492    | -0.0121***   | -0.00933***  | -0.00268**   |
|                  | (0.00317)    | (0.00316)    | (0.00326)    | (0.00268)    | (0.00268)    |
| $\ln(RER^M_{it})$ | 0.0113***    | 0.0119***    | 0.00639**    | 0.00827***   | 0.00285***   |
|                  | (0.00297)    | (0.00297)    | (0.00310)    | (0.00285)    | (0.00285)    |
| $\ln(K_{it-1})$  | -0.0128***   | -0.0162***   | -0.0161***   | -0.0161***   | -0.0161***   |
|                  | (0.00263)    | (0.00262)    | (0.00262)    | (0.00262)    | (0.00262)    |
| $S^X_{it-1}$     | 0.286***     | 0.285***     | 0.259***     | 0.269***     | 0.269***     |
|                  | (0.0212)     | (0.0211)     | (0.0540)     | (0.0539)     | (0.0539)     |
| $S^M_{it-1}$     | 0.3450***    | 0.3433***    | 0.3636***    | 0.3506***    | 0.3499***    |
|                  | (0.0176)     | (0.0198)     | (0.0458)     | (0.0468)     | (0.0454)     |
| Constant         | 3.450***     | 3.433***     | 3.636***     | 3.506***     | 3.499***     |
|                  | (0.0176)     | (0.0198)     | (0.0458)     | (0.0468)     | (0.0454)     |
| Sector FE (5-digit) | Yes         | Yes          | Yes          | Yes          | Yes          |
| Year $\times$ sector FE (2-digit) | Yes | Yes | Yes | Yes | Yes |
| $R^2$            | 0.482        | 0.482        | 0.483        | 0.487        | 0.488        |
| Observations     | 132,288      | 132,288      | 132,288      | 132,288      | 132,288      |

Sweden 1998–2014. Dependent variable: Natural log of share of employees in the firm with at least some post-secondary education. Standard errors in parentheses, clustered at the firm level

*p < 0.10, **p < 0.05, ***p < 0.01

5 Estimation results on firm skill composition and exchange rate risk

Table 2 presents results from the baseline regression (Eq. 7) with yearly data and fixed effects at the five-digit sector and time-varying fixed effects at the two-digit level. Column (1) only includes firm-specific gross real exchange rate risk as explanatory variable in addition to the fixed effects. The coefficient is positive and significant at the 1% level. In column (2) we add the current levels of firm-specific real exchange rates for exports and imports which lowers the estimated effect of risk but the coefficient remains significant at the 1% level. Column (3) adds the natural log of capital and column (4) in addition adds lagged export and import shares.

The results support our hypothesis: higher exchange rate risk is associated with a higher share of high-skilled labor. The main coefficient of interest on firm level exchange rate risk falls somewhat as additional controls are added but remains statistically significant at the 1% level and is non-trivial in magnitude even in column (4). The estimated elasticity is 0.018 and there is substantial variation in
the index of exchange rate risk, which has a standard deviation of 0.01, which is greater than the average 0.008. For example, for a given level of trade intensity, a firm switching its trade activities from Germany to the U.S. would see an increase in exchange rate risk of 130%, and the associated increase in the share of highly skilled by 2.3% (0.0178 × 130%). An average firm in the sample has around 29% high-skilled employees and around 130 employees. An increase of 2.3% in the share is roughly equivalent to such a firm replacing one low-skilled worker with one high-skilled worker. Henceforth, we refer to the results in Table 2 column (4) as the “benchmark” regression.

The estimated effect of a currency depreciation on skill levels is negative for exports \( \ln(\text{RER}_X) \) but positive for imports \( \ln(\text{RER}_M) \). The point estimates differ slightly across columns but under column (4) we note that the magnitude of the (negative) estimated coefficient on exports is greater than that on imports, indicating that a depreciation (appreciation) of SEK leads to a decrease (increase) in the share of high-skilled workers. In recent work (Kaiser and Siegenthaler 2016) claim to be the first to study this issue and, using data from Switzerland, find the same effect: the share of high-skilled workers increase as the Swiss franc appreciates, consistent with the idea that imported inputs are a closer substitute for low-skilled workers.

More capital is associated with a lower skill level, indicating that overall capital and high skilled labor are substitutes. While an off-the-shelf production function would typically have overall labor and overall capital as substitutes the result may still be 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.

Column (4) also controls for export shares and import shares. Again the effect on export and import shares is statistically significant at the 1% level and economically significant. An increase in the export (import) share by 1% is associated with an increase in the share of skilled workers by 0.29% (0.26%). Both of these results square well with the previous literature. A number of articles have shown that exporting, and the composition of export markets, may matter for the firm’s skill composition, even disregarding risk.20 The role of skill in exporting reported with the current data corroborate findings documented for other countries.

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20 Bernard and Jensen (1997) provide early evidence for this on U.S. data, and positive relations between skill intensity and exporting have been found for e.g. Mexican (Verhoogen 2008) and Danish (Munch and Skaksen 2008) data. 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, as is also established in Davidson et al. (2017). Furthermore, a large literature which finds that higher exports are associated with higher wages also support the skill upgrading mechanism [see e.g. Schank et al. (2007) for German evidence]. In terms of imports 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].
Column (5) presents the same specification reported in column (4) but uses net rather than gross currency risk. The estimated coefficient on net currency is positive and statistically significant at the 1% level. The point estimate for the elasticity of 0.014 is somewhat lower than the point estimated for the elasticity of gross currency risk and net volatility is also less variable (means and standard deviations are roughly around half as large). The other coefficients are essentially stable across columns (4) and (5) and explanatory power of regressions as measured by R-squared is almost identical. In the Online Appendix we report regression results that show that these benchmark results are essentially unchanged if we consider the period after the change in educational classifications (Table A.1) or only consider trade with OECD countries (Table A.2).

In Table 3 we consider the equivalent of the benchmark regression (Table 2, column (4)) across subsamples. Column (1) reports the results for the most trade intensive firms (top tercile) and as seen the estimated elasticity with respect to exchange rate risk is over three times as large as in the overall population. More trade intensive firms are more exposed to exchange rate risk, which would motivate firm restructuring. Column (2) reports results for firms that are present in

| Variables | (1) Traders | (2) No exit | (3) 50+ Employees | (4) 50– Employees | (5) Manufacturing |
|-----------|-------------|-------------|-------------------|------------------|------------------|
| ln(σ^G_i) | 0.0615***   | 0.0187***   | 0.0124            | 0.0189***        | 0.0535***        |
|           | (0.0118)    | (0.00469)   | (0.00841)         | (0.00524)        | (0.00887)        |
| ln(RER^X_i) | −0.0443***  | −0.0123***  | −0.0105*          | −0.00942***      | −0.0115*         |
|           | (0.0117)    | (0.00332)   | (0.00608)         | (0.00358)        | (0.00652)        |
| ln(RER^M_i) | −0.00340    | 0.00604*    | 0.0164***         | 0.00454          | −0.0001          |
|           | (0.00796)   | (0.00314)   | (0.00616)         | (0.00348)        | (0.00502)        |
| ln(K_{it−1}) | −0.00838*   | −0.0153***  | 0.00763           | −0.0361***       | −0.0188***       |
|            | (0.00438)   | (0.00264)   | (0.00524)         | (0.00352)        | (0.00446)        |
| SX^it−1   | 0.159***    | 0.294***    | 0.360***          | 0.256***         | 0.300***         |
|           | (0.0255)    | (0.0214)    | (0.0356)          | (0.0256)         | (0.0305)         |
| SM^it−1   | −0.214***   | 0.281***    | 0.342***          | 0.194***         | −0.00763         |
|           | (0.0796)    | (0.0552)    | (0.0881)          | (0.0646)         | (0.0832)         |
| Constant  | 3.369***    | 3.298***    | 2.911***          | 3.607***         | 3.271***         |
|           | (0.0838)    | (0.0467)    | (0.0990)          | (0.0575)         | (0.0864)         |
| Sector FE (5-digit) | Yes | Yes | Yes | Yes | Yes |
| Year × sector FE (2-digit) | Yes | Yes | Yes | Yes | Yes |
| R^2       | 0.438       | 0.503       | 0.628             | 0.438            | 0.319            |
| Observations | 44,096     | 126,260     | 47,371            | 84,146           | 60,572           |
all periods with little difference relative to the benchmark. Columns (3) and (4) reports results for firms with more than 50 employees and less than 50 employees respectively. Point estimates are positive in both cases but not statistically significant for larger firms possibly because the number of observations for 50+ firms is about half of 50− firms. Column (5) reports results for manufacturing firms and again we see a stronger effect than in the benchmark.

The evidence thus far indicates that firms that face high exchange rate risk employ a higher share of high-skilled workers. The effect is robust across specifications and the quantitative impact is strongest for firms that are trade intensive and in manufacturing sectors.

We next study the role of gross and net exchange rate risk and the number of high-skilled and low-skilled employees in firms in Table 4. The dependent variable is \( L_{it}^{HS} \) the number of high-skilled employees at the firm in columns (1) and (3), and

### Table 4: Exchange rate risk and the number of high- and low skilled employees, within-sector variation

| Variables                  | (1) \( L_{it}^{HS} \) | (2) \( L_{it}^{LS} \) | (3) \( L_{it}^{HS} \) | (4) \( L_{it}^{LS} \) |
|----------------------------|-------------------------|------------------------|------------------------|------------------------|
| \( \ln(\sigma_G^{it}) \)  | 0.0178***               | −0.00422               | 0.0143***              | −0.00293              |
|                           | (0.00468)               | (0.00360)              | (0.00294)              | (0.00210)              |
| \( \ln(\sigma_{NE}^{it}) \) |                        |                        |                        |                        |
|                           |                         |                        |                        |                        |
| \( \ln(\text{RER}_G^{it}) \) | −0.0139***             | 0.00815***             | −0.0115***             | 0.00738***             |
|                           | (0.00331)               | (0.00264)              | (0.00274)              | (0.00224)              |
| \( \ln(\text{RER}_M^{it}) \) | 0.00640**              | 0.0112***              | 0.00802***             | 0.0107***              |
|                           | (0.00318)               | (0.00279)              | (0.00292)              | (0.00271)              |
| \( \ln(K_{it-1}) \)       | −0.00228               | 0.0415***              | −0.00227               | 0.0415***              |
|                           | (0.00327)               | (0.00230)              | (0.00327)              | (0.00230)              |
| \( S_X^{it-1} \)          | 0.290***               | −0.111***              | 0.288***               | −0.111***              |
|                           | (0.0219)               | (0.0135)               | (0.0219)               | (0.0135)               |
| \( S_M^{it-1} \)          | 0.282***               | 0.00889                | 0.292***               | 0.00673                |
|                           | (0.0559)               | (0.0437)               | (0.0558)               | (0.0434)               |
| \( \ln(L_{it-1}) \)       | 0.954***               | 0.894***               | 0.954***               | 0.894***               |
|                           | (0.00584)              | (0.00557)              | (0.00584)              | (0.00558)              |
| Constant                  | −1.136***              | −0.614***              | −1.137***              | −0.612***              |
|                           | (0.0483)               | (0.0456)               | (0.0468)               | (0.0439)               |

Sector FE (5-digit)       Yes Yes Yes Yes
Year × sector FE (2-digit) Yes Yes Yes Yes
Observations              132,288 132,009 132,288 132,009
\( R^2 \)                  0.803 0.869 0.804 0.869

Sweden, 1998–2014. Dependent variable in column (1) number of employees with at least some post-secondary education, in column (2) number of employees without such education. Standard errors in parentheses, clustered at the firm level.

\* \( p < 0.10 \), \** \( p < 0.05 \), \*** \( p < 0.01 \)
the number of low-skilled employees at the firm in columns (2) and (4). The explanatory variables are those used in the benchmark regression but include the total lagged number of employees in a firm. In column (1) we see a positive and statistically significant effect of exchange rate risk on the number of high-skilled workers that is of the same size as the coefficient in the benchmark regression with skill share as dependent variable. This specification is essentially a replication of the benchmark regression, the difference being that the number of employees at the firm \( \ln(L_{it}) \) has been shifted to the right hand side of the regression. In contrast, the estimated effect of exchange rate risk on the number of low-skilled workers is closer to zero and not statistically significant as seen in column (2). Columns (3) and (4) confirm that the same results hold for net exchange rate risk. Overall this indicates that it is the hiring of high-skilled workers, rather than fewer low-skilled workers, that drive the results. This latter result contrasts to some earlier work on skill-biased organizational change where for instance (Caroli and Van Reenen 2001) find that organizational change primarily affects skill-composition by lowering the numbers of low-skilled workers. A potential reason for the difference is that, unless there are financial difficulties, it is costly to fire low-skilled workers in Sweden and an adjustment is simpler to achieve with hiring rather than firing. Another potential reason for the somewhat different result with regard to Caroli and Van Reenen (2001) is that they consider a well-defined event (answering yes to a question about organizational restructuring) rather than a continuously evolving exchange rate risk as in our case. Despite this difference with respect to Caroli and Van Reenen (2001) our result is clearly consistent with skill-biased organizational change as a response to greater volatility since the theoretical link between delegation and skill share is silent with respect to whether the share of high-skilled increases via hiring of high-skilled workers or firing of low-skilled workers.

5.1 Controlling for firm fixed effects

For the second part of the analysis, we use fixed effects at the firm level to control for unobserved firm heterogeneity. As discussed in Sect. 4 a challenge for such an identification strategy in the present setting is the persistence of the dependent and key explanatory variables: they are likely to evolve slowly as hiring and firing are associated with substantial costs, and exchange rate volatilities persist. We therefore collapse the data from annual observations to the average over a 4 year period. The purpose is to use longer time period between observations to help identify within-firm effects. Even so, for the full sample the estimated effects of exchange rate risk on the share of high-skilled workers yields a positive point estimate, but the coefficient is close to 0 and not statistically significant as seen in Table A.3 in the online appendix.

To explore our hypothesis, we exploit the idea that effects are likely to be strongest among trade intensive firms. We therefore partition the sample into terciles according each firm’s trade intensity (export share of revenue + import share of cost) and report results from fixed effects specifications for each tercile in Table 5. In the lower two terciles (columns (1) and (2)) we see little effect but for the third
Exchange rate risk and the skill composition of labor

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...tercile of firms, that are the most trade intensive, exchange rate risk has an estimated elasticity with the share of high-skilled labor of 0.071, statistically significant at the 5% level. For context, a firm switching its trade activities from Germany to the U.S. would see an increase in exchange rate risk of 130%, and the associated increase in the share of highly skilled by 9.2% (0.071 × 130%). For a firm with around the average number of employees this would be equivalent to it replacing three low-skilled workers with three high-skilled workers. If adjustment in the share is to come about only via hirings, it is approximately equivalent to such a firm hiring five high-skilled workers.

A key difference between the current and previous estimates is that the longer time periods allow for a greater scope of responding by adjusting the share of different employees. Overall the other explanatory variables are not statistically significant, most likely reflecting that with a limited number of periods the firm fixed

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Table 5  Exchange rate risk and the skill level of employees

| Firm fixed effects | 5 Digit sector fixed effects |
|-------------------|-----------------------------|
| (1)               | (2)                         | (3)               |
| (4)               | (5)                         | (6)               |
| **Low trade**     | **Middle trade**             | **High trade**    |
| **Low trade**     | **Middle trade**             | **High trade**    |
| **ln(σ_{ij}^{ε})**| **0.005**                   | **0.008**         | **0.071***** |
|                   | (0.008)                     | (0.014)           | (0.029)      |
| **ln(RER_{ij}^{X})**| **0.006**                   | **0.003**         | **0.044**    |
|                   | (0.006)                     | (0.009)           | (0.037)      |
| **ln(RER_{ij}^{M})**| **0.004**                   | **0.007**         | **0.016**    |
|                   | (0.005)                     | (0.009)           | (0.015)      |
| **ln(Κ_{ij−1})** | **0.006**                   | **−0.016****      | **−0.003**   |
|                   | (0.007)                     | (0.007)           | (0.007)      |
| **S_{ij−1}^{X}**  | **−0.149**                  | **0.099**         | **−0.033**   |
|                   | (0.129)                     | (0.061)           | (0.030)      |
| **S_{ij−1}^{M}**  | **0.282**                   | **−0.041**        | **0.065**    |
|                   | (0.187)                     | (0.104)           | (0.093)      |
| Constant          | **3.052*****                | **2.650*****      | **2.649***** |
|                   | (0.158)                     | (0.166)           | (0.548)      |
| Firm FE           | Yes                         | Yes               | Yes          |
| Sector FE (5-digit)| No                          | No                | No           |
| Period × sector FE(2-digit)| Yes | Yes | Yes |
| R²                | **0.926**                   | **0.882**         | **0.882**    |
|                   | (0.9803)                    | (0.9803)          | (0.9802)     |
| Observations      | **9803**                    | **9803**          | **9802**     |

**Within-firm variation and within-sector variation by trade intensity tercile**

Sweden 2003–2014. Dependent variable: Natural log of share of employees in the firm with at least some post-secondary education. Time periods set to 4 year periods. Standard errors in parentheses, clustered at the firm level

* p < 0.10, ** p < 0.05, *** p < 0.01
effects soak up much of the variation and furthermore much of the time series variation is absorbed by the period \times two-digit sector fixed effects.\textsuperscript{21} For comparison the last three columns in Table 5 provide the corresponding regressions estimated without firm fixed effects and instead including fixed effects at the 5-digit industry level. The pattern with lower estimated coefficients on firm-specific exchange rate risk in the firm fixed effects specification is consistent with a situation where firms that are faced with high firm-specific risk in a previous period are also faced with high firm-specific risk in the next period. To the extent that these firms already have a higher skill-share in the first period this will be captured by the firm fixed effect and the coefficient on exchange rate risk will be identified by within-firm variation only.

Again, we are interested in how the results may vary across different subsamples when firm fixed effects are included. In Table 6 we therefore consider only firms in the top tercile of trade intensity and examine the same subsamples we reported in Table 3. In column (1) we reported results for the balanced panel and the point estimate is close to what we found for the entire tercile. For firms with more than

\textsuperscript{21} Results are similar if we instead use period fixed effects that are common across all firms.
50 employees the estimated effect is small and not statistically significant. For firms with fewer than 50 employees the coefficient is large and statistically significant at the 1% level. A 10% increase in exchange rate risk is associated with a 1% increase the share of high-skilled. Again illustrating for a shift from Germany to the U.S. the associated change the share of high-skilled would increase by some 13% (0.102 × 130%). Several other means by which firms manage risk are likely to be more challenging for smaller firms—with a weaker bargaining position it may for instance be harder to shift suppliers and smaller firms are substantially less likely to use derivatives to manage risk [see e.g. Allayannis et al. (2012) or, for Swedish evidence, Amberg and Friberg (2016)]. Finally, the estimated elasticity for manufacturing firms is similar in magnitude to the average effect in this tercile.

6 Concluding remarks

Little is known about firms’ responses to risk and how they impact labor demand. Some work has centered on volatility of labor demand: Kurz and Senses (2016) document systematic links between the volatility of employment growth and exporting/importing status; and Bergin et al. (2011) document how U.S. firms appear to use maquiladora production in Mexico as a margin of adjustment in response to demand shocks, with consequential high volatility of employment in these plants. Other work focuses on the interaction between sunk entry costs in foreign markets and uncertainty [see e.g. Handley and Limão (2017) whose findings point to large positive welfare effects of lowering trade policy uncertainty]. Related are also Hershbein and Kahn (2018) who show how large shocks (in their case the great recession) can accelerate an adjustment to a higher skill share and more generally work that documents changes in the relative demand for skilled labor over the business cycle (Modestino et al. 2016).

Given the level and variety of risks currently facing firms, further investigation of firm responses to risk are likely to be useful. This paper has examined the relationship between 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 of second moment shocks and firms that face higher exchange rate risk employ a higher share of skilled labor.

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