Exchange rate exposure under liquidity constraints

Stefano Schiavo, Sarah Guillou

Industrial and Corporate Change Advance Access published November 5, 2014

Industrial and Corporate Change, pp. 1–21
doi:10.1093/icc/dtu033

Exchange rate exposure under liquidity constraints

Sarah Guillou* and Stefano Schiavo,†**

This article presents a simple model in which exporting firms are heterogeneous, both in terms of productivity and liquidity, with the latter being affected by exchange rate changes. This configuration is used to analyze the profits sensitivity to exchange rate changes. The originality of the article lies in the assumption that exchange rate shocks can either boost or depress liquidity, thus allowing one to study exposure in different scenarios. The model predicts that the sensitivity of a firm's profits to exchange rate changes depends on its financial condition: an increase in the cost of external funds makes profits less sensitive to exchange rate shocks when a firm's liquidity decreases following a depreciation of the domestic currency. The predictions of the model are tested using a large data set of French exporting firms: results confirm that for firms whose liquidity is negatively correlated with exchange rate movements, an increase in financial costs lowers exposure.

JEL classification: F23, F31, G32.

1. Introduction

This article investigates the interaction between exchange rate changes and liquidity constraints, and their joint effect on the profits of exporting firms. The topic is particularly relevant in the present context, where external financial resources are still scarce as a result of the financial crisis, and currency values are fluctuating widely. The article both contributes to the growing body of literature that examines the role played by financial factors in determining firm behavior in international

*OFCE SciencesPo, SKEMA Business School and GREDEG UMR CNRS 7321. e-mail: sarah.guillou@sciencespo.fr

**School of International Studies and Department of Economics and Management, University of Trento and OFCE SciencesPo., via T. Gar 14, 38122 Trento, Italy. e-mail: stefano.schiavo@unitn.it

†Main author for correspondence.

markets, and increases our understanding of the relationship between exchange rates and exports.

It is well known that exchange rate fluctuations have relatively little effect on aggregate export flows. Recently, a number of studies have exploited newly available data sets to address the issue from a firm-level perspective, showing that aggregate stability hides a much more complex picture, and that, depending on their specific characteristics, firms may react very differently to the same exogenous disturbance (Muûls, 2008; Berman *et al.*, 2012). Strasser (2013), for instance, claims that incomplete pass-through, whereby firms decide to absorb part of an exchange rate fluctuation to stabilize their prices, is determined by financial constraints at the firm level. Similarly, Héricourt and Poncet (2013) find that real exchange rate volatility negatively affects both the intensive and the extensive margins of export. Their analysis of a sample of Chinese firms shows that this negative effect is much stronger for financially constrained firms, and is magnified by weak financial development.

While most of the existing literature investigates the impact of exchange rate movements either on export quantities or prices, here we focus on profits. They are, at least according to economic theory, the main goal of firms, a major index of performance, and a crucial determinant of firm investment and growth. Indeed, theory suggests that firms take decisions on the basis of (discounted) profits whenever they have to commit resources. This is also true for export and other international activities and the associated fixed costs.

This article looks at the interaction between exchange rate fluctuations, financial conditions, and profits and provides evidence that financial factors affect the way profits react to exchange rate movements. Disregarding financial aspects of an exchange rate change, a depreciation of the domestic currency is expected to give exporters a cost advantage that increases their profitability. The article shows that the story is more complicated: a firm facing higher financing costs due to greater reliance on external credit is less able to take advantage of a depreciation. Moreover, a depreciation may either increase or decrease the liquidity of a firm, affecting its need for external finance and, because of the higher cost of external relative to internal funds, will impact its marginal costs. But the change in liquidity in response to the exchange rate change may depend on the macroeconomic shock that triggered the exchange rate change or on firms' characteristics.

Although a number of authors has investigated how a firm's dependence on imported inputs can change its response to exchange rate fluctuations (e.g. Nucci and Pozzolo, 2001; Greenaway *et al.*, 2010), and others have shown that financial constraints change how real exchange rate fluctuations affect exporters' behavior and pricing decisions (see Strasser, 2013; Héricourt and Poncet, 2013), this is the first article that demonstrates that the severity of liquidity constraints, and the cost of financing may themselves be functions of the exchange rate. The impact of exchange rate movements on exporter profits thus depends on the interplay between currency fluctuations and firms' financial conditions.

Our results are similar to the conclusions reached by Devereux *et al.* (2006) in the open-economy macroeconomics literature: they find that financial market imperfections magnify the effect of exchange rate volatility, making stabilization much harder than in perfect financial markets. Here we go beyond the aggregate results by showing one possible way to microfound the relationship between the exchange rate and a firm's financial conditions, and by showing that the latter affects how firms respond to currency fluctuations.

More specifically, the article links the literature on heterogeneity, finance, and export with the more classic issue of exchange rate exposure, defined as the sensitivity of profits to exchange rate changes.[1] We develop a simple model in which exporting firms are characterized by heterogeneous productivity and are endowed with a certain amount of liquidity with which they have to cover both fixed and variable costs. When firms are short of liquidity, they resort to external finance, which comes at a higher cost. Exchange rate movements affect both revenues and costs. They also influence liquidity, thereby having a further indirect impact on a firm's profits. The model gives rise to a number of testable implications which are investigated using a rich data set comprising information on around 30,000 French exporting firms over the years 1995–2007.

Consistent with the model we find that the impact of exchange rate variations on profits is heterogeneous across firms, and it crucially depends on the financial health of a firm. Furthermore, the effect is mediated by the nature of exchange rate shocks, and their interplay with firms' financial position. Then, since a depreciation does not have an homogeneous effect on firms, these results also contribute to explain why the aggregate effect of exchange rate movements on trade is generally not as strong as expected.

The article is organized as follows: Section 2 presents the model and derives the main testable implications. Section 3 describes the data, while Section 4 discusses the results of the empirical analysis. The last Section highlights some possible paths for future research and presents our conclusions.

2 The model

The article builds on a recent contribution by Buch *et al.* (2010) to derive a model based on heterogeneous firms engaged in exporting activities, which may face liquidity constraints, defined as the need to finance their fixed and variable costs using (costlier) external financial resources.

Although our work is rooted in the new-new trade theory and belongs to the family of Melitz-type (2003) models, we avoid modeling explicitly the selection effect

[1] Exposure has long been studied in the finance literature Bodnar *et al.* (2002); Muller and Verschoor (2006), by relating firms' stock market return to exchange rate changes.

that results in the usual segmentation between exporting and non-exporting firms, concentrating instead on the former.

Firms face a fixed entry cost F, plus a constant marginal cost $(ec + d)/\beta_i$, where β_i captures (firm-specific) productivity, ec is the imported component of the cost (such as imported intermediate materials), e is the exchange rate (domestic currency units per foreign currency), and d is the domestic part of variable costs.

Demand is derived from the usual monopolistic competition setup in which consumer preference is characterized as a constant elasticity of substitution (CES) utility function:

$$U = \left(\int_i x(i)^{\frac{\sigma-1}{\sigma}} di \right)^{\frac{\sigma}{\sigma-1}} \tag{1}$$

where $x(i)$ is the consumption of variety i and $\sigma > 1$ is the elasticity of substitution. Utility maximization subject to the constraint of total expenditure being lower or equal to R yields the demand faced by each firm, which takes the usual form:

$$x_i = \frac{R p_i^{-\sigma}}{P^{1-\sigma}} \tag{2}$$

with p_i being the price charged by firm i (i.e. the price of variety i) and $P = (\int_i p(i)^{1-\sigma} di)^{\frac{1}{1-\sigma}}$ the overall price index.

We further assume—again following Buch *et al.* (2010)—that the firm possesses a certain amount of cash L_i that can be used to finance its fixed and variable costs. The idea here is that these costs need to be met in advance. The opportunity cost of internal finance (i.e. the outside option for investing L_i) is normalized to 1. When firms have to finance their costs through external financial resources (i.e. when $L_i < \frac{ec+d}{\beta_i} x_i + F$), they have to pay a firm-specific premium $\tilde{\phi}_i > 1$. This premium is firm-specific because it depends on the firm's debt structure, financial situation, and reputation. Exporting firms also face an iceberg transport cost $\tau > 1$, which is assumed to be equal for all exporting firms.

Profits are given by the following expression:

$$\pi_i = \frac{e p_i x_i}{\tau} - \phi_i \left[\frac{ec + d}{\beta_i} x_i + F - L_i \right] - L_i \tag{3}$$

We introduce a relationship between liquidity and exchange rate shocks, in a way similar to Dekle and Ryoo (2007). To do this we need first to assume that the exchange rate is hit by a random macroeconomic shock ε with zero mean and finite variance υ_ε

$$e = \overline{e} + \varepsilon \tag{4}$$

This shock can be either positive, implying a depreciation, or negative, implying an appreciation of the domestic currency given our definition of the exchange rate. At the same time, we suppose that this macroeconomic shock, ε, will affect the amount of liquidity a firm can rely on. This assumption is a simple way of capturing the fact that the exchange rate and sales are jointly determined by underlying macroeconomic variables (see for instance Russ, 2007). Hence,

$$L_i = \overline{L}_i(1 + \alpha\varepsilon) \tag{5}$$

where α represents the correlation between the firm's liquidity and the random shock (as in Dekle and Ryoo, 2007). According to this formulation, the effect of a macroeconomic shock on firm liquidity depends on the correlation between the latter and exchange rate movements.[2]

Although modeling the determinants of the correlation (α) is beyond the scope of this article, we can nevertheless conjecture that its sign depends on both the nature of the macroeconomic shock (monetary, fiscal, or trade policy changes, productivity or labor supply shocks, ...) and on firm- and industry-specific characteristics that affect the reactions to these disturbances.

Consider for instance a depreciation of the exchange rate (i.e. a positive shock, $\varepsilon > 0$). The sign of α will determine whether the depreciation will ease or tighten the liquidity constraint. If $\alpha > 0$, then liquidity increases. This could be the result of an expansionary monetary policy shock which, by lowering interest rates, leads to a depreciation of the domestic currency and to higher demand and liquidity. On the other hand, if $\alpha < 0$ then liquidity goes down following a depreciation. A macroeconomic supply side shock, e.g. an increase in the oil price, would increase costs and trigger a depreciation of the exchange rate aimed at restoring the trade balance. At the same time, firms are more likely to be constrained since their costs are higher. This is more likely to happen for firms (or sectors) that are highly dependent on imported inputs. Moreover, a depreciation lowers the value of domestic assets in terms of foreign currency, reducing firms' ability to access foreign financial resources (a similar argument is used in Chaney, 2013, to explain why an appreciation of the domestic currency, by increasing the relative value of domestic assets, may ease access to foreign markets).

Table 1 summarizes the different possibilities. As Dekle and Ryoo (2007), in the rest of the article we simply assume $\alpha \neq 0$ to impose as little structure as possible on the model.

At this point we can study the effect of an unexpected exchange rate change (i.e. a shock) on profits. We assume that when liquidity constraints are binding, and firms

[2] This formulation also states that the extent of the effect of the macroeconomic shock on the liquidity available depends on the given liquidity level. This is coherent with the idea that liquidity reflects the history of the firm performance. More productive firms should have more liquidity as a result of greater profit accumulation. At the same time, more productive firms are likely to be larger exporters. Thus firms with higher liquidity are expected to be the larger exporters and therefore more exposed.

Table 1 Effects of shocks depending on α

Shock	$\alpha > 0$	$\alpha < 0$
Depreciation	Increases liquidity	Decreases liquidity
($\varepsilon > 0$)	Eases constraints	Tightens constraints
Appreciation	Decreases liquidity	Increases liquidity
($\varepsilon < 0$)	Tightens constraints	Eases constraints

have to rely on external financial resources, they face a higher cost. Normalizing the opportunity cost of internal finance to 1 we get:

$$\phi_i = \begin{cases} 1 & \text{if} \quad \overline{L}_i(1+\alpha\varepsilon) \geq \dfrac{ec+d}{\beta_i} x_i + F \quad \text{(no liquidity constraint)} \\ \tilde{\phi}_i > 1 & \text{if} \quad \overline{L}_i(1+\alpha\varepsilon) < \dfrac{ec+d}{\beta_i} x_i + F \quad \text{(liquidity constraint)} \end{cases}$$

We can now rewrite the profit equation (3) as

$$\pi_i = \frac{ep_i x_i}{\tau} - \phi_i \left[\frac{ec+d}{\beta_i} x_i + F - \overline{L}_i(1+\alpha\varepsilon) \right] - \overline{L}_i(1+\alpha\varepsilon). \tag{6}$$

Firms maximize profits in their own currency and set prices in foreign currency. The first order condition for profit maximization is

$$\frac{\partial \pi_i}{\partial p_i} = \frac{ex_i}{\tau} - \frac{eRp_i \sigma p_i^{-\sigma-1}}{\tau P^{1-\sigma}} + \frac{\sigma \phi_i (ec+d) R p_i^{-\sigma-1}}{P^{1-\sigma} \beta_i} = 0 \tag{7}$$

The optimal price charged by firm i is thus

$$p_i^* = \frac{\phi_i \tau (ec+d)}{\beta_i e} \frac{\sigma}{\sigma - 1} \tag{8}$$

whereas

$$x_i^* = \frac{R}{P^{1-\sigma}} \left(\frac{\phi_i \tau (ec+d)}{\beta_i e} \frac{\sigma}{\sigma-1} \right)^{-\sigma} \tag{9}$$

defines the optimal quantity exported, i.e. the intensive margin.[3]

[3] From equation (9) it is easy to derive the exchange rate elasticity of exports $d\ln(x_i^*)/d\ln(\varepsilon) = \sigma(1-\gamma) > 0$, where $\gamma = ec/ec + d$ is the share of imported marginal costs in total marginal cost. Since this elasticity is not affected by financial variables, and the issue has

Profits can be obtained by plugging the expressions for optimal price (8) and quantity (9) into equation (6):

$$\pi_i^* = \frac{eR}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma} - \phi_i \frac{ec+d}{\beta_i}\frac{R}{P^{1-\sigma}} p_i^{-\sigma} - \phi_i F + (\phi_i - 1)L \tag{10}$$

or

$$\pi_i^* = \frac{eR}{\tau\sigma}\left(\frac{\phi_i \tau(ec+d)}{\beta_i eP}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} - \phi_i F + (\phi_i - 1)L. \tag{11}$$

Exposure, i.e. the sensitivity of profits to exchange rate changes can be computed as

$$\begin{aligned}\frac{d\pi_i}{d\varepsilon} &= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[1+\frac{e(\sigma-1)}{p_i}\frac{\phi_i\sigma\tau d}{\beta_i(\sigma-1)e^2}\right] + (\phi_i - 1)\overline{L}_i\alpha \\ &= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma}[1+(\sigma-1)(1-\gamma)] + (\phi_i - 1)\overline{L}_i\alpha \\ &= \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma+\sigma(1-\gamma)}{\sigma}\right] + (\phi_i - 1)\overline{L}_i\alpha\end{aligned} \tag{12}$$

where $\gamma = ec/(ec+d)$ is the share of imported marginal costs, and we have used equation (8) to simplify the first expression in square brackets. Using the definition of ϕ_i given above we can easily see that

$$\frac{d\pi_i}{d\varepsilon} = \begin{cases} \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma+\sigma(1-\gamma)}{\sigma}\right] & \text{no liquidity constraint} \\ \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma+\sigma(1-\gamma)}{\sigma}\right] + (\tilde{\phi}_i - 1)\overline{L}_i\alpha & \text{liquidity constraint}\end{cases} \tag{13}$$

From expression 13 we can see that the sensitivity of profits to exchange rate changes may increase or decrease relative to the benchmark case of no liquidity constraint, depending on the sign of the correlation (α) between liquidity and the random shock.[4]

already received extensive coverage in the literature, we do not explore the topic any further, and simply note that our prediction is in line with Berman *et al.* (2012).

[4] In the derivation of equation (12) we have implicitly assumed—as in Chaney (2013) and Bas and Berthou (2012)—that foreign prices have a negligible effect on the domestic price index, so that the latter is not affected by exchange rate changes ($dP/d\varepsilon = 0$). This hypothesis greatly simplifies the analysis and is reasonable when pass-though into import prices is small as extensively documented in the literature (see for instance Goldberg and Campa, 2010).

Since p_i depends on financial costs ϕ_i, as seen in equation (8) above, the sensitivity of profits to exchange rate changes is affected by the potential liquidity constraints faced by a firm due to their effect on marginal costs. Indeed,

$$\frac{dp_i}{d\phi} = \frac{\tau(ec + d)}{\beta e} \frac{\sigma}{\sigma - 1} = \frac{p_i}{\phi}$$

so that the same shock will affect firms differently depending on their financial conditions. To investigate this issue further we take the derivative of equation (12) with respect to liquidity and financial costs:

$$\frac{d^2\pi_i}{d\bar{L}_i d\varepsilon} = \alpha(\tilde{\phi}_i - 1) \tag{14}$$

$$\frac{d^2\pi_i}{d\tilde{\phi}_i d\varepsilon} = (1 - \sigma)\frac{R}{\phi\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma + \sigma(1 - \gamma)}{\sigma}\right] + \bar{L}_i\alpha \tag{15}$$

The former expression implies that exposure increases (decreases) with liquidity when $\alpha > 0$ ($\alpha < 0$). Equation (15) states that an increase in the cost of external finance relative to internal funds will decrease the sensitivity of profits to exchange rate changes when aggregate shocks are negatively correlated with firm liquidity ($\alpha < 0$). In the opposite case ($\alpha > 0$) the sign of equation (15) is undetermined (the two components have opposite signs), although we can expect the relationship to be less markedly negative.

The model yields a set of testable implications for the determinants of profit exposure and the differential effect of exchange rate changes on profits conditional on a firm's financial conditions:

- profits increase with liquidity, productivity, but are negatively affected by financial costs; furthermore, they respond positively to exchange rate depreciations;
- exposure – profit sensitivity to exchange rate changes – increases (decreases) with liquidity when $\alpha > 0$ ($\alpha < 0$), i.e. when a depreciation increases (decreases) liquidity;
- exposure – profit sensitivity to exchange rate changes– decreases (increases) with financial costs when $\alpha < 0$ ($\alpha > 0$), i.e. when a depreciation decreases (increases) liquidity.

3 Data

We use data on French firms derived from an annual survey conducted by the French Ministry of Industry (*Enquête Annuelle d'Entreprises*). This gathers information on all manufacturing firms with at least 20 employees, plus some smaller firms with large sales (over 5 million euros); most of the data come from the income statements of participating firms. For the period 1995–2007, the original data set comprises around 250,000 observations for nearly 35,000 French firms, 75% of which are exporters.

We focus on exporting firms, since the decision whether to export is not modeled. We do some basic cleaning of the data, excluding observations for which profits are negative.[5] The top and bottom 1% of the observations in the key variables used in the analysis (profit, liquidity, financial costs, size and productivity) are then winsorized.[6] This leaves us with a sample of roughly 30,000 exporting firms, totaling some 186,500 observations. To measure profit, we rely on earnings before interest, taxes, depreciation and amortization, or gross profits.[7] This measures the economic performance of a firm before its financing operations are taken into account, so it should not be influenced by how a firm finances its activities. Note that while the model refers to profits from export sales only, in the empirical analysis we cannot determine the origin of revenues and therefore have to consider total profits.[8] We use industry-specific producer price indexes computed by the French National Institute for Statistics and Economic Research (INSEE) to deflate profits. Firm (total factor) productivity (TFP) is computed according to the so-called *multilateral productivity index* (Caves *et al.*, 1982; Good *et al.*, 1997), an index approach which works particularly well when comparing firms operating in different sectors across time.[9] Average labor productivity (sales per employee) is used as a robustness check. We use two measures of firm size: number of employees and total sales (in real terms).

To proxy for liquidity we take the ratio between firm cash flow and fixed tangible and intangible assets, while the cost of external financial resources is measured as interest and financial expenses over fixed assets.[10] Data limitations prevent us from

[5] Given the double log specification of our regression equations this operation is irrelevant as those observations would be dropped from the analysis anyway.

[6] Winsorizing a variable entails setting its extreme realizations, e.g. those pertaining to the top/bottom 1%, to a specified percentile of the data, say the 99th percentile.

[7] In the French data this is represented by *Excédent Brut d'Exploitation*.

[8] Although we are aware this poses empirical problems, it is not a major issue with respect to the model. Indeed, the Melitz (2003) setup implies that variable profits in each market are proportional to revenues, so that export sales are proportional to total profits (see Redding, 2010).

[9] This non-parametric methodology of multilateral translog index numbers accommodates the use of multiple inputs (capital, labor, and intermediates), is relatively easy to compute and, differently from other parametric methods that rely on structural estimations, does not face endogeneity issues. These features have made it a popular choice in the applied literature on firm heterogeneity (see for instance Bailey *et al.*, 1992; Aw *et al.*, 2000, 2001; Delgado *et al.*, 2002).

[10] These variables correspond to the French *Capacité d'autofinancement* and *Intérêts et charges assimilées*, respectively.

computing financial costs as a ratio of debt, which would probably be a better measure of the cost associated with external finance.[11]

We use different exchange rate measures, to evaluate the robustness of our results. The first one is the nominal effective exchange rate (EER) for France computed monthly by the Bank for International Settlements (BIS) on a broad basket of currencies comprising 61 economies (Klau and Fung, 2006). Since we only have annual data on profits, we select (based on a dominant "end-of-the-year" date firms' book closing) the December value of the index. Note that EER computed by the BIS is such that an appreciation is associated with an increase in the index, opposite with respect to the definition of exchange rate we have used in the model. The second measure is the crude euro/dollar exchange rate, which we extended backward to the 1990s with the proper use of the French franc/dollar rate and the franc/euro official conversion rate. In this case, an increase in the exchange rate represents a depreciation of the domestic currency. Last, we build an industry-specific EER at the four-digit level of the International Standard Industrial Classification system (ISIC), using data on the 26 biggest importers of French products.[12] Weights are calculated from each industry's export share to the different destinations. Here as well, an increase of the EER means a depreciation of the domestic currency relative to the basket of the 26 currency-partners, implying a gain in price-competitiveness.

The correlation between liquidity and the different exchange rates (α in the model) can be computed either across all observations, by sector (across the whole period, 1995–2007), or by year (across all four-digit sectors present in the data, 107), but not by firm, since the exchange rate is either common to all firms or sector specific. Computing an industry-specific correlation coefficient (that does not vary over time) implicitly assumes that the latter represents a structural feature of each sector depending, for instance, on the share of imported inputs in total cost or on invoicing practices common to all firms in a given industry. On the other hand, computing α by year accounts for time-specific macroeconomic shocks common to

[11] This implies that we are unable to determine whether high financial costs are due to high interest rates, high levels of debt, or a combination of the two. Fortunately, this distinction is not crucial: although the model assumes no relationship between the level of corporate debt and its cost, this is a simplifying assumption and the implications of the model are unaltered so long as total financial costs rise with both the (unitary) cost of finance and the stock of debt. It is important, however, to account for the possibility that large firms may face lower interest rates by normalizing for size, as our measure does.

[12] The destination markets are Germany, Austria, Italy, Belgium-Luxembourg, Denmark, United Kingdom, Netherlands, Spain, Portugal, Greece, Ireland, Finland, United States, Japan, Canada, China, Poland, Norway, Sweden, Switzerland, Russia, Turkey, Hong Kong, Singapore, Thailand, and South Korea.

Table 2 Summary statistics on correlation coefficients

Exchange rate	Grouping	Mean	St. dev	Min	Max	Number of sectors $\alpha < 0$
€/$	By sector	0.012	0.038	−0.350	0.266	38
	Overall	0.012	–	–	–	0
EER^{BIS}	By sector	−0.018	0.045	−0.253	0.593	67
	Overall	−0.013	–	–	–	all
EER	By sector	−0.018	0.043	−0.528	0.021	39
	By year	−0.021	0.015	−0.054	−0.002	all

all firms. Table 2 gives summary statistics of the different correlation coefficients with liquidity.[13]

For both the euro/dollar rate and the EER computed by the BIS a depreciation is, on average, associated with a mild improvement in firm's liquidity; although the size and magnitude of the correlation vary by industry, for almost two-thirds of the manufacturing sectors (67–69 out of 107) depreciation was concomitant with larger liquidity of firms, thus reinforcing its direct positive effect on profits. A similar result carries over to the industry-specific EER we have computed. For the latter, when the correlation is computed by year, it is always negative: on average, depreciations have lowered the availability of internal funds for firms in our sample.[14]

4 Empirical results

The first hypothesis we wish to bring to the data tests the notion that profits are positively affected by exchange rate depreciations, and that firms with higher liquidity and lower financial costs enjoy higher profits. To this end, we perform a fixed effect estimation of the following regression equation:

$$PROFIT_{ist} = a_0 + a_1 EER_{st} + a_2 PROD_{ist} + a_3 SIZE_{ist} + a_4 LIQ_{ist} + a_5 FINC_{ist} + \nu_i + \varepsilon_{ist} \quad (16)$$

where i, s, and t index firm, sector, and time, respectively, $PROD_{ist}$ measures productivity, LIQ_{ist} stands for liquidity, $FINC_{ist}$ for the cost of financial resources, and ν_i

[13] Liquidity is defined at the firm level. Note that the different ways the EER is defined by the BIS and by us lead to opposite signs of the correlation reported in the table.

[14] When computing the correlation by year we exclude 2000, which is our base year in the computation of the EER index and therefore shows no variation across industries.

is a firm-specific fixed effect. All variables enter the regression in logs.[15] To measure exchange rate movements we first use the BIS index (EER_t^{BIS}), which varies over time but not across sectors. It is reminded that EER^{BIS} is such that a depreciation implies a decrease in the index, meaning that we expect a negative coefficient. Second, we use the industry-specific effective exchange rate EER_{st}. In this case a depreciation implies an increase in the index, and we expect a positive effect on profit.[16] When the exchange rate is a sector-specific variable, we need to correct the downward bias introduced by the fact that error terms across firms are not independent (Moulton, 1990). This is done by clustering standard errors within each four-digit sector.

Table 3 reports results for the estimation of equation (16): we use both TFP and labor productivity, and employ both measures of firm size, namely, total sales and the number of employees.[17] Columns (1–3) concern the total economy EER from the BIS, while columns (4–6) concern the sectoral exchange rate; results obtained using the €/$ exchange rate are similar and are not displayed. All coefficients have the expected sign across the different specifications of the empirical model. Larger and more productive firms are more profitable and this holds irrespectively of productivity index, size, and exchange rate measures. Liquidity also has a positive impact on profits, consistent with the model, while firms facing higher financial costs tend to report lower profits. The estimated coefficients are very stable across specifications, and they confirm that exchange rate depreciations are associated with an increase in profits as predicted by the model.

The model yields further predictions concerning the effect of exchange rate changes on profits conditional on a firm's financial conditions and the relationship between liquidity and exchange rate shocks. These conditional effects can be best evaluated using interaction terms. In particular, to test the main results of the model, we need to classify firms based on the sign of the correlation between liquidity and exchange rate changes. Our estimating equation takes the following form:

$$PROFIT_{ist} = a_0 + a_1 EER_{st} + a_2 PROD_{ist} + a_3 SIZE_{ist} + a_4 LIQ_{ist} + a_5 FINC_{ist} + a_6(Z_{ist} \times EER_{st}) + a_7(Z_{ist} \times D^{\alpha}) + a_8(EER_{st} \times D^{\alpha}) + a_9(Z_{ist} \times EER_{st} \times D^{\alpha}) + \nu_i + \varepsilon_{ist} \quad (17)$$

[15] More precisely, for each variable (X), except TFP, entering the regression equation we apply the transformation $\hat{X} = log(X + 1)$ and use $\hat{X}$ in the analysis. This is done to avoid losing observations featuring zero in any of the relevant variables.

[16] Since the exchange rate changes are common to all firms in the same sector, adding time dummies makes the identification of exchange rate effects dependent on variation across sectors only. This asks too much to the data, and the exchange rate is never significant.

[17] Results obtained measuring size in terms of hours worked and capital stock are qualitatively similar and are not shown.

Table 3 Determinants of firm profits

Exchange rate as:	EER–BIS			EER by industry		
Productivity as:	TFP	TFP	Labor Productivity	TFP	TFP	Labor Productivity
Size as:	Sales	Employees	Sales	Sales	Employees	Sales
	(1)	(2)	(3)	(4)	(5)	(6)
EER	−2.483***	−2.328***	−3.147***	1.547***	1.419***	2.076***
	(0.097)	(0.121)	(0.149)	(0.244)	(0.260)	(0.323)
Productivity	1.744***	2.845***	1.084***	1.570***	2.677***	0.983***
	(0.085)	(0.098)	(0.049)	(0.090)	(0.100)	(0.051)
Size	0.835***	0.726***	0.765***	0.825***	0.720***	0.743***
	(0.021)	(0.028)	(0.022)	(0.023)	(0.031)	(0.022)
Liquidity	1.942***	1.970***	1.754***	1.973***	1.996***	1.803***
	(0.195)	(0.198)	(0.181)	(0.210)	(0.212)	(0.196)
Financial costs	−1.631***	−1.377***	−1.240***	−1.468***	−1.200***	−1.086***
	(0.269)	(0.305)	(0.207)	(0.289)	(0.325)	(0.228)
Observations	148,264	148,264	148,264	131,068	131,068	131,068
Firms	26,212	26,212	26,212	23,151	23,151	23,151
R^2	0.364	0.339	0.403	0.359	0.335	0.394

***$P<0.01$.

Clustered standard errors in brackets.

where Z_{ist} is either liquidity (LIQ_{ist}) or financial costs ($FINC_{ist}$), and D^{α} is a dummy variable taking the value of 1 if the correlation between firm liquidity and exchange rate is positive and zero otherwise. Hence, the effect of an exchange rate movement on profits, conditional on Z, is $(a_1 + a_6 Z)$ for firms whose liquidity increases following an appreciation of the domestic currency ($\alpha < 0$); the marginal effect becomes $(a_1 + a_8) + (a_6 + a_9)Z$ for firms with a positive correlation ($\alpha > 0$).[18]

Table 4 reports the estimation results, using different EER measures and different ways to compute the correlations. The first two columns in the table display results

[18] Since all variables were centered before the regression (by subtracting the sample mean, see for instance Aiken and West, 1991), a_1 represents the effect of exchange rate movements on the profits of an "average firm" whose liquidity increases following an appreciation ($\alpha<0$). Note that the correlation α can be computed either by year (for all firms) or by sector (across all years). In the first case, α turns out to be negative for all years in the sample (see Table 1 above), implying that higher financial costs make firm profits less responsive to exchange rate changes: the marginal effect on profits of a change in the exchange rate in this case is simply given by $a_1 + a_6 Z$.

Table 4 Exchange rate effect on profits, conditional on liquidity and financial cost

Exchange rate:	EER–BIS		EER by industry					
α computed:	By industry		By industry		By year		By industry	
Interaction variable Z:	Financial costs (1)	Liquidity (2)	Financial costs (3)	Liquidity (4)	Financial costs (5)	Liquidity (6)	Financial costs (7)	Liquidity (8)
EER	−2.621***	−2.919***	0.824***	0.835***	1.751***	1.938***	1.033***	0.848***
	(0.124)	(0.132)	(0.203)	(0.201)	(0.295)	(0.341)	(0.277)	(0.243)
TFP	1.747***	1.749***	1.591***	1.589***	1.549***	1.551***	1.599***	1.140***
	(0.086)	(0.087)	(0.092)	(0.094)	(0.091)	(0.092)	(0.090)	(0.069)
Size	0.832***	0.826***	0.820***	0.817***	0.827***	0.824***	0.819***	0.786***
	(0.021)	(0.021)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.018)
Liquidity	1.941***	2.019***	1.966***	1.879***	1.989***	1.972***	1.963***	0.545***
	(0.195)	(0.277)	(0.209)	(0.192)	(0.215)	(0.214)	(0.209)	(0.107)
Financial Costs	−1.673***	−1.597***	−1.235***	−1.451***	−1.468***	−1.450***	−1.480***	−0.534***
	(0.339)	(0.269)	(0.295)	(0.295)	(0.285)	(0.283)	(0.318)	(0.172)
$Z \times$ EER	9.047***	5.345***	−5.746**	0.166	−8.086**	−2.116		
	(2.813)	(1.584)	(2.781)	(0.572)	(3.283)	(1.289)		
$D^{\alpha} \times$ EER	0.682***	0.854***	1.288***	1.578***			1.294***	0.690
	(0.229)	(0.246)	(0.377)	(0.392)			(0.428)	(0.515)
$D^{\alpha} \times Z$	0.379	−0.170	−0.267	0.198				
	(0.342)	(0.308)	(0.379)	(0.317)				
$Z \times$ EER	−0.578	−4.018**	−3.772	−4.862***				
	(3.596)	(1.886)	(4.559)	(1.205)				
Z second quartile $\times$ EER							−0.251*	0.116
							(0.127)	(0.262)
Z third quartile $\times$ EER							−0.179	−0.392
							(0.180)	(0.263)
Z fourth quartile $\times$ EER							−0.417	−0.624**
							(0.282)	(0.241)
$D^{\alpha} \times Z$ second quartile $\times$ EER							0.455**	0.115
							(0.221)	(0.430)
$D^{\alpha} \times Z$ third quartile $\times$ EER							−0.109	0.084
							(0.311)	(0.451)
$D^{\alpha} \times Z$ fourth quartile $\times$ EER							−0.411	−0.361
							(0.425)	(0.466)
Observations	148,264	148,264	131,068	131,068	119,688	119,688	131,068	131,068
Firms	26,212	26,212	23,151	23,151	22,899	22,899	23,151	23,151
R^2	0.365	0.366	0.361	0.362	0.359	0.359	0.361	0.549

Clustered standard errors in brackets; $^{***}P<0.01$; $^{**}P<0.05$; $^{*}P<0.1$.

Productivity as TFP; size as total sales; constant term (and quartile dummies in cols 7 and 8) not shown.

Regression performed on centered variables.

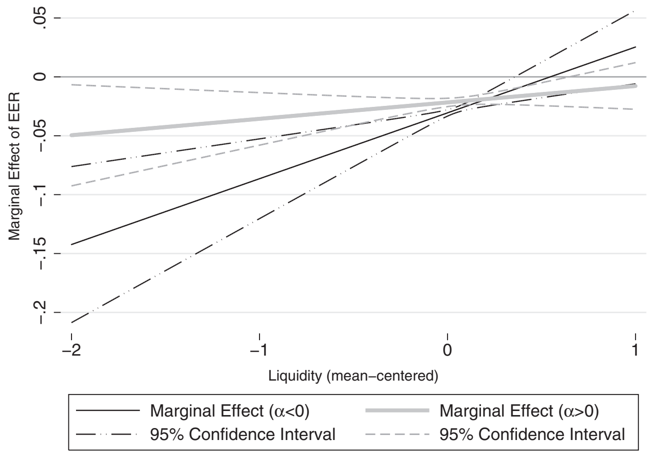

Figure 1 Exchange rate effect on profits conditional on liquidity. The figure refers to the BIS EER; the correlation between firm liquidity and the exchange rate (α) is computed by four-digit ISIC sector.

obtained using the BIS EER index, and computing the correlation α between firm's liquidity and exchange rate industry by industry. Results are in line with the predictions of the model: an appreciation is associated with lower profits, and the effect depends on financial conditions, as the significant coefficient of the interaction term $Z \times EER$ shows. Furthermore, the interaction term changes depending on whether the correlation α is positive or negative: when the interaction is performed on financial costs, the coefficient of the three-way interaction has the correct sign but it is not significant. Results are stronger when the interaction is with liquidity (column 2): here the data confirm the existence of a differential effect of the exchange rate on profits for firms characterized by a positive α relative to the reference group ($\alpha < 0$).

This can be seen more easily with the help of Figure 1, where the marginal effect of EER on profits is plotted against different values of liquidity: both for firms characterized by positive and negative correlation, appreciation lowers profits, but the effect is milder (and its dependence on liquidity much weaker) when the correlation α is positive.[19] The same qualitative picture emerges using the euro/dollar exchange rate (results not reported), although in that case interactions are not always significant. This may be due to the fact that the dollar exchange rate is not equally relevant for all firms in the sample, and by using it as a measure of the exchange rate shocks we introduce additional noise in the estimation.

[19] Results obtained using a single correlation coefficient for all firms are also consistent with the model, but in that case we do not have a three-way interaction because all firms would have the same α.

In the remaining part of the table we concentrate on results stemming from the use of our industry-specific EER, which is more detailed and incorporates more information into the regression model. In columns 3 and 4 of Table 4, α is again computed by sector. The model suggests that financial costs negatively affect exposure when $\alpha < 0$, and that the relationship should be flatter when the correlation has the opposite sign (see equation (15) above). The data support only the first part of the prediction: exposure equals $0.824 - 5.746 FinCosts$ for firms whose liquidity responds negatively to a depreciation ($\alpha < 0$), whereas the coefficient of the three-way interaction ($D^{\alpha} \times FinCosts \times EER$) is not significant. In the case of liquidity, the interaction $LIQ \times EER$ is not significant, while the coefficient of the three-way interaction $D^{\alpha} \times LIQ \times EER$ is significantly negative, something that runs against the model predictions. Here, although we do find that the impact of an exchange rate shock on profit varies according to the sign of the correlation α, this difference is not fully in line with the model.

Our industry-specific EER allows us to compute the correlation between the exchange rate and liquidity also by year. Columns 5 and 6 display the relevant results: here the correlation is always negative, so that the marginal effect of a depreciation on profits should be a decreasing function of liquidity or financial costs. Indeed, the interaction terms are negative (and significant in the case of financial costs): although depreciation tends to increase profits, its effect decreases for higher values of liquidity or financial costs. All the other controls retain the expected sign and significance.

Figure 2 proposes a graphical representation of the impact of *EER* on profits, conditional of financial costs. It is worth noting that over 95% of the values taken by

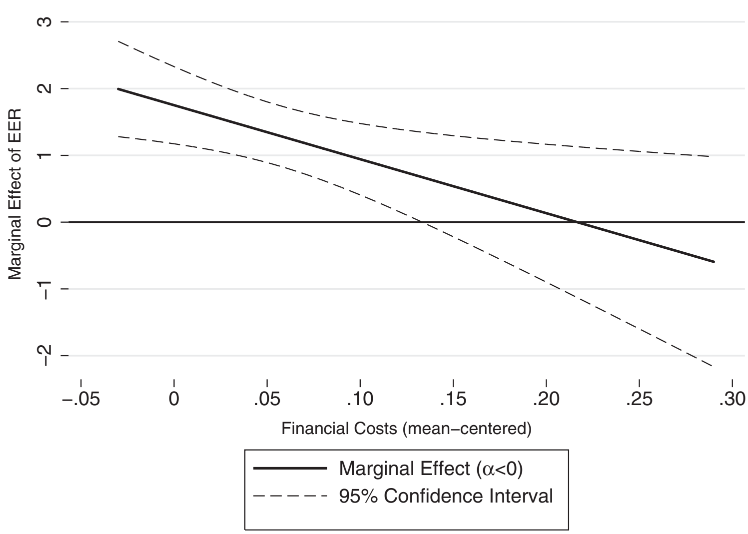

Figure 2 Exchange rate effect on profits conditional on financial costs. The correlation between firm liquidity and the exchange rate (α) is computed by year.

our measure of financial costs (in logs and mean-centered) are below 0.10: Figure 2 shows that within that range the marginal effect of depreciation is significantly above zero, consistently with the model.

To further investigate the relationship between exposure and financial variables, we look at how profits respond across different quartiles of the distribution of either liquidity or financial costs: this allows us to check for possible nonlinear effects. If these were present, the analysis based on simple linear interactions may not be able to adequately capture the whole picture. We tackle the problem by modifying the estimating equation to allow the exchange rate to have differential effects on firms belonging to the various quartiles of the distribution (of financial costs or liquidity). For the sake of brevity we only report results using the industry-specific EER. The regression equation takes the following form:

$$PROFIT_{ist} = a_0 + a_1 EER_{st} + a_2 PROD_{ist} + a_3 SIZE_{ist} + a_4 LIQ_{ist} + a_5 FINC_{ist} + a_6 (EER_{st} \times D^{\alpha}) + \sum_{k=2}^{4} \left(q_k Q_{ist}^k \right) + \sum_{k=2}^{4} \left(b_k Q_{ist}^k \times D^{\alpha} \right) + \sum_{k=2}^{4} \left(c_k Q_{ist}^k \times EER_{st} \right) + \sum_{k=2}^{4} \left(d_k Q_{ist}^k \times EER_{st} \times D^{\alpha} \right) + \nu_i + \varepsilon_{ist} \quad (18)$$

where Q^k is an indicator variable for firms in the *k-th* quartile of the distribution of financial variables, and $D^{\alpha} = 0$ when the correlation between liquidity and exchange rate is negative ($D^{\alpha} = 1$ otherwise).[20]

The model suggests that a_1 is positive (as before); the coefficients $c_2 - c_4$ are negative; $d_2 - d_4$ (marking the difference between firms belonging to the same quartile of financial variables, with $\alpha > 0$) are positive. Results are broadly consistent with the predictions of the model (although not all the coefficients are significant), especially when the interaction takes place with financial costs (column 7 of Table 4): moving from the first to the second quartile of financial costs distribution lowers exposure when $\alpha < 0$, while increases it otherwise. More specifically, the marginal effect of a depreciation on profits goes down from 1.033 to 0.782 ($1.033 - 0.251$) in the former case ($\alpha < 0$), and goes up from 2.327 ($1.033 + 1.294$) to 2.782 ($2.327 + 0.455$) when $\alpha > 0$. Coefficients for higher quartiles are not significant. A joint test of significance for the dummies ($H_0 : d_2 + d_3 + d_4 = 0$) is rejected when the interaction takes place with financial costs (column 7), not in the case of liquidity (column 8).

Figure 3 gives a graphical representation of the effect of exchange rate changes on profits across different quartiles of the *financial cost* distribution. Clearly, profits react

[20] So, for instance, the marginal effect of a currency depreciation on profits for firms in the second quartile of the distribution when $\alpha < 0$ is $a_1 + c_2$, and $(a_1 + a_6) + (c_2 + d_2)$ for firms of the same quartile characterized by a positive correlation between liquidity and the exchange rate ($\alpha > 0$).

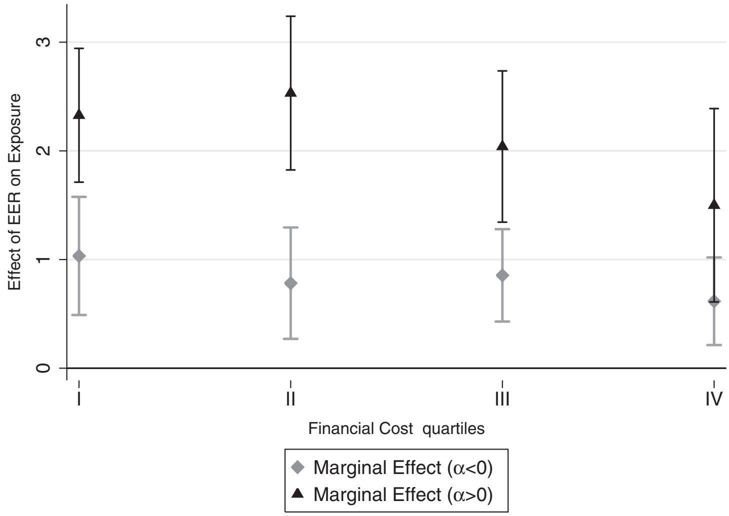

Figure 3 Exchange rate effect on profits across quartiles of the distribution of financial costs. The correlation between firm liquidity and the exchange rate (α) is computed by four-digit ISIC sector.

differently to exchange rate shocks depending on the sign of the correlation α, and the position within the distribution of financial costs. What is more, we find evidence of a nonlinear effect that may explain why the simple linear interaction between continuous variables fails to capture the predictions of the model precisely. When $\alpha < 0$ higher financial costs are associated with lower exposure: the change is more pronounced when moving from the first to the second quartile, after which the relationship flattens out. The picture changes for $\alpha > 0$: in this case the effect of a currency depreciation is stronger for firms in the second quartile of financial costs (compared to firms in the first quartile, which are our reference group) and starts to decline only afterward.[21] When we interact the exchange rate with liquidity, we get qualitatively similar results: firms in different quartiles of the liquidity distribution behave differently. This time it is the coefficient associated with the fourth quartile to be significantly negative (-0.614) when $\alpha < 0$, while the coefficients on the interaction terms are nonsignificant for observations with $\alpha > 0$.

The empirical analysis broadly supports the main prediction of the model, although the results are not always strong in terms of statistical significance. In particular, we find that a firm's financial conditions affect its ability to benefit from exchange rate movements, and this relationship is mediated by the interplay between currency depreciations and liquidity. Moreover, there are marked differences in the behavior of firms in the bottom half of the distribution of financial costs. Further

[21] It is worth noting, however, that standard errors are relatively large.

research to unveil the sources of these differential effects is needed to shed more light on this issue.

With respect to the existing literature, we confirm the fact that firms may react very differently to similar shocks, as already suggested by Muûls (2008) and Berman *et al.* (2012). In particular, firm-level export sales display a heterogeneous response to not only exchange rate movements but also profits. Furthermore, in line with what is reported by Héricourt and Poncet (2013) and Strasser (2013) for export quantities and prices, we find that the financial situation of the firm critically affects the way it reacts to exchange rate shocks. In fact, low liquidity or high financial costs (likely sign of a deteriorated financial position) reduce a firm's ability to take advantage of depreciations. In addition to these results, which confirm recent findings in the empirical literature, we have shown that the exchange rate may itself affect the financial position of a firm, and therefore determine an additional layer of heterogeneity.

5 Conclusion

Our article develops a simple model in which exporting firms are characterized by heterogeneous productivity and may face liquidity constraints. This setup is used to analyze exchange rate exposure, i.e. the sensitivity of profits to exchange rate changes, and to derive testable implications that we then bring to the data.

Overall, the empirical results support the model's general framework: the analysis of a large panel of French exporting firms confirms that exchange rate depreciations tend to boost profits, and that size, liquidity, and low financial costs exert a positive effect on them.

Regarding the main prediction of the model, we find that a firm's financial profile significantly affects the response of its profits to exchange rate movements. Moreover, the sign of the correlation between firm liquidity and exchange rate matters for exposure. The effects of liquidity constraints on profit exposure depend on the nature of the exchange rate shocks exporting firms face, and on their ability to react to them. Less financially constrained firms tend to reap larger benefits from currency depreciations. More generally, our investigation into the effects of the exchange rate on profits conditional on financial variables shows a marked difference in the behavior of firms belonging to the bottom half of the distributions (which appear to comply more closely with the predictions of the model), from those in the upper quartiles. The article offers new insights into both the firm-level channels through which depreciation affects export activities, and exchange rate exposure. It highlights the fact that a firm's financial characteristics affect its profit sensitivity to exchange rate changes.

The policy relevance of our results is threefold. First, our conclusions confirm the main message that emerges from the literature on firm heterogeneity: distinctive firm characteristics result in differentiated responses to exogenous shocks. Hence, any measure aimed at stimulating a specific behavior by firms must consider that the average effect under scrutiny may mask large and persistent differences across groups of firms. Second, financial factors are crucial because they may act not only as direct constraints on firms' choices but also indirectly, as they affect the reaction of firms to shocks or incentives. Last, our results suggest that exchange rate depreciations tend to be beneficial for firm profits, but at the same time they make clear that such variations trigger a complex set of adjustment mechanisms that needs to be better investigated and integrated in the policy debate.

The analysis can be further refined, both theoretically and empirically, in several directions. With respect to the model, possible extensions would entail allowing firms to hedge, at least partially, their exchange rate risk. From the empirical point of view, a deeper understanding of the sign of the correlation between liquidity and exchange rate should provide more information on the characteristics of a firm that affect its exposure. Finally, further studies might try to quantify the relative importance of the imported-input versus the liquidity channel in determining the effects of exchange rate fluctuations.

References

Aiken, L. and S. West (1991), *Multiple Regression: Testing and Interpreting Interactions*. Sage: London, UK.

Aw, B. Y., X. Chen and M. J. Roberts (2001), 'Firm-level evidence on productivity differentials and turnover in Taiwanese manufacturing,' *Journal of Development Economics*, **66**(1), 51–86.

Aw, B. Y., S. Chung and M. J. Roberts (2000), 'Productivity and turnover in the export market: micro-level evidence from the Republic of Korea and Taiwan (China),' *World Bank Economic Review*, **14**(1), 65–90.

Bailey, M. N., C. Hulten and D. Campbell (1992), 'Productivity dynamics in manufacturing plants,' *Brooking Papers on Economic Activity. Microeconomics*, **4**, 187–249.

Bas, M. and A. Berthou (2012), 'The decision to import capital goods in India: Firms' financial factors matter,' *The World Bank Economic Review*, **26**(3), 486–513.

Berman, N., P. Martin and T. Mayer (2012), 'How do different exporters react to exchange rate changes?' *Quarterly Journal of Economics*, **127**(1), 437–492.

Bodnar, G., B. Dumas and R. Marston (2002), 'Pass-through and exposure,' *Journal of Finance*, **57**(1), 199–231.

Buch, C. M., I. Kesternich, A. Lipponer and M. Schnitzer (2010), 'Exports versus FDI revisited: does finance matter?' *Discussion Paper Series 1: Economic Studies 2010.03, Deutsche Bundesbank, Research Centre.*

Caves, D. W., L. R. Christensen, W. R. Laurits and W. E. Diewert (1982), 'Multilateral comparisons of output, input, and productivity using superlative index numbers,' *Economic Journal*, **92**(365), 73–86.

Chaney, T. (2013), 'Liquidity constrained exporters,' *Working Paper 19170*, NBER.

Dekle, R. and H. Ryoo (2007), 'Exchange rate fluctuations, financing constraints, hedging, and exports: evidence from firm level data,' *Journal of International Financial Markets, Institutions and Money*, **17**, 437–451.

Delgado, M. A., J. C. Farinas and S. Ruano (2002), 'Firm productivity and export markets: a non-parametric approach,' *Journal of International Economics*, **57**(2), 397–422.

Devereux, M. B., P. R. Lane and J. Xu (2006), 'Exchange rates and monetary policy in emerging market economies,' *Economic Journal*, **116**(511), 478–506.

Goldberg, L. S. and J. M. Campa (2010), 'The sensitivity of the cpi to exchange rates: distribution margins, imported inputs, and trade exposure,' *Review of Economics and Statistics*, **92**(2), 392–407.

Good, D. H., M. I. Nadiri and R. Sickles (1997), 'Index number and factor demand approaches to the estimation of productivity,' in H. Pesaran and P. Schmidt (eds), *Handbook of Applied Econometrics: Microeconometrics*. Blackwell: Oxford, UK, pp. 14–80.

Greenaway, D., R. Kneller and X. Zhang (2010), 'The effect of exchange rates on firm exports: the role of imported intermediate inputs,' *The World Economy*, **33**(8), 961–986.

Héricourt, J. and S. Poncet (2013), 'Exchange rate volatility, financial constraints, and trade: empirical evidence from Chinese firms,' *Policy Research Working Paper 6638*, World Bank.

Klau, M. and S. S. Fung (2006), 'The new BIS effective exchange rate indices,' *BIS Quarterly Review*, **2006**, 51–65.

Melitz, M. J. (2003), 'The impact of trade on intra-industry reallocations and aggregate industry productivity,' *Econometrica*, **71**(6), 1695–1725.

Moulton, B. R. (1990), 'An illustration of a pitfall in estimating the effects of aggregate variables on micro units,' *The Review of Economics and Statistics*, **72**(2), 334–338.

Muller, A. and W. F. C. Verschoor (2006), 'Foreign exchange risk exposure: survey and suggestions,' *Journal of Multinational Financial Management*, **16**(4), 385–410.

Muûls, M. (2008), 'Exporters and credit constraints. a firm-level approach,' *Research series 139*, National Bank of Belgium.

Nucci, F. and A. F. Pozzolo (2001), 'Investment and the exchange rate: an analysis with firm-level panel data,' *European Economic Review*, **45**(2), 259–283.

Redding, S. J. (2010), 'Theories of heterogeneous firms and trade,' *Working Paper 16562*, NBER.

Russ, K. N. (2007), 'The endogeneity of the exchange rate as a determinant of FDI: a model of entry and multinational firms,' *Journal of International Economics*, **71**, 344–372.

Strasser, G. (2013), 'Exchange rate pass-through and credit constraints,' *Journal of Monetary Economics*, **60**, 25–38.