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ORIGINAL PAPER

Backward participation in global value chains and exchange rate driven adjustments of Swiss exports

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Abstract This paper examines the effect of exchange rate movements on export volume, export revenues and propensity to export taking into account the extent of foreign value added content of exports ("backward integration") in global value chains (GVCs). Using both product-level and firm-level panel data, our results suggest that Swiss exports (intensive margin) and the export probability (extensive margin) are negatively affected by a currency appreciation. However, this adverse effect is mitigated in sectors and firms that are more integrated in GVCs, which could be explained by the "natural hedging" of exchange rate movements. Our findings are robust to the use of different measures of natural hedging and GVC integration and also hold across various specifications and estimation methods that control for sample selection, firm heterogeneity, heteroskedastic errors and persistence in export behavior. The dynamic specifications also reveal that export hysteresis driven by a currency appreciation is a concern particularly for firms that are not established in export markets.

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1 Introduction

The sharp appreciation of the Swiss Franc and its ongoing strength despite the exchange-rate peg that the Swiss National Bank introduced in 2011 (and lifted in 2015) have raised fears about negative export growth and resulting losses for Swiss exporters. From an economic perspective, a temporary currency appreciation may even have a permanent adverse effect on exports. However, a high level of integration into global value chains (GVCs) could potentially mitigate these negative effects by simultaneously rendering imported intermediate inputs cheaper.

An indicator of a country's integration in GVCs is the extent to which its exports rely on the share of imported intermediate inputs in foreign value added (backward participation) and the extent to which its exports serve as inputs in value added in the exports of other countries (forward participation). Switzerland was ranked 16th in GVC participation amongst OECD and BRICS economies in the year 2009, with a higher share of backward than forward participation (28 vs. 23%, OECD 2013). This was especially true of manufacturing industries such as chemicals, machinery and electrical equipment. In fact, 35% of the final demand for manufactured goods and market services in Switzerland in 2009 represented value added created abroad, with foreign value added shares for textiles and transport equipment being close to 100%.

This significant use of intermediate inputs by Swiss manufacturing industries has implications for their economic resilience to short and long-term changes in macroeconomic fundamentals, in particular exchange rates. Thus, adverse effects on Swiss manufacturing exporters resulting from an appreciation of the Swiss Franc would be expected to be mitigated at both margins of trade by decreasing the relative prices of imported intermediate inputs, thereby reducing the need for export price increases or losses due to reduced profit margins. This would result in a higher resilience of export demand to exchange rate fluctuations.

This mechanism is referred to as "natural hedging", which would depend on the extent to which exchange rate changes are transmitted to traded prices (exchange rate pass-through). The objective of this research is to examine exchange rate-driven adjustments of the Swiss manufacturing industry given the latter's pronounced reliance on the use of imported inputs. Another related research objective is to examine the extent to which export propensities in the current period depend on those in the preceding period to examine the "export hysteresis" hypothesis (for instance see Baldwin and Krugman 1989). If past export status has a positive effect on the export probability, then this is an indication that temporary exchange rate fluctuations can have a lasting effect on the export structure.

We employ two different yet complimentary datasets to examine our research questions: HS 6-digit product-level data from the Swiss Federal Customs

Administration (Eidgenössische Zollverwaltung) over 2004–2013 and firm-level data from the KOF innovation survey covering a sample of manufacturing firms in seven different years in time between 1996 and 2013. Our twofold approach offers the unique possibility to study heterogeneous patterns in firm reactions to exchange rate changes while providing the ability to control for a rich number of characteristics that are unobserved in aggregate data over a largely overlapping time period.

Our results are robust to the use of different estimation strategies and qualitatively similar in both product- and firm-level analyses. They suggest that an appreciation of the Swiss Franc has a negative impact on both the propensity and the value of Swiss exports, but that this negative effect is mitigated in sectors where the Swiss import share of intermediate inputs is high. The strong appreciation of the Swiss Franc during the sample period (see Fig. 1) highlights the economic relevance of our results.

Using product-level data, the negative effect of an appreciation on exports is estimated to range from 0.7 to 1.0, i.e. a 1% appreciation of the Swiss Franc is associated with a 0.7 to 1% fall in exports, ceteris paribus and on average. An increase of the Franc by 1% also reduces the likelihood that the product is exported by approximately 0.04 to 0.24 percentage points in our results.

We also investigate the effect of imported inputs on the overall exchange rate effect, taking two different measures of "natural hedging" into account. Our analyses reveal that a 1% appreciation of the imported-inputs-weighted exchange rate increases the probability of exporting by 0.3%, thereby completely offsetting the adverse direct exchange rate effect.

Our firm-level results suggest that a 1% increase in the exchange rate index is associated with a 0.3% reduction in the volume of exports, ceteris paribus and on average. However, once the degree of international integration approximated by the overall share of intermediate inputs in sales is considered, this negative effect

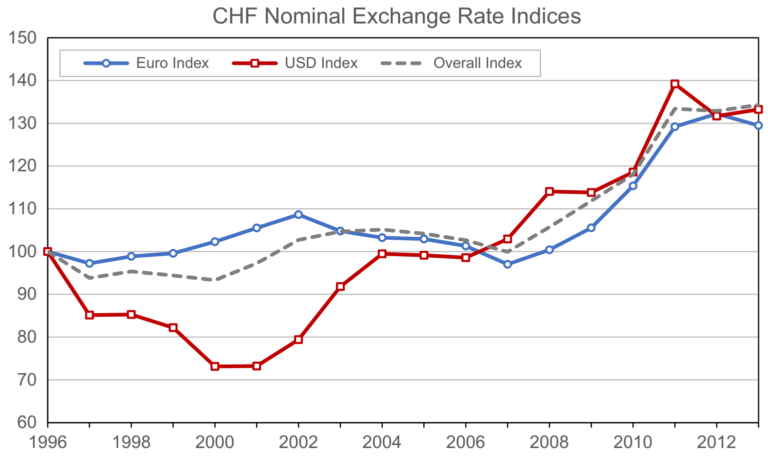

Fig. 1 Swiss Franc appreciation during the sample period

is found to be considerably mitigated and—with increasing intermediate input shares—even offset in various empirical specifications.

We also find strong evidence for export hysteresis in our findings. This suggests that products not exported in the previous year require larger exchange rate depreciations to achieve positive export profits and to be exported in the following year than products that are already present in an export market. Past exporting experience is found to be the most important determinant of export probability with the magnitude of the effect ranging from 0.1 to 0.7 (10–70 percentage points) in the product-level results to 0.38 (38 percentage points) in our firm-level results. This suggests the existence of significant entry costs and implies that companies no longer exporting due to the strong Swiss Franc require a disproportionate devaluation to export again profitably. It is therefore possible that temporary exchange rate fluctuations have permanent negative effects on the export structure of Switzerland. Moreover, we also find empirical support that export hysteresis related to currency appreciations is particularly pronounced for products that are not established in destination markets.

In sum, the qualitatively similar results obtained from the two data sets reveal a significant overall extent of "natural hedging" of exchange rate fluctuations. This applies both to the probability of exporting and the value of exports. Sectoral integration into GVCs is an approximate indicator of a given industry's exposure. Going by our results, major Swiss export sectors such as chemicals and engineering that have a high foreign share of value added in exports of 42 and 33%, respectively, are most likely to be less adversely affected by a strong Franc. In contrast, the food and paper industry (backward participation of 24%) are likely to be more exposed to the vagaries of exchange rate fluctuations. Overall, our results imply that firms and sectors with a higher degree of international integration are likely to be less affected by the negative effects of a stronger Swiss Franc.

The remainder of the paper is structured as follows. We provide a brief review of the relevant literature in Sect. 2. Section 3 outlines the theoretical framework underlying our empirical analyses. Section 4 describes the measures of natural hedging. Section 5 presents the product-level analysis, while Sect. 6 discusses the firm-level analysis. Section 7 concludes.

2 Literature review

The purpose of this section is to describe the main studies and results related to our paper. We do not aim at giving a complete overview of the rich exchange rate literature. Auboin and Ruta (2013) provide a good survey of the relationship between exchange rates and international trade.

Greenaway et al. (2010) is the study most closely related to this paper. The authors examine a panel of UK manufacturing firms and show that the negative effect of an exchange rate appreciation on the probability to export is lower in industries that import a greater share of inputs. Interestingly, a similar cushioning effect of imported inputs on the adverse effect of a currency appreciation is not found in export sales regressions (the intensive export margin). In contrast, Berman et al.

(2012) show—using French firm-level data—that the export volume reacts less to exchange rate movements for firms that employ a larger fraction of imported inputs. Similarly, Amiti et al. (2012) find that French firms that source more foreign inputs display a lower exchange rate pass-through rate, which implies a lower sensitivity of export volume to currency fluctuations.

In the Swiss context, using disaggregated product-level data over 2005Q1–2010Q3, Auer and Saure (2011) estimate a considerable negative effect of an exchange rate appreciation on export value of around - 0.42, implying a 4.2% reduction in export value when the CHF appreciates against the foreign destination currency by 10%. Unlike us, however, the authors attribute the resilience of Swiss export performance to the strong Franc to the rebounding global demand in the aftermath of the global financial crisis. Using Swiss firm-level and customs transaction-level data over 1999Q2–2011Q4 and 2004–2012 respectively, Lassmann (2013) and Fauceglia et al. (2014) show that a CHF appreciation results in substantially cheaper imported inputs. A high pass-through rate into imported input prices is an important precondition for finding a compensating effect of foreign inputs on exchange-rate driven export performance. Relative to these studies, we use both product- and firm-level data in complementary analysis and also focus on the role of international integration in GVCs in mitigating the adverse trade effects of currency appreciation.

This paper is also related to the literature examining export hysteresis, namely the persistence in exporting depending on export history. From a policy point of view this matters because, as shown theoretically by Baldwin and Krugman (1989), a large exchange rate shock—like the Swiss franc appreciation in the wake of the Eurozone crisis—can lead to exporters' exit decisions that are not reversed after the currency approaches its pre-crisis level. Their theoretical result relies on the existence of entry sunk costs into export markets. Empirically, the existence of sunk costs is well supported (see Roberts and Tybout 1997; Bernard and Wagner 2001; Bernard and Jensen 2004 and Das et al. 2007). For instance, the results by Bernard and Wagner 2001 and Bernard and Jensen 2004 for Germany and the US, respectively, imply a large increase in export probability of about 30–60 percentage points for firms that are already established in a foreign market.

In addition, these studies reveal that the sunk cost investment related to foreign market entry depreciates quickly over time: the effect of having exported in the previous two years is usually much smaller than having exported in the previous year. Roberts and Tybout (1997) also show that the impact of an exchange rate shock on predicted export probabilities is larger for firms that are already exporting. As a result, an average non-exporter requires a greater currency depreciation than an average exporter to generate positive export profits. These results are in line with the export hysteresis theory outlined in Baldwin and Krugman (1989). Campa (2004) confirms the importance of sunk exporting costs for the extensive export margin using Spanish firm-level data. However, he also finds that the aggregate response of export volume to exchange rate changes is mainly driven by quantity adjustments (the intensive export margin) and not by entry and exit decisions of firms.

Finally, the paper is also situated within recent literature that studies the effects of global value chains on export elasticity (such as Ahmed et al. 2017 who find similar results for the extensive margin only with more aggregated sectoral data) and within literature that relates to constructing real exchange rates taking into account vertical specialization in global value chains (Bems and Johnson 2015).

3 Theoretical framework

3.1 Intensive export margin and imported inputs

In order to derive the implications of exchange rate changes moderated by backward participation in global value chains on export quantities and revenues, we rely on a small extension of the framework presented in Burstein and Gopinath (2013) that emphasizes the factors affecting exchange rate pass-through.

A Swiss firm i that supplies to a destination j can charge an optimal export price that is the sum of the log marginal cost and a mark-up:

$$p_{ij} = \mu_{ij}(p_{ij} - p_j) + mc_{ij}(q_{ij}, w_{ch}, e_j, \alpha_{ij}), \tag{1}$$

where the mark-up μ_{ij} depends on the Swiss export price expressed in the destination's currency p_{ij} relative to an industry price index p_j in the export market j (note that lower case letters denote variables in natural logs). The marginal cost mc_{ij} in the destination's currency is a function of the produced quantity q_{ij}, the factors w_{ch} that affect the costs denominated in Swiss francs (i.e. wages) and the exchange rate e_j—defined as foreign currency per unit of Swiss franc. Importantly, a higher expenditure share of imported inputs priced in the destination's currency α_{ij} reduces the sensitivity of marginal costs to exchange rate fluctuations. Taking the log-differential of (1), the price changes in the export market can be proxied as:

$$\Delta p_{ij} = -\Gamma_{ij}(\Delta p_{ij} - \Delta p_j) + mc_q \Delta q_{ij} + \Delta w_{ch} + (1 - \alpha_{ij})\Delta e_j, \tag{2}$$

where $\Gamma_{ij} \equiv -\frac{\partial \mu_{ij}}{\partial (p_{ij} - p_j)}$ is the markup elasticity with respect to the relative price, $mc_q \equiv \frac{\partial mc_{ij}}{\partial q_{ij}}$ is the marginal cost elasticity with regard to export output.[1] Log demand is denoted by $q_{ij} = q(p_{ij} - p_j) + q_j$ where q_j is the aggregate demand in market j. Log-differentiating demand, we obtain changes in firm demand:

$$\Delta q_{ij} = -\epsilon_j(\Delta p_{ij} - \Delta p_j) + \Delta q_j, \tag{3}$$

where $\epsilon_j \equiv -\frac{\partial q}{\partial p_{ij}}$ corresponds to the price elasticity of foreign demand. Inserting (3) into (2) and assuming that exchange rate movements have no effect on aggregate variables (i.e $\Delta p_j = \Delta q_j = 0$) and on production costs denominated in Swiss francs ($\Delta w_{ch} = 0$), the exchange rate pass-through (ERPT) can be expressed as:

[1] Implicitly, we assume full-pass through into imported input prices, $\frac{\partial mc_{ij}}{\partial e_j} = 1$ and $\frac{\partial mc_{ij}}{\partial wi} = 1$. When demand is CES, constant mark-up pricing implies $\Gamma_{ij} = 0$. Constant returns to scale (CRS) technology of production translates into $mc_q = 0$, while decreasing return to scale (DRS) leads to $mc_q > 0$.

$$\eta_{ij} = \frac{\Delta p_{ij}}{\Delta e_j} = \frac{1 - \alpha_{ij}}{1 + \Gamma_{ij} + \Phi_{ij}}, \tag{4}$$

where $\Phi_{ij} = mc_q \epsilon_j$ is the partial price elasticity of marginal costs. Combining (4) and (3), we obtain the response of the firm export quantity to changes in exchange rates:

$$\Delta q_{ij} = -\epsilon \eta_{ij} \Delta e_j = -\epsilon_j \left(\frac{1 - \alpha_{ij}}{1 + \Gamma_{ij} + \Phi_{ij}} \right) \Delta e_j. \tag{5}$$

From (5) we see that the change in the export quantity consequent upon a change in the exchange rate equals ERPT times the foreign demand elasticity. With constant mark-up pricing ($\Gamma_{ij} = 0$), CRS production technology ($\Phi_{ij} = 0$) and no imported inputs ($\alpha_{ij} = 0$), ERPT is complete ($\eta_{ij} = 1$). In contrast, when some inputs are sourced internationally and priced in the export price currency ($0 < \alpha_{ij} \leq 0$), it follows that ERPT is incomplete ($\eta_{ij} < 1$) because marginal costs are in this case less affected by exchange rate movements (“natural hedging”). Therefore, a higher share of imported inputs α_{ij} reduces the need to adjust export prices (“natural hedging”) and weakens quantity responses to exchange rate fluctuations.[2]

Proposition 1 *The higher the share of imported inputs α_{ij} in total cost, the less export quantities react to exchange rate fluctuations. Specifically, a higher α_{ij} dampens the positive (negative) quantity response Δq_{ij} to Swiss franc depreciations (appreciations), all else equal.*

Log export revenues measured in Swiss francs and denoted by r_{ij} can be expressed as

$$\Delta r_{ij} = \Delta p_{ij} + \Delta q_{ij} - \Delta e_j. \tag{6}$$

Using (5) we obtain the export revenues as a function of ERPT and the foreign demand elasticity:

$$\Delta r_{ij} = \big((1 - \epsilon_j) \eta_{ij} - 1 \big) \Delta e_j. \tag{7}$$

Given that firms with market power set prices in the elastic part of the demand curve $\epsilon_j > 1$ and assuming that ERPT ranges realistically between zero and one ($0 \leq \eta_{ij} \leq 1$), the reactions of export revenues to exchange rate movements are qualitatively the same as in the case of export quantities described in Proposition 1 ($\frac{\Delta r_{ij}}{\Delta e_j} < 0$). Equation (7) reveals that revenues also increase after a depreciation because of a positive export valuation effect even in the absence of a quantity

[2] This result also holds when mark-ups decrease with the relative price, $\Gamma_{ij} > 0$ and in the case of decreasing return to scale, $\Phi > 0$.

response resulting from local currency pricing($\eta_{ij} = 0$). Proposition 2 summarises the theoretical predictions following from the revenue Eq. (7) in combination with the pass-through Eq. (4).

Proposition 2 *A Swiss franc depreciation (appreciation) increases (reduces) export revenues. The response of export revenues to exchange rate fluctuations becomes smaller the higher the cost share of imported inputs α_{ij} is.*

3.2 Export extensive margin and imported inputs

The extensive margin analysis studies the entry and exit behaviour of firms and products in and out of export markets. Exchange rate changes affect export participation decisions through its effect on operating profits. As we saw in the previous section, export revenues rise when a currency depreciates. It follows that whenever variable costs of exporting are proportional to export revenues, a Swiss franc depreciation would raise operating profits, while an appreciation would lower them. However, backward participation in global value chains may weaken the relationship between exchange rate fluctuations and operating profits. To see this, assume that the operating or gross export profits π_{ij} for a Swiss exporter i to country j are denoted as follows:

$$\pi_{ij}(E_j, \alpha_{ij}) = \frac{P^*_{ij} Q^*_{ij}}{E_j} - \underbrace{A_{ij} W_{ch}^{1-\alpha} \left(\frac{W_j}{E_j}\right)^{\alpha_{ij}} Q^*_{ij}}_{=C_{ij}}, \quad A_{ij} = \alpha_{ij}^{-\alpha_{ij}} \cdot (1 - \alpha_{ij})^{\alpha_{ij}-1}, \tag{8}$$

where P^*_{ij} and Q^*_{ij} are the optimal foreign currency price and quantity, E_j is the bilateral exchange rate, W_{ch} and W_j are the prices of domestic and imported inputs respectively. C_{ij} is the cost function net of fixed costs dual to the the following Cobb–Douglas production function $Q_{ij} = \left(K_j\right)^{\alpha_{ij}} \cdot \left(K_{ch}\right)^{1-\alpha_{ij}}$ with α_{ij} being the share of imported inputs K_j and $1 - \alpha_{ij}$ the share of domestic inputs K_{ch}. Then, taking the derivative with respect to exchange rate E_j and using the envelope theorem, we obtain

$$\frac{\partial \pi_{ij}(E_j, \alpha_{ij})}{\partial E_j} = -\frac{P^*_{ij} Q^*_{ij}}{E_j^2} + \alpha_{ij} A_{ij} W_{ch}^{1-\alpha_{ij}} W_j^{\alpha_{ij}} \frac{Q^*_{ij}}{E_j^{1+\alpha}}. \tag{9}$$

Equation (9) shows that firm gross profits in the producer currency respond more strongly to exchange rates when production costs only arise in the producer currency ($\alpha_{ij} = 0$). Intuitively, when the exchange rate increases by one unit, the gross profits rise by $\frac{P^*_{ij} Q^*_{ij}}{E_j^2}$. On the other hand, when total costs and revenues are both incurred in the same foreign currency ($\alpha_{ij} = 1$), the depreciation raises profits only by $(P^*_{ij} - A_{ij} W_j)\frac{Q^*_{ij}}{E_j^2}$. More generally, it is unequivocal that a depreciation has a positive and an appreciation a negative impact on firm profits even when exporters do not adjust the price P^*_{ij} and quantity Q^*_{ij}. Moreover, a higher cost share of imported inputs α_{ij} dampens the positive effect of a depreciation and the negative effect of an appreciation on gross profits. Next, we extend the profit function (8) to allow for sunk entry costs F_j required to enter a destination market j. Then, the export profits can be written as

$$\widetilde{\pi}_{ijt}(E_{jt}, \alpha_{ij}) = Y_{ijt}\left[\pi_{ijt}(E_{jt}, \alpha_{ij}) - F_j(1 - Y_{ijt-1})\right] \tag{10}$$

where t denotes a time period. Profits in (10) depend on whether a firm exported in the last period or not, i.e. whether Y_{ijt-1} is 1 or 0. If a firm exported last period ($Y_{ijt-1} = 1$) and still exports ($Y_{ijt} = 1$), then sunk entry costs have already been covered and (10) collapses to profit function (8) $\widetilde{\pi}_{ijt} = \pi_{ijt}$. If a firm did not export in the last period but starts to export in the current period, profits become $\widetilde{\pi}_{ijt} = \pi_{ijt} - F_j$.

As a consequence, a firm will enter an export market if gross profits are larger than the sunk costs, $\pi_{ijt}(E_{jt}, \alpha_{ij}) > F_j$. Conversely, if a firm has already incurred F_j, it will only cease exporting if gross profits become negative, $\pi_{ijt}(E_{jt}, \alpha_{ij}) < 0$. This implies that there is a range of profits between $\pi^H_{ijt} = F_j$ and $\pi^L_{ijt} = 0$ in which a potential exporter decides not to enter a destination j, while an actual exporter does not stop exporting to the same destination. This range $\pi^H_{ijt} - \pi^L_{ijt} = F_j$ is called the "hysteresis band" or "band of inaction". Empirically, the presence of sunk costs generates state dependence and can be identified by testing whether a firm's past export status helps predict its current export status after controlling for a firm's export profitability. If the export history of a firm matters, then a firm's exit decision in response to an appreciation of the Swiss Franc is also likely to have a negative bearing on its export probability in the future. This export hysteresis is driven by the necessity to reincur sunk costs of market re-entry related to marketing, reputation, distribution networks etc., which implies that a return of the Swiss franc to normal levels will not be enough to induce past exporters to reenter an abandoned market profitably (Baldwin and Krugman 1989). In this sense, even temporary exchange rate fluctuations can have a lasting negative effect on the export structure.[3]

The previous discussion suggests that exchange rate movements have a weaker effect on export profits and thus on the probability to export for firms and in sectors that rely more on imported inputs and for products and firms already present in an export market due to export hysteresis, as summarised in the following two propositions:

[3] We acknowledge that this hysteresis result may turn out to be weaker if exporters anticipate that a future exchange rate shock will be of temporary nature. However, such an expectation would contradict that an exchange rate process is best approximated by a random walk, which implies that exchange rate changes should be regarded ex-ante as permanent and not predictable by fundamentals (Engel and West 2005). It is also clear, however, that agents may form (irrational) exchange rate expectations not in line with a random walk, as shown in Frankel and Froot (1987).

Proposition 3 *The impact of exchange rate movements on the export probability is lower for firms that rely more on imported inputs (higher α_{ij}).*

Proposition 4 *The impact of exchange rate movements on the export probability is less pronounced for actual exporters than for potential exporters (export hysteresis).*

4 Measures of natural hedging and GVC integration

We use three different indicators to estimate the potential natural hedging effect of exchange rate risks through imported inputs. The first two measures are used in the product-level estimations, while the last measure is employed in the firm-level regressions.

4.1 Imported input weighted real exchange rate index

To account for the sensitivity of imported input prices to exchange rates in our regression framework, time-varying sectoral imported input weighted exchange rates are calculated based on supplier-specific imported input values similarly to Greenaway et al. (2010) and Fauceglia et al. (2014).[4] These real exchange rate indices are then reweighted according to the import share of each input sector in the respective output/export sector. These import shares are calculated from the 2001 I–O table for Switzerland stemming from OECD (2012).[5]

More formally, these imported input weighted real exchange rates are constructed as follows:

$$Import\_RER_{so,t} = \sum_{si} \left\{ \left[\sum_{j} \left(\left(W_{si}^{j} \right)_{t} \cdot \left(\frac{e_{j,t} \cdot p_{ch}}{e_{j,o} \cdot p_j} \right) \right) \right]_{t,si} \cdot \left(R_{so}^{si} \right) \right\}, \qquad (11)$$

where t is the time period, j is the source country of imported inputs, si is the input-output (I–O) imported input sector and so is the I–O output sector. $e_{j,t}$ and $e_{j,o}$ are the supplier-specific bilateral nominal exchange rates in time t and in the base period 2004, and $\frac{p_{ch}}{p_j}$ measures the inflation differential between Switzerland ch and import origin j. Therefore, $\frac{e_{j,t} \cdot p_{ch}}{e_{j,o} \cdot p_j}$ corresponds to a real exchange rate index.

$(W_{si}^{j})_t$ is the value of imported inputs (in CHF expenses) from source country j relative to the total value of imported inputs in sector si during year t. This term is

[4] The classification of inputs (or intermediates) used in this paper is available at: http://wits.worldbank.org/wits/data_details.html.

[5] The sector classification used to calculate the indices corresponds to those used in Swiss I–O tables. Each I–O table sector consists of one up to five 2-digit ISIC product groups.

included to obtain an average imported input weighted exchange rate for each input sector *si*. Ultimately, these exchange rates are multiplied by R_{so}^{si}, corresponding to the share of imported inputs from sector *si* to total imported inputs in output/export sector *so*. The weights R_{so}^{si} do not vary over time so that the index reflects primarily changes in the bilateral exchange rates.[6]

On the one hand, exchange rate movements may affect the prices of imported inputs from a given origin. In addition, Eq. (11) also captures changing import patterns across countries over time through $(W_{si}^{i})_t$ that are also related to exchange rate changes. Thus, $Import\_RER_{so,t}$ is the imported input weighted real exchange rate faced by each (output) sector *so* in each period *t*. We will employ the log version of this index, $\ln(Import\_RER_{so,t})$ in some of our estimations. This measure takes into account the geographic dispersion of import origins and how changes in the exchange rate between the CHF and the currencies of those importer countries affect costs of imported inputs.[7]

4.2 Ratio between imported inputs from the export destination and total imported inputs

As a second more restrictive measure of natural hedging, which is a variant of $Import\_RER_{so,t}$, we construct the following measure called $\alpha_{j,so,t}$ where:

$$\alpha_{j,so,t} = \sum_{si} \left(\left(W_{si}^{j} \right)_t \cdot R_{so}^{si} \right), \tag{12}$$

$\alpha_{j,so,t}$ can be interpreted as the ratio of imported inputs stemming from the export destination *j* within an export/output-sector *so* in year *t* to total imported inputs. This measure can then be interacted with the bilateral real exchange rate against the export destination currency. From an econometric point of view, this interaction exploits best the information on export destinations included in the product-level data. However, one drawback is that it restricts the effect of natural hedging to imported inputs coming from the export destination only. However, together with $Import\_RER_{so,t}$, $\alpha_{j,so,t}$ should provide a fuller picture on the relationship between integration in GVCs and the effect of exchange rate changes on exports.

4.3 Ratio of total firm inputs to firm sales

Finally, in the firm-level dataset, we use the ratio between total intermediate inputs stemming from outside the firm and firm sales as an approximation for integration in

[6] R_{so}^{si} is based on the 2001 I–O table for Switzerland taken from OECD (2012). From the OECD, an I–O table for 2005 is also available. Comparisons of Swiss I–O tables between 2001 and 2005 show that the sectoral import shares in total imports in an output sector in fact remain relatively stable over time and are likely to be driven by sector-specific technological factors.

[7] We do not differentiate between input and output-sector in the following sections and use the *k* subscript for a specific sector.

GVCs. This measure has the advantage that it varies at the firm-level. It should also capture international integration whenever firms that have higher total input to sales ratios also exhibit higher imported inputs over sales ratios. While this is not testable in our data, we think that the assumption of a positive correlation between the total and the imported input ratio is reasonable and should hold, at least, on average.[8]

This said, as robustness checks, we multiplied the intermediate input share by foreign imports of intermediate goods at the sectoral level (using the Swiss sectoral data provided by OECD 2012) to re-conduct the empirical analysis using firm level data (the results are reported in Table 8); the corresponding estimates yielded stronger effects. We also used sectoral foreign value added data from the OECD-WTO TIVA tables and found the corresponding results to be both economically and statistically very strong.

5 Product-level analysis

5.1 Product-level empirical strategy

Our empirical product-level analysis is conducted in a gravity framework in a two-stage estimation procedure, which following Helpman et al. (2008), accounts for biases emanating from both sample selection and firm heterogeneity.

We use the Heckman (1979) two-step estimator to control for the large number of zero trade flows between trading partners, which also characterize our disaggregated product-level data at the HS-6 digit level. The Heckman estimation also enables a decomposition of the exchange rate effects at both the extensive and intensive margins of trade.

The Heckman two-step estimation involves running a first stage Probit in the selection Eq. (13) that estimates the effect of explanatory variables on the probability of exporting. The dependent variable in Eq. (13) is a dummy variable that takes the value one if an HS 6-digit product is exported to a specific export destination in a given time period and zero otherwise. We consider only those HS 6-digit products that are exported to at least one country in the sample period to ensure that the specific products are manufactured in Switzerland.

The second stage of the Heckman corrects for sample selection by including the inverse Mills ratio (η_{jpt}) constructed using predicted probabilities ($\hat{\rho}_{jpt}$) from the selection Eq. (13) in the outcome Eq. (14). Equation (14) comprises an OLS estimation of the natural logarithm of positive exports as the dependent variable on the same set of control variables as in step one with the exclusion of at least one variable that should ideally affect trade only at the extensive margin in (13). We use the time taken to import by the destination country from Switzerland because the selection variable as it has a relatively great bearing on the probability of exporting.

[8] As large firms that are overrepresented in our sample tend to import more (see e.g., Bernard et al. 2007), this assumption may be plausible.

From a theoretical viewpoint the time to import should mainly affect the fixed cost of exporting and thus mainly the extensive margin.

This said, we acknowledge the exclusion restriction issue in Heckman-type estimations emphasized in the heterogeneous firm trade literature (for instance see Head and Mayer 2013) and thus, closely follow Helpman et al. (2008) in our estimation strategy to further control for biases emanating from firm heterogeneity in the outcome equation by including a cubic polynomial of z_{jpt} where $z_{jpt} = \eta_{jpt} + \hat{\rho}_{jpt}$.[9]

Formally, we have the following baseline specifications:

Step 1 Selection equation (export participation)

$$
\begin{aligned}
Pr(X_{jpt} > 0) =&\beta_0 + \beta_1 E_{jt} + \beta_2 \alpha_{jkt} + \beta_3 E_{jt}\alpha_{jkt} + \beta_4 \ln(GDP_{jt}) \\
&+ \beta_5 \ln(1 + \tau_{jpt}) + \beta_6 \ln(Dist_j) + \beta_7 Contig_j + \beta_8 Lang_j \\
&+ \beta_9 Time2Import_{jt} + \beta_{10} MR_{jt} + \lambda_t + \lambda_k + \epsilon_{jkt},
\end{aligned}
\tag{13}
$$

Step 2 Outcome equation (export sales)

$$
\begin{aligned}
\ln(X_{jpt}|X_{jpt} > 0) =&\beta_0 + \beta_1 E_{jt} + \beta_2 \alpha_{jkt} + \beta_3 E_{jt}\alpha_{jkt} + \beta_4 \ln(GDP_{jt}) \\
&+ \beta_5 \ln(1 + \tau_{jpt}) + \beta_6 \ln(Dist_j) + \beta_7 Contig_j + \beta_8 Lang_j \\
&+ \beta_9 MR_{jt} + \beta_{10} \eta_{jpt} + \beta_{11} z_{jpt} + \lambda_t + \lambda_k + \epsilon_{jkt}
\end{aligned}
\tag{14}
$$

where X_{jpt} is the nominal export value of HS-6 product p in destination j at time t, GDP_{jt} is the real GDP in destination j at time t, τ is the effectively applied tariff rate on Swiss exports of HS-6 product p in destination j, and MR denotes the "Bonus-vetus-OLS" multilateral resistance terms that are constructed *a la* Baier and Bergstrand (2009). Bilateral trade costs in our framework are proxied by bilateral distance between capitals of the two countries ($Dist_{ij}$), and indicators for common international borders ($Contig_{ij}$) and common language ($Lang_{ij}$).

Equation (13) also includes the time taken to import ($Time2Import_{jt}$) by the destination country j from Switzerland as the exclusion variable while Eq. (14) includes the inverse Mills ratio (η_{jpt}) to control for sample selection and the cubic polynomial of z_{jpt} to control for firm heterogeneity. We also control for year (λ_t) and sector-specific fixed effects (λ_k) at the ISIC two-digit level in both equations.

Our main explanatory variable of interest E_{jt} is the log bilateral real exchange rate ($\ln(RER)$) between Switzerland and the destination country j at time t. We expect an appreciation of the Swiss franc against an importer's currency to diminish the propensity to export (see Eq. 13) or export sales (see Eq. 14) of an HS 6-digit product to this destination, $\beta_1 < 0$. However, in line with Propositions 1–3, we also test how the relationship between exchange rates and export propensity is altered by the degree of sectoral (k) backward participation, measured by the α_{jkt} term, in cross-border supply chains. The interaction term $E_{jt} \times \alpha_{jkt}$ is approximated in some specifications by the imported input weighted exchange rate, $\ln(Import\_RER_{kt})$, which varies along the k and t dimension (see Eq. 11), and in others with α_{jkt} (see Eq. 12). Specifically,

[9] Following Helpman et al. (2008), we do not use the normality assumption to recover η_{jpt} and z_{jpt} from the selection equation and instead work directly with the predicted probabilities, $\hat{\rho}_{jpt}$.

we expect a mitigating effect of backward integration in GVCs, i.e. $\beta_3 > 0$ at both the extensive and intensive export margins.

Finally, to incorporate "hysteresis" into the empirical framework, the RHS of the selection Eq. (13) is augmented by X_{jpt-1}, which is an indicator variable for export participation in destination j at time $t-1$, and an interaction term between the exchange rate and past export status ($E_{jt} \times X_{jpt-1}$). In line with Proposition 4, the interaction term examines whether the relationship between exchange rate changes and the export probability is less pronounced for actual as opposed to potential exporters not already present in the export market.

5.2 Estimation issues

Estimating a Probit model with fixed effects may yield inconsistent estimates due to the incidental parameter problem (Wooldridge 2002). We thus also estimate Eq. (13) using a linear probability model (LPM).[10] In some specifications, we replace $Contig_{ij}$, $Lang_{ij}$ and $\ln(Dist_{ij})$ by country-fixed effects to control more thoroughly for time-invariant factors at the country-level.

While there is no consensus in the literature on clustering the standard errors (for instance see Cameron et al. 2011), we would like to argue that our main variable of interest is not just the exchange rate, but also the $E_{jt} \times \alpha_{jkt}$ interaction term, which varies mainly at the $HS2 \times partner$ level. In our preferred specifications in the product-level analysis, we therefore cluster the standard errors at this level. This clustering strategy also allows errors to be correlated over time and within relatively large sectors in the cross-section. Moreover, it is in line with our theoretical motivation, which posits that the exchange rate effect on exports depends on the extent of sectoral backward integration in GVCs captured by the α_{jkt} term.[11] We also estimate our empirical model using the Poisson-PML (PPML) estimator proposed by Silva and Tenreyro (2006) due to the likely presence of heteroskedastic errors that bias OLS estimates.

Finally, the "hysteresis" equation is estimated using the dynamic LPM. While it is likely that the past export status is biased downwards, the coefficient of the past export status from an LPM with fixed effects may provide a lower-bound estimate for the importance of export hysteresis (for instance see Bernard and Jensen 2004).

[10] The estimates from LPM usually constitute reasonable approximations of average partial effects according to Wooldridge (2002).

[11] However, at the suggestion of an anonymous referee, we also clustered the standard errors at the destination level to account for potential aggregation bias and found qualitatively similar results that are reported in Tables 12 and 13. In fact, the significance of results with product-level data is found to be robust to a variety of clustering in Appendix 3 strategies such as at the $HS2 \times destination$ level, at the $HS6 \times destination$ level (panel unit) and at the destination-year level.

5.3 Swiss product-level data, explanatory variables and construction of the dataset

Product-level bilateral trade data are obtained from the Swiss Federal Customs Administration (Eidgenössische Zollverwaltung) and covers traded Swiss HS 8-digit products between 2004 and 2013. The dataset is reduced to the 37 most important trading partners for Switzerland, including all OECD countries and the BRICS, accounting for more than 90% of Swiss exports. These data allow us to control for destination, time and product-specific factors of export adjustments that might otherwise confound the estimation of the exchange rate effect.

The monthly recorded data are collapsed to annual data by summing revenues and quantities over disaggregated Swiss HS 8-digit product categories within export destinations. In the next step, we further aggregate (sum) revenues and quantities at the international HS (2002) 6-digit and destination level, which results in the variables "Export value" and "Export volume" employed in the regression analysis. Moreover, we inflate the dataset by generating export zeros at the destination-product level which allows us to define a 0/1-export participation dummy in order to conduct a binary choice analysis. We restrict the creation of export zeros to HS 6-digit products that are not exported to a given destination and year but have been exported at least once to one of the included 37 destinations during the sample period. This rule prevents us from considering products that Switzerland might not produce and export at all.

We then match annual average exchange rates that are taken from the Swiss National Bank at the destination-year level with the customs data. The bilateral trade cost variables at the destination level are taken from the CEPII gravity dataset and added to our dataset. Since these variables are time-invariant, they are excluded from our estimations that include destination-specific fixed effects. Data on time taken to import come from the World Bank's Doing Business Indicators. Data on real GDP are taken from the World Bank's World Development Indicators, while the MR terms are constructed *a la* Baier and Bergstrand (2009). Time to import, GDP and MR terms are merged to the customs data at the destination-year level.

Tariff data categorised in the HS classification are sourced from WTO IDB using WITS and added to our dataset at the destination- product (HS 6-digit)-year level. Sectoral-level indicators of backward participation in GVCs described in Sects. 4.1 and 4.2 are calculated using the OECD's Swiss input-output table of 2001 (see OECD 2012 and Fauceglia et al. 2014). As these indicators are categorised in the ISIC 2-digit (Rev. 3.1) classification, we use the HS2002 versus ISIC Rev. 3.1 correspondence table provided by the World Bank's WITS website to merge the GVC indicators to our estimating sample.

5.4 Data description

The product-level data are summarized in Table 1. We have close to 2 million observations on our variables of interest. The average Swiss export value to the OECD

Table 1 Summary statistics of product-level data

Variable	Obs.	Mean	SD	Min	Max
Export value (CHF mn)	2,042,770	0.8	18.5	0	4950
Export volume ('000 kg)	2,042,770	74.2	2781.6	0	1,380,000
Export probability	2,042,770	0.4	0.5	0	1
RER (index)	2,042,770	98.11837	13.5	56.3	152.2
Import_RER	1,972,840	102.3	7.4	90.1	117.2
Imported input share (α_{jkt})	1,972,840	0	0.1	0	0.6
Distance (km)	2,042,770	4085	4746.2	436.1	19,006.7
RGDP_partner (USD bn)	1,838,493	1180	2300	15.2	14,200
PCRGDP_partner (USD)	1,838,493	27,787.5	18,468.4	687.3	87,716.7
Simple avg tariffs	1,299,282	1	3.9	0	495
Weighted avg tariffs	1,299,281	1	3.9	0	495
PTA	2,042,770	0.8	0.4	0	1
Time to import (days)	1,832,972	13.1	6.8	5	41
Contiguity	2,042,770	0.1	0.3	0	1
Common language	2,042,770	0.2	0.4	0	1

and BRICS countries over 2004–2013 was CHF 0.8 million while the average export propensity was 0.4.

5.5 Results

5.5.1 Estimations with the imported input weighted exchange rate

Table 2 presents the results from estimating Eqs. (13) and (14). We begin by estimating a Heckman selection model in columns 1–4, using the probit model and LPM in the selection equation separately.

The statistically significant inverse mill's ratio in the outcome equation in columns 2 and 4 of Table 2 indicate that the concern of a non-randomly selected export sample and the use of the Heckman model is justified. In the first-step regressions explaining the extensive margin (see columns 1 and 3), the time required (recorded in days) to enter a destination country acts as an exclusion variable and exerts a negative effect on the exporting probability. The statistically significant coefficients of the the cubic polynomial of z_{jpt} in columns 2 and 4 show that firm heterogeneity also matters in our Heckman specifications.

The negative coefficient of E_{jt} in columns 1 and 3 suggests that exchange rate appreciation has an adverse effect on the probability of exporting. However, the estimate of the imported-inputs-weighted exchange rate, $\ln(Import\_RER_{kt})$, reveals that the adverse effect of a currency appreciation at the extensive margin is more than offset, with a 1% appreciation of the import-weighted exchange rate leading to a 0.30 percentage point higher export probability in column 1 and a 0.24 percentage point higher export probability in column 3.

Table 2 Direct exchange rate effect and imported input share from destination (results with imported input weighted exchange rate)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$\Pr(X_{jpt} > 0)$	$\ln(X_{jpt} \vert X_{jpt} > 0)$	$\Pr(X_{jpt} > 0)$	$\ln(X_{jpt} \vert X_{jpt} > 0)$	X_{jpt}	X_{jpt}	$\Pr(X_{jpt} > 0)$	$\Pr(X_{jpt} > 0)$
	Heckman		Heckman		PPML		FE	LPM
$E_{jt} * X_{jpt\text{-}1}$							0.0138	0.113***
							(0.0145)	(0.0162)
$X_{jpt\text{-}1}$							0.0691	0.166**
							(0.0654)	(0.0741)
E_{jt}	− 0.245***	− 0.171	− 0.227***	− 0.0141	− 0.850*	− 0.495	− 0.0831***	− 0.109***
	(0.00865)	(0.272)	(0.0538)	(0.271)	(0.483)	(0.632)	(0.0142)	(0.0174)
$\ln(\text{Import\_RER}_{kt})$	0.299***	− 3.377***	0.241*	− 3.356***	− 0.122	− 0.331	0.229***	0.126**
	(0.0847)	(0.769)	(0.137)	(0.865)	(1.544)	(1.552)	(0.0652)	(0.0566)
$\ln(\text{GDP}_{jt})$	0.108***	0.0548	0.0891***	0.0527	0.854***	0.952***	0.132***	0.0303***
	(0.000637)	(0.109)	(0.00503)	(0.102)	(0.0691)	(0.0856)	(0.0165)	(0.00130)
$\ln(1 + \tau_{jpt})$	0.0626***	− 0.329***	0.0532***	− 0.337***	− 0.258*	− 0.346	− 0.000140	0.0193***
	(0.00156)	(0.0715)	(0.00749)	(0.0727)	(0.140)	(0.237)	(0.00306)	(0.00216)
Contig_j	0.109***	0.0299	0.0976***	− 0.0194	0.566*	0.333		0.0261***
	(0.00266)	(0.153)	(0.0233)	(0.134)	(0.336)	(0.409)		(0.00618)
Lang_j	0.0434***	− 0.264*	0.0432	− 0.311**	0.146	− 0.0527		0.0182***
	(0.00314)	(0.143)	(0.0264)	(0.138)	(0.292)	(0.484)		(0.00674)
$\ln(\text{Dist}_j)$	− 0.0467***	− 0.125	− 0.0333*	− 0.159*	− 0.0373	− 0.346		− 0.000607
	(0.00228)	(0.0878)	(0.0187)	(0.0861)	(0.116)	(0.318)		(0.00521)
Time2Import_{jt}	− 0.00589***		− 0.00488***					
	(0.000133)		(0.00110)					
Inverse mills (n_{jpt})		2.256*		103.1**				
		(1.186)		(40.82)				

Table 2 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	$Pr(X_{jpt} > 0)$	$ln(X_{jpt} \| X_{jpt} > 0)$	$Pr(X_{jpt} > 0)$	$ln(X_{jpt} \| X_{jpt} > 0)$	X_{jpt}	X_{jpt}	$Pr(X_{jpt} > 0)$	$Pr(X_{jpt} > 0)$
	Heckman		Heckman		PPML		FE	LPM
z_{jpt}		22.45***		576.0**				
		(8.607)		(255.7)				
z^2_{jpt}		− 10.62*		− 329.6**				
		(5.637)		(161.8)				
z^3_{jpt}		2.023		70.35*				
		(1.291)		(37.30)				
Observations	1,038,348	5,11,683	1,038,348	575,725	1,262,707	1,156,887	1,043,680	1,043,680
R-squared	0.162	0.164	0.203	0.156	0.017	0.018	0.021	0.577
Estimation	Probit	OLS	LPM	OLS	PPML	PPML	FE	LPM
MR terms	Yes	Yes	Yes	Yes	No	Yes	No	Yes
Fixed effects	k,t	k,t	k,t	k,t	k,t	k,t	k,t	k,t

LPM linear probability model. Significance levels: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors in parentheses, error correction for clustering at the hs2*partner country level. All columns include industry (ISIC 2-digit) and year dummies and "Bonus-vetus" multilateral resistance terms (except columns 5 and 7). Marginal effects at means are reported in the Probit specification in column 1. The first stage of the Heckman is estimated using Probit in column 1 and using LPM in column 3

Table 3 Direct exchange rate effect and imported input share from destination (results with sectoral and destination-specific foreign input share)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	$Pr(X^{vol}_{jpt} > 0)$	$ln(X^{vol}_{jpt} \| X^{vol}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$	$ln(X^{val}_{jpt} \| X^{val}_{jpt} > 0)$	$Pr(X^{vol}_{jpt} > 0)$	$ln(X^{vol}_{jpt} \| X^{vol}_{jpt} > 0)$
	Heckman		Heckman		Heckman	
X_{jpt-1}						
X_{jpt-2}						
α_{jkt}	0.00267	− 10.50***	0.0527	− 9.182***	− 0.568*	− 14.41***
	(0.408)	(3.839)	(0.411)	(3.204)	(0.304)	(4.205)
E_{jt}	− 0.0636***	− 0.672***	− 0.0650***	− 0.942***	− 0.0590***	− 0.709***
	(0.0112)	(0.225)	(0.0113)	(0.158)	(0.00932)	(0.242)
$E_{jt}{}^{*}\alpha_{jkt}$	0.0707	3.129***	0.0595	3.077***	0.166**	3.844***
	(0.0885)	(0.865)	(0.0892)	(0.701)	(0.0661)	(1.011)
$ln(GDP_{jt})$	0.212***	2.653***	0.216***	3.223***	0.170***	2.567***
	(0.0111)	(0.757)	(0.0111)	(0.520)	(0.00905)	(0.714)
$ln(1 + \tau_{jpt})$	0.0131***	0.0970*	0.0106***	0.0168	0.0126***	0.109*
	(0.00131)	(0.0556)	(0.00132)	(0.0423)	(0.00108)	(0.0600)
$Time2Import_{jt}$	− 0.000926***		− 0.00131***		− 0.000793***	
	(0.000357)		(0.000360)		(0.000291)	
Inverse mills (n_{jpt})		5.424***		8.303***		104.9*
		(1.919)		(1.365)		(90.71)
z_{jpt}		9.565		21.62***		542.1
		(10.08)		(7.519)		(580.4)
z^2_{jpt}		− 7.000		− 14.31***		− 340.1
		(6.584)		(4.813)		(371.5)
z^3_{jpt}		1.537		2.945***		77.64
		(1.519)		(1.085)		(86.72)

Table 3 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	$Pr(X_{jpt}^{vol} > 0)$	$ln(X_{jpt}^{vol} \mid X_{jpt}^{vol} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$ln(X_{jpt}^{val} \mid X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{vol} > 0)$	$ln(X_{jpt}^{vol} \mid X_{jpt}^{vol} > 0)$
	Heckman		Heckman		Heckman	
Observations	1,129,939	5,58,470	1,129,939	575,725	1,129,939	5,58,470
Pseudo-R-squared	0.170	0.198	0.174	0.163	0.213	0.198
Estimation	Probit	OLS	Probit	OLS	LPM	OLS
Fixed effects	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t
Variables	(7)	(8)	(9)	(10)	(11)	(12)
	$Pr(X_{jpt}^{val} > 0)$	$ln(X_{jpt}^{val} \mid X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$
	Heckman		FE	Probit	LPM	LPM
$X_{jpt\text{-}1}$			0.123***	0.696***	0.674***	0.465***
			(0.00507)	(0.00215)	(0.00226)	(0.00217)
$X_{jpt\text{-}2}$						0.308***
						(0.00196)
α_{jkt}	0.024***	5.675***	− 0.536*	− 1.378***	− 0.433**	− 0.782***
	(0.2046)	(1.178)	(0.315)	(0.535)	(0.206)	(0.241)
E_{jt}	− 0.0577***	− 1.071***	− 0.0550***	− 0.0779***	− 0.0391***	− 0.0441***
	(0.00906)	(0.186)	(0.0112)	(0.0153)	(0.00789)	(0.0105)
$E_{jt}{}^{*}\alpha_{jkt}$	0.165**	2.982***	0.138*	0.346***	0.110**	0.181***
	(0.0258)	(0.8604)	(0.0723)	(0.116)	(0.0453)	(0.0523)
$ln(GDP_{jt})$	0.170***	3.586***	0.131***	0.0752***	0.0347***	0.0161
	(0.00902)	(0.567)	(0.0129)	(0.0152)	(0.00806)	(0.0111)
$ln(1 + \tau_{jpt})$	0.0108***	0.069	− 0.00474**	0.00344	0.00250	0.00189
	(0.00108)	(0.0483)	(0.00216)	(0.00317)	(0.00162)	(0.00147)

Table 3 (continued)

Variables	(7)	(8)	(9)	(10)	(11)	(12)
	$\Pr(X^{val}_{jpt} > 0)$	$\ln(X^{val}_{jpt} \vert X^{val}_{jpt} > 0)$	$\Pr(X^{val}_{jpt} > 0)$	$\Pr(X^{val}_{jpt} > 0)$	$\Pr(X^{val}_{jpt} > 0)$	$\Pr(X^{val}_{jpt} > 0)$
	Heckman		FE	Probit	LPM	LPM
$Time2Import_{jt}$	− 0.000959***					
	(0.000287)					
Inverse mills (n_{jpt})		152.6**				
		(71.9)				
z_{jpt}		737.8				
		(455.1)				
z^2_{jpt}		− 447.5				
		(289.7)				
z^3_{jpt}		97.56				
		(67.2)				
Observations	1,129,939	575,725	1,135,271	1,135,271	1,135,271	1,004,463
Pseudo-R-squared	0.218	0.163	0.019	0.482	0.575	0.615
Estimation	LPM	OLS	FE	Pooled probit	LPM	LPM
Fixed effects	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t

LPM linear probability model. Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. Robust standard errors in parentheses, error correction for clustering at the hs2*partner country level. All columns include country, industry (ISIC 2-digit) and year dummies. Marginal effects at means are reported in the Probit specifications in columns (1), (3) and (10). The first stage of the Heckman is estimated using Probit in columns (1) and (3), and using LPM in columns (5) and (7)

Table 4 Summary statistics of firm-level data

Variable	Obs.	Mean	SD	Min	Max	Total
No. firms	5875	–	–	–	–	2516
Exporter	4413	–	–	–	–	1914
Initial exporter	4407	–	–	–	–	1813
Export share	5875	0.365	0.368	0	1	
Export volume	5875	4.55E+07	4.43E+08	0	2.41E+10	
Export volume (> 0)	4407	6.06E+07	5.10E+08	4603.60	2.41E+10	
Log TFP	5875	0.001	0.360	− 0.990	3.406	
Value added	5875	3.44E+07	1.81E+08	62,680.74	8.89E+09	
Wage	5875	1.72E+07	7.11E+07	13,058.49	2.54E+09	
Material costs	5875	4.04E+07	3.19E+08	8001.17	1.65E+10	
No. employees	5875	185	603	1	20,180	
R&D	5875	0.60	0.49	0	1	
Interm. input share	5875	0.42	0.17	0.01	0.95	
REER (SNB)	5875	9.714	0.107	9.524	9.826	
REER (own)	5875	4.635	0.065	4.451	4.745	
REER (own, HS 2-digit)	5875	4.565	0.066	4.451	4.664	
Foreign GDP	5875	4.558	0.069	4.389	4.822	

Employees: total number of employees in full-time equivalents; exports, wages, intermediate inputs, turnover and value added per employee in Swiss Francs; TFP is the (Solow) residual from a regression of log value added on log wages and log material costs. Source for REER: SNB real effective exchange rate index, base = 1999, 24 countries; own calculations using annual HS 6-digit export data from Swiss Customs Administration EZV; foreign GDP refers to real foreign activity weighted by export region based on Europe, the US, and Japan as obtained from KOF Swiss Economic Institute; real variables are deflated using implicit deflators according to 2-digit sector based on national accounts for Switzerland (gross domestic product) with base year 1997 = 100

In contrast, we do not observe this mitigating effect at the intensive margin in either the Heckman or the PPML results (columns 5 and 6), which is counter-intuitive. The PPML results are reported for comparison only as the statistically significant coefficient of the inverse Mills ratio in our Heckman estimations suggest that the latter may be preferable to the PPML (Xiong and Chen 2014).

In the fixed effects and linear probability models (columns 7 and 8), the compensating effect of the import-weighted exchange rate on export probability is positive and the magnitudes more than enough to offset the adverse effect of an exchange rate appreciation in each case. Altogether, the results of Table 2 suggest that sourcing inputs abroad leads to a "natural hedging" of exchange rate risks, albeit only at the extensive margin.

Results reported in column 8 also show that the export status in the previous period is a strong determinant of the export probability in the following period. Moreover, the coefficient of the interaction term between the exchange rate and past export status is also found to be positive and statistically significant, suggesting that products already established in foreign markets are less affected by exchange rate movements. Both findings are indicative of export hysteresis, namely that temporary exchange rate shocks may have permanent negative effects on the export structure. For instance, a firm that dropped out of the export market because of a currency appreciation requires a much lower exchange rate to profitably serve a foreign market than a current exporter. This empirical persistence in export status is usually explained by substantial market entry sunk costs.

5.5.2 Estimations with the sectoral and destination-specific foreign input share

In this section, we estimate specifications that more thoroughly exploit the bilateral dimension of our product-level data. Specifically, we employ the α_{jkt} approximation of natural hedging working through imported inputs stemming from the export destination (see Eq. 12) and therefore likely to be traded in the same currency as the exported good. Furthermore, we replace $Contig_j$, $Lang_j$ and $\ln(\text{Dist}_j)$ by country-fixed effects to control more carefully for time-invariant factors at the country-level. Table 3 reports the results from these estimations.

In columns 1–8 of Table 3, we estimate Heckman selection models (using the Probit and LPM in stage one separately), that take into account the non-randomness of the HS6-digit products that are exported: in volume terms in columns 1, 2 and 5, 6 and in value terms in columns 3, 4 and 7, 8.

The results of the stage one regressions in columns 1, 3, 5 and 7 are consistent with our theoretical predictions. To begin with, an exchange rate appreciation—an increase in E_{jt}—reduces the probability to export (see columns 1, 3, 5 and 7). Our theoretical model suggests that this works through a reduction in operating profits of exporting firms. However, the importance of the exchange rate decreases with backward participation in global value chains, as one can see from the positive coefficient of the interaction term $E_{jt} \times \alpha_{jkt}$ especially in the stage-one LPM estimates (columns 5 and 7); the stage-one Probit estimates in columns 1 and 3 lack statistical significance. Reassuringly, the export volume and value results are qualitatively similar.

To clarify the relationship between exchange rates and global value chains, based on the results of column 7 of Table 3, the left panel of Fig. 2 depicts the effect of the exchange rate on export probability as a function of α_{jkt}. When the α_{jkt} term is zero, implying that no imported inputs stem from the destination country for a specific output sector, a 1% increase in the exchange rate reduces export probability by 0.058 percentage points. In contrast, the importance of the exchange rate for the decision to supply an export market declines when the share of imported inputs from that export market for a given output sector rises. When the imported input share reaches a value of about 0.35, the exchange rate does not have a statistically significant effect anymore.

Thus in the case of Swiss exports to Germany, which have an average α_{jkt} value of 0.33 (and a value ranging from 0.23 to 0.58 depending on the sector), whether or not a product is exported to Germany is not affected by currency movements because of natural hedging through imported input costs. However, in the area where α_{jkt} is below 0.35, exchange rate fluctuations still matter for the exporting decision. For instance, in the case of the US, α_{jkt} equals 0.06 and for China, α_{jkt} has a value of

0.03. In both cases, the role of exchange rate fluctuations on Swiss export propensities matters.

Columns 2, 4, 6 and 8 report the results related to the intensive export margin: in volume terms in columns 2 and 4 and in value terms in columns 6 and 8. A similar picture to the extensive export margin emerges in the stage-two Heckman results—an exchange rate appreciation exerts a substantial negative effect on both exported volume and value, but this effect is more than offset when more inputs are sourced from the destination country.

The right panel of Fig. 2 shows graphically the impact of the exchange rate and its interaction with imported inputs based on column 8 of Table 3. The main effect of E_{jt} is -1.071. This means that a 1% appreciation of the CHF against the destination country currency reduces the export value by 1.07% when α_{jkt} equals zero. When α_{jkt} is above 0.36, the impact of an exchange rate appreciation on export value is statistically indifferent from zero. In this case, natural hedging reduces the need to raise prices in the local currency, implying a lower exchange rate pass-through and buoyant exports.

In columns 9–12, we test for the presence of sunk costs by including one and two year lags of the exporting status. The estimated effects of the lagged exporting status are highly significant in all four columns and are the strongest determinant of export propensity. The size of the effect ranges from 0.1 in the fixed effects model (column 9) to 0.7 in the Probit and LPM (columns 10 and 11). This range of estimates is in line with the firm-level literature (see for instance Bernard and Jensen 2004; Bernard and Wagner 2001; Roberts and Tybout 1997).

The large effect of the lagged export indicator implies that products that are not exported in the previous year require larger exchange rate depreciations to achieve positive export profits and to be exported in the following year than products that are already present in an export market. This is a clear evidence for export hysteresis,

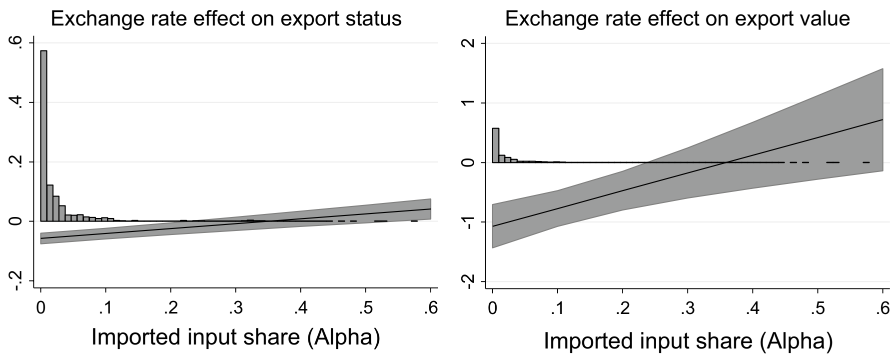

Fig. 2 Product-level exchange rate effect as a function of imported input share. Note: marginal effects at percentiles and the maximum of the distribution of α_{jkt}. LHS: first-step LPM regression with a binary variable for export participation at time t in country j as the dependent variable. RHS: second-step OLS regressions in a Heckman selection model with log export value as the dependent variable. Results are based on columns (7) and (8) of Table 3. 95% confidence intervals shown. A histogram of the distribution of product-level intermediate input shares is shown in both figures

namely that a currency appreciation may reduce the number of exported goods and exporting firms permanently.

Furthermore, the sunk cost investment depreciates very quickly over time, as the much lower coefficient of having been an exporter two time periods ago X_{jpt-2} shows.[12] This result implies that once a product is out of an export market, the investments done in the foreign market lose value rapidly, increasing the necessary export revenues required to overcome sunk export costs and generate positive export profits. Overall, the large magnitudes of the past export coefficients imply that factors such as a higher foreign demand or a depreciated currency do not easily compensate for the lack of presence in a foreign market.[13]

6 Firm-level analysis

6.1 Firm-level data and empirical strategy

6.1.1 Firm-level data

For firm-level data analysis, we use a panel that is revolving in three-year intervals. These data stem from the KOF innovation survey and cover 7 time periods (1996, 1999, 2002, 2005, 2008, 2011, and 2013). This leaves us with 3 business cycles over more than the past decade. The panel is based on a nonrandom sample of 6500 firms that are drawn from the universe of Swiss firms with at least 5 full-time equivalent employees in the manufacturing sector, the construction, and the services sector.[14] As participation is voluntary—the response rate is about 35%—the panel is naturally unbalanced. However, it is rotating in the sense that firms may leave and are replaced or, alternatively, re-enter, such that the number of firms observed per period is approximately constant.

We observe a total of 6576 firms, and the average number of firms per year amounts to 2284 of which 1126 firms are exporters. The total number of observations is 15,837. The number of time periods covered by firms ranges from 1 to 7, and the median in the sample is 3. The data include information on the export volume and the main destination market. In addition, information on firm-level employment, turnover, and investment (among other firm characteristics) as well as answers to qualitative questions (e.g., price-related and non-price-related competition) are obtained. These variables allow us to control for firm-level determinants of exporting that are unobserved in aggregate data and to take the potential heterogeneity across firms into account.

[12] Including a variable Exp_{t-3}, which equals one if a product has been exported in $t-3$, only has a negligible effect on the estimates (results are available upon request). This robustness check confirms that past exporting experience depreciates quickly over time.

[13] In further sensitivity analyses, we find our results to be robust to the exclusion of the chemicals and pharmaceutical sectors. These results are available upon request.

[14] See “Appendix 1” for a detailed description of the data.

Table 5 Exchange rates and firm-level exports (fixed effect and weighted results)

	(1)	(2)	(3)	(4)	(5)	(6)
A. Fixed effects regressions						
TFP	0.546***	0.557***	0.546***	0.553***	0.546***	0.551***
	(0.099)	(0.097)	(0.099)	(0.098)	(0.099)	(0.098)
Employees	1.006***	1.004***	1.006***	1.004***	1.005***	1.004***
	(0.056)	(0.056)	(0.056)	(0.056)	(0.056)	(0.057)
R&D	0.075**	0.070**	0.075**	0.073**	0.075**	0.073**
	(0.034)	(0.033)	(0.034)	(0.033)	(0.034)	(0.034)
REER	− 0.312*	− 1.864***	− 0.339*	− 1.403***	− 0.351**	− 1.181**
	(0.170)	(0.520)	(0.180)	(0.500)	(0.172)	(0.477)
α_{it}	1.637***	− 14.746***	1.636***	− 9.515**	1.636***	− 7.078
	(0.240)	(5.118)	(0.241)	(4.824)	(0.240)	(4.674)
REER*α_{it}		3.544***		2.449**		1.917*
		(1.102)		(1.056)		(1.025)
Foreign GDP	0.887***	0.866***	0.810***	0.785***	0.794***	0.774***
	(0.142)	(0.141)	(0.153)	(0.154)	(0.154)	(0.155)
Observations	4528	4528	4528	4528	4528	4528
No. firms	1983	1983	1983	1983	1983	1983
B. Weighted regressions (using sampling weights)						
TFP	0.485***	0.498***	0.486***	0.500***	0.486***	0.499***
	(0.107)	(0.104)	(0.107)	(0.105)	(0.107)	(0.105)
Employees	0.886***	0.880***	0.887***	0.882***	0.886***	0.883***
	(0.080)	(0.081)	(0.080)	(0.081)	(0.080)	(0.081)
R&D	0.098*	0.091*	0.099*	0.093*	0.099*	0.093*
	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)	(0.054)
REER	− 0.036	− 1.887**	− 0.025	− 1.915**	− 0.034	− 1.730**
	(0.309)	(0.797)	(0.335)	(0.903)	(0.322)	(0.873)
α_{it}	1.458***	− 18.927**	1.459***	− 18.987**	1.459***	− 16.856*
	(0.299)	(7.946)	(0.299)	(9.071)	(0.299)	(8.994)
REER*α_{it}		4.413**		4.499**		4.035**
		(1.717)		(1.991)		(1.977)
Foreign GDP	0.504*	0.544**	0.496*	0.514**	0.495*	0.511*
	(0.266)	(0.263)	(0.264)	(0.261)	(0.265)	(0.263)
Observations	4528	4528	4528	4528	4528	4528
No. firms	1983	1983	1983	1983	1983	1983

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Fixed effects regressions (firm fixed effects) with robust standard errors. The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Dependent variable: log real exports. Independent variables except R&D in logs. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. Sampling weights in Panel B are response-probability adjusted

We clean the panel by assigning NOGA 2008 codes (equivalent to NACE Rev. 2) and HS 2-digit codes to firms in all years, using correspondence tables to previous industry and trade classifications. We keep firms that are active in the agricultural, mining and quarrying, and manufacturing sectors only.[15] Next, we match the innovation panel dataset on the real exchange rate as constructed and described in the previous section, and on variables about economic fundamentals.

Table 4 summarizes descriptive statistics about variables used for analysis. The figures are unweighted, i.e., they do not take the stratification into account. They include sample characteristics as well as the following firm-level variables: number of employees and skill-level specific shares thereof; expenditures on intermediate inputs, investment, and R&D; turnover; value added per employee; the export share; and the main export market. We calculated export volumes, intermediate inputs, and wages by multiplying the respective share by turnover. Overall, Table 4 shows that the coverage is good regarding the variables included in regressions later on. The comparatively high share of exporters and the dynamics in firm-level data illustrated in Table 9 in "Appendix 1" suggest that sample selection, including sample attrition, is present and may be taken into account empirically later on. In any case, these unconditional figures are not informative of a significant relationship between the exchange rate and export participation.

Of the 2516 remaining firms in the sample, 1914 firms report positive exports. We calculate the export volume by multiplying the export share by turnover, where the average export share amounts to 36.5%. The average export volume amounts to approximately 46 million Swiss Francs. The latter is driven by the substantial fraction of zeros in the data: the average of strictly positive exports is 61 million Swiss Francs. Since firms with at least 5 employees have been sampled beforehand solely, and large firms have been oversampled, the average number of employees is large (amounting to 185) as is the standard deviation. Nevertheless, the data are highly right-skewed as expected, with the median amounting to 70 employees. Firms pay on average a total wage sum of 17 million Swiss Francs and report average intermediate input costs of 40 million and average value added of 34 million Swiss Francs. The average intermediate input share amounts to 42%. All variables except shares are deflated using implicit deflators[16] according to 2-digit sector based on national accounts for Switzerland (gross domestic product) with base year 1997 = 100.

6.1.2 *Empirical strategy for firm-level data*

The empirical strategy is as follows. We aim at testing Proposition 2 with the data at hand. For this, let us denote by R_{it} the real export volume R of firm i in time period t; by r_{it} the log thereof; and by e_t the aggregate log real effective exchange rate index (REER_t) at time t. To construct this index, we used annual 6-digit export data from

[15] Specifically, this includes firms in ISIC Rev. 3.1 codes 1 and 14–36. Excluding the agricultural and the mining and quarrying sectors, left our results qualitatively unchanged.

[16] Implicit deflators are calculated by dividing an aggregate measured in current prices by the same aggregate measured in constant prices.

the Swiss Customs Administration as well as currency-specific exchange rates from the SNB.[17] Alternatively, we use an industry-specific exchange rate $\text{REER}_{f(t)}$ for which we match firm-level NOGA codes to HS 2-digit product lines, and the real effective exchange rate based on 24 countries and with base year 1999 = 100 from the Swiss National Bank (SNB).

By α_{it} we denote the i-specific intermediate input share in turnover at t; and by gdp_t the log weighted foreign real GDP, which refers to real foreign activity weighted by export region based on Europe, the US, and Japan as obtained from KOF Swiss Economic Institute. Other firm-specific variables are collected in the vector z_{it}. These include log total factor productivity (TFP), log employees in full-time equivalents as a proxy for firm size, and a binary variable indicating R&D activity. The variables are described in the previous subsection and in "Appendix 1".[18] All variables except shares are deflated using the Swiss manufacturing producer price index from the Swiss Federal Statistical Office (BFS) with base year 1994 = 100.

We model the equation of interest by way of the following regression model for the intensive margin of exports as a baseline model:

$$r_{it} = \beta_0 + \beta_1 e_t + \beta_2 \alpha_{it} + \beta_3 e_t \times \alpha_{it} + \beta_4 gdp_t + \gamma z_{it} + u_{it} \tag{15}$$

We employ the fixed effects estimator to account for time-invariant unobserved effects that are arbitrarily correlated with the variables we observe.

In order to link estimation to the theory outlined in Sect. 3, we account for endogenous selection into exporting by applying a two-step procedure (see also Campa 2004; Helpman et al. 2008).[19] Selection into exporting may imply that sample selection issues arise when estimating (15). Specifically, the outcomes along the extensive and intensive margins are generated by different data processes, respectively, resulting in error terms that are correlated between the equation for selection into exporting and the export volume equation. The binary participation equation is specified by way of the following pooled Probit model with correlated random effects:

$$P(\text{Export}_{it} = 1 | \text{Export}_{it_0}, e_t, \alpha_{it}, e_t \times \alpha_{it}, gdp_t, z_{it}, \bar{z}_i) \tag{16}$$

where the coefficient on the initial conditions, Export_{it_0}, the export status at the time the firm enters the sample, and $\bar{z}_i$ are time averages of the explanatory variables (Zabel 1992; Mundlak 1978). As we include the initial condition rather than past export status, we are interested in effects on the extensive margin of trade in general

[17] Proposition 1 cannot be tested due to the lack of data on export quantities. Note that Proposition 3 would require a test of the joint impact of α_{it} and an import-weighted real effective exchange rate in industry f, II $\text{REER}_{f(t)}$. Because the inclusion of both variables may lead to identification issues, we assume that the export-weighted REER_t equals the II $\text{REER}_{f(t)}$. Furthermore, we tested the sensitivity of results to a lag choice at $t-1$.

[18] In addition, we checked the sensitivity of the regression results to the inclusion of other firm-level variables which did not improve the explanatory power of our model (e.g., foreign ownership status, unit labor costs, skill shares).

[19] This also accounts for the fact that exports are generated by a limited dependent variable process including a large fraction of zeros. Alternatively, the benchmark equation could be modeled by way of a Poisson model of the following form with parameter vectors defined as row vectors: $E(R_{it}|e_t, \alpha_{it}, x_{it}) = exp(\beta_0 + \beta_1 e_t + \beta_1 \alpha_{it} + \beta_3 e_t \times \alpha_{it} + \beta_4 gdp_t + \gamma z_{it})$.

rather than in a direct test of the hysteresis hypothesis. Yet, this approach should be able to provide an adequate approximation of the selection process that we intend to model.[20] Export_{it_0} is excluded from the outcome equation. Because identification relies on the non-linearity of the inverse Mills ratio, this helps us to avoid identification problems due to multicollinearity. As we seek to infer whether the impact of exchange rate movements on the export probability is lower for firms that rely more on intermediate inputs, interaction terms are again included in (16). We use an approximate reduced-form specification for selection in the first period. The outcome equation in log-linear form with correlated random effects is given by:

$$E(r_{it}|\text{Export}_{it} = 1) = \delta_0 + \delta_1 e_t + \delta_2 \alpha_{it} + \delta_3 e_t \times \alpha_{it} + \delta_4 gdp_t + \theta_1 z_{it} + \theta_2 \bar{z}_i + \rho \hat{\lambda}_{it} \tag{17}$$

where $\hat{\lambda}_{it}$, the inverse Mills ratio obtained from estimating (16), is included in the RE estimation of (17) to account for selection.

Stratified sampling and sample selection Recall that firms that are larger in terms of employment have been oversampled by applying variable probability sampling. Furthermore, the response rate of firms is roughly 35% in all periods. There is good reason to believe that larger, more productive firms are possibly more likely to respond simply because they have higher labor endowments, and that firm response depends on firm-specific conditions in t, i.e., the response selection is probably endogenous. Exploiting the panel nature by conditioning on a set of time averages of the explanatory variables as in (17) allows us to account for a general form of sample selection that is evident from the non-response in period t_0.[21]

Sampling issues lead to weighted estimators that allow for the stratification, where observations are weighted by the inverse of the sampling probability. Weighting can be applied to the models specified above. For simplicity, we define the weighted estimator $\hat{\theta}_w$ that is a solution to the general minimization problem as follows:

$$\min_{\theta \in \Theta} \sum_{i=1}^{N_0} p_{\ell_i}^{-1} q(w_i, \theta), \tag{18}$$

where $p_{\ell_i}, \quad \ell = 1, \dots, L$ is the weight that is attached to i, with $i = 1, \dots, N_0$ the stratum for observation i; and $q(w_i, \theta)$ the objective function chosen to identify the population parameters using random draw w_i.[22]

[20] Entry and exit patterns illustrated in Table 9 in "Appendix 1" may indicate lagged effects or a lack of an effect of the exchange rate on export participation at first glance. Yet, the data at hand do not allow us to estimate a dynamic model including the export status in the previous period. The inclusion of $\text{Export}_{i,t-1}$ reduces the number of observations by more than one half as firms drop out and may re-enter over time. As a consequence, we are no longer able to obtain sufficiently precise estimates. Additionally, a Chamberlain approach for the selection model Wooldridge (1995), or bias corrected estimators Fernández-Val and Vella (2011) proved infeasible.

[21] Note that this cannot take a potential correlation of non-response with the business cycle into account.

[22] Standard errors have to be adjusted accordingly. The weights have been adjusted for the response probability of the firm such that $p_{\ell_i} = p_{\ell_i^0} / E(\hat{r}_i)$, where $E(\hat{r}_i)$ was obtained from a binary response model for the response probability on firm characteristics (language and geographic region, industry and size class); see Ley (2013).

6.2 Firm-level results

The results from estimating (15) as shown in Table 5 reveal a number of findings. First, they suggest that the effect of an increase in the real effective exchange rate index by 1% decreases exports by 0.312% (column 1). The choice of different exchange rate indices does not affect the robustness of these results (columns 3 and 5). Second, while the exchange rate effect is considerable in magnitude, TFP, firm size, the intermediate input share, and GDP seem to be more important in magnitude. In contrast, R&D activity has a smaller impact on firm-level exports. Third, the interaction between the exchange rate and the firm-level intermediate input share reported in even columns shows that as the intermediate input share increases, the negative effect of the real effective exchange rate becomes less and less important.

Using the results in column 2 for instance, at the mean intermediate input share of 40%, the effect of the REER is - 0.446. At a share of 53% (the 75th percentile), the effect becomes positive, amounting to 0.015. To provide an interpretation of the interaction effect, we summarize the direct partial effect of the exchange rate evaluated along the distribution of α_{it} visually in the left-hand side panel of Fig. 3. Overall, if one may assume that a large fraction of intermediate input shares are imported from abroad, our findings provide evidence of a natural hedging mechanism through increased firm-level integration. With oversampling of large firms, this may be a plausible assumption since it has been shown empirically that exporting and importing firms are larger in size (Bernard et al. 2007). However, in the absence of precise measures of the imported intermediate input share, the results should be generally interpreted with care.

Next, we estimate Eqs. 16 and 17 to account for selection into exporting. We show the results in Table 6.[23] The table suggests the following. Conditional on firm's export participation, the effect of the exchange rate remains robust compared to the previously reported results and significant after correcting for selection into exporting. This is shown in Panel B. In line with the results for the intensive margins presented without accounting for selection bias, the marginal effects are increasing in firm-level intermediate input share. This may indicate that increased integration allows firms to benefit from exchange rate appreciations of home currency and thus provides further evidence for the relevance of natural hedging.

In contrast, we reject evidence for a significant effect of the REER on export activity with and without taking firm heterogeneity into account (Panel A). As the computation of marginal interaction effects in nonlinear models is complicated, we report the marginal effect evaluated at the average intermediate input share. In addition, the effect of REER evaluated along the distribution of α_{it} is reported in the right-hand side panel of Fig. 3.[24] In line with previous literature (Campa 2004), the strong effect of export participation in the initial period also points to sunk costs that may produce hysteresis in exports. This implies that firms exiting export markets due to an exchange rate appreciation need a disproportionately strong depreciation

[23] Note that we employ the nonparametric bootstrap in these results taking the panel structure into account. While bootstrapping may not be a panacea, as we use FGLS (a random effects probit estimator precisely), this seems to be a better choice than using (cluster) robust estimation.

[24] The correct interaction effects following Norton et al. (2004) are reported in Fig. 4 in Appendix 2.

to re-enter the export market. Overall, the results suggests that the REER affects the intensive rather than the extensive margin of exports, where we are not able to confirm a significant relationship between the two (Panel A).

6.3 Discussion and sensitivity analysis

The results shown in Tables 5 and 6 are informative regarding the heterogeneity of the exchange rate effect across different types of firms. More specifically, we have analyzed—conditional on important firm-level export determinants—how differences in intermediate input shares affect the exposure to exchange rate shocks by way of natural hedging. The conclusions obtained from the analysis may also be viewed in light of the heterogeneity across industries rather than firms.

For this purpose, we may compare average intermediate input shares indicated in the survey at question to integration in GVCs as reported by the OECD Trade in Value Added database (2013) and used in the previous sections.[25] It is evident from Table 7 that total intermediate input shares are slightly higher than the foreign value added content of gross exports with the exception of the chemical and the textile sectors. This is due to home-country sourcing as well as oversampling of large firms. Accounting for the latter would allow us to assume that the shares in column 2 versus column 3 are closely correlated. Then, we may hypothesize that exporters in highly integrated sectors such as textiles, chemicals, and transport equipment are on average able to naturally hedge against exchange rate appreciations. The reverse is true for exporters in industries that are on average integrated to a lesser degree, for instance, in the agricultural, the mining and quarrying, the food products, and the wood products sectors. Of course, these figures have to be interpreted with care as precisely comparable figures are missing.

Along similar lines, we conducted two robustness checks using firm-level data. For the first one, we relaxed the assumption that intermediate input shares α_{it}—consisting of both domestic and foreign inputs—are a good approximation for foreign intermediate input shares. To maintain variation at the firm level, we multiply this variable by (i) foreign value added content shares used in Table 7, and (ii) yearly 2-digit sector-level shares (α_{kt}) of imported intermediate goods in total intermediate goods imports (using Swiss sectoral data provided by OECD 2012). Both yield quantitatively stronger results than the ones reported in Table 5 (we show the results using yearly 2-digit sector-level shares in Table 8). For instance, the average exchange rate effect decreases to -0.4%. In addition, the effect of $\alpha_{it} \times \alpha_{kt}$ is now much stronger and so is the interaction effect, which nearly doubles. However, note that some of this might be due to noise introduced through the industry share variables. Also since domestic inputs should be indirectly affected through the pass-through of exchange rates to the domestic price index, the choice of the "natural hedging" variable in Sect. 4.3 seems reasonable.

[25] It would be preferable to pursue the previous empirical analysis by industry, however, this would restrict the sample size such that we are no longer able to obtain sufficiently precise results. Note that they are given for the year 2009 (cross section) by the OECD and calculated over time for the firm sample, however, the intermediate input shares prove to be stable over time.

Table 6 Exchange rates and firm-level exports (Heckman results)

	(1)	(2)	(3)	(4)	(5)	(6)
A. Participation equation (random effects probit AME)						
Initial export	4.314***	4.319***	4.314***	4.318***	4.311***	4.318***
	(0.208)	(0.208)	(0.208)	(0.208)	(0.208)	(0.208)
TFP	0.356**	0.345**	0.356**	0.352**	0.355**	0.352**
	(0.170)	(0.170)	(0.170)	(0.170)	(0.170)	(0.170)
Employees	0.472***	0.470***	0.471***	0.472***	0.468***	0.471***
	(0.138)	(0.138)	(0.138)	(0.138)	(0.138)	(0.138)
R&D	0.084	0.075	0.083	0.077	0.079	0.074
	(0.119)	(0.119)	(0.119)	(0.119)	(0.119)	(0.119)
REER	0.131	n.r.	0.094	n.r.	− 0.238	n.r.
	(0.572)		(0.619)		(0.605)	
α_{it}	0.693	n.r.	0.693	n.r.	0.690	n.r.
	(0.509)		(0.509)		(0.509)	
Foreign GDP	− 0.303	− 0.355	− 0.282	− 0.335	− 0.374	− 0.429
	(0.384)	(0.386)	(0.414)	(0.417)	(0.421)	(0.424)
Observations	5875	5875	5875	5875	5875	5875
B. Outcome equation						
TFP	0.501***	0.509***	0.501***	0.506***	0.501***	0.505***
	(0.098)	(0.093)	(0.095)	(0.094)	(0.101)	(0.105)
Employees	0.973***	0.971***	0.973***	0.971***	0.972***	0.971***
	(0.058)	(0.058)	(0.055)	(0.057)	(0.057)	(0.054)
R&D	0.074**	0.072**	0.074**	0.073**	0.074**	0.073**
	(0.037)	(0.035)	(0.037)	(0.035)	(0.037)	(0.037)
REER	− 0.323*	− 1.407***	− 0.344*	− 1.087**	− 0.346**	− 0.930*
	(0.167)	(0.516)	(0.187)	(0.521)	(0.173)	(0.506)
α_{it}	1.536***	− 9.924*	1.535***	− 6.258	1.536***	− 4.603
	(0.233)	(5.108)	(0.235)	(5.242)	(0.251)	(5.116)
REER*α_{it}		2.479**		1.712		1.350
		(1.186)		(1.094)		(1.123)
Foreign GDP	1.046***	1.032***	0.968***	0.950***	0.955***	0.941***
	(0.137)	(0.132)	(0.140)	(0.148)	(0.142)	(0.152)
Observations	5904	5904	5904	5904	5904	5904

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Two-step Heckman regressions with bootstrapped standard errors. All estimates stem from random effects regressions that include means of the firm-level explanatory variables over time (not reported). The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Independent variables except R&D and initial export status (binary) in logs. Dependent variables: export status (0 = non-exporter, 1 = exporter) at time t in Panel A, log export volume in Panel B. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. Panel A reports average marginal effects (marginal effects of REER at the mean of α_{it} in uneven columns); constituting terms are included in the probit regressions but not reported (n.r.). The inverse Mills ratio is not reported in Panel B

In addition to the above analysis, we checked the sensitivity of the results to using firm-level sales as the dependent variable. The reason for this is that domestic firms may be affected by movements in real exchange rates if they supply to exporters. In addition, this analysis allows us to shed light on an overall effect on firm-level sales of currency swings, beyond the one on exports. The results are shown in Table 11 and Fig. 5 in Appendix 2. Specifically, we used real firm-level turnover as the dependent variable. This variable is not adjusted by profits due to data availability. To summarize the results, we find that there is no significant effect for non-exporters on sales, while the effect for exporters remains significant. The left-hand side of Fig. 5 in Appendix 2 reveals that the effect is negative and significant for those exporters with lower intermediate input shares, while it becomes slightly positive but never significant at higher shares, indicating also that the *hedging* effect holds for exports rather than for sales. The right-hand side of Fig. 5 in Appendix 2 shows the analogous effect for domestic firms, illustrating that there is a negative impact of a real exchange rate appreciation, but only so for firms with higher intermediate input shares. It also suggests that firms with lower such shares are unaffected.[26]

7 Conclusion

In this study, we examined whether changes in the exchange rate affect both the intensive and extensive margins of trade. To do so, we analyzed Swiss HS 6-digit product panel data and a panel data set of manufacturing firms from the KOF innovation survey. The Swiss franc appreciated sharply after the Eurozone crisis and is still strong, despite the cap that the Swiss National Bank put on the exchange rate in 2011 and subsequently lifted in 2015. We hypothesized that sectors that are highly (backward) integrated into global value chains may naturally hedge against such a development. The decrease in relative prices of imported intermediate inputs may mitigate or even offset the negative effects of an appreciation on profit margins. Furthermore, we studied export hysteresis, i.e., the question whether fluctuations in the exchange rate have a permanent effect on exports. The results obtained from both aggregate and firm-level data are qualitatively robust. Our results suggest that the exchange rate effect is decreasing in firm-level and industry-level integration. We also find evidence for substantial market entry costs as

[26] Finally, at the suggestion of an anonymous referee, we also reproduced the results reported in Tables 5, 6 and 8 using a more aggregate clustering strategy. These results, reported in Tables 14, 15 and 16 in Appendix 3, respectively, were found to be robust to clustering the standard errors at the level of input-output industries. Note that the number of observations drops in the upper panel A of Table 14 as well as Tables 15 and 16 (as compared to Tables 5, 6 and 8) because there are missing observations on the cluster variable, the IO sector variable. Moreover, the number of observations in Table 14 panel B (as well as Table 8) is reduced due to dropping singleton observations when running the weighted regressions. In the presence of many singleton observations and with fixed effects nested within clusters (we utilize firm-level fixed effects, and each firm is assigned one IO sector), one tends to overstate the standard errors when not dropping the former. We thus needed to drop singleton observations in panel B of Tables 14 and 16, in contrast to what we did in Tables 5 and 8, where we kept them. In the end, we find the results reported in Tables 5, 6 and 8 preferable because with the firm-level dataset, it is likely that none of the assumptions for consistency of the cluster robust variance estimation are satisfied (for instance see MacKinnon and Webb 2017).

Table 7 Intermediate input shares. *Source*: OECD TiVA (2013), figures for 2009; Foreign value added content shares (Column 1) of gross exports in USD (Column 1). I-share: total inputs/turnover (α_{it}), *source*: KOF innovation panel (1996–2011)

Industry	Exports	Foreign VA	α_{it}
Agriculture, hunting, forestry and fishing	780.2	19.79	0.31
Mining and quarrying	97.8	16.97	0.25
Food products, beverages and tobacco	11,894.4	24.23	0.53
Textiles, textile products, leather and footwear	2582.9	42.85	0.41
Wood, paper, paper products, printing and publishing	8048.0	23.77	0.39
Chemicals and non-metallic mineral products	54,365.1	42.12	0.43
Basic metals and fabricated metal products	13,274.5	31.42	0.37
Machinery and equipment, nec	26,832.4	33.09	0.44
Electrical and optical equipment	41,040.9	32.43	0.40
Transport equipment	3378.6	40.14	0.45
Manufacturing nec; recycling	4973.7	33.00	0.40

Figures are averages over time. We have roughly allocated ISIC sectors to IO industries

past exports are shown to be important determinants of the extensive margin of trade. This points to the possibility that temporary appreciations may affect the export structure in Switzerland permanently.

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Appendix 1: Firm-level data description

The firm-level data stem from the KOF innovation survey in the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. It consists of a nonrandom sample of about 6500 firms, where multi-stage sampling is applied based on 34 industries such that the sample size is nonrandom. Within industries, the population is further stratified disproportionately based on 3 industry-specific size classes in such a way that large firms with at least 5 employees are oversampled. The sampling method is variable probability sampling, with the probability differing by size class and equalling 1 for the largest size class. According to the Federal Statistical Office, the average number of employees per firm was about 11.2 in 2008 (a total of 3,494,071 employees and 312,861 firms was reported), compared to the average of 285 for all firms in the same year in the sample.[27] Note that we observe firms with < 5 employees in the sample. This is solely due to firms that reduced employment in later periods.

All variables indicated in shares exhibit mass points at integer values resulting from the tendency of firms to round such figures up or down. However, histograms

[27] Source: Betriebszählung 2008.

Table 8 Exchange rates and firm-level exports (results with intermediate input proxy adjusted by imported intermediate inputs)

	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.238***	0.237***	0.238***	0.236***	0.239***	0.237***
	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)	(0.084)
Employees	0.902***	0.895***	0.903***	0.898***	0.905***	0.899***
	(0.109)	(0.108)	(0.109)	(0.108)	(0.109)	(0.108)
R&D	0.066*	0.070*	0.066*	0.068*	0.067*	0.069*
	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
REER	− 0.394**	− 0.595***	− 0.409**	− 0.599***	− 0.390**	− 0.579***
	(0.181)	(0.201)	(0.195)	(0.217)	(0.191)	(0.211)
$\alpha_{it}*\alpha_{kt}$	3.117**	− 28.555**	3.126**	− 26.488**	3.121**	− 26.867**
	(1.457)	(11.413)	(1.457)	(12.358)	(1.456)	(12.227)
REER*($\alpha_{it}*\alpha_{kt}$)		6.669***		6.356**		6.468**
		(2.469)		(2.710)		(2.686)
Foreign GDP	1.068***	1.066***	0.930**	0.928**	0.889**	0.871**
	(0.409)	(0.409)	(0.420)	(0.420)	(0.425)	(0.425)
Observations	2476	2476	2476	2476	2476	2476
No. firms	1354	1354	1354	1354	1354	1354

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Fixed effects regressions (firm fixed effects) with robust standard errors. The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Dependent variable: log real exports. Independent variables except R&D in logs. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. The firm-level variable α_{it} is multiplied by sectoral imported intermediate inputs (α_{kt})

show that the variables are roughly continuously distributed such that they are not interval coded. This response bias concerns wages, intermediate inputs, and export volumes as well. We calculated these variables by multiplying the respective share by turnover.

Table 9 in Appendix 1 indicates the export entry and exit behavior of firms as well as the total number of firms and the number of exporters according to year, shedding light on firm-level dynamics. The number of firms by year ranges from 714 (in 1999) to 989 (in 2002) compared to the overall number of distinct firms that amounts to 2611 over the entire period, hence the panel exhibits substantial dynamics. A substantial fraction of those firms export, as figures reported by year show. Second, the number of firms that change their export status (switchers) varies across time. Furthermore, there is variation in entry and exit dynamics. The distinction between firms that enter and exit illustrates that the pattern of firms that enter into exporting corresponds to the business cycle, increasing between 1999 and 2005, and decreasing over the following two periods, before increasing again in the last period of observation. Firms that exit follow by and large the pattern of the business cycle

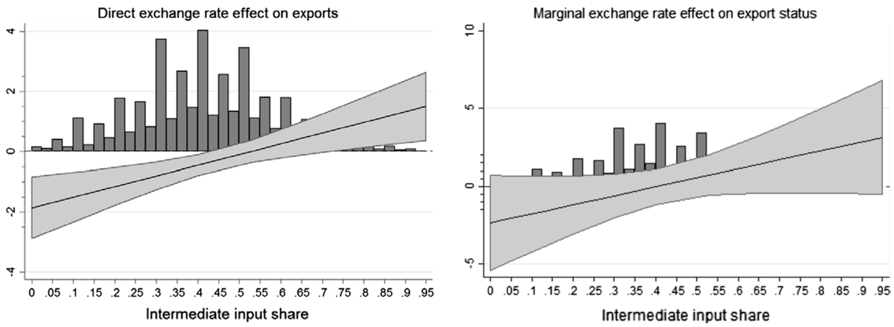

Fig. 3 Firm-level reer effects evaluated at percentiles of intermediate input share. Note: partial and marginal effects at percentiles and the maximum of the distribution of α_{it} (intermediate input share in turnover). LHS: fixed effects regressions with log export volume as the dependent variable. RHS: pooled probit regressions with a binary variable for firm export participation at time t as the dependent variable. 90% confidence intervals shown. A histogram of the distribution of firm-level intermediate input shares is shown in both figures

Table 9 Dynamics in firm-level data

Year	$Switch_{t*}$	$Entry_{t*}$	$Exit_{t*}$	Firms	Export
1996	0	0	0	871	647
1999	23	14	9	709	546
2002	40	14	20	963	716
2005	56	27	17	938	711
2008	58	15	24	789	596
2011	52	16	10	876	658
2013	55	13	23	729	538

Switch denotes firms that changed export status over the panel period; t* denotes a change (switch, entry, exit) with respect to the previous period; Firms and Export refers to the number of firms and exporters by year

too (.i.e. the number of exiting firms tends to increase during economic downturns or crises), with the exception of a drop in exiting firms in 2011.

TFP is obtained as the residual from a regression of the log value added on log wage (the unit labor costs times the number of full-time equivalent employees) and log material costs, with standard errors clustered at the firm level. We use material costs because information on investment is sparse and information about capital is not available. Note that TFP is measured with error.

Appendix 2

See Tables 10, 11 and Figs. 4 and 5.

Table 10 Firm-level probit interaction effects of exchange rate and intermediate input share

Export status	(1)	(2)	(3)
Interaction effect	1.723	1.829	1.643
Standard error	0.723	0.824	0.74
z-statistic	2.188	2.036	2.085
Obs.	5875	5875	5875

Column (1) uses the log REER from SNB; column (2) uses log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); column (3) uses log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Marginal interaction effect of two continuous variables, the log exchange rate index and the firm-level intermediate input share in turnover. Dependent variable: export status at time t (0 = no exports, 1 = exports). Marginal effects of other variables time t suppressed

Table 11 Exchange rates and firm-level sales (fixed effect results)

	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.370***	0.374***	0.370***	0.372***	0.371***	0.372***
	(0.052)	(0.051)	(0.052)	(0.051)	(0.052)	(0.051)
Employees	0.796***	0.796***	0.796***	0.796***	0.796***	0.795***
	(0.048)	(0.048)	(0.048)	(0.048)	(0.049)	(0.048)
R&D	0.009	0.009	0.009	0.009	0.009	0.009
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
Foreign GDP	0.440***	0.438***	0.383***	0.380***	0.370***	0.367***
	(0.050)	(0.051)	(0.057)	(0.058)	(0.058)	(0.058)
Exporter	0.644	7.276***	0.656	5.375**	0.542	4.707**
	(0.825)	(2.423)	(0.754)	(2.193)	(0.693)	(2.026)
REER	− 0.133	0.772*	− 0.14	0.589	− 0.17	0.494
	(0.161)	(0.445)	(0.152)	(0.427)	(0.138)	(0.402)
α_{it}	1.039***	11.318***	1.039***	9.415**	1.040***	8.550**
	(0.120)	(4.293)	(0.121)	(4.505)	(0.120)	(4.266)
Exporter*REER	− 0.139	− 1.577***	− 0.144	− 1.183**	− 0.119	− 1.039**
	(0.180)	(0.526)	(0.167)	(0.482)	(0.154)	(0.445)
Exporter*α_{it}		− 15.901***		− 11.655**		− 10.221**
		(5.214)		(5.232)		(4.880)
REER*α_{it}		− 2.228**		− 1.845*		− 1.658*
		(0.928)		(0.985)		(0.933)
Exporter*REER*α_{it}		3.447***		2.568**		2.258**
		(1.129)		(1.148)		(1.072)
Observations	6043	6043	6043	6043	6043	6043
No. firms	2611	2611	2611	2611	2611	2611

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Fixed effects regressions (firm fixed effects) with robust standard errors. The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Dependent variable: log real turnover. Independent variables except R&D in logs. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8 digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover

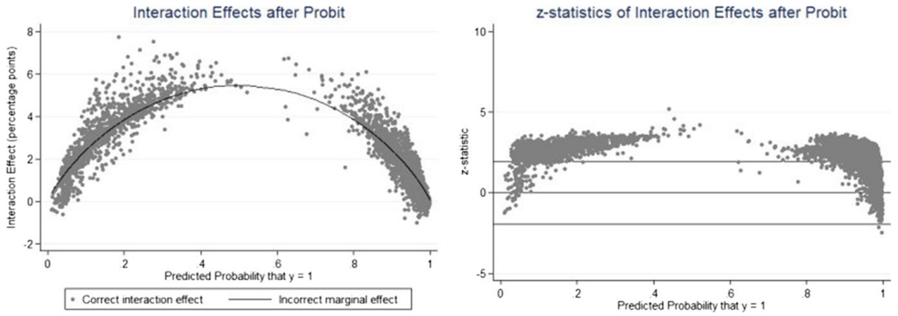

Fig. 4 Firm-level probit interaction effects of exchange rate and intermediate input share. Note: marginal interaction effect of two continuous variables, the log REER index (SNB) and the firm-level intermediate input share in turnover on export status. Left-hand side panel plots the interaction effect for non-linear models calculated as the cross-partial derivative of the expected value of the dependent variable (Norton et al. 2004), and the interaction effect calculated by the conventional linear method) against predicted probabilities. Right-hand side panel plots z -statistics of the interaction effect against predicted probabilities

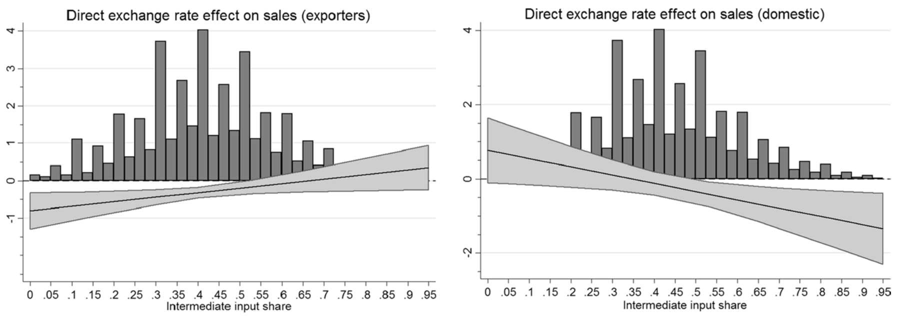

Fig. 5 Firm-level reer effects for sales evaluated at percentiles of intermediate input share. Note: partial and marginal effects at percentiles and the maximum of the distribution of α_{it} (intermediate input share in turnover). LHS: fixed effects regressions with log turnover for exporters as the dependent variable. RHS: fixed effects regressions with log turnover for domestic firms as the dependent variable. 90% confidence intervals shown. A histogram of the distribution of firm-level intermediate input shares is shown in both figures

Appendix 3

See Tables 12–16.

Table 12 Direct exchange rate effect and imported input share from destination (results with imported input weighted exchange rate and alternative clustering strategy)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	$\Pr(X_{jpt} > 0)$	$\ln(X_{jpt} \mid X_{jpt} > 0)$	$\Pr(X_{jpt} > 0)$	$\ln(X_{jpt} \mid X_{jpt} > 0)$	$\Pr(X_{jpt} > 0)$	$\Pr(X_{jpt} > 0)$
	Heckman		Heckman		FE	LPM
$E^*_{jt}X_{jpt-1}$					0.0138	0.116**
					(0.0319)	(0.0452)
X_{jpt-1}					0.0691	0.146
					(0.145)	(0.208)
E_{jt}	− 0.0992***	0.464	− 0.0818***	0.524	− 0.0831***	− 0.114***
	(0.0287)	(0.514)	(0.0238)	(0.548)	(0.0264)	(0.0341)
$\ln(\text{Import\_RER}_{kt})$	0.233***	− 3.571***	0.182**	− 3.654***	0.229***	0.101**
	(0.0891)	(1.043)	(0.0792)	(1.071)	(0.0564)	(0.0473)
$\ln(GDP_{jt})$	0.203***	0.126	0.168***	− 0.00620	0.132***	0.0374**
	(0.0259)	(0.948)	(0.0197)	(1.024)	(0.0177)	(0.0180)
$\ln(1 + \tau_{jpt})$	0.0267***	− 0.154	0.0251***	− 0.201	− 0.000140	0.00683**
	(0.00920)	(0.149)	(0.00826)	(0.173)	(0.00250)	(0.00289)
$Contig_j$	0.0499	− 1.268	0.0524	− 1.060		0.0355
	(0.0455)	(1.558)	(0.0367)	(1.891)		(0.0309)
$Lang_j$	0.107	1.126	0.137	0.787		0.00372
	(0.108)	(3.047)	(0.0928)	(1.292)		(0.0587)
$\ln(Dist_j)$	− 0.0737	− 0.717	− 0.0562	− 0.715		− 0.0168
	(0.0661)	(0.515)	(0.0517)	(0.519)		(0.0332)
$Time2Import_{jt}$	0.00206**		0.00155**			
	(0.000814)		(0.000642)			
Inverse mills (n_{jpt})		2.100		100.6		
		(1.440)		(72.89)		
z_{jpt}		28.22***		548.0		
		(9.652)		(491.1)		
z^2_{jpt}		− 13.84**		− 304.4		
		(5.558)		(310.3)		
z^3_{jpt}		2.733**		62.75		
		(1.252)		(72.07)		
Observations	1,038,348	5,11,683	1,038,348	5,11,683	1,043,680	1,043,680
R-squared	0.177	0.169	0.221	0.169	0.021	0.580
Estimation	Probit	OLS	LPM	OLS	FE	LPM
MR terms	Yes	Yes	Yes	Yes	No	Yes
Fixed effects	j,k,t	j,k,t	j,k,t	j,k,t	j,k,t	j,k,t
SE clustered at	j	j	j	j	j	j

LPM linear probability model. Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. All columns include destination, industry (ISIC 2-digit) and year dummies and "Bonus-vetus" multilateral resistance terms (except colums 5). Marginal effects at means are reported in the Probit specification in column 1. The first stage of the Heckman is estimated using the Probit in column 1 and using the LPM in column 3. Standard errors are clustered at the level of the destination country

Table 13 Direct exchange rate effect and imported input share from destination (results with sectoral and destination-specific foreign input share and alternative clustering strategy)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	$Pr(X^{vol}_{jpt} > 0)$	$\ln(X^{vol}_{jpt} \| X^{vol}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$	$\ln(X^{val}_{jpt} \| X^{val}_{jpt} > 0)$	$Pr(X^{vol}_{jpt} > 0)$	$\ln(X^{vol}_{jpt} \| X^{vol}_{jpt} > 0)$
	Heckman		Heckman		Heckman	
X_{jpt-1}						
X_{jpt-2}						
α_{jkt}	0.00267	− 10.50***	0.0527	− 9.182***	− 0.568	− 14.41***
	(0.835)	(2.745)	(0.892)	(3.135)	(0.572)	(4.322)
E_{jt}	− 0.0636**	− 0.672*	− 0.0650**	− 0.942***	− 0.0590**	− 0.709*
	(0.0301)	(0.379)	(0.0286)	(0.330)	(0.0249)	(0.408)
$E_{jt}{}^{*}\alpha_{jkt}$	0.0707	3.129***	0.0595	3.077***	0.166	3.844***
	(0.197)	(0.780)	(0.208)	(0.690)	(0.143)	(1.262)
$\ln(GDP_{jt})$	0.212***	2.653**	0.216***	3.223***	0.170***	2.567**
	(0.0240)	(1.249)	(0.0247)	(1.104)	(0.0190)	(1.182)
$\ln(1 + \tau_{jpt})$	0.0131*	0.0970	0.0106	0.0168	0.0126*	0.109
	(0.00750)	(0.102)	(0.00744)	(0.0811)	(0.00684)	(0.109)
$Time2Import_{jt}$	− 0.000926		− 0.00131		− 0.000793	
	(0.00212)		(0.00236)		(0.00163)	
Inverse mills (n_{jpt})		5.424*		8.303***		104.9
		(2.868)		(2.506)		(75.98)
z_{jpt}		9.565		21.62***		542.1
		(9.539)		(7.635)		(455.1)
z^2_{jpt}		− 7.000		− 14.31**		− 340.1
		(6.737)		(5.494)		(289.4)
z^3_{jpt}		1.537		2.945**		77.64
		(1.526)		(1.227)		(66.40)

Table 13 (continued)

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	$Pr(X_{jpt}^{vol} > 0)$	$ln(X_{jpt}^{vol} \| X_{jpt}^{vol} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$ln(X_{jpt}^{val} \| X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{vol} > 0)$	$ln(X_{jpt}^{vol} \| X_{jpt}^{vol} > 0)$
	Heckman		Heckman		Heckman	
Observations	1,129,939	5,58,470	1,129,939	575,725	1,129,939	5,58,470
Pseudo-R-squared	0.170	0.198	0.174	0.163	0.213	0.198
Estimation	Probit	OLS	Probit	OLS	LPM	OLS
Fixed effects	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t
SE clustered at	j	j	j	j	j	j

Variables	(7)	(8)	(9)	(10)	(11)	(12)
	$Pr(X_{jpt}^{val} > 0)$	$ln(X_{jpt}^{val} \| X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$	$Pr(X_{jpt}^{val} > 0)$
	Heckman		FE	Probit	LPM	LPM
X_{jpt-1}			0.123***	0.696***	0.674***	0.465***
			(0.0101)	(0.00408)	(0.00484)	(0.00458)
X_{jpt-2}						0.308***
						(0.00250)
α_{jkt}	− 0.500	− 15.11***	− 0.536*	− 1.378**	− 0.433*	− 0.782***
	(0.607)	(3.997)	(0.292)	(0.598)	(0.240)	(0.256)
E_{jt}	− 0.0577**	− 1.049***	− 0.0550**	− 0.0779**	− 0.0391**	− 0.0441**
	(0.0233)	(0.382)	(0.0220)	(0.0346)	(0.0170)	(0.0208)
$E_{jt}{}^{*}\alpha_{jkt}$	0.149	4.219***	0.138**	0.346**	0.110*	0.181***
	(0.149)	(1.091)	(0.0615)	(0.135)	(0.0591)	(0.0609)
$ln(GDP_{jt})$	0.173***	3.351***	0.131***	0.0752**	0.0347**	0.0161
	(0.0201)	(1.172)	(0.0150)	(0.0347)	(0.0166)	(0.0289)

Table 13 (continued)

Variables	(7)	(8)	(9)	(10)	(11)	(12)
	$Pr(X^{val}_{jpt} > 0)$	$ln(X^{val}_{jpt} \| X^{val}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$	$Pr(X^{val}_{jpt} > 0)$
	Heckman		FE	Probit	LPM	LPM
$ln(1 + \tau_{jpt})$	0.0106	0.0484	− 0.00474*	0.00344	0.00250	0.00189
	(0.00675)	(0.0933)	(0.00268)	(0.00438)	(0.00242)	(0.00217)
$Time2Import_{jt}$	− 0.000983					
	(0.00174)					
Inverse mills (n_{jpt})		152.6*				
		(79.30)				
z_{jpt}		748.3				
		(484.2)				
z^2_{jpt}		− 452.8				
		(310.6)				
z^3_{jpt}		98.70				
		(72.18)				
Observations	1,129,939	575,725	1,135,271	1,135,271	1,135,271	1,004,463
Pseudo-R-squared	0.218	0.163	0.019	0.482	0.575	0.615
Estimation	LPM	OLS	FE	Pooled probit	LPM	LPM
Fixed effects	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t	j, k, t
SE clustered at	j	j	j	j	j	j

LPM linear probability model. Significance levels: ***p < 0.01, **p < 0.05, *p < 0.1. All columns include country, industry (ISIC 2-digit) and year dummies. Marginal effects at means are reported in the Probit specifications in columns (1), (3) and (10). The first stage of the Heckman is estimated using the Probit in columns (1) and (3), and using the LPM in columns (5) and (7). Standard errors are clustered at the level of the destination country in all specifications

Table 14 Exchange rates and firm-level exports (results with clustered standard errors at io2_num)

	(1)	(2)	(3)	(4)	(5)	(6)
A. Fixed effects regressions						
TFP	0.542***	0.553***	0.541***	0.549***	0.541***	0.546***
	(0.137)	(0.132)	(0.137)	(0.134)	(0.137)	(0.135)
Employees	1.006***	1.003***	1.005***	1.004***	1.004***	1.004***
	(0.063)	(0.068)	(0.063)	(0.067)	(0.064)	(0.066)
R&D	0.075*	0.071*	0.075*	0.074*	0.075*	0.073*
	(0.037)	(0.038)	(0.037)	(0.038)	(0.037)	(0.038)
REER	− 0.297	− 1.823**	− 0.324	− 1.357**	− 0.338	− 1.138*
	(0.255)	(0.657)	(0.272)	(0.635)	(0.266)	(0.610)
α_{it}	1.629***	− 14.445**	1.627***	− 9.176	1.627***	− 6.766
	(0.294)	(6.202)	(0.294)	(6.012)	(0.293)	(5.902)
REER*α_{it}		3.477**		2.373*		1.846
		(1.326)		(1.305)		(1.284)
Foreign GDP	0.886***	0.864***	0.811***	0.787***	0.795***	0.776***
	(0.195)	(0.195)	(0.236)	(0.235)	(0.240)	(0.240)
Obs.	4493	4493	4493	4493	4493	4493
No. firms	1968	1968	1968	1968	1968	1968
No. clusters	18	18	18	18	18	18
B. Weighted regressions (using sampling weights)						
TFP	0.480***	0.493***	0.480***	0.495***	0.480***	0.494***
	(0.094)	(0.087)	(0.094)	(0.088)	(0.094)	(0.089)
Employees	0.886***	0.880***	0.886***	0.882***	0.886***	0.883***
	(0.060)	(0.066)	(0.060)	(0.066)	(0.060)	(0.065)

Table 14 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
R&D	0.099*	0.091	0.099*	0.093	0.099*	0.093
	(0.056)	(0.057)	(0.055)	(0.057)	(0.055)	(0.057)
REER	− 0.022	− 1.864**	− 0.011	− 1.888*	− 0.021	− 1.704*
	(0.289)	(0.832)	(0.314)	(0.910)	(0.302)	(0.915)
α_{it}	1.441***	− 18.799**	1.442***	− 18.823*	1.441***	− 16.707
	(0.204)	(8.362)	(0.204)	(9.318)	(0.204)	(9.549)
REER*α_{it}		4.382**		4.460**		3.999*
		(1.805)		(2.050)		(2.109)
Foreign GDP	0.499	0.537*	0.494	0.511*	0.493	0.508*
	(0.294)	(0.291)	(0.287)	(0.281)	(0.287)	(0.283)
Obs.	3708	3708	3708	3708	3708	3708
No. firms	1183	1183	1183	1183	1183	1183
No. clusters	16	16	16	16	16	16

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Fixed effects regressions (firm fixed effects) with standard errors clustered at io2_num. The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Dependent variable: log real exports. Independent variables except R&D in logs. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. Sampling weights in Panel B are response-probability adjusted

Table 15 Exchange rates and firm-level exports (Heckman results with industry-clustered standard errors)

	(1)	(2)	(3)	(4)	(5)	(6)
A. Participation equation (random effects probit AME)						
Initial export	4.322***	4.326***	4.322***	4.326***	4.320***	4.320***
	(0.209)	(0.208)	(0.208)	(0.209)	(0.207)	(0.207)
TFP	0.252	0.245	0.252	0.249	0.25	0.25
	(0.176)	(0.217)	(0.216)	(0.217)	(0.216)	(0.216)
Employees	0.478***	0.476***	0.477***	0.478***	0.474***	0.474***
	(0.139)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)
R&D	0.086	0.078	0.085	0.08	0.081	0.081
	(0.120)	(0.132)	(0.132)	(0.132)	(0.132)	(0.132)
REER	0.044	n.r.	0.002	n.r.	− 0.324	n.r.
	(0.574)		(0.644)		(0.646)	
α_{it}	0.493	n.r.	0.492	n.r.	0.488	n.r.
	(0.518)		(0.618)		(0.619)	
Foreign GDP	− 0.348	− 0.394	− 0.349	− 0.398	− 0.442	− 0.442
	(0.386)	(0.372)	(0.426)	(0.426)	(0.436)	(0.436)
Observations	5834	5834	5834	5834	5834	5834
B. Outcome equation						
TFP	0.973***	0.970***	0.972***	0.971***	0.972***	0.971***
	(0.064)	(0.068)	(0.064)	(0.067)	(0.064)	(0.066)
Employees	0.075**	0.072**	0.075**	0.074**	0.075**	0.074**
	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)	(0.036)
R&D	0.506***	0.514***	0.505***	0.511***	0.505***	0.509***
	(0.132)	(0.128)	(0.132)	(0.129)	(0.132)	(0.130)
REER	− 0.296	− 1.370**	− 0.316	− 1.042*	− 0.320	− 0.889
	(0.279)	(0.598)	(0.298)	(0.586)	(0.285)	(0.572)

Table 15 (continued)

	(1)	(2)	(3)	(4)	(5)	(6)
α_{it}	1.544***	− 9.786*	1.543***	− 6.063	1.544***	− 4.434
	(0.286)	(5.625)	(0.286)	(5.604)	(0.286)	(5.474)
REER*α_{it}		2.451**		1.671		1.315
		(1.196)		(1.213)		(1.188)
Foreign GDP	1.050***	1.035***	0.977***	0.960***	0.965***	0.951***
	(0.200)	(0.199)	(0.251)	(0.249)	(0.255)	(0.253)
Observations	4378	4378	4378	4378	4378	4378
No. firms	1899	1899	1899	1899	1899	1899
No. clusters	17	17	17	17	17	17

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Two-step Heckman regressions with standard errors clustered at the industry-level. All estimates stem from random effects regressions that include means of the firm-level explanatory variables over time (not reported). The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Independent variables except R&D and initial export status (binary) in logs. Dependent variables: export status (0 = non-exporter, 1 = exporter) at time t in Panel A, log export volume in Panel B. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. Panel A reports average marginal effects (marginal effects of REER at the mean of α_{it} in uneven columns); constituting terms are included in the probit regressions but not reported (n.r.). The inverse Mills ratio is not reported in Panel B

Table 16 Exchange rates and firm-level exports (results with intermediate input proxy adjusted by imported intermediate inputs) (standard errors clustered at the industry-level)

	(1)	(2)	(3)	(4)	(5)	(6)
TFP	0.230***	0.229***	0.231***	0.229***	0.231***	0.230***
	(0.071)	(0.071)	(0.072)	(0.071)	(0.071)	(0.071)
Employees	0.896***	0.890***	0.897***	0.892***	0.898***	0.893***
	(0.110)	(0.108)	(0.110)	(0.109)	(0.110)	(0.108)
R&D	0.068	0.072*	0.068	0.070*	0.069	0.071*
	(0.039)	(0.038)	(0.039)	(0.038)	(0.039)	(0.038)
REER	− 0.371	− 0.569**	− 0.383	− 0.570*	− 0.365	− 0.552*
	(0.256)	(0.251)	(0.275)	(0.275)	(0.273)	(0.268)
$\alpha_{it}{}^{*}\alpha_{kt}$	3.099***	− 27.711***	3.107***	− 25.654***	3.103***	− 26.081***
	(0.943)	(6.737)	(0.949)	(6.972)	(0.959)	(7.052)
REER$^{*}(\alpha_{it}{}^{*}\alpha_{kt})$		6.487***		6.173***		6.294***
		(1.464)		(1.530)		(1.579)
Foreign GDP	1.107**	1.104**	0.977**	0.974**	0.940**	0.921**
	(0.410)	(0.412)	(0.419)	(0.420)	(0.426)	(0.425)
Observations	1796	1796	1796	1796	1796	1796
No. firms	686	686	686	686	686	686

***, ** and * denote statistical significance at the 1, 5 and 10% levels, respectively. Fixed effects regressions (firm fixed effects) with industry-level clustered standard errors. The sample covers the years 1996, 1999, 2002, 2005, 2008, 2011, and 2013. Dependent variable: log real exports. Independent variables except R&D in logs. Columns (1) and (2) use the log REER from SNB; columns (3) and (4) use log REER calculated from HS8-digit export data (Eidgenössische Zollverwaltung EZV); columns (5) and (6) use log REER calculated at the 2-digit level (matched NOGA industry and HS8 trade classification). Each specification is reported without (in uneven columns) and with (in even columns) interaction effects of REER and firm-level intermediate goods shares in turnover. The firm-level variable α_{it} is multiplied by sectoral imported intermediate inputs (α_{kt})

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