Exchange Rate Exposure under Liquidity Constraints

Sarah Guillou*   Stefano Schiavo†

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Abstract

We develop a simple model where exporting firms are characterized by heterogeneous productivity and may face a liquidity constraint. 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 bring to the data. We find that profits of more productive firms are more sensitive to exchange rate fluctuations (since a larger share of their sales is exported). Moreover, an increase in the cost of external funds (relative to cash flow) makes profit less sensitive to exchange rate shocks for firms whose liquidity increases with an appreciation of the exchange rate. We test the hypotheses using a large dataset of French exporting firms. Results confirm that exchange rate depreciations tend to boost profits, and that size, liquidity and lower financial costs exert a positive effect on profits. Furthermore, empirical results confirm that for firm whose cash flow is negatively correlated with exchange rate movements, an increase in financial costs lowers exposure.

JEL Codes: F23, F31, G32

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*Observatoire Français des Conjonctures Économiques, Département de Recherche sur l'Innovation et la Concurrence (OFCE-DRIC), 250 rue Albert Einstein, 06560 Valbonne, France. E-mail: sarah.guillou@ofce.sciences-po.fr

†Department of Economics, University of Trento (Italy) and OFCE-DRIC (France). E-mail: stefano.schiavo@unitn.it

1 Introduction

In this paper we analyze the exposure of exporting firms' profits to exchange rate changes in presence of liquidity constraints. The topic is particularly relevant in the present context, where access to external financial resources is still scarce as a result of the recent financial crisis, and wide fluctuations in the relative value of currencies are under way. The paper therefore contributes to the growing literature that addresses the role played by financial factors in determining firm behavior in international markets.

Exchange rate volatility is an important part of international risk faced by exporting firms. Strong and increasing international cost competition requires firms to consider exchange rate changes when planning their internationalization strategies. Assessing the extent to which firm profits are affected by exchange rate fluctuations is complicated because different components of profits are affected differently and because firms can or cannot react to exchange rate change.

Depending on which component is the most affected and on firms ability to counteract the exchange rate effect on their export price, import prices will not entirely reflect movements in the exchange rate because of the pricing behavior of exporters (see, among others, Dornbusch, 1987; Krugman, 1987; Knetter, 1989; Gagnon and Knetter, 1995; Goldberg and Knetter, 1997; Gaulier et al., 2008; Guillou and Schiavo, 2009). Exchange rate changes affect in opposite way the revenue and the cost as long as a part of the latter is due to imported inputs used in production. The importance of this cost channel is growing thanks to the increasing internationalization of the supply chain (see for instance, De Backer and Yamano, 2008). While an appreciation of the domestic currency will likely reduce the price competitiveness of the domestic exports and hence the revenue from exports, it may also decrease the cost of imported inputs for the exporting firm and therefore may improve its competitiveness vis-à-vis foreign competitors. The expected change in revenue and in cost will both affect the pricing behavior of exporters facing an exchange rate change. The empirical evidence of incomplete exchange rate pass-through at the firm level implies that adjustments in mark-ups will compensate part of the exchange rate change and limit the effect on prices and, eventually, market shares. As long as at least part of the movement in the exchange rate is passed-through to the final foreign consumer though, market shares of the exporting firms will be affected. Revenues then change because of the variation in both the quantity sold (the market share), and the price (mark-ups). Quantities react to changes in the final price, i.e. to the fraction of exchange rate changes that are passed-through to the consumer. The empirical literature has recently embedded the cost channel to explain the sensitivity of exports to an exchange rate change (Greenaway et al., 2010). Bodnar et al. (2002) present a model that features exchange rate effects on both revenues and costs, and they find that exposure depends on exchange rate pass-through. The financial side, however, is often overlooked. Yet exchange rate considerations play a crucial role in the financial strategy of firms, such as hedging behavior or currency denomination of debt. The way firms react to exchange rate could be linked to their financial structure. More, the exchange rate change could affect directly or indirectly the financial conditions a firm is facing.

How financial constraints affect firm's investment has been assessed in numerous papers. More recently, a growing literature on the role of financial constraints on export status unfold an ambiguous role. Campa and Shaver (2002) show that the export status bring cash flows stability easing firm to invest. More recently empirical papers have addressed the question whether financial constraints hamper firm to enter foreign markets. The few empirical results are not consensual. Greenaway et al. (2007), using data from UK manufacturing firms find no evidence that firms enjoying better ex-ante financial health (measured by liquidity ratio or leverage) are more likely to start exporting while Bellone et al. (2010) show the contrary. Both Greenaway et al. (2007) and Bellone et al. (2010) document the fact that exporting firms are more liquid and less financially constrained.

On the theoretical side, Chaney (2005) embeds a liquidity constraint into a model à la Melitz (2003). He shows that constrained firms are less likely to export because of their inability to incur the fixed cost needed to enter foreign market. In Chaney (2005), the exchange rate interacts with the liquidity constraint: an appreciation, while decreasing exports, would also increase the value of domestic assets in foreign currency. It will ease the financial constraint and may allow previous constrained firms to enter the foreign markets. Muûls (2008) further investigates the link between credit constraints and export behavior, both theoretically and empirically. She shows that financial frictions may well prevent productive firms from entering foreign markets, and that credit constraints only matters for the extensive margin of trade. Buch et al. (2010) support this result showing more generally that "financial frictions matters for the decision to engage internationally". Using Mexican data Majlesi (2010) finds that a larger appreciation of the real exchange rate has a larger effect on the probability of a firm being an exporter in the group of firms characterized by with lower liquidity constraints.

Our paper is closed to these papers and tries to go deeper into the understanding of the interaction between liquidity constraint and exchange rate. In our model, we show that adding a financial cost to the total cost function makes the financial constraint an essential element of the profit exposure of the firm to exchange rate changes. We abstract from the selection effect which is the core mechanism of the Melitz (2003) model. More specifically, we do not consider that financial constraint could hamper firms to enter foreign markets. We focus on firms which have only non domestic customers. This focus emphasizes the issue of exporters facing exchange rate change. In a sense, it is as if the firms were all endowed with an amount of liquidity enough to incur the fixed cost to enter the export market.

By considering the exposure instead of simply looking at the export sensitivity, we want to focus on what really matters for firms. But it has also macroeconomic implications: apart from the direct effect of exchange rate appreciation on export and on current account, this study shed some light on whether exchange rate change has a relevant impact on firm's ability to invest in the future and then on future growth.

Foreign exchange risk exposure has long been studied in the finance literature (see Muller and Verschoor, 2006, for a recent survey), by relating firms' stock market return to exchange rate changes. Our work focus more on competitive forces set in motion by exchange rate changes while liquidity constraint is itseld affected by exchange rate.

The paper is organized as follows: the next Section presents the model and derives the main testable implications; Section 3 describes the data used in the empirical analysis and present the econometric specification. Section 4 displays the results. The last Section highlights a few open path for future research and concludes.

2 The Model

2.1 Baseline specification

The paper builds on a recent contribution by Buch et al. (2010) to derive a model populated by heterogeneous firms engaged in export activities, which may be confronted with a liquidity constraint, defined as the need to finance their fixed and variable costs by means of (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 abstract from explicitly modeling the selection effect that results in the usual segmentation between exporting and non-exporting firms, but rather concentrate directly on the former group.

Firms face a fixed (entry) cost F, plus a constant marginal cost $(ec+d)/\beta_i$, where β_i captures firm idiosyncratic productivity, and the variable cost has an imported component ec, e being the exchange rate. They face a demand that is derived from the usual Dixit-Stiglitz monopolistic competition setup where consumers' utility is characterized by love of variety:

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

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:

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

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

We further assume —again following Buch et al. (2010)— that the firm is endowed with an 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 financed 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 by means of 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 firm's debt structure, financial situation and also on its reputation. Last, exporting firms face also an iceberg transport cost $\tau > 1$, that is assumed common to all (exporting) firms.

Profits are given by the following expression:

$$\pi_i = \frac{e p_i x_i}{\tau} - \phi_i \left(\frac{ec+d}{\beta_i} x_i + F - L_i \right) - L_i \tag{2}$$

where, e is the exchange rate (firms maximize profits in their own currency and set price in foreign currency) defined as the number of domestic currency per unit of foreign currency.

As suggested above, $\phi_i = \begin{cases} 1 & \text{if } L_i \geq \frac{ec+d}{\beta_i} x_i + F \\ \tilde{\phi}_i > 1 & \text{if } L_i < \frac{ec+d}{\beta_i} x_i + F \end{cases}$

The first order condition for profit maximization is

$$\frac{\partial \pi_i}{\partial p_i} = \frac{e x_i}{\tau} - \frac{e R p_i \sigma p_i^{-\sigma-1}}{\tau P^{1-\sigma}} + \frac{\sigma \phi_i (ec+d) R p_i^{-\sigma-1}}{P^{1-\sigma} \beta_i} = 0 \tag{3}$$

The optimal price charged by firm i thus results:

$$p_i^* = \frac{\phi_i \tau(ec+d)}{\beta_i e}\frac{\sigma}{\sigma-1} \tag{4}$$

and the optimal quantity exported (the intensive margin) takes the form

$$x_i^* = \frac{R}{P^{1-\sigma}}\left(\frac{\phi_i \tau(ec+d)}{\beta_i e}\frac{\sigma}{\sigma-1}\right)^{-\sigma} \tag{5}$$

2.1.1 Impact of exchange rate changes on sales

Changes in the exchange rate have a direct impact on the quantity produced and exported.

In order to get the elasticity of quantity with respect to change in exchange rate, η_i, we derive the logarithm of the optimal quantity (equation 5) relative to the exchange rate.

$$\eta_i = \frac{d\ln(x_i^*)}{d\ln(e)} = -\sigma\frac{d\ln(ec+d)}{d\ln(e)} + \sigma\frac{d\ln(\beta_i e)}{d\ln(e)}$$

$$\eta_i = \frac{-\sigma ce}{ec+d} + \sigma = \frac{\sigma d}{ec+d} \quad = \quad \sigma(1-\gamma) > 0 \tag{6}$$

where $\gamma = \frac{ec}{ec+d}$ is the share of imported marginal costs.

A one percent increase in exchange rate, i.e a one percent depreciation, leads to a positive increase in exports. The percentage increase is higher the elasticity of substitution, σ. Actually, when the elasticity of substitution is strong, it means the firm has a lower monopolistic power than when substitution is weak. Firms belonging to industry where products are facing strong competition from local products (for example, a Moroccan firm exporting textile in China) will be more sensitive to exchange rate change. The share of imported cost plays a negative role. To summarize, the firms with the lowest share of imported cost firms and which produce a low differentiated product will be the more sensitive firms. For instance, firms belonging to high-tech industry, because they have a high share of imported costs and a high differentiated product, should experience a less sensitivity of their exports to exchange rate change. We have to point out that the export elasticity to exchange rate is not affected by the liquidity constraint: indeed, η_i is independent of ϕ_i.

The sensitivity of exports to exchange rate is linked to the exchange rate pass-through. It is easy to show that, $\eta = \sigma\varepsilon_{PT}$ where ε_{PT} is the elasticity of pass-through.[1] The reaction of exports depends on how price will vary in response to exchange rate change.[2]

2.1.2 Exposure

Optimal profits can be obtained by plugging the expressions for optimal price (4) and quantity (5) into equation (2):

$$\begin{aligned}\pi_i^* &= \frac{eR}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma} - \phi_i \frac{ec+d}{\beta_i}\frac{R}{P^{1-\sigma}}p_i^{-\sigma} - \phi_i F + (\phi_i - 1)\,L \\ &= \frac{eR}{\tau\sigma}\left(\frac{\phi_i\tau(ec+d)}{\beta_i eP}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} - \phi_i F + (\phi_i - 1)\,L \qquad (7)\end{aligned}$$

The sensitivity of profits to exchange rate changes can be computed as

$$\begin{aligned}\delta_i &= \frac{d\pi_i}{de} = \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma} + \frac{eR(1-\sigma)}{\tau\sigma}\frac{p_i^{-\sigma}}{P^{1-\sigma}}\left(-\frac{\phi_i\sigma\tau d}{e^2\beta_i(\sigma-1)}\right) \\ &= \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left(\frac{\gamma+\sigma-\gamma\sigma}{\sigma}\right) > 0 \qquad (8)\end{aligned}$$

As we can see from equation (A.4), the sensitivity of profits with respect to exchange rate changes is not affected by the potential liquidity constraint faced by the firm since δ_i is not a function of ϕ_i.[3]

Similarly, by taking the second (cross) derivative of profits with respect to the aggregate shock and the productivity parameter β_i we can show that the profits of more productive firms are more sensitive to exchange rate shocks.

$$\frac{d^2\pi_i}{d\beta\partial e} = \frac{\sigma-1}{\sigma}\frac{R}{\beta\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}(\gamma+\sigma(\gamma-1)) > 0 \qquad (9)$$

As it is often the case with this class of models à la Melitz (2003) productivity, profitability and size are jointly determined by the parameter β_i and therefore move together. The result presented in equation (9) is driven by the fact that more productive firms export more and therefore their profit is consequently more exposed to the vagaries of the exchange rate.

[1] See Appendix A for details.

[2] Since demand elasticity does not depend on exchange rate, pass-through depends only on the share of imported marginal cost. The higher the amount of imported cost relative to the total cost, the less the export price will reflect an exchange rate change. This comes from the fact that an appreciation lowers imported costs.

[3] Under the assumption of no imported costs ($\gamma = 0$) the expression for profits is the same as in equation (A.3), but the sensitivity of profits to exchange rate changes is larger than in the previous case: $\frac{d\pi_i}{de} = \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}$ since $\sigma > 0$ implies $\frac{\gamma+\sigma-\gamma\sigma}{\sigma} < 1$ in equation (A.4).

2.2 Cash Flow and Exchange Rate Shocks

In this Section we relax the assumption that firm cash flow L_i is exogenously given and we build into the model 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 ν_ε

$$e = \bar{e} + \varepsilon \tag{10}$$

The shock can be either positive, implying a depreciation , or negative implying an apreciation 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. It is a simple way of considering that the exchange rate and projected sales are jointly determined by underlying macroeconomic variables (see Russ, 2007).

$$L_i = \bar{L}_i(1 + \alpha\varepsilon) \tag{11}$$

where —as in Dekle and Ryoo (2007)— α represents the correlation between the firm's cash flow, hence its liquidity, and the macroeconomic shock. This formulation says that the effect of the macroeconomic shock on firm liquidity depends on the correlation between the latter and movements in the exchange rate.[4]

Although modeling the determinants of the correlation α is beyond the scope of the paper, we can nevertheless conjecture that α depends on the type of macroeconomic shocks (monetary, fiscal or trade policy changes, productivity or labor supply shocks, . . .) as well as on firm- and industry-specific characteristics that affect the reactions to these shocks.

First, a positive α implies that a depreciation is associated to an increase of firm liquidity. It refers typically to a situation of expansionary monetary policy leading to low interest rate and higher demand. On the contrary, an appreciation is associated to a decrease in liquidity. This account is consistent with the mechanism included in Chaney (2005)'s model where a depreciation increases the value of domestic assets in foreign currency and then eases the liquidity constraint.

Second, a negative α can arise from supply side shocks. For instance, an un-

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

Table 1: Effects of shocks depending on α

	$\alpha > 0$ monetary policy shocks	$\alpha < 0$ supply side shocks
Depreciation ($\varepsilon > 0$)	increases the liquidity eases the constraint	decreases the liquidity tightens the constraint
Appreciation ($\varepsilon > 0$)	decreases the liquidity tightens the constraint	increases the liquidity eases the constraint

expected increase in the oil price may lower revenues and cash flows and trigger a depreciation of the exchange rate aimed at restoring the equilibrium in the balance of payments. The Table 1 summarizes the different possibilities. In the rest of the paper we take an agnostic view with respect to the sign of α and simply assume $\alpha \neq 0$.

At this point we can study the effect of an unexpected change (i.e. a shock) in the exchange rate on profits. We assume that when the liquidity constraint is binding, so that firms have to rely on external financial resources, this entails higher cost compared to the use of internal finance, whose opportunity cost is normalized to one:

$$\phi_i = \begin{cases} 1 & \text{if } \bar{L}_i(1+\alpha\varepsilon) \geq \frac{ec+d}{\beta_i}x_i + F \\ \tilde{\phi}_i > 1 & \text{if } \bar{L}_i(1+\alpha\varepsilon) < \frac{ec+d}{\beta_i}x_i + F \end{cases}$$

We can now rewrite the profit equation (2) as

$$\pi_i = \frac{eR}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma} - \phi_i F + (\phi_i - 1)\left(\bar{L}_i(1+\alpha\varepsilon)\right). \tag{12}$$

Profit sensitivity then becomes

$$\begin{aligned} \tilde{\delta}_i = \frac{d\pi_i}{de} &= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[1 + \frac{e(\sigma-1)}{p_i}\frac{\phi_i\sigma\tau d}{\beta_i(\sigma-1)e^2}\right] + (\phi_i - 1)\bar{L}_i\alpha \\ &= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[1 + (\sigma-1)(1-\gamma)\right] + (\phi_i - 1)\bar{L}_i\alpha \\ &= \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma + \sigma(1-\gamma)}{\sigma}\right] + (\phi_i - 1)\bar{L}_i\alpha \end{aligned} \tag{13}$$

using the definition of ϕ_i given above we can easily see that

$$\frac{d\pi_i}{de} = \begin{cases} \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma+\sigma(1-\gamma)}{\sigma}\right] & \text{no liquidity constraint} \\ \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left[\frac{\gamma+\sigma(1-\gamma)}{\sigma}\right] + \left(\tilde{\phi}_i - 1\right)\bar{L}_i\alpha & \text{liquidity constraint} \end{cases} \tag{14}$$

From these two expressions we can conclude that adding a liquidity constraint (i.e. the need for a firm to finance externally part of its fixed and variable operating costs) and assuming that cash flow is affected by exchange rate shocks, introduces a relationship between exposure and financial conditions. In particular, 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 between cash flow and aggregate shocks (α).[5]

We can further investigate the effect of exchange rate shocks on profits of different firms by taking the second derivatives: First, how financial cost affects exposure is given by:

$$\frac{d^2\pi_i}{d\tilde{\phi}_i de} = \bar{L}_i\alpha \tag{15}$$

Equation (15) tells that an increase in the relative cost of external finance (relative to internal funds) may increase or reduce the sensitivity of profits to exchange rate shocks depending on the sign of α, ie on whether aggregate shocks are positively or negatively correlated with firm cash flow.

Similarly, how liquidity endowment affects exposure is given by the second derivative:

$$\frac{d^2\pi_i}{d\bar{L}_i de} = (\tilde{\phi}_i - 1)\alpha \tag{16}$$

Equation (16) tells that an increase in the liquidity endowment, for firms which are liquidity constrained and for a given amount of financial cost, may increase or reduce the sensitivity of profits to exchange rate shocks depending on the sign of α.

2.3 Testable hypotheses

The model yields two sets of implications concenring exchange rate exposure: the first concerns its relationship with firm's characteristics; the second deals more specifically with its dependence on the liquidity constraint.

First of all, the model is consistent with existing empirical evidence associating export and productivity. Equation (9) tells that profits of more productive (or larger, since these two dimensions almost coincide in these classes of models) firms are more sensitive to exchange rate fluctuations (the reason being that more productive firms export more).

Second, Equation (14) shows that an exchange rate depreciation leads to higher profits for non-financially constrained firms. The presence of a liquidity constraint

[5] In the derivation of equation (13) we have implicitly assumed that the overall price index P is not affected by exchange rate changes ($dP/de = 0$). While this hypothesis greatly simplifies the analysis, it is clearly not verified in general. It is still a reasonable representation of relatively closed economies or of situations where pass-though is very small.

will increase or reduce the positive impact of an exchange rate shock depending on the sign of the its correlation with the firm cash-flow. Say α is positive, firms with high financial cost will be more exposed than firms with lower level of financial cost.

From these observations we can derive a set of formal hypotheses to bring to the data, namely:

H1: The profit increases with an exchange rate increase (depreciation), with liquidity and decreases with financial costs.

H2: The sensitivity of profits to exchange rate shocks grows with productivity and then with size.

H3: The sensitivity of exposure to the cost of external finance depends on the sign of the correlation between aggregate shocks and firm liquidity (i.e. the sign of α, see equation (15)).

3 Empirical analysis

3.1 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 (beyond 5 million euros), and contains data mainly derived from the income statement of participating firms. We work on the data for the period 1995–2007: the original dataset comprises around 250,000 observations for nearly 35,000 French firms, 75 percent of which are exporters (186,500 observations on 30,000 firms). We focus our attention on exporting firms only, as the decision whether or not to export is not modeled. We perform some basic cleaning operations on the data: in particular we drop (firm/year) observations for which profits are negative, and set liquidity equal to zero when liquidity is negative.[6] Moreover, we winsorize the top and bottom 1 percent of the observations in the key variables we use in the analysis (profit, liquidity, financial costs, size and productivity).[7] This leaves us with a sample of 23,000 manufacturing exporting firms, totalling 140,000 observations. On average we have 9 observations for each firm, with a median value of 11 years.

[6]Given the double log specification of our regression equations the former operation is irrelevant as those observations would be dropped from the analysis anyway. In the second case, the truncation is aimed at keeping the observations in the analysis.

[7]Winsorizing a variable entails setting its extreme realizations (eg those pertaining the top/bottom 1 percent to a specified percentile of the data, say the 99th percentile.

3.2 Variable Definition

Exchange rate Our exchange rate measure is an effective exchange rate computed at ISIC 4-digit industry level, on the basis of 26 partner countries representing the main destinations for French export.[8] Weights are calculated from the share of exports of each industry to the different destinations. An increase of the effective exchange rate means a depreciation of the domestic currency relative to the basket of the 26 currencies-partners, that is a gain in price-competitiveness.

Profits To measure profits we rely on earnings before interest, taxes, depreciation and amortization (EBITDA), or gross profits.[9] 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.

Productivity and size Firm productivity is defined as both labor productivity (valued added over number of hours worked) and total factor productivity (TFP). The latter is computed according to the so-called *multilateral productivity index* introduced by Caves et al. (1982) and extended by Good et al. (1997).

We have a number of proxies for firm size: number of employees, hours worked, total sales, and the capital stock computed according to the permanent inventory method.

Liquidity and financial cost To proxy for liquidity we take the ratio between firm's 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 computing financial costs as a ratio of debt, which would probably be a better measure of the cost associated to external finance.

Correlation between liquidity and exchange rate The correlation between liquidity and exchange rate (α in the model) is computed by industry over the whole period under consideration (1995–2007). The choice of an industry-specific α is dictated by the fact that a firm-specific one would only be based on the time-series variation experienced by each firm, thus relying on very few observations. Moreover,

[8]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, South Korea.

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

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

considering correlation at the industry level is consistent with the idea that demand and supply shocks are mainly industry-specific.

3.3 Empirical Strategy

Contrary to Bodnar et al. (2002) we do not have a structural equation to bring directly to the data: in fact, equation (12) cannot be directly estimated since we do not have information on many of its elements. Nevertheless, we can derive precise information about what should affect firm profits.

The first hypothesis we wish to bring to the data (H1) aims at testing the main intuition of the model, i.e. the idea that profits are positively affected by exchange rate depreciations, and that firms featuring higher liquidity and lower financial costs enjoy higher profits.

To perform a formal test of H1 we estimate the following regression equation

$$PROFIT_{ist} = a_0 + a_1 EER_{st} + a_2 PROD_{ist} + a_3 SIZE_{ist} + a_4 LIQ_{ist} + a_5 FINC_{ist} + \nu_i + \varepsilon_{ist} \quad (17)$$

where i, s and t index firms, sectors and time respectively, EER_{st} is the effective exchange rate for industry s, $PROD_{ist}$ measures productivity, LIQ_{ist} stands for liquidity, $FINC_{ist}$ for the costs of financial resources, and ν_i is a firm-specific fixed effect. Variables are defined as in Section 3.2 above and all enter the regression in logs.[11]

H2 and H3 concern the differential effect of exchange rate changes on profits of firms with different characteristics in terms of size, productivity and financial costs. We follow two complementary strategies to test H2 and H3. First, we add an interaction dummy to equation (17):

$$\begin{aligned} PROFIT_{ist} = a_0 + a_1 EER_{st} + a_2 PROD_{ist} + a_3 SIZE_{ist} + a_4 LIQ_{ist} \\ + a_5 FINC_{ist} + d\,(high_i \times EER_{st}) + \nu_i + \varepsilon_{ist} \quad (18) \end{aligned}$$

where $high$ is a dummy variable that identifies firms featuring above-median value for size, productivity (H2), or financial costs (H3). The coefficient d indicates the differential effect of exchange rate changes on profits of larger (more productive or with higher financial costs) firms. In the case of H3 we not only differentiate among firms above the median of the distribution of financial costs, but run separate

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

regressions on the subsamples defined by the sign of the correlation α between liquidity and exchange rate movements.

Second, we can perform a thoroughly comparison between firms belonging to different groups by allowing *all* coefficients (not just the one associated to the exchange rate variable as in equation (18) above) to differ freely across firm types. To do so, we estimate the following equation

$$\begin{aligned} PROFIT_{ist} = a_0 &+ a_1(high_i \times EER_{st}) + b_1(low_i \times EER_{st}) \\ &+ a_2(high_i \times PROD_{ist}) + b_2(low_i \times PROD_{ist}) \\ &+ a_3(high_i \times SIZE_{ist}) + b_3(low_i \times SIZE_{ist}) \\ &+ a_4(high_i \times LIQ_{ist}) + b_4(low_i \times LIQ_{ist}) \\ &+ a_5(high_i \times FINC_{ist}) + b_5(low_i \times FINC_{ist}) + \nu_i + \varepsilon_{ist}. \end{aligned} \tag{19}$$

H2 and H3 concentrate specifically on the coefficients a_1 and b_1 and we can apply an F-test to the hypothesis $a_1 = b_1$ in order to assess whether the impact of exchange rate changes on profits is different across firm groups. In fact, we look at whether larger and more productive firms display higher sensitivity of profits to exchange rate changes (H2), and whether firms characterized by higher financial costs and a positive (negative) correlation between their cash flow and the exchange rate feature higher (lower) exposure (H3). In equation (19) $high_{ist}$ and low_{ist} are again dummy variables that identify firms on the basis of the relevant characteristic (size, productivity or financial costs) relative to the median firm operating in the same sector during the same year.

4 Results

4.1 Testing H1: the determinants of profits

Table 2 reports results for the estimation of equation (17). We use both TFP (columns 1–4) and valued added per hour worked (columns 5–8) to proxy for productivity and employ four different measures of size (hours worked, sales, number of workers, capital stock). All coefficients have the expected sign across the different specifications of the empirical model. Larger firms enjoy higher profits, irrespective of how we proxy for size. Similarly, more productive firms are more profitable, and again results do not change whether we use average labor productivity or TFP. Liquidity also exerts a positive impact on profits, consistently with the model, while firms facing higher financial costs tend to report lower profits. Finally, the estimated coefficients confirm that exchange rate depreciations are associated with an increase in profits as predicted by the model.

Table 2: Test of H1 – Determinants of firm profits

	TFP				Average Labor Product.			
size as:	hours worked	sales	workers	capital stock	hours worked	sales	workers	capital stock
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
EER	0.919**	1.247**	0.979**	1.101**	0.660**	0.805**	0.746**	0.344**
	[0.039]	[0.038]	[0.039]	[0.038]	[0.038]	[0.038]	[0.039]	[0.040]
PROD.	2.336**	1.197**	2.247**	2.730**	1.040**	0.0830**	0.986**	0.815**
	[0.018]	[0.020]	[0.018]	[0.018]	[0.008]	[0.010]	[0.00802]	[0.008]
SIZE	0.794**	0.839**	0.747**	0.714**	1.005**	0.994**	0.948**	0.512**
	[0.008]	[0.007]	[0.008]	[0.006]	[0.008]	[0.008]	[0.00810]	[0.006]
LIQ	1.868**	1.852**	1.888**	1.966**	2.012**	2.008**	2.031**	2.181**
	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]	[0.011]
FINC	-1.586**	-1.697**	-1.566**	-1.188**	-1.929**	-1.895**	-1.885**	-1.767**
	[0.040]	[0.039]	[0.040]	[0.039]	[0.040]	[0.039]	[0.040]	[0.041]
obs.	130919	130919	130919	130919	130919	130919	130919	130919
firms	23134	23134	23134	23134	23134	23134	23134	23134
R-sq.	0.403	0.426	0.398	0.422	0.405	0.408	0.398	0.36

** $p < 0.01$, * $p < 0.05$; standard errors in brackets

4.2 Testing H2: exposure, size and productivity

Moving to the next testable implication of the model (H2), we expect to see the sensitivity of profits to exchange rate changes to increase with firm size and productivity. Empirically, this should be captured by the coefficient d in equation (18), and by a significant difference between a_1 and b_1 in equation (19). Tables 3 and 4 report the results obtained using the two methodologies outlined above.

Columns (1–2) of Table 3 report results from estimation of (18) when interacting the exchange rate with measures of firm size.[12] When measuring size in terms of the number of workers, the interaction term turns out not to be significantly different from zero, whereas our hypothesis is verified when we proxy size by means of total sales. Indeed, the estimate for d in column (2) implies that a depreciation increases profits of firms that are above median size (relative to their sector) by roughly 1.7 percent more than it does for smaller firms. All other controls keep the correct sign and are significant, so that larger, more productive and more liquid firms feature larger profits, an exchange rate depreciation has a positive effect on profits, whereas higher financial costs impact negatively on them.

[12]Space considerations suggested us to present only results obtained using two measures of size, namely the number of workers and firm sales. Additional results are available upon request.

When we turn to productivity, results are always in line with the model. Irrespective of whether we use TFP (as in columns 3–4) or labor productivity (columns 5–6), and of the measure of size, the estimate for the interaction term ($high\ PROD \times EER$) is positive and significant. The premium associated with productivity appears larger than the one found for size and ranges between 7.3 and 7.8 percent for TFP and between 2.8 and 3.3 percent for labor productivity.[13] All the other variables maintain the correct sign, and the usual size and significance.

Table 3: Test of H2 - Effect of size and productivity on exposure using interaction dummies

	TFP				LP	
	workers	sales	workers	sales	workers	sales
	(1)	(2)	(3)	(4)	(5)	(6)
EER	0.979**	1.221**	0.644**	0.936**	0.632**	0.706**
	[0.039]	[0.038]	[0.039]	[0.038]	[0.039]	[0.039]
PROD.	2.247**	1.204**	1.806**	0.777**	0.908**	0.013
	[0.018]	[0.020]	[0.019]	[0.021]	[0.009]	[0.011]
SIZE	0.747**	0.814**	0.784**	0.849**	0.956**	0.996**
	[0.009]	[0.007]	[0.008]	[0.007]	[0.008]	[0.008]
LIQ	1.888**	1.849**	1.799**	1.767**	2.023**	2.000**
	[0.011]	[0.011]	[0.011]	[0.011]	[0.0108]	[0.011]
FIN. COSTS	-1.566**	-1.705**	-1.597**	-1.731**	-1.903**	-1.911**
	[0.040]	[0.039]	[0.039]	[0.038]	[0.0397]	[0.039]
large x EER	-0.0001	0.017**				
	[0.002]	[0.002]				
high PROD. x EER			0.0758**	0.0705**	0.0334**	0.0285**
			[0.001]	[0.001]	[0.002]	[0.001]
observations	130919	130919	130919	130919	130919	130919
firms	23134	23134	23134	23134	23134	23134
R-squared	0.398	0.427	0.419	0.445	0.401	0.410

** $p < 0.01$, * $p < 0.05$; standard errors in brackets

Table 4 displays results obtained using the second empirical strategy, i.e. letting the coefficients for all variables to vary across firm types. This amounts to running a thoroughly comparison between small and large firms (Columns 1–2), or between less and more productive ones (Columns 3–6).

With respect to size differences, the model predicts larger firms to be more sensitive to exchange rate fluctuations, so that we should observe $b_1 > a_1$ in the estimation of equation (19). Similarly to what we find above when using interaction dummies, our hypothesis is not fully supported by the data: the estimated coefficients for $high \times EER$ tends to be smaller than the coefficients for $low \times EER$, irrespective of the way we measure size, although an F-test is unable to reject the null of the two coefficient actually being equal at the 1 percent confidence level (as reported in the

[13] This is the extra increase in profits generated by a depreciation for firms above median productivity in their sector of operation, relative to smaller firms.

last two lines of Table 4). For what concerns the other control variables, although we have not derived clear-cut implications on their behavior from the model, we can see that productivity affects more strongly profits of larger firms, whereas the effect of liquidity and financial costs on firms depends on the measure of size we use.

Table 4: Test of H2 - Effect of size and productivity on exposure across groups of firms

	SIZE		TFP		Average Labor Prod.	
	workers	sales	workers	sales	workers	sales
	(1)	(2)	(3)	(4)	(5)	(6)
low x EER	**1.012****	**1.215****	**0.659****	**0.961****	**0.694****	**0.792****
	[-0.040]	[-0.040]	[-0.038]	[-0.038]	[-0.039]	[-0.040]
high x EER	**0.980****	**1.244****	**0.745****	**1.023****	**0.635****	**0.684****
	[-0.040]	[-0.039]	[-0.038]	[-0.037]	[-0.039]	[-0.039]
low x PROD.	2.190**	1.157**	1.748**	0.737**	1.032**	0.153**
	[-0.022]	[-0.024]	[-0.023]	[-0.024]	[-0.012]	[-0.015]
high x PROD.	2.320**	1.264**	2.058**	0.997**	0.858**	-0.0391**
	[-0.024]	[-0.027]	[-0.026]	[-0.027]	[-0.010]	[-0.012]
low x SIZE	0.734**	0.817**	0.773**	0.842**	0.943**	0.980**
	[-0.013]	[-0.010]	[-0.008]	[-0.007]	[-0.009]	[-0.009]
high x SIZE	0.755**	0.812**	0.795**	0.863**	0.956**	1.003**
	[-0.010]	[-0.008]	[-0.008]	[-0.007]	[-0.008]	[-0.008]
low x LIQ	1.778**	1.928**	2.631**	2.620**	2.384**	2.372**
	[-0.014]	[-0.015]	[-0.019]	[-0.018]	[-0.017]	[-0.016]
high x LIQ	2.035**	1.773**	1.468**	1.432**	1.812**	1.783**
	[-0.016]	[-0.015]	[-0.013]	[-0.012]	[-0.013]	[-0.013]
low x FINC	-1.431**	-1.851**	-1.891**	-1.987**	-2.257**	-2.282**
	[-0.051]	[-0.055]	[-0.059]	[-0.057]	[-0.062]	[-0.061]
high x FINC	-1.728**	-1.588**	-1.459**	-1.616**	-1.724**	-1.722**
	[-0.056]	[-0.049]	[-0.044]	[-0.043]	[-0.047]	[-0.047]
observations	130919	130919	130919	130919	130919	130919
firms	23134	23134	23134	23134	23134	23134
R-squared	0.399	0.427	0.436	0.463	0.407	0.416
F test: big=small	6.408	2.141	300.1	60.15	30.23	35.97
p-value	0.011	0.143	0.000	0.000	0.000	0.000

** $p < 0.01$, * $p < 0.05$; standard errors in brackets
Boldface indicates the coefficients relative to $H2$

In columns (3–6) we perform the same exercise with respect to productivity differences, again using both TFP and labor productivity. This means that *high* and *low* are now representing firms above or below the median productivity in a given year and sector of operations (at 4-digit ISIC). This time the estimated coefficients have the correct sign and magnitude: the coefficient for $high \times EER$ is in fact larger than the one for $low \times EER$, and the F-test confirms that such difference is statistically significant. This holds true irrespective of the specific way we measure productivity and size.

Overall we find that more productive firms are indeed characterized by higher exposure, as predicted by the model outlined in Section 2 above. We find that exchange rate changes have larger effects on profits of more productive firms. The evidence for size is more mixed as the data are often unable to reject the null hypothesis of the effect being the same across large and small firms.

4.3 Testing H3: exposure and financial costs

Let us turn now to the last testable implication derived from the model, namely H3, which relates exposure to the presence of liquidity constraints and the need to apply for external financial resources. As shown by equation (15) above, the model suggests that the impact of financial costs on exposure depends on the sign of the correlation between firm cash flow and exchange rate movements (α). In particular, for firms characterized by $\alpha > 0$ the sensitivity of profits to exchange rate changes should increase with financial costs, whereas it should decline when financial costs rise and $\alpha < 0$.

Table 5: Test of H3 - Effect of financial costs on exposure using interaction dummies

	TFP		Avg Labor Prod	
	$\alpha > 0$	$\alpha < 0$	$\alpha > 0$	$\alpha < 0$
	(1)	(2)	(3)	(4)
EER	1.493**	0.589**	1.068**	0.471**
	[0.059]	[0.053]	[0.058]	[0.052]
PROD.	2.392**	2.140**	1.019**	0.958**
	[0.026]	[0.026]	[0.011]	[0.011]
SIZE†	0.731**	0.761**	0.936**	0.959**
	[0.011]	[0.012]	[0.011]	[0.012]
LIQ	1.963**	1.814**	2.153**	1.919**
	[0.016]	[0.015]	[0.016]	[0.015]
FINC	-2.079**	-1.031**	-2.377**	-1.295**
	[0.061]	[0.060]	[0.061]	[0.059]
high FINC x EER	-0.002	-0.005**	-0.006**	-0.009**
	[0.002]	[0.002]	[0.002]	[0.002]
Observations	73041	57878	73041	57878
firms	12866	10704	12866	10704
R-squared	0.384	0.418	0.381	0.421

** $p < 0.01$, * $p < 0.05$; standard errors in brackets
† number of workers

Table 5 reports results from regression analysis based on interaction dummies. Note that here we run two separate regressions on the subsamples of firms featuring $\alpha > 0$ (columns 1 and 3) and $\alpha < 0$ (columns 2 and 4). To keep the exposition simple, while not loosing any relevant insight, we stick to just one measure of size, namely the number of employees.[14]

Results obtained using TFP (columns 1–2) are broadly in line with the model. The estimated coefficient of the interaction term is close to zero and not statistically

[14] Additional results obtained using alternative measures of size are available upon request.

significant, suggesting that firms with higher financial costs and a positive correlation between cash flow and exchange rate changes are *not* characterized by higher exposure. On the contrary, results in column (2) support the model and signal that when firm liquidity is negatively correlated with the exchange rate, exposure does go down.[15]

Unfortunately, results appear not robust to the use of average labor productivity instead of TFP. As shown in columns 3–4 of the Table, the coefficient for the interaction term that is meant to capture the extra effect of exchange rate changes on profits of firms with higher financial costs ($high \times EER$) turns out negative and significant irrespective of the sign of the correlation between the exchange rate and firm cash flow.

Table 6: Test of H3 - Effect of financial costs on exposure across different groups of firms

	TFP		Ave. Labor Prod	
	$\alpha > 0$	$\alpha < 0$	$\alpha > 0$	$\alpha < 0$
	(1)	(2)	(3)	(4)
low FINC x EER	**1.322****	**0.515****	**0.928****	**0.395****
	[-0.059]	[-0.053]	[-0.058]	[-0.053]
high FINC x EER	**1.387****	**0.553****	**0.989****	**0.442****
	[-0.059]	[-0.053]	[-0.058]	[-0.053]
low FINC x PROD.	2.208**	2.045**	1.005**	0.950**
	[-0.032]	[-0.031]	[-0.013]	[-0.013]
high FINC x PROD.	2.564**	2.232**	1.008**	0.956**
	[-0.032]	[-0.031]	[-0.012]	[-0.013]
low FINC x SIZE†	0.746**	0.766**	2.624**	2.194**
	[-0.012]	[-0.012]	[-0.026]	[-0.023]
high FINC x SIZE†	0.715**	0.749**	1.976**	1.778**
	[-0.011]	[-0.012]	[-0.017]	[-0.017]
low FINC x LIQ	2.484**	2.111**	0.656	1.303**
	[-0.027]	[-0.023]	[-0.459]	[-0.453]
high FINC x LIQ	1.763**	1.660**	-2.131**	-1.145**
	[-0.018]	[-0.018]	[-0.062]	[-0.060]
low FINC x FINC	2.564**	2.123**	0.947**	0.967**
	[-0.458]	[-0.461]	[-0.012]	[-0.013]
high FINC x FINC	-1.831**	-0.871**	0.915**	0.944**
	[-0.062]	[-0.061]	[-0.012]	[-0.012]
Observations	73041	57878	73041	57878
firms	12866	10704	12866	10704
R-squared	0.391	0.422	0.387	0.425
F test: big=small	84.76	25.35	35.54	19.04
p-value	0.000	0.000	0.000	0.000

** $p < 0.01$, * $p < 0.05$; standard errors in brackets
†: number of workers
Boldface indicates the coefficients relative to $H3$

When we estimate equation (19) and compare the behavior of different groups

[15]Results in Table 5 are obtained using a coarse classification based on whether a firm lies above or below the median of the distribution of financial costs. We have experimented using a fined classification based on quartiles, but results are qualitatively unchanged.

of firms, we still find that it does not depend on the sign of α. Indeed, as detailed in Table 6, a_1 is always larger that b_1, even when α is negative and therefore the model predicts a smaller impact of an exchange rate change on the profit of firms featuring higher financial costs. Not only is this independence at odds with the model, but the fact that $a_1 > b_1$ (higher exposure for firms with higher financial costs) contrasts with the negative and significant sign for the interaction term that we have reported in Table 5. This is a puzzle that clearly deserves further investigation.

5 Conclusion

The paper develops a simple model where exporting firms are characterized by heterogeneous productivity and may face a liquidity constraint. 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 bring to the data.

Overall, empirical results provide a good support to the theoretical predictions of the model, although they are not always consistent across the different specifications used. In particular, we find that profits of more productive firms are more sensitive to exchange rate fluctuations, and the same holds true also for larger firms, albeit less strongly. Moreover, an increase in the cost of external funds (relative to cash flow) makes profit less sensitive to exchange rate shocks for firms whose liquidity is negatively correlated with exchange rate, meaning whose liquidity increases (decreases) with an appreciation (depreciation) of the exchange rate. On the other hand, we do not find evidence of a comparable effect of the opposite sign when the correlation between exchange rate changes and liquidity is positive. In fact, while the model predicts exposure to be larger for firms with higher financial costs and $\alpha > 0$, such relation does not show up in the data.

Our analysis can be further refined, both theoretically and empirically, along several dimensions. With respect to the model, possible extensions entails allowing firms to hedge, at least partially, their exchange rate risk. This however requires modifying the way the liquidity constraint is modeled: in fact, in the present setup, with all terms entering linearly the profit function, optimal hedging turns out to be undetermined.[16] As a further refinement, we could introduce all firms (not only exporters) in the framework and explicitly model the selection into exporting. This should also be beneficial for the empirical analysis as we cannot distinguish profits earned abroad from domestic ones in the data. From the empirical point of view, we wish to better investigate the robustness of our results to alternative specifications.

[16] See Appendix A for details.

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Appendices

A Derivations

A.1 Impact of exchange rate changes on sales

In order to get the elasticity of quantity with respect to change in exchange rate, η_i, we first take the logarithm of the optimal quantity (equation 5).

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

$$\begin{aligned}
\eta_i = \frac{d\ln(x_i^*)}{d\ln(e)} &= -\sigma \frac{d\ln(ec+d)}{d\ln(e)} + \sigma \frac{d\ln(\beta_i e)}{d\ln(e)} \\
&= -\sigma \frac{d(ec+d)}{de}\frac{e}{ec+d} + \sigma \frac{d(\beta_i e)}{d(e)}\frac{e}{\beta_i e} \\
\eta_i &= \frac{-\sigma ce}{ec+d} + \sigma = \frac{\sigma d}{ec+d} = \sigma(1-\gamma) > 0
\end{aligned} \tag{A.2}$$

A.2 Pass-through

We can compute the elasticity of pass-through, defined as the percentage change in price in response to a percentage change in the exchange rate, as follows:

$$\begin{aligned}
\varepsilon_{PT} = -\frac{d\ln p_i}{d\ln e} &= -e\left[\frac{c}{ec+d} - \frac{1}{e}\right] \\
&= 1-\gamma < 1.
\end{aligned}$$

A.3 Exposure

Optimal profits can be obtained by plugging the expressions for optimal price (4) and quantity (5) into equation (2):

$$\begin{aligned}
\pi_i^* &= \frac{eR}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma} - \phi_i \frac{ec+d}{\beta_i}\frac{R}{P^{1-\sigma}} p_i^{-\sigma} - \phi_i F + (\phi_i - 1)\, L \\
&= R\left(\frac{p_i}{P}\right)^{1-\sigma}\left(\frac{e}{\tau\sigma}\right) - \phi_i F + (\phi_i - 1)\, L \\
&= \frac{eR}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma} - \phi_i F + (\phi_i - 1)\, L
\end{aligned}$$

$$\pi_i^* \quad = \quad \frac{eR}{\tau\sigma}\left(\frac{\phi_i\tau(ec+d)}{\beta_i eP}\frac{\sigma}{\sigma-1}\right)^{1-\sigma} - \phi_i F + (\phi_i - 1)\, L \tag{A.3}$$

The sensitivity of profits to exchange rate changes can be computed as

$$\begin{aligned}
\delta_i = \frac{d\pi_i}{de} &= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma} + \frac{eR(1-\sigma)}{\tau\sigma}\frac{p_i^{-\sigma}}{P^{1-\sigma}}\left(-\frac{\phi_i\sigma\tau d}{e^2\beta_i(\sigma-1)}\right) \\
&= \frac{R}{\tau\sigma}\left(\frac{p_i}{P}\right)^{1-\sigma}\left(1-(1-\sigma)\frac{d}{ec+d}\right) \\
\delta_i &= \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left(\frac{\gamma+\sigma-\gamma\sigma}{\sigma}\right) > 0 \qquad \text{(A.4)}
\end{aligned}$$

Which can be rewritten first considering the export elasticity η_i as:

$$\delta_i = \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left(\frac{\gamma+\eta_i}{\sigma}\right) \tag{A.5}$$

Or alternatively as:

$$\delta_i = \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}\left(\frac{\gamma(1-\sigma)}{\sigma} - 1\right) \tag{A.6}$$

If we set $(\sigma-1)/\sigma = \rho$, then

$$\delta_i = \frac{R}{\tau}\left(\frac{p_i}{P}\right)^{1-\sigma}(\gamma\rho - 1) \tag{A.7}$$

A.4 Hedging

To see this, let us introduce hedging in the form of a share $h \in [0,1]$ representing the amount of cash flow that is hedged against macroeconomic shocks. Cash flow then can be written as $L = \bar{L}_i(1+(1-h_i)\alpha\varepsilon)$. By maximizing expected profits with respect to h we end up with the following first order condition:

$$E\left[\frac{\partial\pi_i}{\partial L}\cdot\frac{\partial L}{\partial h}\right] = E\left[\frac{\partial\pi_i}{\partial L}\right]E\left[\frac{\partial L}{\partial h}\right] + \text{cov}\left(\frac{\partial\pi_i}{\partial L}, \frac{\partial L}{\partial h}\right) = 0$$

$E\left[\frac{\partial L}{\partial h}\right] = E\left[-L_0\alpha\varepsilon\right] = 0$ because $E[\varepsilon] = 0$. Then, $E\left[\frac{\partial\pi_i}{\partial L}\cdot\frac{\partial L}{\partial h}\right] = \text{cov}\left(\frac{\partial\pi_i}{\partial L}, \frac{\partial L}{\partial h}\right)$, but since $E\left[\frac{\partial\pi_i}{\partial L}\right] = (\phi_i - 1)$ is constant and does not depend on ε, then $\text{cov}\left(\frac{\partial\pi_i}{\partial L}, \frac{\partial L}{\partial h}\right) = 0$ and therefore the first order condition is verified for every value of h, and the optimal hedging strategy is undetermined.