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## Exchange Rate Exposure and Firms' Strategies

Florence Mouradian

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# THÈSE DE DOCTORAT

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Exposition au Taux de Change et Stratégies D'Entreprises

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# Exchange Rate Exposure and Firms' Strategies



# Résumé

L'objectif de cette thèse est double. Premièrement, elle vise à proposer une revue de la littérature économique s'intéressant à l'exposition au taux de change de la profitabilité des entreprises non-financières, et à fournir de nouveaux enseignements sur son hétérogénéité intra et inter-sectorielle. Deuxièmement, cette thèse analyse les stratégies de production et de produits mises en oeuvre par les firmes pour se prémunir des effets de ces variations de change. Puisque l'éventail de telles stratégies est large, le dernier chapitre se concentre sur la stratégie de montée en gamme.

**Mots-clé:**

Taux de Change; Entreprises Hétérogènes; Stratégies d'Entreprises; Management du Risque de Change; Différenciation Verticale



# Abstract

This thesis follows a dual objective. First, it aims to summarize previous evidence on the magnitude and channels underpinning a non-financial firm's operating exposure, i.e. the extent to which currency fluctuations can alter a company's future operating cash flow, and to provide new highlights on the heterogeneity of this exposure across firms. Second, this thesis investigates the product and production strategies that are appropriate for coping with the economic consequences of exchange rate changes on firms' operating profits. Since the range of these strategies is large, it focuses on providing theoretical and empirical evidence for the strategy of up-market positioning.

**Keywords:**

Exchange Rate; Heterogeneous Firms; Vertical Differentiation; Economic Exposure; Exchange Rate Risk Management.





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# Contents

<b>Introduction</b>	<b>15</b>
<b>1 Assessing and Managing Economic Exposure</b>	<b>21</b>
1.1 Defining and Estimating Economic Exposure	22
1.1.1 Formal Definition	22
1.1.2 The Empirical Exchange Rate Exposure Puzzle	24
1.2 Managing Economic Exposure	31
1.2.1 Financial Hedges	31
1.2.2 Operational Hedges	34
1.2.3 Financial and Operational Hedges: Complementary or Substitutes?	42
1.3 Conclusion	45
Appendices	47
1.A The Basic Capital Market Approach	47
1.B Existing Evidence on Exchange Rate Exposure	48
<b>2 Firm's Heterogeneity and Operating Exposure</b>	<b>57</b>
2.1 Introduction	58
2.2 A General Accounting Framework	61
2.2.1 Setup	61
2.2.2 Exchange Rate Exposure	64
2.2.3 A Model with Variable Markups	70
2.3 Empirical Framework	72
2.3.1 The Data	72
2.3.2 Estimates of Markups and Marginal Costs in Level	75
2.3.3 Marginal Costs Responses to Exchange Rate Shocks	78
2.3.4 Competitors' Price Responses to Exchange Rate Shocks	80
2.3.5 Firms' Exchange Rate Exposure and Testable Predictions	81

2.4	Results . . . . .	82
2.4.1	Prices and Markups . . . . .	82
2.4.2	Profit Margin Effect and Volume Effect . . . . .	86
2.4.3	Operating Profits Exposure to Exchange Rate Changes . . . . .	89
2.5	Conclusion . . . . .	90
	Appendices . . . . .	93
2.A	Derivations and Proofs . . . . .	93
2.A.1	General case . . . . .	93
2.A.2	Atkeson and Burstein [2008]'s settings . . . . .	95
2.B	Marginal Costs and Markups Measures . . . . .	96
2.B.1	Production Function Estimates . . . . .	96
2.B.2	Practical Implementation . . . . .	101
2.B.3	Input Allocations . . . . .	103
2.C	Figures and Tables . . . . .	105
<b>3</b>	<b>Competitive Exposure and Quality Upgrading</b>	<b>115</b>
3.1	Introduction . . . . .	116
3.2	Model . . . . .	119
3.2.1	Setup . . . . .	119
3.2.2	Firms' optimal choices . . . . .	126
3.2.3	Industry Equilibrium . . . . .	128
3.3	Measuring Quality . . . . .	134
3.3.1	Equilibrium and Demand Approaches of Quality . . . . .	134
3.3.2	Data and Parameters . . . . .	137
3.3.3	Quality Patterns of Exports from the Euro Area . . . . .	139
3.4	Currency shocks and Quality Changes . . . . .	144
3.4.1	Predicted Effects and Econometric Specifications . . . . .	144
3.4.2	Results . . . . .	146
3.4.3	Channels . . . . .	151
3.5	Conclusion . . . . .	156
	<b>General Conclusion</b>	<b>157</b>
	<b>Bibliography</b>	<b>174</b>

# List of Figures

<b>1 Assessing and Managing Economic Exposure</b>	<b>21</b>
<b>2 Firm's Heterogeneity and Operating Exposure</b>	<b>57</b>
2.1 Exchange rate elasticity of local currency prices and markups along market share	85
2.2 Exchange rate elasticity of profit margins and sales volumes along market share	88
2.3 Operating exchange rate exposure along market share . . . . .	90
2.4 Marginal costs and output quantities by sector, French manufacturing industry, 1999-2007 . . . . .	107
2.5 The valuation/volume effect trade-off in export markets, French manufacturing industry, 1999-2007 . . . . .	111
2.6 Distribution of operating exchange rate exposures, French manufacturing firms, 1999-2007 . . . . .	112
<b>3 Competitive Exposure and Quality Upgrading</b>	<b>115</b>
3.1 Distribution of quality and real exchange rate indices in 2007 (base 100 = 1999) by country, All industries combined . . . . .	142
3.2 Distribution of quality and real exchange rate indices in 2007 (base 100 = 1999) by country, Vertical Differentiated Industries . . . . .	143
3.3 Estimated RER elasticities of quality and quality-adjusted prices along sigma and alpha deciles and income group of partners . . . . .	150



# List of Tables

<b>1 Assessing and Managing Economic Exposure</b>	<b>21</b>
1.1 Classification of hedging instruments . . . . .	29
1.2 Percentage (%) of firms using financial derivatives, by firms' sales in USD millions	33
1.3 Invoicing currency (in %) of euro area exports and imports of goods vis-a-vis non-euro area trading partners . . . . .	36
1.4 Percentage (%) of exchange rate economic exposure managed via operational vs. financial methods; and popularity of various methods used for operational and financial hedging of exchange rate risk. . . . .	43
1.5 Existing evidence on exchange rate exposure of non-financial firms in market-based approaches. . . . .	49
1.6 Theoretical exchange rate exposures of non-financial firms in cash flow-based approaches . . . . .	55
<b>2 Firm's Heterogeneity and Operating Exposure</b>	<b>57</b>
2.1 Descriptive Statistics by firm and sector . . . . .	74
2.2 Correlations between prices, markups, marginal costs, productivity and volume of sales . . . . .	78
2.3 Exchange rate elasticities of firms' own markups, marginal costs and prices, and competitors' prices . . . . .	84
2.4 Heterogeneity of exchange rate elasticities of markups and local currency prices along market shares, French manufacturing industries, 1999-2007 . . . . .	85
2.5 Profit margin effect, volume effect, and operating exchange rate exposure . . . . .	87
2.6 Heterogeneity of exchange rate elasticities of profit margins, sale volumes and profits along market shares, French manufacturing industries, 1999-2007 . . . . .	88
2.7 Median output elasticities by sector, French manufacturing industry, 1999-2007	105
2.8 Domestic and export markups by sector, French manufacturing industry, 1999-2007	106



2.9	Exchange rate elasticities of marginal costs by sector, French manufacturing industry, 1999-2007 . . . . .	108
2.10	Exchange rate elasticities of markups by sector, French manufacturing industry, 1999-2007 . . . . .	108
2.11	Exchange rate elasticities of prices by sector, French manufacturing industry, 1999-2007 . . . . .	109
2.12	Exchange rate elasticities of profit margins by sector, French manufacturing industry, 1999-2007 . . . . .	109
2.13	Exchange rate elasticities of export volumes by sector, French manufacturing industry, 1999-2007 . . . . .	110
2.14	Exchange rate elasticities of profits by sector, French manufacturing industry, 1999-2007 . . . . .	110
<b>3</b>	<b>Competitive Exposure and Quality Upgrading</b>	<b>115</b>
3.1	Parameters . . . . .	138
3.2	Trade costs, fixed costs of exporting and exchange rates . . . . .	139
3.3	Quality indices: Equilibrium approach . . . . .	141
3.4	Quality indices: Demand approach . . . . .	141
3.5	Correlations between quality index adjustments and RER movements . . . . .	141
3.6	Predicted effects of real exchange rate changes on quality . . . . .	144
3.7	Quality and real exchange rate adjustments . . . . .	147
3.8	Quality adjusted prices and real exchange rate adjustments . . . . .	149
3.9	Quality, imported value added, competition and real exchange rate adjustments	154
3.10	Quality-adjusted prices, imported value added, competition and real exchange rate adjustments. . . . .	155

# Introduction

The increasing globalization of business activity makes exchange rate fluctuations a key component of corporate strategy. All firms, whether engaged in international markets or only operating in the domestic market, are affected by changes in currency values. While exchange rate swings form a key component of price competitiveness and investment choices for firms involved in commercial and financial foreign operations, even firms with no foreign currency transactions, debts, or assets can be exposed to foreign exchange: changes in exchange rate may, for instance, alter export opportunities and/or the level of competition from foreign competitors; or a domestic firm's customer base may include importing or exporting firms whose activities are affected by exchange rate changes [Bodnar and Marston, 2001]. Corporate managers and policy-makers have thus become increasingly concerned about exchange rate risk, and consider measuring and managing foreign exchange exposure as an important task in their endeavour to maximize profitability.

With this in mind, this thesis follows a dual objective. First, it aims to summarize previous evidence on non-financial firms' exchange rate economic exposure in [Chapter 1](#), and to provide new highlights on the heterogeneity of this exposure across firms in [Chapter 2](#). Second, this thesis investigates the product and production strategies that are appropriate for coping with the economic consequences of exchange rate changes on firms' operating profits. Since the range of these strategies is large, [Chapter 3](#) focuses on providing theoretical and empirical existing evidence for just the strategy of up-market positioning.

To begin with, it is useful to be more explicit on what precisely economic exchange rate exposure is, and how to measure it. In technical terms, economic exposure is the extent to which the value of a firm, as measured by the present value of its expected cash flows, changes when exchange rates vary. As such, it can indeed be decomposed into two components<sup>1</sup>: a transaction exposure,

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<sup>1</sup>To be more specific, three basic types of exposure are usually identified: translation exposure, transaction exposure, and operating exposure. Translation exposure, also known as accounting exposure or balance-sheet exposure, arises from the need, for purposes of reporting and consolidation, to convert the financial statements of foreign operations from the local currencies involved to the home currency. The measurement of accounting exposure is retrospective in nature, as it is based on activities that occurred in the past. Furthermore, this exposure is not real, as it only becomes material when the subsidiary closes. There is thus a broad agreement among theorists that translation losses and gains are only notional accounting losses and gains. Since the approach followed in this thesis is

which results from transactions that give rise to known, contractually binding future foreign-currency-denominated cash inflows or outflows; and an operating exposure, which measures the extent to which currency fluctuations can alter a company's future operating cash flows, i.e. its future revenues and costs. As highlighted in the first part of [Chapter 1](#), the formal definition of a firm's specific exchange rate exposure implies that the exposure can be zero only if the firm takes on foreign currency financial liabilities, or a short forward position in the foreign currency, equal to the present value of its operating profit's sensitivity to changes in the exchange rate. However, given that this hedging depends on a lot of factors independent to the firm, including financial market changes, it is hard to believe that exposure would be anything but different from zero. This is not to mention domestic firms, which have no transaction exposure by definition, but are nevertheless affected by changes in the domestic currency's value through at least their domestic competitive position.

From a theoretical perspective, exchange rate shocks should thus have a significant impact on firms' value, regardless of their domestic or international market orientation [e.g. [Hodder, 1982](#), [Levi, 1994](#), [Marston, 2001](#), [Shapiro, 1975](#)]. However, empirical research on exchange rate exposure appear conflicting, and have tended to document extremely low levels of incremental exposure at best (see [Table 1.5](#) in the Appendix). This has been considered somewhat of a puzzle. Nevertheless, since operational cash flows are difficult to measure, the exchange rate exposure of firms has been almost exclusively empirically addressed by a large financial literature, pioneered by [Jorion \[1990\]](#), which has examined exposure by studying how a firm's market value responds to changes in exchange rates [[Bodnar et al., 2002](#)]. While this "market-based" approach has its benefits, such as its flexible and forward-looking-based-expectation formation of the whole impact of exchange rate risk on a firm's value, it also has many limitations as a tool for assessing and managing exposure. These include notably its lack of an explicit modelization of firms' behavior, which impede interpreting the results in terms of economic behavior; the heavy assumption of capital markets' efficiency on which it relies; and the sample that it covers, which is by definition limited to large companies quoted on stock markets.

This thesis contributes to the partial resolution of this exchange rate exposure rate exposure puzzle in [Chapter 2](#), by providing a general micro-founded accounting framework and an empirical application that help to explain how and to what extent exchange rate fluctuations affect the profitability of heterogeneous import-competing and exporting firms. The theoretical framework has three particular features. First, in contrast to the majority of previous micro-founded models that focused either on pass-through or exposure, but did not study these two phenomena together, this framework takes into account the fact that, because pricing directly affects prof-

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real and prospective, and so based on cash-flows, it will rather focus on transaction exposure and operating exposure which combine to form a company's economic exposure. Note that the measurement of transaction exposure mixes the retrospective and prospective because it is based on activities that occurred in the past but will be settled in the future.

itability, the characteristics that determine pricing behavior also govern the exposure of firms' profits. In other words, exchange rate exposure and pass-through are closely related. Second, the theoretical analysis follows the recent trends in the pass-through literature and decomposes the response of a firm's markup and price to exchange rate shocks into two components [Amiti et al., 2015, Auer and Schoenle, 2016]: a response to its own marginal costs (idiosyncratic cost pass-through) and a response to the price changes of its competitor (strategic complementarity elasticity). Third, the model is the first to provide a decomposition of heterogeneous firms' operating exposure without any functional-form assumptions on market demand or on the competition environment. Therefore, the analysis can be applied to a large set of firms, industries, and destinations.

This framework implies that the exposure of a firm's operating profit to exchange rate shocks is related to the firm's pass-through rate, and it is decomposed into two components that are negatively correlated: a profit margin effect and a volume effect. The pass-through rate is shown to be U-shaped in market share, and thus, the exchange rate elasticity of profit margin and that of sales volume are U-shaped and hump-shaped, respectively. In other words, firms that face the lowest and the highest perceived demand elasticities incur a large loss of sales volumes, but almost no loss of profit margins. Conversely, medium-sized firms incur a large loss of profit margins, but this allows them to limit the fall in sales volumes. Note that these results apply equally well to any domestic and export market. Despite these non-monotonic effects, the impact of currency shocks on profits is linear on the whole. Using French firm level data over the period 1999–2007, the empirical study corroborates these theoretical predictions, and concludes that the euro appreciation had no effect on profits made by the largest French firms; however, it significantly reduced profits made by the smallest firms and medium-sized firms. Since the former accounts for a substantial amount of total sectoral profits, this finding provides a strong explanation for the "exchange rate exposure puzzle" found in previous empirical studies based on stock market or aggregate data.

After having discussed and provided new micro-founded evidences on heterogeneous firms' operating exchange rate exposure, the second part of this thesis focuses on studying strategies deployed by firms to cope with the economic consequences of exchange rate fluctuations on their competitiveness and profitability. Whereas firms can easily hedge transaction exposures with financial techniques, competitive exposure, which arises from competition with firms based in other currencies, requires making longer-term operating adjustments that help ensure profitability over the long run. As described in the second part of [Chapter 1](#), the scope of these competitive strategies is large, ranging from marketing to production initiatives. In particular, product strategies, which include notably new-product introduction or product line decisions, have been found to be an important leverage of competitive gains internationally.

Chapter 3 provides a contribution to this literature by developing a micro-founded theoretical background coupled with an empirical framework, which helps to explain how currency appreciations encourage firms to enhance product quality. The model builds on Melitz [2003] and Feenstra and Romalis [2014] to allow choices made by heterogeneous firms in terms of price, input and output quality to be endogenous, and analyzes the impact of a currency shock on these choices and the subsequent changes in the industry's equilibrium.

In this framework, firms' pass-through is shown to be incomplete, so that the demand for domestic products falls when the home currency appreciates. As a consequence, domestic firms upgrade the quality of their product to compensate for the loss in their price competitiveness, and so prevent their market shares and their revenues from falling. At the same time, this strategy of up-market positioning is made easier by the access to cheaper and higher quality inputs simultaneously allowed by the appreciation of the home currency. However, this quality-enhancing process is still costly, so that not all firms can afford such a strategic move. In the model, the zero-profit condition of Melitz [2003] therefore implies that the less competitive firms, which notably produce the lowest quality goods, are driven out of the market. This entails a reallocation of market shares towards the highest quality varieties, so that the average product quality at the industry level increases *ceteris paribus*. Interestingly, the magnitude of this effect is shown to be larger in industries with a high price elasticity of demand, as the latter experience the largest reallocation movements.

The model also predicts that exchange rate appreciations encourage firms to enhance the quality/price ratio of their products. This arises as long as the scope for product differentiation is positive, that is (i) in markets where the intensity of preferences for quality is high; (ii) in industries where firms can achieve a higher level of output quality at the expense of a small marginal costs increase; and (iii) in markets with moderate price elasticity of demand, i.e. nor perfectly vertically differentiated, neither horizontally structured.

The equilibrium quality and adjusted-quality price equations drawn from the theoretical model are then used to perform two alternative measures of product quality applied to a detailed database on goods traded by the euro area member countries worldwide over the period 1999-2007, and to test the predictions of the model. All the conclusions of the theoretical model are significant, and robust in terms of sign and magnitude. Chapter 3 finally analyses the channels mentioned above at the industry level. This last exercise leads to the following conclusion: currency appreciations diminish the mass of exporting firms and increase the share of the imported value added content of domestic industries' gross exports, and these two effects, in turn, increase the quality and the quality/price ratio of domestic goods.

This thesis also contributes somehow to the literature pioneered by Feenstra [1989], by emphasizing that enduring exchange rate movements lead to persistent shifts in the behavior of plants and entail irreversible real reallocation effects. Besides new proofs on competitive exposures and on the existence of an associated product strategy, the analysis as a whole indeed provides evidence of anti-competitive effects induced by currency appreciations: Chapter 2 emphasizes a reallocation of profits towards largest firms; while Chapter 3 implies not only a reduction of the mass of exporters as in Melitz [2003], but also a reallocation of market shares towards those producing the highest quality varieties.

Behind these reallocations, there is thus a story of structural changes that can strengthen or dampen sectors, and of a changing pattern of specialization, which may then have persistent long term effects on growth. This allows understanding why the impact of the exchange rate on economic activity is a central question of macroeconomics and economic policy in general.

The remainder of this thesis is organized as follows. Chapter 1 lays the foundation for the exchange rate economic exposure concept, and presents a literature review on the appropriate firms' strategies to cope with the economic consequences of changes in exchange rates on their competitiveness and profitability. Chapter 2 provides new evidence on the heterogeneity of operating exchange rate exposure by theoretically and empirically analyzing the impact of currency changes on heterogeneous firms' operating profits. Chapter 3 provides new evidence on firms' strategies implied by the impact of currency fluctuations on their competitive exposure, while focusing on the strategy of up-market positioning.



## Chapter 1

# Assessing and Managing Exchange Rate Economic Exposure: A Literature Review

*Ce premier chapitre fournit une synthèse de la littérature théorique et empirique étudiant l'impact des variations de change sur la profitabilité des entreprises non-financières, et les subséquentes stratégies de management du risque de change à leur disposition. L'exposition économique au risque de change a été surprenamment jusqu'à présent l'objet d'analyse d'une littérature quasi essentiellement financière, qui en a évalué l'ampleur en estimant économétriquement le degré de réaction de la valeur des actions boursières des grandes entreprises et des multinationales aux fluctuations de change. Ces études concluent que cet impact tend à être faible, tant de par son ordre de grandeur que de par la proportion des entreprises significativement exposées. Nombreuses sont celles qui en ont alors cherché des explications d'ordre méthodologique.*

*Ce faible résultat trouve cependant une explication fort rationnelle dans les stratégies de couverture financières et compétitives mises en oeuvre par les entreprises. En particulier, les opérations de couverture économique, qui permettent de se prémunir contre le risque de change à long-terme — et qui incluent notamment les stratégies de prix, de production, de marketing et de produits — sont largement utilisées par une vaste majorité de petites et moyennes entreprises, mais n'ont toutefois que fait l'objet de rares études d'impact économique jusqu'à présent.*



## 1.1 Defining and Estimating Exchange Rate Economic Exposure

### 1.1.1 Formal Definition

The general concept of exchange rate exposure refers to the degree to which a company's value in national currency is affected by changes in exchange rate [Adler and Dumas, 1984]. Two basic types of economic exposure are typically identified: transaction and operating exposure. Transaction exposure results from transactions that give rise to known, contractually binding future foreign-currency-denominated cash inflows or outflows. As exchange rates change between now and when these transactions settle, so does the value of their associated foreign currency cash flows, leading to currency gains and losses. Examples of transaction exposure for a French company would be the account receivable associated with a sale denominated in yens, or the obligation to repay a debt denominated in dollars. Some elements of transactions exposure, such as foreign-currency-denominated accounts receivable and debts are included in a firm's accounting exposure because they already appear on the firm's balance sheet. Other elements of transaction exposure, such as foreign currency sales contract that have been entered into but where the products have not yet been delivered, and so receivables have not yet been created, do not appear on the firm's current financial statements. Instead, they are part of the firm's operating exposure.

Operating exposure measures the extent to which currency fluctuations can alter a company's future operating cash flows, i.e. its futures revenues and costs. Any company whose revenues or costs are affected by currency changes has operating exposure, even if it is a purely domestic corporation and has all its cash flows denominated in home currency. Formally, the value of a firm  $f$  in its standard form, namely as the present value of the after-tax profit stream, with this assumed to be perpetuity, can be expressed as in Levi [1994] at any period  $t$  as follows:

$$V_{ft} = \frac{\tau}{\beta} \Upsilon_{ft} / \prod_{l=1}^{L_{ft}} E_{lt} X_{flt} \quad (1.1)$$

with  $V_{ft}$  the value of the firm;  $\Upsilon_{ft}$  its operating profits;  $\beta$  the risk-adjusted shareholder opportunity cost of capital;  $\tau$  the tax rate;  $E_{lt}$  is the nominal exchange rate between the home country and country  $l$ , defined as the foreign currency  $l$  price of one unit of the domestic currency; and  $X_{flt}$  the net monetary asset/liability position in currency  $l$  (negative for liabilities). This final term gives the home currency value of all foreign assets and liabilities, that is, the home currency value of foreign currency denominated financial assets or debts, as well as future commercial contracts. If one assumes that (i) a change in  $E_{lt}$  is real and permanent; (ii) the corporate tax rate is not affected by the exchange rate, which would be reasonable if corporate taxes are paid to the home government which cares about profit, not where or how the profit was earned; and (iii) the required shareholder rate of return is invariant to the exchange rate; the response of firm's value to a change in the exchange rate vis-à-vis currency  $l$  can be written as:

$$\frac{\partial V_{ft}}{\partial E_{lt}} \left[ \frac{2}{\beta} \frac{\tau + \partial \Upsilon_{ft}}{\partial E_{lt}} \right] / X_{flt} \quad (1.2)$$

Operating exposure and transaction exposure appear clearly distinct from equation (1.2). The former encompasses the competitive and indirect effects of exchange rate risk on the firm's operating, and as such, typically has a long-term dimension. It arises from changes in the firm's prices, volumes and marginal costs of domestic sales and exports, and those of its competitors, induced by exchange rate movements. The latter refers to the effects of changes in exchange rate on cash flows of specific identifiable foreign currency-denominated transactions, and arises because the value of the foreign currency may change from the time a transaction is contracted and the time it is actually settled. As such, it typically has a shorter-term dimension. The difference between the two is that transaction exposure is a contractual obligation, while operating exposure focuses on foreign currency cash flows generated from operation that might change because a change of exchange rates. Note also that, unlike transaction exposure, operating exposure can affect firms that are exclusively involved in domestic operations.

Equation (1.2) suggests that a lot of factors influence exposure. First, the net financial and (forward) contractual position of a firm in currency  $l$  determines its transaction exposure. Second, all factors that may influence the impact of currency fluctuations on a firm's profit, such as import and export pass-through, domestic and exports volumes of sales, imported intermediates costs - and thus, its competitive position in input and output product markets overall - also affect its economic exposure through operating profits. Formally, this microeconomic approach suggests that exposure can be zero only if the firm takes on foreign currency-denominated liabilities, or a short forward position in the foreign currency, equal to the present value of the after-tax firm's operating profits sensitivity to exchange rate changes, that is, only if:

$$X_{flt} \left[ \frac{2}{\beta} \frac{\tau + \partial \Upsilon_{ft}}{\partial E_{lt}} \right] \quad (1.3)$$

This is, of course, as it should be, but given that the hedging  $X_{flt}$  depends on much that the firm does not know, and is also influenced by financial market changes and other factors, it is hard to believe that exposure would be anything but different from zero. This is not to mention purely domestic firms which have, by definition, no transaction exposure but are still affected by changes in currency value at least through their domestic competitive position. From a theoretical perspective, currency changes should thus have a significant impact on firm value, regardless of whether the firm is domestically or internationally oriented [Hodder, 1982, Levi, 1994, Marston, 2001, Shapiro, 1975]. However, in contrast to theoretical expectations, empirical research on exchange exposure appears conflicting and is mixed at best.

### 1.1.2 The Empirical Exchange Rate Exposure Puzzle

Previous empirical studies have indeed tended to document extremely low levels of exposure to exchange rate movements for most firms, even when the firms examined have significant foreign operations. This has been considered somewhat of a puzzle [Bartram and Bodnar, 2007]. Since cash flows are operationally difficult to measure, this evidence on low firms' exchange rate exposure has been almost exclusively put forward by a large financial literature, pioneered by Jorion [1990], which has examined exposure by studying how firms' market value responds to changes in exchange rates [Bodnar et al., 2002]. The methodology used by this literature, nowadays part of the well known capital asset pricing models (CAPM), is presented in Appendix 1.A. In short, the exposure elasticity of firms or industries' value is obtained from a regression of stock returns on an exchange rate change, often with additional control variables such as a market portfolio return.

Table 1.5 in Appendix 1.B reports a summary of these firm and industry level studies. While these researches have so far documented weak contemporaneous relationships between exchange rates and US stock returns overall, evidence on other open economies yields more significant exchange rate exposure, even if the reported figures are low. Dominguez and Tesar [2006] find, for instance, that for five of the eight countries in their sample over 20% of firms are exposed to weekly exchange rate movements, and that exposure at the industry level is generally much higher, with over 40% of industries exposed in Germany, Japan, the Netherlands and the UK. Muller and Verschoor [2006] report that only 13% of the 817 European multinational firms in their sample experience significant exposure effects to the Japanese yen, 14% to the US dollar and 22% to the UK pound<sup>1</sup>. Overall, the review of this research suggests that a majority of these studies find significant exposures in just 10–25% of the cases, with marginally higher percentages for firms in open, export-oriented economies and nonlinear exposures. This level still appears to be below the prior expectations of the researchers based upon theoretical and anecdotal predictions.

Starting from Bodnar and Gentry [1993], a large part of the capital market studies has therefore focused on explaining this exchange rate exposure puzzle. In general, they suggest that while the market-based methodology has its benefits, such as a flexible and forward-looking-based-expectation formation of the whole impact of exchange rate risk on a firm or an industry's value, it also has many limitations as a tool for assessing and managing exposure. First, the market-based approach heavily relies on the assumption of efficient capital markets. In particular, investors are supposed to use all freely available information (past changes in the exchange rate, and past relations between exchange rate changes and a firm's value) to predict future changes in the firm's value from current exchange rate changes.

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<sup>1</sup>For other evidence on European firms, see also Bartram and Karolyi [2006] and Hutson and O'Driscoll [2010] who find that respectively 36% and 10% of firms in their sample are significantly exposed to exchange rate changes.

Second, a lot of practical issues with respect to the methodology used have been raised: the selectivity of the firms (targeted subsamples versus entire populations), the level of analysis (individual firms versus industry portfolios), the geographic coverage (single country versus multicountries), the choice of the dependent and control variables, the choice of the measure for exchange rates, and the data/return frequency. Finally, the capital market methodology is not based explicitly on a model of firms' behavior; so that it is difficult to interpret findings of low exposure in terms of economic behavior. However, the fact that a large percentage of firms are associated with insignificant exchange risk sensitivity may not be inconsistent with the theory. For instance, the multinational firms included in the samples are likely to have sizable operations and sourcing abroad, whose value might change in ways that offset changes in the values of the domestic export-oriented operations. In what follows, the three of these explanations for the exchange rate exposure puzzle are described, and the remaining gaps in the literature are highlighted.

#### 1.1.2.1 Methodological issues

The literature on exchange rate exposures has largely focused on attempting to solve the exposure puzzle on the basis of shortcomings in the way exchange rate exposures are estimated. These include the issues of the choice of the exchange rate variable and the control variables, the possibility of nonlinearities in the exposures, the allowance for a lag in the exchange rate-return relation, allowing for time variation of the exposure estimates, as well as changes in the return horizons used to measure the exposures.

The majority of the early exposure studies use a trade-weighted multilateral exchange rate. However, it can be argued that this exchange rate is not representative for individual firms and can lead to diversification effects across currencies, thus reducing the significance of the empirical exposure estimates. As a result, several studies use bilateral exchange rates to investigate the impact of the choice of the exchange rate variable on the results. However, this modification does little to change the prevalence of significant exposures among nonfinancial firms. Representative among these is a study by [Khoo \[1994\]](#), in which the percentage of Australian mining companies with significant exposures to individual exchange rates remains low: 8% for the U.S. Dollar, 12% for the South African Rand, 6% for the Japanese Yen, 18% for the British Pound, 4% for the German Mark, and 14% for the Mexican Peso. [Miller and Reuer \[1998a\]](#) also fail to find the use of bilateral rates improve the measurement of exposure. In looking at exposure to the Canadian Dollar, German Mark, Japanese Yen, Mexican Peso, Hong Kong Dollar and Korean Won, they do not find more than 15% of the firms with significant exposure to these currencies. [Bartram \[2004\]](#) is a natural experiment with respect to this issue in that he uses both bilateral and multilateral exchange rates. While the results using the bilateral rate between the Deutsche Mark and the U.S. Dollar provide a greater percentage of significant exposures, the difference is economically irrelevant with respect to solving the exposure puzzle.

Another issue consists of the choice of control variables for the exposure regression. Most studies have departed from the original [Adler and Dumas \[1984\]](#) model and, starting with [Jorion \[1990\]](#), include control variables, such as the return to a market index in the empirical specification for measuring exchange rate exposure. Such control variables can be useful in reducing the standard error of the regression and improving the precision of the exposure estimates. It also ensures that the exchange rate exposure estimate captures only those influences of the exchange rate movements that are not correlated with the control variables. As noted by [Doukas et al. \[2003\]](#), the association between endogenous variables, such as stock market returns and exchange rates, may however just reveal the simultaneous influence of monetary factors or exogenous shocks on exchange rates and stock returns. That is, if exchange rates and stock returns are generated by a set of common macroeconomic factors, stock prices should be responsive to unanticipated exchange-rate changes, after controlling for the influence of common macroeconomic factors. As a result, currency exposure tests have also relied on an econometric process of orthogonalization that is achieved through the estimation of the residual market factor that is not explained by the set of predetermined macro variables, including the unexpected exchange rate change (see [Appendix 1.A](#))<sup>2</sup>.

At the same time, it must be recognized that the use of control variables makes the exposure estimates “residual exposures” rather than “total exposures” that arise from the regression without control variables. This difference in research design can result in significant differences in the distribution and resulting interpretations of the sign, size, and significance of the firms’ exposure estimates depending on the correlation of the control variables with the exchange rate [[Bodnar and Wong, 2003](#)]. Naturally, studies that use exchange rate variables as the only explanatory variable of stock returns, or orthogonalize the market index, yield higher significance for exchange rate exposures, because in this setting the exchange rate variable picks up additional effects that may be correlated with exchange rates, but that can hardly be interpreted economically as exchange rate risk. To illustrate, [Kiymaz \[2003\]](#) finds that 46.8% of the 109 firms studied are significantly affected by exchange rate risk for estimations without market index, and 61.5% show significant exchange rate exposures when using the residual market index that is orthogonal to the exchange rate variable. However, in general this practice does little to alter the situation of a lower prevalence of exchange rate exposures than expected by the motivation of the paper, and few other papers seem to choose to orthogonalize the control variables with respect to the exchange rate. Studies that orthogonalize the exchange rate variable with respect

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<sup>2</sup>The common macroeconomic factors reflect the persistent impact of business conditions on the foreign exchange and stock markets. To the extent that economic agents form expectations about exchange-rate and stock market movements based on information that is available to them at the beginning of each period, exchange rates will adjust in response to changing economic conditions and their changing currency risk perceptions. This implies that exchange rate and stock market changes must be expressed as functions of a set of macroeconomic variables that determine the way expected exchange-rates and market returns vary systematically through time. Note that the orthogonalization used is also motivated by the widely-held view that foreign exchange market movements are more likely to influence the stock market, rather than being influenced by stock market changes. Investors’ ex ante conditioning information can be expressed in terms of instrumental variables.

to the control variables typically do not find different results for exchange rate exposures compared to using the control variables and complete exchange rate variable [e.g. [Choi and Prasad, 1995](#)].

Another explanation of low significance of exchange rate exposures consists of the observation that the traditional approach to estimate exposures only assesses the linear exposure component, but does not consider non-linear or asymmetric exchange rate exposures with respect to appreciation/depreciation periods [[Bartram, 2004](#), [Bartram et al., 2010](#)]. In fact, the exposure may be in part non-linear due to corporate cash flows being a non-linear function of exchange rates. While several studies investigate non-linear and asymmetric features of exchange rate exposures [[Bartram, 2004](#), [Koutmos and Martin, 2003](#), [Miller and Reuer, 1998b](#)], the evidence does not fully resolve the exposure puzzle either, as non-linear exposures appear more significant, but still only for a limited number of firms. To illustrate, [Bartram \[2004\]](#) documents significant linear exposures to a trade-weighted exchange rate index for 8% of the sample firms in Germany as one of the most export-oriented economies in the world, while 11.5% exhibit a significant nonlinear exposure. [Miller and Reuer \[1998b\]](#) study all U.S. manufacturing firms during the period 1988-1992 and analyze exposure separately for appreciating and depreciating currency movements. They find the following fractions of firms with significant exchange rate exposure for currency appreciations (depreciations): 2.9% (2.5%) for the Canadian dollar, 8.0% (5.8%) for the Japanese yen, and 9.1% (5.0%) for the Mexican peso. This evidence indicates some, but limited evidence for non-linear/asymmetric exposures that is marginally more significant than the linear ones.

Other studies look at the effect that different time horizons for the return calculation have on the significance of exposures [[Bodnar and Wong, 2003](#), [Chow et al., 1997a,b](#)]. The results of these studies suggest that the percentage of significant exposures rise as the return horizon lengthens. While the change is relatively minor for return horizons of up to 24 months, the effect becomes very noticeable at long horizons of 36 – 60 months as the percentage of firms with significant exposures often rises to more than 50%. Nevertheless, the increase of exposures with horizon is likely due to the fact that the exchange rate changes (in real terms in these studies) tend to mean revert towards zero with time due to purchasing power parity, while the real equity returns they are attempting to explain theoretically grow linearly with time. These results suggest that noise in short horizon returns is probably a contributing factor for the low prevalence of significant exposures in the literature, but estimating exposure at very long return horizons is not always a feasible option<sup>3</sup>.

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<sup>3</sup>A related issue related to the construction of the exchange rate variable is the implied assumption that the simple change in the exchange rate is the correct variable to measure exchange rate exposure. The use of the simple change as the appropriate exchange rate variable implicitly assumes that the expectation for the future level of the exchange rate is the current exchange rate (simple random walk assumption). While this has been shown to be reasonable as a short term forecast for nominal exchange rates, it is likely to be less appropriate for real exchange rates, especially if the market maintains an assumption of long run mean reversion of the relevant real exchange rate towards some equilibrium level (say a Purchasing Power Parity level).

### 1.1.2.2 Capital markets' behavior

The difficulties in relating either exchange rates or equity prices to the present value of expected future fundamentals have led some to suggest that both are the outcomes of the workings casino. If equity prices and exchange rates are the outcomes of the roulette wheels of two casinos, why should one expect there to be any relationship between the two? This explanation however, is not particularly satisfying, since it leaves little or no room for further inquiry.

Prior research that focused on monthly stock returns may have failed to detect exposure because short-horizon returns contain errors made by investors in forecasting the long-term effects of current exchange rate changes. [Bartov and Bodnar \[1994\]](#) find evidence that investors do not use all freely available information, that is for instance, past changes in the currency's value and past relations between changes in the exchange rate and firm value, to predict future changes in firm value from current exchange-rate changes. Consequently, estimation errors are corrected and reflected in stock returns only when information about the effects of exchange-rate changes on future cash flows is revealed over time. Utilizing long-horizon exchange rate changes and asset returns may be more informative about the relationship between these variables than short-horizon measures because of the complexity faced by the investor with modeling and forecasting the relationship between firm value and fluctuations in the dollar.

Thus, in addition to contemporaneous exchange rate effects, some studies have investigated potential mispricing of exchange rate effects. The examination of lagged exchange rates is justified by the fact that the exposure relation within a firm is often complex and the disclosure of company information detailing these effects typically takes place with some delay and may thus be fully reflected in stock prices only with a time lag. Moreover, the assessment of the impact of exchange rate risk is a highly complex issue, since market participants have to distinguish between temporary and permanent exchange rate effects. [Amihud \[1994\]](#) detects some evidence of lagged exposures in his study of the largest U.S. exporters, both at monthly and quarterly horizons. [Bartov and Bodnar \[1994\]](#) find significance for lagged exchange rate variables for a selected sample of U.S. firms. [Bartov and Bodnar \[1995\]](#) relate the lagged exposure to the choice of accounting methodologies and document it diminishing over time. Several other studies [[Donnelly and Sheehy, 1996](#), [Walsh, 1994](#)] find only weak significance for lagged exchange rates and, in contrast, most others considering this possibility find no significant lag variables and are thus in line with the market efficiency hypothesis [e.g. [Amihud, 1994](#)].

### 1.1.2.3 Firms' behavior

Given the difficulty of the variation in methodological approaches in raising the percentage of significant exposures to a level consistent with researchers' priors, the possibility that these priors are the source of the puzzle might be considered. As mentioned above, the market-based

approach is not explicitly based on a model of firms' behavior, but the low estimated exchange rate exposure reported by the studies is not necessarily inconsistent with the theory.

The priors that researchers have formed on the percentage of firms with significant exposures based upon measurable operational features may not fully take into account the fact that firms endogenously make rational decisions to reduce these exposures through exchange rate risk management techniques. It is precisely the most exposed firms that will be most likely to use these methods most intensively, reducing their exposure to less significant levels. Hence, both firms with low underlying exposure that do not need to hedge, as well as firms with large underlying exposures that employ one or several forms of hedging, may exhibit only weak exchange rate exposures net of hedging.

More specifically, there are two ways in which firms can mitigate the impact of exchange rate changes on their profitability (see [Table 1.1](#)). The first is that the firm can structure its operations, so that the firm is operationally hedged against exchange rate fluctuations. The other method is the use of financial hedges to take financial positions to offset inherent exposures, so that the overall profitability and reported performance of the firm is less sensitive to exchange rate movements. Both techniques, as well as their impact on firms' exchange rate exposure, are described in more detail in [Section 1.2](#) of this chapter.

**Table 1.1: Classification of hedging instruments**

Operational Hedges	Financial Hedges	
Natural Hedges		Derivative Hedges
<ul style="list-style-type: none"> <li>■ Choice of invoicing currency</li> <li>■ Pricing policies (pass-through)</li> <li>■ Production strategies, includ. overseas diversification; input mix; plant locations etc.</li> <li>■ Product strategies, includ. new product introduction; product line decision; product innovation.</li> </ul>	<ul style="list-style-type: none"> <li>■ Foreign currency debt</li> </ul>	<ul style="list-style-type: none"> <li>■ Forward contracts</li> <li>■ Futures contracts</li> <li>■ Options</li> <li>■ Others</li> </ul>

Source: Adapted from [Döhring et al. \[2008\]](#)

Given the apparent necessity to take into account exchange rate risk management strategies in order to properly assess the gross (pre-hedging) exposure, some studies have followed a cash flow approach, employing a simple model to measure a firm's economic exposure without using stock return and market return data. Pioneered by [Bodnar and Marston \[2001\]](#), this approach uses perfect market assumptions and derives from a standard model of firm value an expression for the foreign currency exposure elasticity of a home currency firm's operating profits,  $\frac{\partial \Pi_{ft}}{\partial E_{it}}$  in



(1.3), as a function of just three inputs:

$$\frac{\partial \Upsilon_{flt}}{\partial E_{lt}} \left[ \frac{\mathcal{U}_{1,flt}}{\mathcal{U}_{1,flt} - \mathcal{U}_{2,flt}} \right] \phi_{flt}^{-1} \quad (1.4)$$

with  $\mathcal{U}_{1,flt}$  the share of foreign currency  $l$ -denominated revenue in the firm's total revenue;  $\mathcal{U}_{2,flt}$  the share of foreign currency  $l$ -denominated costs in total costs; and  $\phi_{flt}$  the profit margin in currency  $l$ . Equation (1.4) is very intuitive, as it indicates that greater foreign currency revenues (costs) lead to a greater increase (decrease) in firm value in response to a depreciation of the home currency. Note that in this framework, the partial derivative of the firm's operating exposure with respect to  $\phi_{flt}$  is a negative function of the net foreign currency revenue position of the firm  $\mathcal{U}_{1,flt} - \mathcal{U}_{2,flt}$ . The basic effect is that an increase in profit margin makes the exposure elasticities smaller in size (i.e. closer to zero). This arises because an increase in profit margin increases firm value without changing the nominal value exposure, which is purely a function of the net foreign currency position.

This simple model has not been extensively used in the literature, but it appears to be a very effective tool to measure competitive exposure, especially when the exposures of the unlisted firms are to be measured where the stock return data are not available. In addition, unlike the market-based approach, the cash flow approach expressed in (1.4) allows to actually predict (and not assess a posteriori) the sign of a firm's exposure. Using firm-level data, a few studies have thus employed this methodology to evaluate exchange rate exposure, and have compared these theoretical exposures to the Jorion [1990]'s regression exposures. These studies are summarized in Table 1.6 in the Appendix. In general, the estimated regression exposures obtained from stock returns are smaller than the predicted theoretical exposures. As argued by Bartram et al. [2010], this is particularly the result of firms with high model exposures undertaking exchange rate risk management, or undertaking it to a greater extent.

The cash flow approach in (1.4) suggests indeed how a firm's operations in terms of costs and revenues can vary the size of its exposure elasticity. However, it assumes no strategic response on the part of the firm in response to the new competitive environment, post exchange rate change, in particular in terms of pricing strategy and market positioning. Bodnar et al. [2002] and Bartram et al. [2010] are the only two cash flow-based studies, to the extent of our knowledge, explicitly relating a firm's pass-through rate to its exposure. However, their model assumes implicitly constant market share and markup over-time. This particularly rules out the possibility of heterogeneous behavior between firms, which may explain the low level of exchange rate exposure found in the data (see Section 1.2.2.2 in this Chapter). Chapter 2 provides a contribution to this gap in the literature by explicitly formalizing how a firm's strategic response to a change in market competition in terms of markup and costs determines its competitive exchange rate exposure.

## 1.2 Managing Economic Exposure

As mentioned in the previous section, the main difference between transaction and operating exposure is that, transaction exposure disturbs the present cash flows, while operating exposure is a long-term risk. Therefore, the management risk techniques that are appropriate for coping with the economic consequences of both exposures are different. The transaction exposure can be effectively minimized by various tools, including financial instruments such as currency options, currency futures, cross currency swaps, or non-financial techniques such as foreign-currency loans. Hedging operating exposure requires firms to react to the new competitive environment implied by the predicted permanent changes in exchange rates, and to modify their economic behavior correspondingly. This may involve reconsidering pricing, production or product strategies.

### 1.2.1 Financial Hedges

Firms can first neutralise exchange rate exposure through financial instruments, such as exchange rate derivatives or foreign currency debt. The standard derivative instruments are available both "over-the-counter" (OTC), i.e. non-exchange traded and with the contractual parties freely choosing amounts and maturities, and in the form of exchange-traded products. OTC instruments comprise forwards, swaps and options, while the most common exchange-traded instruments are futures and options (see [Box 1.2.1](#)). It should be noted that while standard products, in particular forwards, allow easily to hedge translation exposure, their effectiveness to manage economic exposure overall has been largely questioned.

Hedging through financial derivatives becomes indeed more difficult for the longer term, because the future cash flow may be uncertain. Applying standard products to uncertain future cash flows thus creates the risk of over- or underhedging. What is more, standard products for the long run may not be available (futures) or quite expensive (options). It is true that derivatives with short maturities can in principle be "rolled over" to cover long-term exposure. However, rolling over short-term instruments does not eliminate risk in the same way as an instrument with the correct maturity would. Finally, even perfect derivative hedges can lead to temporary losses between the moment of purchase and their maturity due to accounting practices and obligations to "mark to market". Although such losses are temporary and unrealised, they can constitute a significant drain on a firm's liquidity<sup>4</sup>.

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<sup>4</sup>An example illustrates the limitations of derivative hedges when it comes to economic risk. Consider a euro-area exporter who regularly receives orders for sales denominated in US dollar. As the time between the order and final delivery (payment) is several years, the exporter "locks in" the EUR-USD exchange rate using exchange-rate forwards each time an order is firmly committed. However, the forward exchange rate varies over time. Therefore, the value in euro of equivalent hedged US dollar sales differs depending on the forward rate at which the transaction was hedged. In the case of a prolonged appreciation of the euro against the US dollar (assuming a constant interest-rate differential), the exporter thus has to accept less favourable forward rates for its exchange rate hedges, cutting into its profit margin.

Natural hedges are an alternative way of reducing exchange rate exposure. Typically, the matching of foreign-currency assets with foreign-currency liabilities offers protection against transaction exposure. As compared to derivatives, foreign currency loans can easily cover longer maturities, e.g. a European firm with access to international capital markets may hedge future revenues in US dollar by issuing a US dollar bond. However, as in the case of forward derivatives, the risk of over- or underhedging still exists given the uncertainty of future operational cash flows. In addition, hedging through foreign currency loans is almost by definition the domain of large multinational companies that have the capacity to relocate, to tap international financial markets and dispose of internationally accepted collateral.

Consistent with this view, it is known from survey evidence that firms who recognize that they have an exposure to exchange rates are active users of financial derivatives [e.g. Bartram, 2004, Bodnar et al., 1998, 2003]. In addition, the use of financial hedges is positively related to firms' size, probably due to fixed costs for setting up a hedging function. For the US, evidence on hedging has been gathered in the "Wharton Surveys for Financial Risk Management" carried out between 1994 and 1998 among large non-financial firms and published in several articles by G. Bodnar.

#### Box: Derivatives Instruments

**Forwards and futures** A forward foreign exchange rate contract is an agreement to buy or sell a given amount of foreign currency at a certain point in time at an exchange rate fixed today. Forward contracts are traded "over-the-counter", in tailor-made amounts and maturities. Their standardised and exchange-traded equivalents are called exchange rate futures. For instance, the contract traded at Euronext-Liffe has a nominal amount of USD 20,000 and maturities of 1, 3, 6, 9 and 12 months and 3 years. The disadvantage of futures for hedging stems from the difficulty of matching maturities and amounts exactly to the underlying exposure. Moreover, they exist only for the most common currency pairs.

**Swaps** Cross-currency swaps exchange a cash flow in one currency against a cash flow in another currency. If, say, a multinational enterprise wishes to issue a bond to finance a subsidiary in an emerging market country, it may obtain best financing conditions by issuing a bond denominated in euro, rather than in the local currency of its subsidiary and then use a swap to convert the payment of interest and principle into the relevant local currency.

**Options** Whereas a forward or future contains the contractual obligation to deliver at the agreed time and forward rate, an option offers a choice. The option protects the exporter against adverse moves in the exchange rate without removing the opportunity to benefit from favourable movements. Put differently, hedging with an option leads to an asymmetric risk distribution. The seller of the option, however, faces a loss if the option is exercised and has no gain if it is not exercised. In order to compensate for this risk, he will demand a premium (rather like an insurance premium) for writing the option. There also exist more complex constructions such as "exotic" options or combinations of several simple options. It is possible, for instance, to reduce the option premium by combining sell and buy options with different strike prices. Of course, this also implies a more complex risk structure.

The results are reported in Table 1.2 below<sup>5</sup>. Bodnar et al. [2003] report that while 90% and 75% of the largest US and Dutch firms use financial derivatives, only 18% and 50% of the smallest firms use financial exchange rate risk techniques, respectively. Bodnar and Gebhardt [1999] find comparable results for US and German firms. Finally, empirical evidence suggests that the usage of financial exchange rate risk techniques is concentrated in firms with significant foreign operations, while the usage of operational techniques are largely more extended [Allayannis and Ofek, 2001, Bartram et al., 2009, 2010].

Are financial risk techniques efficient to hedge exchange rate exposure? While this effect is difficult to study empirically as it requires controlling for the firms' pre-hedging exposure, market-based studies tend to report mixed evidence on the effectiveness of financial derivatives and foreign-currency debt to reduce the estimated exchange rate exposure. In a survey of Swedish firms, Hagelin and Pramborg [2004] find, for instance, that derivative hedging as well as hedging with foreign-currency denominated debt reduce both transaction risk and translation risk. Using a sample of 1,150 firms in 16 countries, and comparing the coefficients from regression exposures to theoretical exposures (see Section 1.1.2.3), Bartram et al. [2010] find that financial risk management, i.e. foreign-currency debt and foreign exchange derivatives, accounts for about 40% reduction in exposure. However, the effectiveness of financial hedges is disputed, for instance, by Jong et al. [2006], who use a sample of Dutch firms. Their results suggest that off-balance hedging using derivatives has no significant effects, while on-balance sheet hedging, i.e. through foreign loans and by producing in factories abroad, does reduce firms' exposure.

Table 1.2: Percentage (%) of firms using financial derivatives, by firms' sales in USD millions

	Bodnar and Gebhardt [1999]		Bodnar et al. [2003]	
	United States 1995	Germany 1997	United States 1998	Netherlands 1998
>6600	90	75		
3300-6600	73	94		
1660-3300	57	88		
660-1660	64	84	>800	82
330-660	44	55	250-800	46
<330	18	50	<250	12

Source: Adapted from Döhning et al. [2008]

<sup>5</sup>The 1998 survey finds 44% of respondents used financial derivatives, 79% of which used them to hedge currency risk; 73% hedged interest rate risks; and 44% commodity risks.

### 1.2.2 Operational Hedges

Most international finance textbooks argue indeed that the first-best way for a firm to permanently deal with exchange rate exposure is to consider the structure of their operations. Unlike financial hedging, which provide firms with a deterministic cash flow response to exchange rate movements without any real economic actions, operational strategies require indeed firms to react to the new economic environments resulting from the exchange rate change, and to modify their economic behavior. This involves (re)considering the mix of outputs, inputs and locations of production in such a way as to minimize the net exposure to exchange rates, subject to the adjustment and operating costs of such structures.

Domestic-currency invoicing is of course one of the first ways allowing to shift exchange rate risk to counterparts abroad. However, once economic-risk and market structures are also taken into account, it becomes less certain that an exporter always has an interest in using domestic currency invoicing. For a firm with foreign currency revenues from export sales, i.e. invoicing in local currencies or in a vehicle currency, matching cash flows in each currency might entail diversifying operations to include importing operations, structuring sourcing to make greater use of foreign currency based inputs, or in the extreme to move the production of foreign sales to foreign markets by becoming a multinational firm.

#### 1.2.2.1 Domestic currency invoicing

When major exchange rates became flexible after the breakdown of Breton Woods in 1973, the first question of interest was who was to bear the exchange rate risk in trade when exchange rates were flexible. It was assumed then that a risk-averse exporter preferred to invoice in his own currency - producer currency pricing (PCP) - and the main findings in the early literature were: first, that trading firms seek to avoid currency risk by using their own currency; and second, that trade in manufactured goods between industrialised countries is mostly invoiced in the exporter's currency because he enjoys a first-mover advantage in bargaining ([Grassman \[1973\]](#)'s law).

While PCP clearly allows to reduce translation exposure, the exporter who invoices in his own currency runs however the risk of a reduction in demand when the currency appreciates, if prices do not adjust instantly. This arises because if prices are set before the exchange rate fluctuations are known, and orders are placed after the shock to the exchange rate, the "*seller does not know the effective price at the time the importer will make its purchases*" [[Baron, 1976](#)]. As highlighted by [Kamps \[2006\]](#), there is thus price uncertainty when exports are priced in the local currency (LCP), as the exporter does not know which price in his own currency he will receive, and demand uncertainty when the exporter chooses PCP.

Given this trade-off between price and demand uncertainty, a large theoretical literature — pioneered by McKinnon [1979] — has therefore tried to distinguish the determinants for invoicing. The basic intuition is related to the type of tradables concerned. For a differentiated good, a firm can set the selling price as it faces a downward sloping demand curve, while for homogeneous goods, the exporter is a price taker and more likely to choose the local currency. The recent work of Bacchetta and Van Wincoop [2005] confirms that the degree of product differentiation, which in turn affect the demand elasticity, is the main factor driving the choice of the invoicing currency. Note that this implies that there are therefore two distinctive sets of determinants for invoicing. If the firm is trying to avoid demand uncertainty, then the choice of LCP is determined by microeconomic considerations concerning the demand and cost structure. However, if the firm is more concerned about price uncertainty, because the demand for its goods is less price sensitive, macroeconomic considerations such as the liquidity and the volatility of currencies, local inflation, and transaction costs, will play the decisive role. In some case, it may even be optimal for an exporter of homogeneous goods to align himself to the same invoicing currency as his main competitors, which may lead to using a vehicle currency [Goldberg and Tille, 2008].

Because of all these micro and macro-economic considerations, the actual use of domestic currency invoicing varies greatly across countries worldwide. With respect to the euro area member states, the European Central Bank compiles and provides some figures on the actual use of the euro as invoicing currency, which are summarized in Table 1.3 below. The euro is today the dominant invoicing currency for euro-area exports of goods outside the Eurozone, but the US dollar also plays a significant role. The share of imports invoiced in euro is lower than the share of exports in all member states for which the data are available, which is in line with the Grassman [1973]’s law. Correspondingly, imports of goods from outside the Eurozone denominated in US dollar as vehicle currency plays an important role, probably due to the high share of commodities imports. An important implication of these figures in terms of exchange rate exposure is that the majority of exports and imports of goods traded with partners outside the euro-area are either invoiced in euro, or in US dollar, so that invoicing in other currencies only plays a minor role.

As mentioned above, from the perspective of the early models of invoicing, euro invoicing allows european firms to eliminate transaction exposure, much like hedging with an exchange-rate forward. Invoicing is then a substitute to derivate hedging, and firms would be expected to opt for the one or the other depending on the relative cost of these strategies. In the more sophisticated models of invoicing however, firms consider both transaction exposure and economic exposure when deciding on the currency for invoicing, making the decision of hedging more complex. As argued by Friberg [1998], the existence of forward currency markets makes foreign-currency invoicing more attractive; hedging and invoicing may become complements. For instance, an exporting european firm faced with high price-sensitive demand can use US dollar invoicing to

reduce economic risk, while at the same time eliminating transaction exposure through derivative hedges.

**Table 1.3: Invoicing currency (in %) of euro area exports and imports of goods vis-a-vis non-euro area trading partners**

		BEL	DEU	FRA	ITA	LUX	NLD	PTG	ESP
<b>Exports</b>	<b>EUR</b>	55.0	61.0	50.0	57.3	54.0	52.0	55.8	61.0
	<b>USD</b>	34.0	23.9	39.5	37.5	32.7	35.2	35.9	31.2
<b>Imports</b>	<b>EUR</b>	51.9	55.2	42.9	37.7	44.1	48.0	51.2	53.8
	<b>USD</b>	40.7	37.1	46.5	59.5	40.9	43.8	43.8	43.8

Source: European Central Bank (2006)

### 1.2.2.2 Pricing Strategy

The currency in which goods are priced has also important implications for the pass-through of exchange rates into traded goods prices, which is another mechanism at firms' disposal to mitigate economic exposure. In early open macroeconomic models, the currency of pricing is exogenous, and in the short run, when prices are rigid, pass-through into the price of goods invoiced in the producer's currency is 100%, and it is 0% for goods priced in local currency. However, when prices adjust, there is no difference in pass-through.

A large literature on optimal currency choice, as surveyed in [Engel \[2006\]](#), has nevertheless presented an important equivalence result between optimal pass-through and the optimal invoicing currency, and showed that the difference in pass-through between PCP and LCP firms persists even conditional on adjusting prices. The intuition for this result is as follows: If prices adjust at every period, currency choice is irrelevant. However, when prices are sticky, firms that must set prices in advance will choose PCP (so that ex post, there is 100% pass-through) exactly when their price would exhibit high pass-through if they were set flexibly, and they choose LCP (zero ex post pass through) exactly when their prices could display low pass-through under flexible prices. In other words, the higher is the desired pass-through, the higher are the gains from pricing in producer currency compared to local currency<sup>6</sup>.

<sup>6</sup>See also [Gopinath et al. \[2010\]](#) who provide a dynamic multi-period staggered price setting model and yield the same conclusion.

An important implication of these models is that a firm's optimal currency choice and pricing strategy implemented to deal with economic exposure are completely dependant on the firm's market power and price-elasticity of demand, since they are both crucial determinants of the extent of the desired pass-through. The key issue for the firm that must be addressed is whether to emphasize market share or profit margin. Following an appreciation of the euro, for instance, a French firm will loose competitive price advantage worldwide. The French exporter then has the option of lowering its euro price and reducing its profit margins, or keeping its euro price constant and shriking its market share<sup>7</sup>. The decision is influenced by several factors, such as whether this change is likely to persist, economies of scale, the cost structure of expanding output or consumer price sensitivity. In particular, the greater the firm's perceived price elasticity of demand, which depends particularly on the firm's market power [e.g. [Bresnahan, 1989](#)], the greater the incentive to reduce the price, and thereby shrinking profit margin. Of course, in general the exchange rate pass-through is not likely to be either complete or zero, so that both profit margins and sales volume will adjust.

One of the main contribution of this thesis is related to this relationship between a firm's economic exposure and exchange rate pass-through. Indeed, as compared to financial hedging, little is known so far empirically on the extent to which pricing strategy allows firms to mitigate their economic exposure. In particular, the only two theoretical studies explicitly incorporating pass-through behavior and industry competition as important determinants of exposure, [Bodnar et al. \[2002\]](#) and [Bartram et al. \[2010\]](#), analyse the impact of pricing strategy on a firm's economic exposure by holding market share and markup constant. In this framework, [Bartram et al. \[2010\]](#) show that depending on the level of product substitutability, pass-through reduces exposure by about 10% to 15%.

In contrast, the theoretical model presented in [Chapter 2](#) allows marginal costs, markups and market shares to vary over time; so that a firm's competitive exposure is related to its pass-through rate, which depends itself on both the firm's own marginal costs (idiosyncratic cost pass-through) and the price changes of its competitor (strategic complementarity elasticity). In addition, the firm's exposure is decomposed into two components negatively correlated: a profit margin effect and a volume effect, as described above. In this framework, the theoretical model provides evidence on heterogeneous pricing strategies across firms depending on their market power, and shows how these diffences in pricing behavior implies various degrees of competitive exposure management.

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<sup>7</sup>Note that the same reasoning applies to domestic pricing, even if domestic firms facing import competition may have much greater latitude in pricing. After an appreciation of the euro for instance, a French firm facing stronger foreign competition on the French domestic market. It then has the choice of potentially raising prices consistent with import prices increases, or of holding prices constant in order to improve market share.



### 1.2.2.3 Production Strategies

By its very definition, operating exposure is the impact of exchange rate changes on a firm's actual operations. Therefore, the first place to consider how to manage this exposure is to consider operation responses to exchange rate changes. Ideally, a firm would like to set up its operations, production and sourcing, such that the firm can respond to change in exchange rates so as to take advantage of the improved competitive position, and/or limit the harm caused by the degradation of competitiveness. In the long-term, a complete operational hedge would consist, for instance, of offshoring production and sourcing to the destination market in order to match revenues and costs in each currency as best as possible, or to tie costs more closely to that of foreign competitors. As noted by Shapiro [2008], product sourcing and plant location are the principal variables that firms manipulate to manage competitive exposure, but this can be accomplished more than one way.

**Plant location** The most obvious way to be able to take advantage of relative costs changes due to real currency movements is to have production costs based in different currencies, by actually having production capacity in different countries. The simplest response for a firm is to move production to competitors market, so that any relative cost advantage they may gain from changes in exchange rates will also accrue to the firm as well. Alternatively, placing a plant in a third-country based upon the intensity of some inputs to production, i.e. labor or raw materials, may make more sense; however, the firm needs to think about the correlations between the third country exchange rate and that of its foreign competitors' to evaluate the hedge value of such a decision. The relative advantages of a third-country plant location also depend on the labor intensity of production or the projections for further monetary realignments. As noted by Shapiro [2008], many Japanese automakers, such as Toyota, shifted production offshore in the beginning of the 1990's – to Taiwan, South Korea, Singapore, as well as to the United States – in order to cope with the high yen. Although it made companies less vulnerable to a strong yen, it meant less of a payoff when the yen began to weaken in 1995, so that Japanese manufacturers with foreign production facilities found they could not take full advantage of the yen's fall.

**Shifting production among plants** The primary advantage to having plant locations arises from the ability of the firm to shift production among the plants in response to currency movements. Firms with worldwide production systems can indeed allocate production among their several plants, in line with the changing value of the domestic currency, increasing production in a nation whose currency has devaluated and decreasing production in a country where there has been a reevaluation. However, the theoretical ability to shift production is limited in reality, depending on many factors, not the least of which is the local labor unions involved. In addition, the cost of multiple sourcing may be particularly high when there are economies of scale that would ordinarily dictate the establishment of only one or two plants to service the global market. However, faced with the volatility of exchange rates, some firms may find significant

benefits in production diversification, which allows them to execute volume shifts fairly easily. Thus, despite the higher unit costs associated with smaller plants and excess capacity, currency risk may provide one more reason for the use of multiple production facilities. [Choi and Prasad \[1995\]](#) take the example of Hewlett Packard, which derived in 1994 approximately 50% of its revenues from foreign markets, but had production facilities in more than ten countries, and thus displayed an insignificant exchange risk sensitivity coefficient in their studies.

**Input Mix** A more flexible solution to deal with an appreciation of the home currency is to change the input mix by purchasing more components overseas. Following an appreciation of the euro for instance, European companies can take advantage of falling import prices to increase their global sourcing. While there are only few studies focusing on currency movements, a large body of work initiated by [Amiti and Konings \[2007\]](#) has investigated the relationship between trade liberalization episodes and the use of imported intermediate inputs, and have showed that a decline in tariffs provides indeed domestic firms with greater access to cheaper and new imported input varieties [[Goldberg et al., 2009](#)]. By increasing their share of imported inputs when the domestic currency appreciates, firms have the means to naturally hedge against the negative effects of changes in the exchange rate on their competitive position and profits. This arises both because a share of this exchange-rate-induced cost reduction is translated into a partial decrease in output price, so that their market share decreases less, and because the remaining share is used to stabilize profit margin [[De Loecker and Koujianou, 2014](#)]. In line with this theory, [Amiti et al. \[2014\]](#) find that the largest exporters are simultaneously high-market-share and high-import-intensity firms, which helps explain the low aggregate pass-through and exchange rate disconnect observed in the data. Consistently, [Greenaway et al. \[2010\]](#) investigate a panel of UK manufacturing firms and suggest that the negative effect of an exchange rate appreciation on firm exports is lower in industries that import a greater share of inputs. Similarly, [Berman et al. \[2012\]](#) find a positive "natural hedging" effect, defined as the interaction between the real exchange rate and firm intermediate imports over sales, on French export prices denominated in euro, and thus smaller exchange rate pass-through into foreign currency prices when taking the cost adjustment into account.

#### 1.2.2.4 Product Strategies

Companies can also respond to exchange risk by altering their product strategy which deals with areas such as new product introduction, product line decision, and product innovation. One way to cope with exchange rate fluctuations is to change the timing of the introduction of new products. For example, because of the competitive price advantage, the period after a home currency depreciation may be the ideal time to develop a brand franchise. Exchange rate fluctuations can also affect product line decisions. Following home currency devaluation, a firm will potentially be able to expand its product line and cover a wider-spectrum of consumers and foreign locations. Conversely, home currency appreciation may force a firm to reorient its product line and

target it to a higher income, more quality-conscious, less price-sensitive constituency.

This link between international competition and firms' product scope has been investigated lately by several theoretical and empirical studies. On the theoretical side, several studies have extended the Melitz [2003]'s firm heterogeneity model to multiproduct firms, and pointed out that productivity may differ not only across firms, but also within each firm across various products. Despite diverging focuses and different modeling techniques, almost all those models conclude that multiproduct firms invariably reduce their product scope in response to trade liberalization [Bernard et al., 2011, Eckel and Neary, 2010, Mayer et al., 2014]. The logic is simple: just like the least productive firms (in any single-product firm model) are forced to exit in the face of increasing competition, the least productive products within each multiproduct firm should also be dropped.

Correspondingly, empirical studies have revealed that the range of products within a firm was indeed an important margin of adjustment to changes in the competitive environment. However, they also emphasized the heterogeneous responses of firms in this margin of adjustment. Berthou and Fontagné [2013] found, for instance, that after the eurozone was established in 1999, the most productive French firms increased the number of products exported to eurozone destinations, while less-productive French firms concentrated their exports on a smaller range of product lines. Baldwin and Gu [2009] showed that tariff cuts in Canada between 1973 to 1997 induced scope contraction by small or non-exporting Canadian firms, but had no effect on large or exporting firms. Using Taiwanese firms' data from the 1990s, Aw and Lee [2009] emphasized that plants whose products have large technological gaps were more likely to give up product lines when international competition increased. Furthermore, these plants performed better than those that continued to produce a wider range of products. Finally, using North-American firms-level data from 1980 to 1996, Lopresti [2016] find that firms with less than 10–20% of total sales accounted for by foreign markets reduced product diversification as trade costs fell, while more foreign-oriented firms increased diversification.

Qiu and Yu [2013] argue that this difference in patterns of scope adjustment across firms arises because new products are increasingly costly to introduce<sup>8</sup>, and because a variety's marginal cost of production rises as it moves further away from a firm's core competence variety. Given declining production efficiency and rising variety-introduction fee, firms that sell more products – large firms – must have more productive marginal products than smaller firms, in order to be

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<sup>8</sup>Ample evidence indicates within-firm diminishing returns to product development. Empirical studies have shown that the number of patents or innovations per dollar of research and development (R&D) investment declines as a firm grows larger or a firm's R&D expenditure increases, and that small firms account for a disproportionately large number of innovations relative to their size. Cohen and Klepper [1992, 1996] summarized these findings into "the stylized fact that the average productivity of R&D, measured in terms of the number of patents or innovations per dollar of R&D spending, tends to be lower for larger firms even though R&D tends to increase proportionately with firm size."

able to cover the higher fixed costs. In response to a trade liberalization, it is the most productive products in the market that expand and the least productive products that are dropped. Thus, it is the large firms with highly efficient marginal products that expand product scope as trade costs fall, while smaller firms with less efficient marginal products contract.

The equivalent strategy for firms confronting a strong home currency is product innovation, financed by an expanded R&D budget, i.e. a shift of production from commodity-type goods to more sophisticated, high-value products. Demand for such goods, which embody advanced technology, high-quality standards, and other nonprice features, is less sensitive to price increases caused by an appreciation of the domestic currency. Alternatively, firms can also differentiate their product offerings by adding service features that customers value.

This exchange-rate-induced product differentiation is indirectly supported by several empirical studies, which provide evidence that firms, particularly from developed countries, rely more on innovation when international competition increases. Using firm-level data from Italian manufacturing, [Bugamelli et al. \[2008\]](#) have shown, for instance, that the euro adoption has entailed a larger shift of business focus from production to upstream and downstream activities — such as product design, advertising, marketing and distribution — in sectors that once relied more on competitive devaluations. Using data across twelve European countries over 1996–2007, [Bloom et al. \[2011\]](#) argue that the increasing Chinese import competition led to increased technical change (IT, R&D and management practices) within firms<sup>910</sup>.

In addition, there is reason to believe that faced with increased international competition, a firm's quality differentiation process is facilitated by the easier access to new imported inputs simultaneously allowed by an appreciating domestic currency. It has been indeed shown that the new inputs imported following a decline in trade costs (see Section 1.2.2.3) were of higher quality than those imported prior to the trade shock within each input category [[Goldberg et al., 2010](#), [Kugler and Verhoogen, 2009](#)]. Moreover, there is recent evidence that the introduction of these new and higher-quality imported inputs encourages, correspondingly, the creation of new and potentially higher-quality domestic products. Using product-level information for 25 EU countries over 1995–2007, [Colantone and Crinò \[2014\]](#) show, for instance, that new imported inputs explain more than a quarter of new domestic products, and that these new products exhibit higher prices relative to existing goods. [Manova and Zhang \[2012a\]](#) also document a relationship between changes in input and output prices, using Chinese firms' data.

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<sup>9</sup>Similar results are noted in several case studies, such as in [Bartel et al. \[2007\]](#) using plant-level data in US valve manufacturing, or [Freeman and Kleiner \[2005\]](#) in USA shoe manufacturing.

<sup>10</sup>Together with innovation and RD, import competition from low-wage countries would also induce an increase in the share of highly educated workers employed by firms [Bugamelli et al. \[2008\]](#).

Surprisingly, there is however no direct evidence on the relationship between currency movements and quality upgrading. This thesis contributes to this literature in [Chapter 3](#) by showing theoretically and empirically that, along with changes in firms' product scopes, currency movements additionally induce changes in firms' product range in terms of quality.

### 1.2.3 Financial and Operational Hedges: Complementary or Substitutes?

To investigate operational structures and decisions used to manage exchange rate exposure more fully, [Bodnar et al. \[2011\]](#) asked a sample of non-financial firms worldwide to indicate what percentage of their total exchange rate economic exposure they thought they were managing with operational structures and decisions, as compared to what percentage of total exchange rate economic exposure they thought they were managing with financial contracts and derivatives. They were then asked to indicate usage across a set of operational and financial methods for managing exchange rate risk. The results are reported in [Table 1.4](#) below.

Non-financial firms declare that they believe to manage 35% of their exchange rate exposure with operational methods, with 5% indicating that they manage 100% of their exchange rate risk operationally. In contrast, non-financial firms declare that they manage on average 29% of their total exchange rate exposure through financial instruments and derivatives, with only 2% of firms indicating that they managed 100% of the total economic exchange rate exposure this way. In terms of operational hedges, pricing strategies appear to be the most common method, used by 62% of all responding non-financial firms, followed closely by the use of foreign currency debt (resp. 39%) and product strategies (resp. 34%). Two other offered choices that receive 25% and 19% usage votes among non-financial firms are shifting production location and push on increasing productivity. Finally, 9% choose "other" and listed their methods, which include most frequently increasing geographic diversification, and better matching of the currencies of revenues and costs. In terms of financial instruments, the winner is by far the simple exchange rate forward contracts.

Corporate firms thus appear to use both operational and financial methods to hedge against transaction and competitive exchange rate risk, even if they declare that they are able to manage a larger share of their total economic exposure through operational methods. This firms' preference for operational hedging techniques over financial ones may be a first indication of the relative efficiency of the two exchange rate risk management methods. However, one could argue that this statement could be reinforced by coupling the results of this survey with real economic evidence.

**Table 1.4: Percentage (%) of exchange rate economic exposure managed via operational vs. financial methods; and popularity of various methods used for operational and financial hedging of exchange rate risk.**

	Non-financial firms (n=190)	Financial firms (n=135)
<b>% of total exchange rate economic exposure managed..</b>		
Using operational activities	35%	28%
<i>indicating 100% of risk managed with oper. activ.</i>	5%	1%
Using financial derivatives	29%	49%
<i>indicating 100% of risk managed with fin. deriv.</i>	2%	14%
<b>Popularity of various methods of operational hedging</b>		
Foreign currency debt	39%	56%
Pricing strategies	62%	44%
Shifting product location	25%	14%
Product strategies	34%	19%
Promotional strategies	8%	6%
Increase productivity	19%	6%
Other	9%	9%
<b>Popularity of various methods of financial hedging</b>		
Forward contracts	66%	62%
Cross currency swaps	27%	54%
Futures contracts	23%	45%
Money market deposits/loans	25%	39%
Foreign currency debt financing	25%	29%
Exchange rate traded options	13%	24%
Option combinations (e.g. caps, collars)	13%	22%
OTC options	9%	26%
Non-deliverable forwards (NDFs)	10%	22%

Source: [Bodnar et al. \[2011\]](#)

With respect to this issue, the economic literature does not however allow a formal conclusion, since there is still some disagreement among empirical studies testing the relative efficiency of both hedging techniques. [Allayannis and Ofek \[2001\]](#), for instance, analyse the effectiveness of operational and financial hedging by US non-financial multinationals over the period 1996–1998. The authors use various measures of the geographical dispersion of the firm’s operations as a proxy for operational hedging, and find that operational hedging on its own does not, on average, reduce exchange rate risk exposure. However, they conclude that financial hedges are effective on their own, and so is a combination of financial and operational hedging. [Carter et al. \[2003\]](#) also analyse US multinationals over the period 1994–1998, and are more positive about the effectiveness of operational hedges. They find that operational hedges and financial hedges reduce exchange rate risk, whether used on their own or in a coordinated manner, and conclude that operational and financial hedges are complementary risk management strategies. Using a sample of 953 US firms over the period 1999–2006 and 1999–2009, [Hutson and Laing \[2014\]](#) also address the issue of whether operational and financial hedging are complements or substitutes, and conclude that operational hedging and financial hedging are both significantly inversely related to foreign exchange exposure.

Another main result of the surveys is that firms predominantly use financial derivatives to hedge short-term exposures, which is consistent with the fact that they prefer to use operational methods to deal with longer-term exposure. This is also consistent with the fact that whereas short-term exposure, e.g. resulting from foreign currency receivables or payables, are typically well known, long-term exposures are subject to considerable uncertainty. In their survey of U.S. non-financial firms, [Bodnar et al. \[1998\]](#) find, for instance, that more than 60% of firms do all of their currency hedging within a one-year maturity, suggesting that they are mostly hedging existing exposures, hedging for the reporting period, or hedging the short-term competitive impact of exchange rate changes on performance. At the same time, the cash flows from and the value changes of the derivatives portfolios of nonfinancial firms are small relative to firm’s operating cash flows, suggesting that derivatives are used to fine-tune an overall risk management program that makes effective use of operational and other forms of hedging [[Guay and Kothari, 2003](#)].

Interestingly, [Hutson and Laing \[2014\]](#) show that the relation between operational hedging and financial hedging is nonlinear, i.e. that the use of foreign currency derivatives initially increases with operational hedging and then decreases. According to them, this arises because for firms with highly internationalised activities, operational hedging is sufficiently effective, and in this case, financial hedging is not necessary. In addition, they show that the apparent complementarity between operational and financial hedging appears to break down in times of significant stress. Importantly, while operational hedging remains strongly significant, financial hedging tends to lose its effectiveness. This suggests that this is because the heightened exchange rate volatility that accompanied the financial crisis revealed many firms’ financial hedging programs to be

inadequate. An important message for firms is that operational hedges work, and that they can potentially provide better protection than financial hedges both during times of high volatility, and for the longer-term.

### 1.3 Conclusion

This chapter has described how, inconsistently with researchers' priors, empirical studies on firms' exchange rate exposure – mostly provided by the market-based approach pioneered by [Jorion \[1990\]](#) – have so far documented weak contemporaneous relationships between changes in exchange rates and firms' value. The literature argues that the main reasons for this puzzling weak relationship are 1) methodological shortcomings to the way exposure is measured, 2) not accounting for time variation in exposure, and 3) firms pass-through part of the exposure to customers, and use operating and financial hedges. Surprisingly, the literature on exchange rate exposure contains however a very small number of theoretical works that explicitly incorporate firms' strategic behavior, in particular pricing strategies, as main determinants of their competitive exposure. [Chapter 2](#) contributes to this literature by developing a theoretical framework, coupled with an empirical implementation, that helps to explain how and to what extent exchange rate fluctuations affect the profitability of heterogeneous import-competing and exporting firms, notably in terms of market power.

With respect to exchange rate risk management strategies, there is a consensus that firms predominantly use financial derivatives to hedge short-term exposures, which is consistent with the fact that they prefer to use operational methods to deal with longer-term exposure. In addition, there is evidence that the use of financial hedges is mainly the domain of large multinational companies that have the capacity to relocate, to tap international financial markets and dispose of internationally accepted collateral; while operational hedges are used by the majority of firms. However, despite the existence of some empirical studies, little is also known on how currency movements implies long-term strategic response on the part of the firm in response to the new – post exchange rate change – competitive environment, in particular in terms of market positioning, product strategy and production strategies. This thesis contributes to this literature in [Chapter 3](#) by showing theoretically and empirically how currency movements encourage firms to develop a strategy of up-market positioning.





# Appendix

## 1.A The Basic Capital Market Approach

Within the three last decades, three waves of capital market-based methodologies have taken place. Each successive wave is marked by refinements on research methods that provide shifts in the empirical evidence on the impact of changes in exchange rate and firms' stock return.

The first wave is considered as the fundamental exchange risk exposure estimation model. It starts with the seminal articles of [Adler and Dumas \[1984\]](#) and [Adler and Simon \[1986\]](#) which develop an easy applicable technique to measure exchange risk exposure. The latter is simply measured by the part of firm  $f$ 's stock return variance that is correlated to exchange rate movements, i.e. by running the following regression:

$$R_{ft} [ \alpha / \beta_f \Delta E_t / \epsilon_{ft} \tag{a}$$

where  $R_{ft}$  designates the total return of firm  $f$  in period  $t$ ,  $E_t$  is the exchange rate change in period  $t$ ,  $\beta_f$  is firm  $f$ 's exposure to these currency movements,  $\alpha$  the constant term and  $\epsilon_{ft}$  the white noise error term. Under strong market efficiency, the exchange rate exposure coefficient,  $\beta_f$ , describes the sensitivity of firm  $f$ 's stock returns to unanticipated changes in exchange rates, and therefore, expresses the overall effect of exchange rate risk on the value of firm  $f$ . Thus, it is referred to as firm  $f$ 's *exchange rate exposure*.

However, other macroeconomic variables may simultaneously covary with exchange rate movements and stock returns, and failure to include them in the exposure model could result in exaggerated estimates of the proportion of variance in stock returns attributable to foreign currency movements. That is why [Jorion \[1990\]](#) prefers measuring the firm-specific exchange rate sensitivity in excess of the market's reaction to exchange rate movements. The two-factor model of [Jorion \[1990\]](#) is thus an "augmented market model" which takes the following form:

$$R_{ft} [ \alpha / \beta_f^R R_{mt} / \beta_f^E \Delta E_t / \epsilon_{ft} \tag{b}$$

where  $R_{ft}$  designates the total return of firm  $f$  in period  $t$ ,  $R_{mt}$  the overall stock market return in period  $t$ ,  $\beta_f^R$  firm  $f$ 's return sensitivity to market risk,  $\Delta E_t$  the movement in exchange rate in period  $t$ ,  $\beta_f^E$  firm  $f$ 's exposure to the exchange rate independent of the effect these currency movements have on the overall market, and  $\epsilon_{ft}$  denotes the white noise error term. Implicit in this model is the fact that the modified exposure coefficient,  $\beta_f^E$ , measures the sensitivity of firm  $f$ 's stock returns to exchange rate changes as the residual between the firm's total exposure and the market's exposure adjusted by the firm's market beta,  $\beta_f^R$ . Therefore,  $\beta_f^E$  is referred to as firm  $f$ 's *residual exchange rate exposure*.

A potential problem when estimating the [Jorion \[1990\]](#)'s two-factor model is the possibility that the market and exchange risk factors may be correlated or jointly influenced by an external shock. [Choi and Prasad \[1995\]](#) and [Doukas et al. \[2003\]](#) suggested that it is possible to avoid biases from factor correlation by orthogonalizing the exchange risk factor according to a standard approach by [Elton et al. \[2009\]](#). The orthogonalization is in general accomplished through the estimation of the residual market factor that is not explained by a set of predetermined macro variables. This is motivated by the generally held view that it is the exchange rate movements that influence the stock market and not contrariwise. The exchange rate exposure is then estimated by model (b) with the only exception of replacing  $E_t$  with the part of the exchange rate variation that cannot be explained by the overall market behavior.

Finally, several studies have documented conditional heteroskedasticity in asset returns [e.g. [Hsieh, 1989](#), [Tse, 1998](#)], which results in inefficient parameter estimates as well as biased test statistics in the ordinary least squares regression. In general, market-based studies use the Lagrange multiplier test proposed by [Engle \[1982\]](#) to check whether the residuals,  $\epsilon_{ft}$ , exhibit time-varying heteroskedasticity. If so, a conditional variance is incorporated into the system by adding a GARCH(p, q) process to (b):

$$R_{ft} = \alpha + \beta_f^R R_t + \beta_f^E \Delta E_t + \epsilon_{ft}$$

$$\text{with } \epsilon_{ft} \sim \overline{\sigma_{ft}^2} \text{ and } \sigma_{ft}^2 = \gamma + \prod_{i=1}^p \delta_i \sigma_{f,t-i}^2 + \prod_{i=1}^q \phi_i \epsilon_{f,t-i}^2 \quad (c)$$

where  $\sigma_{ft}$  denotes the conditional variance of the residuals  $\epsilon_{ft}$ ;  $\gamma$ ,  $\delta_i$  and  $\phi_i$  are unknown parameters; and  $\mu_{ft}$  represents the white noise error term. The [Akaike \[1998\]](#) Information Criterion (AIC) and the [Schwarz et al. \[1978\]](#) Information Criterion (SIC or BIC) are used to determine the optimal GARCH (p, q) model for each firm. [Muller and Verschoor \[2006\]](#) have shown that the GARCH (1, 1) specification is optimal for modeling the variance-generating process of financial time series. Hence, with a few exceptions, the criteria in all market-based studies tend to select GARCH (1, 1) as the optimal model for almost all of the firms.

Table 1.5: Existing evidence on exchange rate exposure of non-financial firms in market-based approaches.

Authors	Sample	Period	% of the sample significantly exposed	Extent of exposure
<b>Firm-level studies</b>				
Jorion [1990]	287 US multinational firms	1971-1987	5%	R: [-1.45; 0.56]; M: -0.09; p50: -0.07
Loudon [1993a]	141 Australian firms	1984-1989	6%	R: [-1.60; 0.64]; M: -0.10; p50: -0.01
Bartov and Bodnar [1994]	208 US exporting firms	1978-1989	n.s.	M: -0.22; p50: -0.13
Khoo [1994]	98 Australian mining companies	1980-1987	22%	R: [-1.18; -0.36]
Levi [1994]	32 top US leading exporters	1979-1988	n.s.	M: -0.05 1-month returns; -0.29 1-year returns.
Walsh [1994]	391 US firms	1982-1993	10%	n.s.
Choi and Prasad [1995]	409 US multinational firms	1978-1989	15%	R: [-1.19; 1.66]; M: -0.16
Allayannis [1997]	124 US firms	1987-1990	11%	R: [-0.90; 0.57]; M: -0.09; p50: -0.09
Chow et al. [1997b]	213 US MNCs	1977-1991	28% for 1-year returns; 55% for 2-years returns. 3% for 1-month returns;	R: [-0.75; 0.35]; M: -0.11; p50: -0.11 for 1-month returns; R: [-2.30; 1.42]; M: -0.16; p50: -0.10 for 1-year returns; R: [-3.52; 1.87]; M: -0.12; p50: -0.30 for 2-years returns;
Chow and Chen [1998]	1,110 Japanese firms	1975-1992	30% for 1-month returns; 47% for 1-year returns; 70% for 2-years returns.	R: [-1.31; 0.94]; M: -0.20; p50: -0.25 for 1-month returns; R: [-2.10; 1.42]; M: -0.51; p50: -0.50 for 1-year returns; R: [-3.66; 1.25]; M: -0.95; p50: -0.95 for 2-years returns.
Fatemi et al. [1997]	1,402 US firms	1986-1990	8%	R: [-1.72; 2.38]; M: -0.11
He and Ng [1998]	171 Japanese MNCs	1979-1993	26%	R: [-0.81; 0.58]; p50: -0.45
Miller and Reuer [1998a]	239 US manufacturing firms	1988-1992	From 9% to 14% depending on the currency	n.s.
Miller and Reuer [1998b]	404 US manufacturing firms	1988-1992	From 13% to 17% depending on the currency	n.s.
Glaum et al. [2000]	71 German firms	1974-1997	55%	M: -0.11

Dominguez and Tesar [2001]	2,387 firms in 8 countries	1980-1999	19% in Chile; 21% in France 22% in Germany; 28% in Italy; 31% in Japan; 24% in Netherlands; 20% in Thailand; 11% in UK	n.s.
Pantazalis et al. [2001]	220 US MNCs	1989-1993	15%	R: [-2.50 ; 1.90]; M: -0.27; p50: -0.08
Williamson [2001]	11 US and Japanese automotive firms	1973-1995	40% against the bilateral rate JPY/USD; 0% against the bilateral rate JPY/DEM	M: -0.34; p50: -0.24 for the US portfolio; M: -0.21; p50: -0.22 for the Japanese portfolio.
Parsley and Popper [2006]	849 firms in 11 East Asian countries	1990-2002	From 13% in New Zealand to 68% in Korea	n.s.
Bodnar and Wong [2003]	910 US firms	1977-1996	22% for 1-month returns; 24% for 1-year returns; 30% for 2-years returns.	M: -0.13; p50: -0.10 for 1-month returns; M: 0.24; p50: -0.18 for 1-year returns; M: -0.03; p50: -0.01 for 2-years returns.
Carter et al. [2003]	208 US MNCs	1994-1998	35%	R: [-4.47; 2.21]; M: -0.32; p50: -0.29
Doukas et al. [2003]	1,079 Japanese firms	1975-1995	14%	-0.12 for domestic firms; -0.18 for low exporters; -0.45 for high exporters.
Kiyamaz [2003]	109 Turkish firms	1991-1998	46%	M: -0.75
Bartram [2004]	373 nonfinancial German firms	1991-1995	8%	M: -0.29 against USD; -0.24 against CHF; -0.22 against JPY.
Fraser and Pantzalis [2004]	310 US manufacturing and mining firms	1995-1999	35%	n.s.
Hagelin and Pramborg [2004]	98 nonfinancial Swedish firms	1997-2001	11%	R: [-4.08; 0.00]; M: -0.52; p50: -0.33
Rossi [2004]	165 nonfinancial Brazilian firms	1996-2002	40%	R: [-3.81; 2.28]; M: -0.22; p50: -0.20
Faff and Marshall [2005]	123 UK, US and Asian MNCs	1997-1998	25%	R: [-2.23; 0.00]; M: -0.50; p50: -0.34
Rees and Unni [2005]	90 European firms	1987-1998	100% of French; 97% of British and German firms against USD. 13% of French; 17% of British; 26% of German firms against JPY.	M: -0.62 for French; -0.53 for British; -0.64 for German firms against USD. M: -0.05 for French firms; -0.05 for British; 0.06 for German firms against JPY.
Bartram and Karolyi [2006]	3,220 nonfinancial European firms	1990-2001	36%	R: [-0.38; 0.40]; M: -0.21
Doidge et al. [2006]	17,929 nonfinancial firms in 18 countries	1975-1999	8% in developed countries; 11% in developing countries.	M: -0.21

Dominguez and Tesar [2006]	2,387 firms in 8 countries	1980-1999	12% in Chile; 19% in France; 21% in Germany; 29% in Italy; 31% in Japan; 28% in Netherlands; 21% in Thailand; 19% in the UK	16%	Positive exposure: 0.42 in Chile; 2.03 in France; 0.63 in Germany; 0.73 in Italy; 0.33 in Japan; 1.45 in Netherlands; 0.81 in Thailand; 0.39 in UK Negative exposure: -0.12 in Chile; -1.12 in France; -0.50 in Germany; -0.55 in Italy; -0.42 in Japan; -1.80 in Netherlands; -1.00 in Thailand; -0.47 in UK.
El-Masry [2006]	364 nonfinancial UK firms	1981-2001		38%	R: [-0.32; 0.10]; M: -0.19; p50: -0.25
Jong et al. [2006]	47 Dutch firms	1994-1998		22% against GBP. 14% against USD. 13% against JPY;	R: [-1.37; 0.42]; M: -0.67; p50: -0.36
Muller and Verschoor [2006]	817 European firms	1998-2002		42%	R: [-1.61; 1.87], M: -0.18; p50: -0.17 against GBP; R: [-1.57; 2.40], M: -0.06; p50: -0.06 against USD. R: [-0.91; 1.21], M: -0.03; p50: -0.02 against JPY;
Entorf and Jamin [2007]	28 German corporations	1977-1995		n.s.	
Aysun and Guldi [2008]	3,227 firms in 6 developing countries	1995-2005	36% in Brazil; 61% in Chile; 54% in Israel; 66% in Korea; 39% in Mexico; 54% in Turkey for 1-year returns.		M: -0.17 in Brazil; -0.35 in Chile; -0.45 in Israel; -0.21 in Korea; -0.41 in Mexico; -0.38 in Turkey for 1-year returns in 2005.
Bartram et al. [2008]	113 US firms with foreign acquisitions	1996-2004		19%	M: -0.21 for firms with positive exposure; 0.11 for firms with negative exposure.
Chue and Cook [2008]	931 firms in developing countries	1999-2002	Total sample: 33%. 30% in Brazil; 15% in Chile; 5% in Colombia and India; 41% in Korea; 39% in Mexico; 22% in Morocco; 2% in Pakistan and Philippines; 75% in Indonesia; 38% in South Africa; 48% in Taiwan; 69% in Thailand; 64% in Turkey; 13% in Venezuela.		M: -0.51 total sample. -0.11 in Brazil; -0.28 in Chile; -0.11 in Colombia; -0.26 in India; -0.89 in Indonesia; -1.18 in Korea; -0.50 in Mexico; -0.18 in Morocco; 0.01 in Pakistan; -0.28 in Philippines; -0.25 in South Africa; -1.81 in Taiwan; -1.80 in Thailand; -0.39 in Turkey.
Bartram et al. [2010]	1,150 manufacturing firms in 16 countries	1998-2002		n.s.	R: [-0.90; 0.50]; M: -0.18; p50: -0.15
Hutson and O'Driscoll [2010]	1,154 European firms in 11 countries	1990-2008	10% post and 12% pre-euro period		R: [-0.30; -0.85]; M: -0.58
Patnaik and Shah [2010]	100 Indian firms	1998-2004		n.s.	R: [p25:-0.34; p75: -0.93]; M: -0.76; p50: -0.58

Aggarwal et al. [2011]	837 Chinese firms	2005-2006	16% against EUR; 7% against USD; 18% against JPY; 21% against TWD; 25% against INR.	M: -0.04 against EUR; -0.02 against USD; -0.15 against JPY; -0.16 against TWD; -0.03 against INR.
Asaolu [2011]	117 Nigerian firms	1998-2007	88% against USD; 75% against GBP; 53% against EUR	R: [-0.64; 0.01]; M: -0.22 against USD; R: [-0.81; 0.19]; M: -0.32 against GBP; R: [-0.82; 0.32]; M: -0.26 against EUR
Aysun and Guldi [2011]	367 nonfinancial firms in 6 countries	1995-2006	Linear/Non-parametric approach: 2%/17% in Brazil; 5%/29% in Chile; 11%/53% in Korea; 6%/19% in Mexico; 6%/44% in Turkey; 5%/16% in the US.	M: Linear/Non-parametric approach: -0.56/-1.04 in Brazil; -0.65/-0.55 in Chile; -1.57/-0.56 in Korea; -0.93/-1.19 in Mexico; -0.80/-1.03 in Turkey; -0.42/-0.33 in the US.
Kanagaraj and Sikarwar [2011]	361 nonfinancial Indian firms	2006-2011	16%	R: [-1.01; 0.56]; M: -0.42; p50: -0.51
Kang and Lee [2011]	392 Korean firms	1994-2007	41%	n.s.
Bartram and Bodnar [2012]	4,404 nonfinancial firms in 37 countries	1994-2006	11% for the total sample, Ranging from 6% in Portugal to 39% in Brazil.	M: -0.04. 0.14 for depreciation periods; -0.08 for appreciation periods. 0.83 for firms with positive exposure; -0.79 for firm with negative exposure.
Júnior [2012]	196 nonfinancial Brazilian firms	1999-2009	38%	R: [-2.83; 1.71]; M: -0.22; p50: -0.18 with a linear model; R: [-0.20; 0.16]; M: -0.03; p50: -0.03 with a non-linear model
Varga [2012]	107 nonfinancial Taiwanese firms	1990-2000	50%	R: [-0.79; -0.03]; M: -0.24; p50: -0.19 for firms negatively exposed; R: [0.05; 1.24]; M: 0.41; p50: 0.28 for firms positively exposed
Agyei-Ampomah et al. [2013]	269 nonfinancial UK firms	1984-2003	15% with a standard linear model; 85% when time-varying exposure regressions with orthogonalized market returns are used.	M: -0.06 with a standard linear model; -0.04 when time varying exposure regressions with orthogonalized market returns are used.
Bacha et al. [2013]	158 Malaysian firms	1990-2005	71%	R: [-3.90; 1.74]; M: -0.16

Bae and Kwon [2013]	337 Korean firms	1998-2005	n.s.	M: -0.29 for firms with dollar-denominated debt; -0.69 for firms without.
Chaieb and Mazzotta [2013]	496 US manufacturing firms	1973-2005	7%	M: -0.29
Chang et al. [2013]	2,920 nonfinancial Taiwanese firms	2001-2010	12%	R: [-2.67; 0.51]; M: -1.27; p50: -0.98
Demirhan and Atis [2013]	17 manufacturing Turkish firms	2005-2011	40% against both USD and EUR	R: [-1.41; -0.24]; M: -0.82 against USD; R: [-1.13; 0.23]; M: -0.72 against EUR.
Ito et al. [2013]	227 nonfinancial Japanese firms	2009	n.s.	R: [-2.18; 0]; M: -0.52; p50: -0.40 against USD; R: [-2.22; -0.10]; M: -0.52; p50: -0.41 against NEER
Miao et al. [2013]	2,777 nonfinancial Chinese firms	2002-2012	18%	M: -0.13
Akay and Cifter [2014]	173 nonfinancial Turkish firms	2002-2010	Non-significant only for small firms.	M: -0.13 (non-significant) for small firms; -0.15 for medium firms; -0.05 for large firms.
Flota [2014]	71 Mexican firms	1994-2003	38%	R: [-2.98; -0.37]; M: -0.49; p50: -0.62
Hutson and Laing [2014]	953 nonfinancial US firms	1999-2006	10%	M: -1.11; p50: -0.89 for firms positively exposed; M: -1.87; p50: -1.33 for firms negatively exposed
Jayasinghe and Premaratne [2014]	40 US firms in electronics and electrical goods sector	1989-2004	28%	R: [-0.64; 0.32]; M: -0.22; p50: -0.20
Ye et al. [2014]	1,523 firms in 20 developing countries	1999-2010	42% non-floating regimes; 49% floating regimes.	M: Non-floating regimes: 1.10 for firms positively exposed; 0.67 for firms negatively exposed. Floating regimes: 0.27 for firms positively exposed; -0.43 for firms negatively exposed.
Kim and Kim [2015]	200 Korean firms	2005-2012	n.s.	M: 1.14 for firms positively exposed; -1.15 for firms negatively exposed.



Industry-level studies					
Jorion [1991]	20 US value-weighted industry portfolios	1971-1987	20%	R: [-0.41; 0.27]; M: -0.17; p50: -0.11	
Bodnar and Gentry [1993]	39 Canadian, Japanese and US value-weighted industry portfolios	1979-1988	21% in Canada, 35% in Japan; 28% in US.	R: [-0.73; 1.26]; M: -0.11	
Loudon [1993b]	23 Australian industry-based portfolios	1971-1987	33%	R: [-0.44; 0.35]; M: -0.27; p50: -0.23	
Prasad and Rajan [1995]	20 US, 12 German, 25 Japanese and 89 British industry-based portfolios	1981-1989	15% in US, 17% in Germany, 4% in Japan and 6% in UK.	R: [-1.01; -0.26] in US; [-0.39; -0.21] in Germany; [-0.36; -0.17] in Japan; [-0.33; 0.31] in UK	
Chow et al. [1997a]	65 industry stock portfolios	1977-1989	9% for 1-month returns; 65% for 1-year returns; 84.6% for 4 years returns	R: [-1.23; 0.33]; M: -0.23; p50: -0.20 for 1-year returns.	
Dominguez [1998]	18 Japanese industry-portfolios	1984-1995	50%	R: [-0.41; 0.40]; M: -0.13; p50: -0.08	
Di Iorio and Faff [2000]	24 Australian industry indices	1988-1996	21%	R: [-0.64; 0.32]; p50: -0.25	
Allayannis and Ofek [2001]	82 US industry-portfolios	1979-1995	22%	R: [-0.53; 0.33]; M: -0.13; p50: -0.05	
Griffin and Stulz [2001]	58 Japanese industry stock indices	1975-1997	66%	R: [-0.33; 0.18]; M: -0.09; p50: 0.12	
Jayasinghe and Tsui [2008]	14 Japanese industry stock indices	1992-2000	29%	R: [-0.18; 0.04]; M: -0.10; p50: -0.12	
Bredin and Hyde [2011]	9 industry-based portfolios in G7 countries	1975-2007	66% in Canada; 22% in France and US; 44% in Germany; 33% in Italy; 11% in Japan and UK.	M: 0.15 in the US; -0.51 in Japan; -0.38 in Italy; -0.23 in Germany; -0.10 in France; 0.58 in Canada.	
Al-Shboul and Anwar [2014]	13 Canadian industry sector indexes	2003-2011	23%	R: [-0.17; 0.14], p50: -0.11	
Tsai et al. [2014]	19 Taiwanese industry-based portfolios	2001-2010	53%	R: [-1.23; 0.54]; M: -0.18; p50: -0.23	
Tang [2015]	24 Chinese industry-based portfolios.	1991-2013	21%	R: [-0.78; 0.89]; M: -0.24; p50: -0.54	

Table 1.6: Theoretical exchange rate exposures of non-financial firms in cash flow-based approaches

Authors	Sample	Period	Extent of exposure	Notes
Bartram [2008]	1 German multinational company	1996-1998	M: -0.17	Estimation of cash flows exposure directly and decomposition between operating cash flows; Investing cash flows; Financing cash flows. In contrast to exposures of the operating cash flow, cash flows from financing and investing activities do not exhibit significant foreign exchange rate exposures.
Bodnar et al. [2002]	8 Japanese exporting industries	1986-1995	R: [-2.28;-0.68]; M: -1.11 ; p50: -1.26	Link firm's pass-through rate to exposure. The model is for a pure exporter.
Flodén et al. [2008]	8 Japanese industries	1986-1995	R: [-1.68; -0.39]; M: -1.21; p50: -1.08	Extension of Bodnar et al. [2002]'s model. Convexity of costs is an important determinant of both pass-through and exposure, and that an increase in the convexity of costs typically reduces both pass-through and exposure.
Bartram et al. [2010]	1150 manufacturing firms in 16 countries	1998-2002	R: [-1.35; 0.10]; M: -0.42; p50: -0.40 (high pass-through 0.1) R: [-1.94; 0.24]; M: -0.55; p50: -0.53 (low pass-through 0.5)	Extension of Bodnar et al. [2002]'s model for a firm that can both export and import. NB: regression exposures are R: [-2.74; 0.04]; M: -1.26; p50: -1.15
Prasad and Suprabha [2015]	30 large Indian companies	2012-2013	R: [-12.95;6.65]; M: -1.52; p50: -0.23	Implementation of Bodnar and Marston [2001]'s simple exposure.

**Notes:** This table reports existing evidence on exchange rate exposures separately for studies working on firm-level data, and those using industry-level data. For each study referred to, it provides information on the sample used, the period covered, the magnitude of the estimated exposure coefficients, and additional notes when needed. In the column "Extent of exposure", R stands for the interval range of the estimated exposure coefficient, M for its mean, p50 for its median.



## Chapter 2

# Firm's Heterogeneity and Operating Exposure

*Cherchant à combler le manque de travaux ayant modélisé formellement cet impact au niveau microéconomique, ce chapitre propose un cadre théorique et empirique décrivant comment et par quel ampleur les fluctuations de change affectent la compétitivité et la profitabilité d'entreprises hétérogènes, tant sur le marché domestique que sur les marchés à l'export. L'exposition au taux de change de chaque entreprise est notamment reliée au degré de transmission de ce choc de change sur son prix de vente, et elle est ainsi décomposée en deux effets: un effet sur la marge de profit et un effet sur le volume de ventes. Par ailleurs, la réponse du prix de vente au choc de change est elle-même décomposée en deux parties: la réponse des coûts marginaux propres à l'entreprise; et sa réaction stratégique aux variations du prix de ses concurrents. Dans ce cadre, le degré de transmission d'une variation de change sur le prix d'une entreprise suit une relation en U avec sa part de marché, de telle sorte que l'impact sur sa marge de profit et son volume de ventes suivent une relation en U et U-inversé, respectivement, avec son pouvoir de marché. Malgré ces effets non-linéaires, la relation entre variations de change et profitabilité dans son ensemble apparaît monotone.*

*En utilisant des données d'entreprises françaises sur la période 1999–2007, la partie empirique de ce chapitre confirme les prédictions théoriques, et conclue que l'appréciation de l'euro sur cette période n'a eu aucun effet sur les profits réalisés par les plus grandes entreprises, tandis qu'elle a significativement réduit ceux des petites et moyennes entreprises. Puisque les premières constituent une proportion substantielle des profits totaux sectoriels, ce résultat fournit une explication pertinente à la "mystérieuse" faible exposition économique au taux de change mise en évidence par les précédentes études basées sur des données agrégées et de marchés financiers.*

## 2.1 Introduction

The previous chapter reports that market-based empirical studies have tended to document extremely low levels of economic exposure to exchange rate swings for most firms, even when the firms examined have significant foreign operations. This result has appeared surprising for a long time, given that theoretical studies predict – and empirical studies document – significant effects of exchange rate shocks on firms' sales volume [e.g. Baggs et al., 2009, 2011, 2013], pricing strategies [e.g. Goldberg and Hellerstein, 2008, Goldberg and Knetter, 1997, Krugman, 1986] and cost structures [e.g. Amiti and Konings, 2007, Gron and Swenson, 1996], and thus, on their competitive positions in product markets on the whole [e.g. Campa and Goldberg, 1995, 2001, Williamson, 2001]. As explained in Section 1.1.2.3, this so-called exposure puzzle is nevertheless not necessarily inconsistent with the theory, once the fact that firms endogenously make rational decisions to reduce these exposures through exchange rate risk management techniques is taken into account<sup>1</sup>.

Surprisingly, only two theoretical studies to the extent of our knowledge, Bodnar et al. [2002] and Bartram et al. [2010], have developed a theoretical model to explain how this main firms' operational hedging technique, namely pricing strategy, affects their competitive exposure. While these studies are the only ones explicitly incorporating pass-through behavior and industry competition as important determinants of exposure, their analyses rely on a heavy set of assumptions on demand and supply functional forms, which in particular do not vary over time, so that markups and market shares are supposed constant in the short run. In addition, the possibility of heterogeneous behavior between firms, which may explain the low level of exchange rate exposure found in the data, is completely ruled out.

This chapter attempts to fill this gap by providing a general accounting framework, which nestes a broad class of model – including oligopolistic competition models – under very general demand and cost structures, in order to improve our understanding of the exchange rate exposure across firms with heterogeneous pass-through behavior. This framework allows (i) confirming generally recent results regarding the impact of market structure on exchange rate pass-through and markups elasticity; and (ii) explaining how these heterogeneities affect the exchange rate elasticities of profit margins, sales volumes, and total profits. Using French manufacturing firms' data over the period 1999–2007, the empirical part of the chapter then allows testing the results of the theoretical model, and offers a complete and representative assessment of the exchange rate exposure channels and an analysis of their heterogeneity across all firms in the economy.

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<sup>1</sup>It is precisely the most exposed firms that will be most likely to use these methods most intensively, reducing their exposure to less significant levels. Thus, both firms with low underlying exposure that do not need to hedge, as well as firms with large underlying exposures that employ one or several forms of hedging, may exhibit only weak exchange rate exposures net of hedging.

The chapter begins with an explicit formalization of operating cash flows' sensitivity to exchange rate changes, for a firm which can compete and produce in both a foreign and local competitive market. This derivation, inspired by [Clarida \[1997\]](#) and [Hung \[1992\]](#), provides a time-varying theoretical operating exposure that can be calibrated for any firm-product-destination triplet (variety) observed in the sample. The theoretical operating exposure implies that the sensitivity of a firm's profit to exchange rate shocks can be decomposed into two effects: an effect on profit margin for a given sales volume (profit margin effect) and an effect on sales volume for a given profit margin (volume effect).

This theoretical framework has two particular features. First, in contrast to the majority of previous micro-founded models that focused either on pass-through [e.g. [Dornbusch, 1987](#), [Feenstra et al., 1996](#), [Froot and Klemperer, 1989](#), [Krugman, 1986](#), [Yang, 1997](#)] or exposure [e.g. [Adler and Dumas, 1984](#), [Campa and Goldberg, 1999](#), [Flood Jr and Lessard, 1986](#), [Hekman, 1985](#), [Levi, 1994](#), [Marston, 2001](#), [Shapiro, 1975](#), [von Ungern-Sternberg and von Weizsäcker, 1990](#)]<sup>2</sup> but did not study these two phenomena together, this framework takes into account the fact that, because pricing directly affects profitability, the characteristics that determine pricing behavior also govern the exposure of firms' profits. In other words, exchange rate exposure and pass-through are closely related. Second, the theoretical analysis follows the recent trends in the pass-through literature and decomposes the response of a firm's markup and price to exchange rate shocks into two components [[Amiti et al., 2015](#), [Auer and Schoenle, 2016](#)]: a response to its own marginal costs (idiosyncratic cost pass-through) and a response to the price changes of its competitor (strategic complementarity elasticity).

In this framework, the exchange rate elasticities of markups and prices are shown to be U-shaped functions of firms' market power, as measured by the perceived demand elasticities [[Bresnahan, 1989](#)]. While this theoretical result is not new in the literature [[Auer and Schoenle, 2016](#), [Garetto, 2016](#)], the model provides new theoretical evidence that these relationships further imply that the profit margin effect and the volume effect are U-shaped and hump-shaped, respectively, in firms' market power. In other words, firms that face the lowest and the highest perceived demand elasticities incur a large loss of sales volumes, but almost no loss of profit margins. Conversely, firms lying in the middle of the distribution incur a large loss of profit margins, but this allows them to limit the fall in sales volumes. Note that these results apply equally well to any domestic and export market. Finally, a new interesting result of the model is that, despite these non-monotonic effects, the relationship between a firm's whole operating profit exchange rate exposure and its market power is clearly linear. In other words, the lower a firm's perceived demand elasticity, the less its profits fall when the domestic currency appreciates.

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<sup>2</sup>For most of these models that do not consider pass-through when estimating exchange rate exposure, the structural background is that of a monopoly firm whose revenues and expenses are exposed to changes in exchange rates. This simply demonstrates that exposures are related to net foreign currency revenues and profit margins.

The theoretical framework is then extended to [Atkeson and Burstein \[2008\]](#)'s demand structure in order to be empirically tested. This demand structure has indeed a commendable feature to express firms' perceived demand elasticity as a decreasing function of market shares, and thus, to generate variable markups. This allows testing the theoretical predictions by using firms' market share as the determinant of their perceived demand elasticity, and thus, their markup level. This empirical framework is built in three parts. First, since the extent and heterogeneity of exchange rate exposure depend in particular on firms' markup level and their marginal costs' response to currency shocks, the first part of the empirical framework follows the methodology initiated by [De Loecker and Warzynski \[2012\]](#) and [De Loecker et al. \[2012\]](#) and uses the firm's cost-minimization problem to estimate variety-specific markups and marginal costs in levels. Note that this approach allows dealing with both multi-product and multi-destination firms. The second part builds upon [Campa et al. \[2005\]](#), [Goldberg and Hellerstein \[2008\]](#), and [Berman et al. \[2012\]](#) to estimate how firms' own marginal costs and their competitors' prices respond to currency shocks. These estimates in turn allow calibrating the response of firms' own prices and markups to currency changes and to recover the variety-specific profit margin effect, volume effect, and operating exposure. Finally, the third part of the empirical framework tests how these calibrated elasticities are correlated with varieties' market share.

Besides its theoretical contribution, this study is the first to provide direct evidence on the extent and heterogeneity of operating exposure and its components using firm-product-destination-level data. It concludes that the predictions of the theoretical model are all empirically verified. Thus, whereas the responses of prices, markups, and profit margins to currency fluctuations are U-shaped in market shares, the response of sales volumes is hump-shaped and that of profits is linear. In particular, the econometric model predicts that the largest firms do not experience any shrinkage in operating profits when the home currency appreciates. Since they account for a substantial amount of total sectoral profits, this finding provides a significant explanation for the low level of exchange rate exposure found in previous studies using stock markets data or aggregate industry-level data.

The remainder of the chapter is organized as follows. [Section 2.2](#) sets out the accounting framework to draw theoretical predictions and to guide the empirical analysis. [Section 2.3](#) presents the empirical framework that helps to calibrate the various exchange rate elasticities and to test the theoretical predictions of the model. [Section 2.4](#) describes the results and [Section 2.5](#) concludes the study.

## 2.2 A General Accounting Framework

### 2.2.1 Setup

Consider a simple accounting identity for the profit of firm  $f$  in a given period, which equals the sum of profits made from selling each product  $g \in \{1, \dots, G_{ft}\}$  manufactured by the firm on each destination market  $l \in \{1, \dots, L_{fgt}\}$ , including the domestic one:

$$\Upsilon_{ft} \left[ \prod_{g=1}^{G_{ft}} \prod_{l=1}^{L_{fgt}} \Upsilon_{fglt} \left( \prod_{g=1}^{G_{ft}} \prod_{l=1}^{L_{fgt}} \right) \frac{P_{fglt}}{E_{lt}} \right] C_{fglt} \left[ Q_{fglt} - F_{fglt} \right] \quad (2.1)$$

where  $Q_{fglt}$ ,  $P_{fglt}$ ,  $C_{fglt}$ , and  $F_{fglt}$  are respectively the firm-product and destination-specific quantity sold, f.o.b price expressed in foreign currency  $l$ , marginal cost and fixed cost of shipping, both expressed in units of the domestic currency.  $E_{lt}$  is the nominal exchange rate between the firm's home country and country  $l$  in period  $t$ , defined as the foreign currency  $l$  price of one unit of the domestic currency. Note that an increase in the exchange rate thus implies an appreciation of the home currency. This identity simply states that profits are the difference between the firm's revenues earned in each destination market, i.e., the product of each volume of sales with its associated price, and its costs of producing and delivering this output. In what follows, exchange rate changes are shown to be a key determinant of the adjustment of each one of these components.

#### 2.2.1.1 Demand Structure

Firm  $f$  can operate in multiple industries  $g$  with  $N_{glt}$  competing firms in destination  $l$ . Each firm is denoted with  $f \in \{1, \dots, N_{glt}\}$ , where  $N_{glt}$  may be finite or infinite.  $P_{glt} \leq (P_{1glt}, \dots, P_{N_{glt}})$  denotes the vector of final prices of all firms in the industry, and  $Q_{glt} \leq (Q_{1gt}, \dots, Q_{N_{glt}})$  denotes the corresponding vector of quantities demanded. Each final price includes one plus the ad valorem trade costs  $\tau_{fglt}$ , including one plus the ad valorem tariff, and an additive (per unit) distribution cost,  $D_{fglt}$ , paid in local currency. The (foreign currency) consumer price of firm  $f$  is therefore expressed as  $P_{fglt} = (\tau_{fglt} P_{fglt} / D_{fglt} + P_{-fglt})$ , where  $P_{-fglt} \leq (P_{1glt}, \dots, P_{f-1,glt}, P_{f+1,glt}, \dots, P_{N_{glt}})$  denotes the vector of prices of a firm  $f$ 's competitors, and the notational convention  $P_{glt} \leq (P_{fglt}, P_{-fglt})$  is made.  $Y_{glt}$  denotes the industry's expenditure function defined in the traditional way, that is  $Y_{glt} = \min_{Q_{fglt}} \left\{ \sum_{f=1}^{N_{glt}} P_{fglt} Q_{fglt} \right\}$  with  $\mathcal{V}$  the preference indicator. The following two assumptions are discussed in [Amiti et al. \[2015\]](#).

**Assumption 1** *Firms are static profit maximizers under full information, and follow a two-stage cost-scale decision compatible with any model of competition.* The profit-maximization problem of the firm associated with (2.1) is broken down into two stages: first, determining the amount of each input to be employed to produce a given amount of output in the least costly way, and second, choosing the most profitable output or price level taking the demand conditions and in-



puts price as given. The assumption of *static* profit maximization excludes dynamic price-setting considerations such as menu costs [Gopinath et al., 2010] or inventory management [Alessandria et al., 2010]. The framework could theoretically be generalized to allow for dynamic price-setting, but the estimated equation would then be sensitive to the specific dynamic structure. In addition, Amiti et al. [2015] have shown empirically that this assumption induces only small biases in the estimates.

**Assumption 2** *The demand system  $Q_{fglt} [ S_{fgl} P_{fglt} = P_{-fglt} \epsilon_{glt} [ \text{for } f \in \mathcal{C} \} 2, \dots, N_{gl} |$  is invertible. This means that the demand system constitutes a one-to-one mapping between any vector of prices  $P_{glt}$  and a corresponding vector of quantities demanded  $Q_{glt} \leq Q_{1lt}, \dots, Q_{N_{gl}lt}$  given the vector of demand shifters  $\epsilon_{glt} [ \epsilon_{1glt}, \dots, \epsilon_{N_{gl}lt}$  which summarize all variables that cause changes in the quantity demanded, given a constant price vector of the firms.*

Considering the first two assumptions, there exists a markup function,  $\mu_{fglt} [ Q_{fgl} P_{fglt} = P_{-fglt} \epsilon_{glt} [$  such that, for any given invertible demand system and any given competition structure, the firm's static profit-maximizing price,  $P_{fglt}$ , here expressed in terms of the domestic currency, is the solution to the following fixed-point equation for any vector of competitor prices,  $P_{-fglt}$ :

$$\frac{P_{fglt}}{E_{lt}} \leq \mu_{fglt} * C_{fglt} \quad (2.2)$$

$$\text{with } \mu_{fglt} [ Q_{fgl} P_{fglt} = P_{-fglt} \epsilon_{glt} [ [ \frac{\sigma_{fglt}}{\sigma_{fglt} - 2} \quad (2.3)$$

where  $\sigma_{fglt} [ \sigma_{fgl} P_{fglt} = P_{-fglt} \epsilon_{glt} [$  is the perceived elasticity demand of the firm [Amity et al., 2015]. In the price equation (3.13), the markup is directly related, as in Lerner [1934], to the definition of market power as the ability of a firm to charge prices above its marginal costs. Importantly, note that this result imposes no restriction on the nature of market competition, allowing for both monopolistic competition (as  $N$  becomes unboundedly large or as firms do not internalize their effect on aggregate prices) and oligopolistic competition (for any finite  $N$ ). In particular, in the case of oligopolistic and monopolistic Bertrand competition, the perceived elasticity of demand equals the partial price elasticity of the residual demand of the firm:

$$\sigma_{fglt} [ \frac{\partial S_{fgl} P_{fglt} = P_{-fglt} \epsilon_{glt} [}{\partial P_{fglt}}$$

Since the firm-specific residual demand curve depicts the relationship between the firm's quantity and price, taking into account the supply response of all other firms in the market, equation (3.13) characterizes the behavior of the firm given its competitors' prices. Hence, it refers to the firm's best response schedule (or reaction function) [Amity et al., 2015].

## 2.2.1.2 Cost Structure

Consider a basic production function that relates the quantity of a given product  $g$  manufactured by firm  $f$   $Q_{fgt}$ , to a vector of physical variable inputs that the firm can freely adjust  $V_{fgt}$ , and a vector of fixed inputs that face adjustment costs  $K_{fgt}$ :

$$Q_{fgt} = \mathcal{M}_{gt}(V_{fgt}, K_{fgt}) A_{ft} \quad (2.4)$$

Each variable input  $V_{fgt}$  is costless assembled from a continuum of intermediates [Grossman and Rossi-Hansberg, 2008, e.g.], which may be either domestically produced,  $V_{fgt}^d$ , or imported,  $V_{fgt}^m$ , so that the vector of physical variable inputs is defined as:  $V_{fgt} = \mathcal{W}_{gt} \left( V_{fgt}^d, V_{fgt}^m \right)$ . All inputs are collected into a vector  $X = \{V, K\}$ , and we denote  $W_{fgt}^v = \mathcal{W}_{gt} \left( W_{fgt}^{v,d}, W_{fgt}^{v,m} \right)$  (and  $W_{fgt}^k$  the prices of a variable input,  $V_{fgt}$ , and a dynamic input,  $K_{fgt}$ , respectively, both expressed in terms of the firm's domestic currency. The following three assumptions are discussed in De Loecker et al. [2012].

**Assumption 3** *The Hicks-neutral productivity  $A_{ft}$  is log-additive and firm-specific.* In line with the traditional way of modeling productivity in the multi-product firm literature [e.g. Berman et al., 2012], this assumption implies that a multi-product firm has the same productivity in the production of all its products  $g \in \{1, 2, \dots, G_{ft}\}$ .

**Assumption 4** *The production technology,  $F_{gt}$ , is product-specific and is continuous and twice differentiable with respect to at least one freely adjustable input,  $V_{fgt}$ .* The first part of this assumption implies that a single-product firm and a multi-product firm that manufacture the same product have the same production technology. As noted by De Loecker et al. [2012], while this framework rules out differences in the production technology between single- and multi-product firms, it allows for economies of scope through cost synergies. In addition, this framework allows costs to differ within a firm-product pair across destinations, e.g., due to product differentiation. The second part of this assumption ensures that firm cost minimization involves at least one static first order condition with respect to a variable input.

**Assumption 5** *Expenditures on all variable and fixed inputs are supposed to be attributable to products.* Thus, the expenditure on input  $X$  attributable to product  $g$  can always be expressed as  $W_{ft}^x X_{ft} = \rho_{fgt} \sum_{g=1}^{G_{ft}} W_{fgt}^x X_{fgt}$ , where  $\rho_{fgt}$  is the share of input expenditures attributable to product  $g$ , with the restriction that  $\sum_{g=1}^{G_{ft}} \rho_{fgt} = 1$ . Note that  $\rho_{fgt}$  is actually never observed in the data.

Since costs are separable across products, they can be minimized product by product (for multi-product firms) with respect to variable inputs. As a result, firms minimize short-run costs in each period  $t$  by product, taking demand conditions and input prices given, and conditioning on a vector of state variables,  $s_{ft}$ . This firms' cost minimization problem implies that marginal costs (in units of currency of the home country) of producing  $Q_{fglt}\tau_{fglt}$  units of good (inclusive of transport costs) and selling them in country  $l$  are firm-product and destination specific, and depend on both the marginal cost of production and the (per unit) destination cost<sup>3</sup>. Therefore, marginal cost expressed in terms of the domestic currency can be rewritten as the sum of a function of variable input prices, productivity and output quantity, plus the distribution cost:

$$C_{fglt} \left[ \tau_{fglt} * \mathcal{F}_{gt} \right) W_{fgt}^v = A_{ft} Q_{fglt} \left( / D_{fglt} \right) E_{lt}^{-1} \quad (2.5)$$

Equation (3.9) perfectly adapts to the traditional pass-through literature, which provides four complementary reasons why marginal costs can be affected by exchange rate changes: (i) increasing returns to scale, implying a downward sloping marginal cost curve  $\mathcal{F}_{gt}$ ; (ii) the price of imported inputs used in the firm's production process, which appear in  $W_{fgt}^v$ ; (iii) increase in productivity,  $A_{ft}$ ; and (iv) the existence of local, non-traded costs,  $D_{fglt}$  [De Loecker and Koujianou, 2014, Goldberg and Hellerstein, 2008].

## 2.2.2 Exchange Rate Exposure

### 2.2.2.1 Profit Margin Effect and Volume Effect

In this section, the term  $\xi_x$  indicates the elasticity of a given variable,  $x$ , with respect to any bilateral exchange rate<sup>4</sup>. The exchange rate elasticity of profits made on the domestic market and foreign market  $l$ , denoted by  $\xi_{\Pi_{fgdt}}$  and  $\xi_{\Pi_{fglt}}$ , and thereafter referred to domestic and foreign *operating exchange rate exposure*, are simply obtained by deriving the profit equation (2.1) with respect to the exchange rate:

$$\xi_{\Pi_{fgdt}} \left[ \frac{P_{fgdt} Q_{fgdt}}{\Upsilon_{fgdt}} * \xi_{P_{fgdt}} \quad \sigma_{fgdt} * \right) \xi_{P_{fgdt}} \quad \xi_{P_{-fgdt}} \left( \frac{C_{fgdt} Q_{fgdt}}{\Upsilon_{fgdt}} \xi_{C_{fgdt}} \quad (2.6)$$

$$\xi_{\Pi_{fglt}} \left[ \underbrace{\frac{P_{fglt} Q_{fglt}}{E_{lt} \Upsilon_{fglt}}}_{(a)} \xi_{P_{fglt}} \quad 2 \left( \underbrace{\sigma_{fglt} *}_{(b)} \right) \xi_{P_{fglt}} \quad \xi_{P_{-fglt}} \left( \underbrace{\frac{C_{fglt} Q_{fglt}}{\Upsilon_{fglt}}}_{(c)} \xi_{C_{fglt}} \quad (2.7)$$

<sup>3</sup>Formally, marginal costs are defined by:

$$C_{fglt} = \frac{\partial \left[ \left( W_{fgt}^x \tilde{X}_{fgt} + D_{fglt} (\tau_{fglt} E_{lt})^{-1} \right) \tau_{fglt} Q_{fglt}(\cdot) \right]}{\partial Q_{fglt}(\cdot)}$$

with  $\tilde{X}_{fgt}$  the vector of optimal amounts of each input chosen by the firm to produce a given amount of output  $g$ .

<sup>4</sup>Formally, the exchange rate elasticity of any variable  $x$  is  $\xi_x = \frac{\partial x}{\partial E_{lt}} \frac{E_{lt}}{x}$ .

Setting exchange rate elasticities of prices and marginal costs constant,  $\xi_{P_{fglt}} \in [\xi_{P_{-fglt}} \in [\xi_{C_{fglt}} \in [1$ , equation (2.7) states that a domestic currency appreciation always hurts export profits by translating foreign currency revenues into fewer units of the domestic currency. Thus, firms in the home country are likely to increase local currency prices strategically to prevent their revenues, expressed in terms of domestic currency, from falling.

If firms choose a strategy of "complete pass-through" and raise foreign currency prices to the full extent of the domestic currency's appreciation,  $\xi_{P_{fglt}} \in [2$ , unit domestic currency revenues remain unchanged, since prices expressed in terms of the Home currency are fixed. However, they become less price-competitive relative to their competitors in the destination market, and therefore, their volume of sales decrease. Thus, firms' revenue falls proportionally to their specific price elasticity of demand, that is,  $\sigma_{fglt}\%$ . If firms choose a strategy of "zero-pass-through" and keep foreign currency price unchanged ( $\xi_{P_{fglt}} \in [1$ ), prices expressed in terms of the domestic currency fall to the same extent that the domestic currency has appreciated. With this strategy, firms prevent export volume, and therefore revenues measured in foreign currency terms, from declining. However, these foreign currency revenues are translated into fewer units of the domestic currency: a 1% appreciation in the home currency reduces prices expressed in domestic currency by 1%, such that the translation effect equals the ratio of export revenues to total profits. In general, the exchange rate pass-through is likely to be incomplete but higher than zero,  $\xi_{P_{fglt}} \in [1=2]$ , so a domestic currency appreciation hurts export profits by both translating foreign currency revenues into fewer euros and lowering the volume of exports. There is, in fact, a trade-off between (a) the *translation effect* (or *valuation effect*) and (b) the *volume effect*: as the exchange rate pass-through to local currency prices becomes larger, appreciations hurt export profits more through a fall in export volumes, but less through a translation effect.

On the import-competing side, foreign firms that sell their output on the domestic market are also likely to partially lower their prices in response to a domestic currency appreciation. Hence, the domestic price of import-competing firms' also responds to exchange rate changes in reaction to the price adjustments of their foreign competitors, or because of falling marginal costs [Amiti et al., 2015]. Equation (2.6) therefore implies a negative *domestic valuation effect* that equalizes  $\xi_{P_{fgdt}}\%$  times the share of domestic revenue into profit. In addition, as long as foreign exporters lower their price on the domestic market more than domestic producers, an appreciation of the home currency reduces the relative price competitiveness of import-competing firms on the domestic market. This further lowers import-competing firms' revenue through a *domestic volume effect*.

Whether a firm is only import-competing, an exporter, or both, the negative impact of a domestic currency appreciation on its profit may be mitigated if the latter simultaneously reduces its marginal cost. This would indeed allow the firm to stabilize its profit margins. Formally, a 1%

domestic currency appreciation induces a total decrease in a firm's production costs, and thus an increase in its profits, that equalizes the product of the firm's exchange rate elasticity of marginal costs  $\xi_{C_{fglt}}$  times the share of these production costs into its profits. This effect (c) is thereafter referred to as *cost effect*. The valuation and cost effects combine to form a *profit margin effect*, so that the domestic and foreign operating exchange rate exposures can always be rewritten as:

$$\xi_{\Pi_{fgdt}} \left[ \frac{P_{fgdt} Q_{fgdt}}{\Upsilon_{fgdt}} \right] \xi_{P_{fgdt}} \quad \mu_{fgdt}^{-1} \xi_{C_{fgdt}} \left( \sigma_{fgdt}^* \right) \xi_{P_{fgdt}} \quad \xi_{P_{-fgdt}} \left( \quad \right) \quad (2.8)$$

$$\xi_{\Pi_{fglt}} \left[ \underbrace{\frac{P_{fglt} Q_{fglt}}{E_{lt} \Upsilon_{fglt}} \xi_{P_{fglt}}}_{(a')} \quad \mu_{fglt}^{-1} \xi_{C_{fglt}} \quad 2 \left( \underbrace{\sigma_{fglt}^*}_{(b)} \right) \xi_{P_{fglt}} \quad \xi_{P_{-fglt}} \right] \quad (2.9)$$

In other words, an appreciation of the home currency reduces firms' profits by lowering profit margins for a given volume of sales, effect (a'), and/or by lowering sales volumes for a given profit margin, effect (b). Since the amplitude of the exchange rate pass-through inversely affects both effects, there is a clear theoretical trade-off between them.

### 2.2.2.2 Exchange Rate Elasticities of Marginal Costs, Markups and Prices

The price expression (3.13) suggests that a firm's exchange rate pass-through and markup changes depend on both the sensitivity of its own marginal costs and the response of its competitors' prices to exchange rate shocks<sup>5</sup>. Thus, equations (2.8) and (2.9) can be further simplified. Under any oligopoly or monopoly theory, equation (3.13) indicates that exchange rate shocks alter a firm's perceived demand elasticity, so that its anticipated marginal revenue shifts, and that its markup adjusts accordingly. The strategic interaction between the firm and its competitors in a given market, which governs the convexity of the demand curve faced by the firm, that is how the demand elasticity changes along the demand schedule, dictates the extent of markup responses to exchange rate fluctuations [Feenstra et al., 1996]. In general, if demand becomes more elastic as the firm's relative local currency price rises, the markup falls. This case corresponds to the standard intuition of the pricing-to-market literature, according to which domestic currency appreciations, by intensifying the price competition faced by firms from the home country, lead to lower markups [Krugman, 1986].

<sup>5</sup>Recent studies highlights that changes in the average competitors' price is the most important determinant of changes in a firm's own price. See for instance Föllmi et al. [2016] who find that not only the probability, but also the size of a price change increase to a greater extent the further a price is from the average price of the product.

However, exchange rate shocks also cause both shifts in and movements along the marginal cost curve [Gron and Swenson, 1996, 2000], which simultaneously alters a firm's perceived demand elasticity. Thus, besides their direct pro-competitive effects, exchange rate appreciations also drive markups adjustments by shifting marginal costs, so that there is incomplete pass-through of marginal costs changes to prices. In that case, the post-shock equilibrium might be associated with a higher markup, although the price expressed in units of the domestic currency is lower than before [De Loecker and Koujianou, 2014].

In other words, because exchange rate shocks are simultaneously demand and cost shocks, their effects on markups are *a priori* undetermined and primarily depend on the perceived demand elasticities, that is, on firms' market power. Both effects on markups and prices are formalized below. The exchange rate elasticity of marginal costs is first obtained by simply deriving equation (3.9) with respect to the exchange rate:

$$\xi_{C_{fglt}} \left[ \frac{\dot{d}_{fglt}}{d_{fglt}} \right] = 2 \frac{\dot{d}_{fglt}}{d_{fglt}} + \xi_{C_{gt}(\cdot)} \quad (2.10)$$

where  $\frac{\dot{d}_{fglt}}{d_{fglt}} \left[ \frac{D_{fglt}}{\tau_{fglt} E_{lt}} \left[ \frac{-1}{\mathcal{F}_{gt}} \right] \right]$  is the ratio of the local (per unit) distribution costs to the marginal production costs, and  $\xi_{C_{gt}(\cdot)}$  is the exchange rate elasticity of the latter. Thus, as indicated in the previous subsection, equation (2.10) highlights that the sensitivity of marginal cost to exchange rate changes depends on both the extent of local distribution costs and the exchange rate elasticity of marginal production cost,  $\xi_{C_{gt}(\cdot)}$ , which is likely to be negative [Amiti and Konings, 2007, Campa and Goldberg, 2008]. The latter depends primarily on the share of imported inputs in firms' total expenditures, but also on the extent of their returns to scale and productivity adjustment.

Let  $\theta_{fglt} \left[ \frac{\partial \sigma_{fglt} s_{fglt}}{\partial s_{fglt} \sigma_{fglt}} < 1 \right]$  capture the extent of the price elasticity adjustment with respect to a change in a firm's market share  $s_{fglt}$ , or in other words, the convexity of the firm's residual demand curve. Using the markup definition in (2.3), and the exchange rate elasticity of marginal cost in (2.10), the sensitivity of markups with respect to currency fluctuations can be expressed as follows:

$$\xi_{\mu_{fglt}} \left[ \frac{\theta_{fglt}}{2 \frac{\theta_{fglt}}{\theta_{fglt}}} \right] = 2 \frac{\dot{d}_{fglt}}{d_{fglt}} \left( \frac{\theta_{fglt}}{\theta_{fglt}} \right) / \xi_{C_{gt}(\cdot)} \left( \mu_{fglt} * \xi_{P_{-fglt}} \left( \right) \right) \quad (2.11)$$

Substituting (2.11) into the derivative of the price expression (3.13) with respect to the exchange rate, the following expression is obtained for the exchange rate pass-through:

$$\xi_{P_{fglt}} \left[ \frac{2}{2 \frac{\theta_{fglt}}{\theta_{fglt}}} \right] = 2 \frac{\dot{d}_{fglt}}{d_{fglt}} \left( \frac{\theta_{fglt}}{\theta_{fglt}} \right) / \xi_{C_{gt}(\cdot)} \left( \frac{\theta_{fglt}}{2 \frac{\theta_{fglt}}{\theta_{fglt}}} \mu_{fglt} * \xi_{P_{-fglt}} \right) \quad (2.12)$$

Equations (2.11) and (2.12) decompose the exchange rate elasticities of markup and price, respectively, into two components: a response to the movement in firms' own marginal costs (idiosyncratic cost pass-through) and a response to the price changes of its competitors (strategic complementarity elasticity) [Amiti et al., 2015, Auer and Schoenle, 2016]. Equation (2.11) states that in response to a positive currency shock, the more firms' own marginal costs decrease and their competitors' prices increase, the less markups shrink. Thus, equation (2.12) indicates that firms only partially translate marginal cost decreases to lower prices, since the remaining share results in higher markups. Conversely, the strategic complementarity in price settings implies that an increase in competitors' prices only affect a firm's own price through its markup, so that it simultaneously rises both markup and price to the same extent.

Equation (2.11) further suggests that the larger a firm's market power, i.e., the lower is the perceived demand elasticity, the more the firm's markup increases when its own marginal cost declines. Intuitively, the smallest firms have tiny markups and thus no room for absorbing either cost changes, or competitors' price adjustment into markup changes [Garetto, 2016]. However, the response of a firm's markup to a change in its competitors' prices clearly appears non-linear. On one hand, as a firm's markup increases, there is more space to absorb competitors' prices changes into markup changes. On the other hand, the price elasticity of demand declines with market power, in such a way that that the largest firms do not fear external competition and become continuously less characterized by any strategic consideration [Garetto, 2016]. At the extreme limit, the demand for largest firms' products approaches the one in a standard model with monopolistic competition and CES preferences, so that prices are characterized by the CES constant mark-up. The firm's combined response, which appears in (2.11), thus implies a U-shaped relationship between the exchange rate elasticity of markups and its perceived demand elasticity.

In equation (2.12), the coefficient measuring the own cost pass-through of the firm,  $\theta_{fglt}^{-1}$ , and that measuring the strength of strategic complementarities in price setting,  $\mu_{fglt}\theta_{fglt}^{-2}$ , appear consistently to be shaped by the convexity of the firm-product-destination-specific demand curve and negatively correlated. Thus, the firms that react the most to changes in their own cost react the least to changing competitor prices [Auer and Schoenle, 2016]. The smallest firms ( $\theta_{fglt} \leftrightarrow 1$ ) pass most of their cost changes into changes in prices, but do not adjust their price in reaction to a change in competitors' price. Conversely, the largest firms ( $\theta_{fglt} \leftrightarrow \infty$ ) take advantage of competitors' prices increases to raise their own markup and price, but pass almost zero percent of their cost changes into changes in prices. The medium-sized firms take into consideration both their competitors' optimal response their own cost changes, and thus, their markups shrink and (local currency) prices stabilize. This implies a U-shaped relationship between exchange rate pass-through and firms' market power, as measured by their perceived demand elasticity.

**Proposition 1** *The exchange rate elasticity of a firm's markup and (local currency) price is U-shaped in its perceived demand elasticity.*

**Proof:** See [Appendix 2.A.1.1](#)

### 2.2.2.3 Operating Exchange Rate Exposure

The expression for the exchange rate elasticity of price (2.12) is then used to simplify the profit margin effect and the volume effect as defined in (2.9):

$$\xi_{ma_{fglt}} = \frac{2 \varphi_{fglt} \left[ \frac{1}{\xi_{C_{fglt}}} \left( \frac{\varphi_{fglt} \mu_{fglt} \xi_{P_{-fglt}}}{2} \right) \right]}{\xi_{vo_{fglt}}} \quad (2.13)$$

$$\xi_{vo_{fglt}} = \frac{2 \lambda_{fglt} \left[ \frac{1}{\xi_{C_{fglt}}} \left( \frac{\lambda_{fglt} \mu_{fglt} \xi_{P_{-fglt}}}{2} \right) \right]}{\xi_{C_{fglt}}} \quad (2.14)$$

with  $\varphi_{fglt} = \left[ \frac{\sigma_{fglt}^* \theta_{fglt}}{2 \theta_{fglt} + 1} \right] \frac{1}{\sigma_{fglt}}$  and  $\lambda_{fglt} = \left[ \frac{\sigma_{fglt}^* \theta_{fglt}}{2 \theta_{fglt} + 1} \right] \frac{1}{\sigma_{fglt}}$ . Since the decline in marginal costs that follows a domestic currency appreciation simultaneously allows firms to increase markups but to decrease prices, it also allows firms to maintain sales volumes. This clearly appears in (2.14). However, the effect of strategic complementarities in price setting on a firm's volume of sales is undetermined. Intuitively, a rise in competitors' prices has both a direct and an indirect effect on a firm's sales volume. On one hand, the relative price competitiveness of the firm directly improves, and consecutively, its sales rise. On the other hand, the perceived demand elasticity shifts, so that the firm's own markup and price rise, and that its relative price competitiveness declines. The former effect directly increases with a firm's demand elasticity. The latter effect is inversely related to the U-shaped relationship between exchange rate pass-through and firms' market power. This implies a hump-shaped relationship between a firm's volume effect and its market power, as measured by its perceived demand elasticity.

**Proposition 2** *The exchange rate elasticity of a firm's sales volume is hump-shaped in its perceived demand elasticity.*

**Proof:** See [Appendix 2.A.1.2](#)

Comparing equation (2.13) and (2.14) clarifies that the level and convexity of a firm-product-destination-specific demand curve shape the response of both a firm's profit margin and its sales volume to exchange rate changes, and more precisely, to the exchange rate elasticities of its own marginal cost and its competitors' prices. In addition, these responses are negatively correlated. More precisely, the smallest and largest firms absorb (not for the same reason) exchange rate shocks through (local currency) price changes, so that a domestic currency appreciation hurts their profits more through the volume effect than through the profit margin effect. Conversely, medium-sized firms keep prices expressed in terms of foreign currency constant to avoid losing market share, so that their profits diminish more through the profit margin effect than through the volume effect. Summing up (2.13) and (2.14) finally allows simplifying the domestic and for-



own operating exchange rate exposures as follows:

$$\xi_{\Pi_{fgdt}} \left[ \frac{\partial \Pi_{fgdt}}{\partial \sigma_{fgdt}} \right] = \frac{\partial \Pi_{fgdt}}{\partial \sigma_{fgdt}} \left( \frac{\partial \Pi_{fgdt}}{\partial \xi_{C_{fglt}}} \right) \left( \frac{\partial \xi_{C_{fglt}}}{\partial \sigma_{fgdt}} \right) \xi_{P_{-fgdt}} \quad (2.15)$$

$$\xi_{\Pi_{fglt}} \left[ \frac{\partial \Pi_{fglt}}{\partial \sigma_{fglt}} \right] = \frac{\partial \Pi_{fglt}}{\partial \sigma_{fglt}} \left( \frac{\partial \Pi_{fglt}}{\partial \xi_{C_{fglt}}} \right) \left( \frac{\partial \xi_{C_{fglt}}}{\partial \sigma_{fglt}} \right) \xi_{P_{-fglt}} \quad (2.16)$$

Interestingly, while the effect of a currency change on firms' markups and sales volumes is non-monotonically shaped by the perceived demand curves, its overall effect on firms' domestic and export profits is clearly monotonically decreasing with the perceived demand elasticities. In this regard, the larger a firm's perceived demand elasticity is, the more its profits rise when its own marginal cost declines and when its competitors' prices rise.

**Proposition 3** *The exchange rate elasticity of a firm's domestic and export profits is monotonically increasing with its perceived demand elasticity.*

**Proof:** See [Appendix 2.A.1.3](#)

### 2.2.3 A Model with Variable Markups

Propositions 1 to 3 are obtained without the need of functional form choices. However, in order to *empirically* measure the extent of a firm's idiosyncratic cost pass-through and strategic complementarity elasticity, the parameter measuring the convexity of the firm's demand curve,  $\theta_{fglt}$ , needs to be estimated. This implies to specify a demand and competition structure that generates markup variability and incomplete pass-through. With this in mind, the [Atkeson and Burstein \[2008\]](#)'s demand system is adopted from now on, and within this framework, two additional assumptions are specified below. Note importantly that this does not question the level of generality of the theoretical Propositions 1 to 3. These additional assumptions are made for an empirical purpose only.

**Assumption 2.bis** *Customers in country  $l$  have a CES demand aggregator over a continuum of industries,  $g$ , while each industry's output is a CES aggregator over a finite number of products, each produced by a separate firm,  $f$ . Under this assumption, each firm faces the following demand curve:*

$$Q_{fglt} = \epsilon_{fglt} Y_{glt} P_{fglt}^{\eta_{lt} - \varrho_{glt}} P_{glt}^{-\varrho_{glt}} \quad (2.17)$$

where  $\eta_{lt} \approx 2$  is the elasticity of substitution across industries and  $\varrho_{glt} \approx \eta_{lt}$  is the elasticity of substitution across products within an industry. The firms are large enough to affect the price

index, but not large enough to affect the economy-wide aggregates that shift  $Y_{glt}$ . The industry price index,  $P_{glt}$ , which corresponds to the expenditure function is

$$P_{glt} \left[ \prod_{f=1}^{N_{glt}} \epsilon_{fglt} P_{fglt}^{1-\varrho_{glt}} \right]^{\frac{1}{1-\varrho_{glt}}} \quad (2.18)$$

In this manner, the market share of each firm can be written as

$$s_{fglt} \left[ \epsilon_{fglt} \right] \left( \frac{P_{fglt}}{P_{glt}} \right)^{1-\varrho_{glt}} \quad (2.19)$$

Thus, a firm has a large market share when it charges a low relative price  $P_{fglt}/P_{glt}$  and/or when its product has a strong appeal  $\epsilon_{fglt}$  in the eyes of the consumers.

**Assumption 6** *Firms compete in terms of prices and the competition is oligopolistic.* Note however that the qualitative implications are the same for the model with oligopolistic price competition, i.e. Bertrand-Nash, or quantity competition, i.e. Cournot-Nash. Under the market structure specified by assumptions 2.bis and 6., the firm sets its prices according to the following markup rule:

$$P_{fglt} \left[ \frac{\sigma_{fglt}}{\sigma_{fglt} - 2} C_{fglt} \right] \quad \text{with} \quad \sigma_{fglt} \left[ \frac{\eta_{lt} s_{fglt}}{\varrho_{glt} - 2} s_{fglt} \right] \quad (2.20)$$

Equation (2.20) thus allows specifying a firm's perceived demand elasticity (resp. markup) as a decreasing (resp. increasing) function of its market share, and two exogenous parameters, namely the elasticities of substitution between varieties across and within industries,  $\eta_{lt}$  and  $\varrho_{glt}$ . The exchange rate elasticity of markups and (foreign currency) prices are then given by:

$$\xi_{\mu_{fglt}} \left[ \kappa_{fglt} \right] \left( \frac{\mu_{fglt}}{\xi_{P_{fglt}}} \right) \quad (2.21)$$

$$\xi_{P_{fglt}} \left[ \kappa_{fglt} \right] \left( \frac{\mu_{fglt}}{\xi_{P_{fglt}}} \right) \quad (2.22)$$

$$\text{with } \kappa_{fglt} \left[ \frac{\varrho_{glt} \eta_{lt} s_{fglt}}{\varrho_{glt} - 2} \left( \frac{\varrho_{glt} \sigma_{fglt}}{\varrho_{glt} - 2} C_{fglt} \right)^{-1} \right] \quad (2.23)$$

**Proposition 1.bis.** The exchange rate elasticity of a firm's markup and (local currency) price is U-shaped in market share.

**Proof:** See [Appendix 2.A.2.1](#)

This follows the arguments put forward previously and is a common result in the "new" pass-through literature [e.g. [Auer and Schoenle, 2016](#), [Garetto, 2016](#)]. The volume and profit margin



Institute (INSEE), which reports relevant firm-level information including sales, value added, employment, capital, intermediate consumption, wages and other balance-sheet items over the period 1999–2007. Note that during this period, the nominal effective exchange rate of the euro in France rose by around 10%. These firm-level characteristics are merged with a comprehensive panel of French trade flows provided by the French Directorate General of Customs and Indirect Taxes (DGDDI) using a unique firm identifier. This database reports the volume (in tons) and value (in euros) of exports and imports for each eight-digit product (combined nomenclature) and country of destination and/or provenance for all firms located in the French metropolitan territory. As reported in [Table 2.1](#), this sample comprises 21,295 French manufacturing firms in 2007, including 75% exporters and 71% importers. These shares have been stable over the observed period. At the firm-level, [Table 2.1](#) indicates that in 2007, the average share of exports into total output was 18% and that imported inputs represented on average 22% of firms' total intermediate costs. However, whereas the former has slightly risen between 1999 and 2007 (+2% points on average), expenses in intermediate inputs have largely increased over these nine years (+10% points on average). In sum, during this period of the euro appreciation, the proportion of French exporters and importers has stabilized and the share of exports in French exporters' revenue has increased only marginally. However, imports have significantly gained importance in firms' total costs.

Regarding international markets, the empirical framework focuses on trade in manufacturing goods with all non-member countries of the euro area from 1999 to 2007, that is all trade partners excluding Austria, Belgium, Finland, Germany, Greece<sup>6</sup>, Ireland, Italy, Luxembourg, Netherlands, Portugal, and Spain. [Table 2.1](#) indicates that in 2007 these trade flows represented on average 55% of exporting firms' total exports value and 40% of importing firms' total imports value. Note that these trade flows with non-member countries of the euro area have increased sharply after the adoption of the euro.

The specificity of this combined database is that it reports disaggregated data on prices and quantities at the firm-product-destination-year level on the export side, but aggregated data at the firm-year level on the domestic side. This implies that, in what follows, the term “variety” refers to each firm-product-destination triplet in export markets, but to the single firm's dimension in the French domestic market. Thus, the results are reported separately for the domestic market and export markets throughout the paper, and one is expected to pay closer attention to export results, as they are likely to be more accurate. In addition, the estimation of production function coefficients performed in the next subsection are run exclusively on export data, since they allow us to distinguish multi-product firms from single producers.

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<sup>6</sup>From 2001 onward.

In this regard, Table 2.1 indicates that the share of multi-product exporters in the sample was 90% in 2007, and that this share has been constant between 1999 and 2007. The large proportion of multi-producers in the sample is an important feature driving the estimation of production function coefficients. Since input expenditures are typically recorded at the firm level, not across products within a firm, the estimation procedure in the case of multi-product firms is not possible unless one of the following three approaches is adopted: (a) exclude multi-product firms from the sample and focus on only single-product firms, (b) aggregate product values and conduct the analysis at the firm level, or (c) design a mechanism for firms' input expenditure allocation across products and conduct the analysis at the firm-product level.

Table 2.1: Descriptive Statistics by firm and sector

Firm-level						
		mean	p25	p50	p75	sd
Share of exports in output	1999	0.16	0.00	0.24	0.50	0.22
	2007	0.18	0.00	0.29	0.60	0.25
Share of imported inputs	1999	0.12	0.00	0.14	0.60	0.27
	2007	0.22	0.00	0.30	0.69	0.29
Share of exports to non-EZ	1999	0.51	0.17	0.50	0.90	0.37
	2007	0.55	0.23	0.56	1.00	0.36
Share of imports from non-EZ	1999	0.37	0.20	0.22	0.70	0.37
	2007	0.40	0.30	0.29	1.00	0.37
Sector-level						
		mean	p25	p50	p75	sd
Nb. of firms*	1999	21,395*	1,222	1,494	2,376	1,400
	2007	21,102*	8,43	1,439	2,117	1,338
Share of exporters	1999	0.74	0.65	0.78	0.81	0.09
	2007	0.75	0.67	0.80	0.83	0.10
Share of importers	1999	0.69	0.54	0.76	0.80	0.13
	2007	0.71	0.56	0.76	0.82	0.13
Share of multi-product firms	1999	0.90	0.82	0.90	0.92	0.03
	2007	0.90	0.88	0.89	0.93	0.04

Notes: This table reports descriptive statistics on the sample of French manufacturing firms at the firm-level and at the 2-digit sector-level in 1999 and 2007, the first and last year of our period of observation. "non-EZ" refers to non-member countries of the EuroZone. In the "Firm-level" part, the first two rows reports figures for the entire sample, while the last four displays statistics only for exporting or importing firms. \*In the "Sector-level" part, the case "mean" of the first row reports the total number of firms in the sample, not the mean of the number of firms by sector.

As noted by Berman et al. [2012], each one of these approaches has its drawbacks. Given that multi-product firms account for a significant fraction of firms in the sample, Approach (a) is hard to defend. Approach (b) requires specifying a demand system that allows aggregation in a consistent manner and creates the need for additional assumptions on market competition.

Approach (c) requires specifying the assumptions on how input expenditures are allocated across products. Since the empirical results of this study apply to a large cross section of industries and destinations, Approach (b) would imply the assumption of common consumer utility preferences and market structure across these industry-destination pairs in a far more complicated way. For this reason, markups and marginal costs are recovered in the next subsection by exploiting the previous theoretical works of [De Loecker and Warzynski \[2012\]](#) and [De Loecker et al. \[2012\]](#) in the spirit of Approach (c).

### 2.3.2 Estimates of Markups and Marginal Costs in Level

#### 2.3.2.1 Identification Framework

Considering the markup definition in (2.3) and the cost minimization problem presented in [Section 2.2.1.2](#), [De Loecker et al. \[2012\]](#) have shown that the first-order condition for any variable input used on product  $g$  can be rearranged to express the firm-product specific markup as the deviation between the elasticity of output with respect to a variable input and the share of this input in the total revenue. This result is extended here to take into account the fact that, besides the possibility of being multi-producers, firms may also ship each one of their products to multiple destinations. Let  $\rho_{fglt} \equiv Q_{fglt} * Q_{fglt}^{-1}$  be the fraction of the total production of good  $g$  produced by firm  $f$  at time  $t$  delivered to market  $l$ , with the restriction that  $\sum_{l=1}^{L_{fgt}} \rho_{fglt} \leq 2$ . The input cost share attributable to each product-market sales pair within a firm,  $\rho_{fglt}$ , is then given by  $\rho_{fglt} \equiv \rho_{fglt} \rho_{fgt}$ . Therefore, the first-order condition for any variable input used on product  $g$  can be rearranged to express the firm-product-destination specific markup at each period as follows:

$$\mu_{fglt} \equiv \left[ \psi_{fgt}^v * \alpha_{fglt}^v \right]^{-1} \quad (2.26)$$

where  $\psi_{fgt}^v$  denotes the output elasticity of the variable input  $V^v$  for product  $g$ , and  $\alpha_{fglt}^v$  is the share of expenditure on input  $V^v$  allocated to product  $g$  that is shipped to destination  $l$  in the total sales of this product on this specific destination:

$$\psi_{fgt}^v \equiv \frac{\partial \mathcal{S}_{fgt} \cdot V_{fgt}^v}{\partial V_{fgt}^v * \mathcal{S}_{fgt}} \quad (2.27)$$

$$\alpha_{fglt}^v \equiv \frac{\rho_{fglt} \sum_{g=1}^{G_{ft}} W_{fgt}^x X_{fgt}}{P_{fglt} Q_{fglt}} \quad (2.28)$$

In other words, equation (2.26) indicates that for any variable input free of adjustment costs, the firm-product-destination-specific markup drives a wedge between the input's output elasticity and revenue share. This allows estimating a firm-product-destination-specific markup at each period,  $\mu_{fglt}$ , as the deviation between the elasticity of the firm's output with respect to a

given variable input,  $\psi_{fgt}^v$ , and the share of this input in the firm's total revenue,  $\alpha_{fglt}^v$ . From an empirical perspective, the measure of markups expressed by equation (2.26) thus requires two parameters: (i) the output elasticity on a variable input for each firm-product pair, which in turn implies to estimate the parameters of the production function,  $F_{gt}$ , and (ii) the firm-specific share of input expenditures allocated to each product-destination pair,  $\rho_{fglt}$ . Once markups are obtained, marginal costs can be simply calculated by dividing the observed prices by the estimated markups.

This empirical framework implies that at least one input is freely adjustable, in this case materials, but it allows for frictions in the adjustments of capital and labor, and does not impose any assumptions on the returns to scale, nor on the demand and market structure for each industry. This allows avoiding to rely on an extensive set of assumptions about functional forms for consumer utility and market structure [see for instance [Atkeson and Burstein, 2008](#), [Berry et al., 1995](#), [Feenstra and Weinstein, 2010](#)], that would have been defensible only in the context of case studies of particular industries, for which knowledge on institutional details can guide the choice of the appropriate structure. However, this approach relies on output elasticity estimates, and thus, the production functions need to be specified. In particular, estimations of the production function parameters imply that three challenges have to be tackled: (i) output and input prices biases; (ii) the well-known unobserved productivity issue, which leads to both simultaneity and selection biases; and (iii) the challenge of multi-product firms, which lies on the fact that input allocation between products within a plant is never observed. [Appendix 2.B](#) discusses in detail the production function estimation method and the identification strategy employed to obtain consistent estimates of output elasticities for both single- and multi-producers. Then, it presents solutions on how to recover the yearly shares of input expenditures for each product-firm pair,  $\rho_{fgt}$ , required to construct  $\alpha_{fglt}^v$ .

### 2.3.2.2 Output Elasticities, Marginal Costs and Markups

The entire procedure compels us to choose a functional form for the production function. The translog production function is selected here, since it has the advantage, unlike the Cobb-Douglas one, of generating output elasticities that can vary both across firms and across products within a firm [[De Loecker et al., 2012](#)]. [Table 2.7](#) in [Appendix 2.C](#) reports the median output elasticity estimates by sector. The reasonable values reported in this table give us confidence in the efficiency of the estimation procedure, notably in the input price control, which effectively allows comparing output quantities to input expenditures, and in the correction implemented for unobserved productivity, which prevents the coefficients from being biased by simultaneity and selection issues. The essential insights of [Table 2.7](#) are that many industries exhibit increasing returns to scale, and that the contribution of each factor of production varies significantly across them. In addition, since inputs interact in complicated ways with each other in the general translog specification, the output elasticities also vary greatly across firm-product pairs within industries.

However, note that 73% of the firm-product pairs in the sample exhibit increasing return to scale.

The mean, median, and standard deviation of export and domestic markups estimates are reported in the first three and the last three columns of [Table 2.8](#), respectively. Unlike [De Loecker et al. \[2012\]](#), markups are estimated for each firm-product-destination-year quadruplet, and thus, are reported separately for the domestic and export markets. The mean and median export markups are 2.82 and 1.65, while the mean and median of domestic markups are 1.87 and 1.46, respectively. Three essential insights emerge from these figures. First, markups on export markets are higher than on the domestic market. This confirms the existence of an "exporter markup premium" revealed by [De Loecker and Warzynski \[2012\]](#). Second, considerable heterogeneity of markups across sectors and across firm-product-destination triplets within sectors can be observed. Finally, export markups are more dispersed than domestic markups, which is confirmed by higher values of their standard deviations. This high dispersion implies in particular that the high average of export markups is being driven by outliers.

The plausibility of these estimates can be tested by comparing the relationship between observed prices and volume of sales with estimated marginal costs, markups, and productivity. The correlation matrix between these observed and estimated variables is shown in [Table 2.2](#) below. One way of assessing the plausibility of the measures is to analyze the correlation between the volume of exports and marginal costs. Indeed, the methodology provides measures of markups and marginal costs without *a priori* assumptions on returns to scale. As mentioned above, since many firm-product pairs are characterized by increasing returns, one could expect an inverse relationship between marginal costs and production/export quantities. [Figure 2.4](#) in [Appendix 2.C](#) plots (log) quantities against (log) marginal costs for each plant-product-destination-year quadruplet in the sample. Clearly, all sectors appear to be characterized by a downward-sloping marginal cost curve. The first column of [Table 2.2](#) confirms that marginal costs and quantities are strongly negatively correlated, with an average coefficient of -0.59, and shows conversely that markups and quantities are positively correlated, with an average coefficient of 0.31. This reveals that firms producing more output face lower marginal costs and thus could possibly charge higher markups. The results also provide a strong support to the recent empirical evidence and theoretical works on multi-product firms. In particular, as predicted by [Mayer et al. \[2014\]](#), products that have higher marginal costs and are thus further away from firms' "core competency", tend to have lower markups. Finally, consistently with [Melitz \[2003\]](#) and [Melitz and Ottaviano \[2008\]](#), firms with higher productivity have lower marginal costs, which is revealed by a coefficient of correlation between productivity and marginal costs of -0.81, charge higher markups (0.51), and set lower prices (-0.44).



Table 2.2: Correlations between prices, markups, marginal costs, productivity and volume of sales

	Quantities	Prices	Markups	Marginal Costs
Prices	-0,571***			
Markups	0,309***	0,133***		
Marginal Costs	-0,592***	0,532***	-0,717***	
Productivity	0,597***	-0,449***	0,513***	-0,811***

Note: All variables are expressed in logs. Prices, volumes of sales, markups and marginal costs vary at the firm-product-destination level, while productivity varies at the firm level. The table trims observations with markups that are above and below the 98th and 2nd percentiles within each sector. \*\*\* indicates coefficients significantly different from zero at the 1% level.

### 2.3.3 Marginal Costs Responses to Exchange Rate Shocks

Once variety-specific and time-varying markups and marginal costs are obtained in level, the second step of the empirical framework involves estimating the extent to which such measured marginal costs respond to currency shocks. Since the purpose of the whole empirical exercise is to measure exchange rate pass-through and operating exposures that are specific to each one of the firm-product-destination-year quadruplet in the sample, this subsection develops a methodology close to the one used in [Campa et al. \[2005\]](#), which allows estimating of exchange rate elasticities of marginal costs that can vary across firm types, destinations targeted, and types of goods manufactured.

Equation (2.10) indicates that four complementary reasons may explain why a firm's marginal cost is affected by exchange rate changes: (i) increasing returns to scale, which imply a downward-sloping marginal cost curve; (ii) changes in the price of imported inputs; (iii) increases in productivity; and (iv) the existence of local, non-traded costs [[De Loecker and Koujianou, 2014](#), [Goldberg and Hellerstein, 2008](#)]. A firm's productivity is likely to affect the extent to which marginal costs respond to changes in the exchange rate through these channels. First, by increasing the foreign competition faced by domestic producers and exporters, currency appreciations reduce firms' output. This in turn increases marginal costs if returns to scale are increasing [[Knetter, 1989](#)]. By definition, high-performance firms are more resistant to a fiercer price competition. Therefore, one could expect their marginal costs to be less responsive to this channel. Second, a more intensified exposure to international competition can reduce X-inefficiency at the firm level, or encourage firms to undertake actions to become more efficient. For instance, firms can find it profitable to hire more efficient managers, to adopt better management practices [e.g. [Bugamelli et al., 2008](#)] or to increase investment in new technology and R&D [e.g. [Bartel et al., 2007](#), [Bloom et al., 2011](#)]. Since reductions in X-efficiency, investments in R&D, and changes in production technologies are costly, only some firms above a certain productivity cutoff can be able to implement them. Finally, a large stream of recent empirical and structural works emphasizes a

positive relationship between a firm's productivity and its import intensity [e.g. [Amiti and Konings, 2007](#), [Halpern et al., 2011](#)]. In particular, high-performance firms tend to be the largest importers [[Amiti et al., 2012](#)], so that changes in imported input prices cause larger marginal cost adjustments for these import-intensive and high-performance firms [[Amiti et al., 2015](#)].

This heterogeneity along the productivity dimension is exploited below to estimate exchange rate elasticities of marginal costs that can vary across firm performances, destinations targeted, and types of products manufactured. In order to achieve this, a non-parametric specification similar to [Campa et al. \[2005\]](#) and [Berman et al. \[2012\]](#) is implemented, where exchange rate variations interact with (i) different bins constructed from percentiles of firms' productivity; (ii) product fixed effects,  $\delta_{gt}$ , which account for differences in production functions<sup>7</sup> and international shocks between product categories; and (iii) destination fixed effects,  $\delta_l$ , which account for the fact that all firms from the home country may be more exposed to some currencies than to others<sup>8</sup>. Using the marginal cost definition in (3.9), this formally results in the following econometric specification:

$$\Lambda c_{fglt} \left[ \alpha_0 / \right) \alpha_1 / \prod_g \prod_t \alpha_{gt} \equiv \delta_{gt} / \prod_l \alpha_l \equiv \delta_l / \prod_{i=1}^{10} \alpha_{\Omega_i} \equiv \delta_{\Omega_i} \left[ \Lambda e_{lt} / \Lambda v_{fglt} \right. \quad (2.29)$$

where  $\delta_{\Omega_i}$  are dummies for deciles of firms' productivity calculated within each one of the four-digit industry-year pair in the sample, and  $\Lambda v_{fglt}$  amounts to changes in marginal costs that are not related to exchange rate changes, and for which the following general decomposition is postulated:  $\Lambda v_{fglt} \left[ \sum_g \sum_t \delta_{gt} / \sum_l \delta_l / \sum_{i=1}^{10} \delta_{\Omega_i} / \Lambda q_{fglt} / \Lambda \tau_{fglt} / u_{fglt} \right]$ . Thus, for a firm  $f$  manufacturing a given product  $g$  with a productivity included in the  $i^{th}$  decile of productivity within this industry, the elasticity of marginal cost with respect to currency  $l$  at time  $t$  is given by:  $\xi_{C_{fglt}} \left[ \alpha_0 / \alpha_{gt} / \alpha_l / \alpha_{\Omega_i} \right]$ .

These estimates are reported in the first two rows of [Table 2.3](#) that displays descriptive statistics on exchange rate elasticities of variety-specific marginal costs separately for goods sold in the domestic market and those sold in foreign markets. [Table 2.9](#) in [Appendix 2.C](#) reports these estimates broken down by two-digit industry. Two main insights emerge from these figures. First, a 1% appreciation of the euro induces on average a -0.13% decrease in the marginal costs of the varieties produced for the domestic market, and a -0.11% decrease in the marginal costs of the varieties sold in export markets. The medians are -0.16% and -0.11%, respectively. Second,

<sup>7</sup>Some sectoral-specific features imply that some industries rely more on imported intermediates than others. This would be especially the case for raw materials. For example, one could expect transport equipment industries to spend more on natural resources, e.g., imported oil, than publishing and recording media industries.

<sup>8</sup>Intensified horizontal and vertical trade between the home country and some specific trade partners, arising for instance from a common border, historical free-trade agreements or colonialism, and thus affecting the share of imported input expenditures from these specific partners, can explain the fact that firms from the home country are more exposed to some currencies than others on the whole.

the range of these values is large, both across and within industries, with the lower tail of the distribution exhibiting large negative values (-0.39% for varieties sold on the domestic markets and -1.05% for varieties exported from home) and the upper tail of the distribution exhibiting positive values<sup>9</sup> (0.13% for varieties sold on the domestic markets and 0.86% for varieties exported from home).

### 2.3.4 Competitors' Price Responses to Exchange Rate Shocks

Competitors' price responses to currency shocks are measured by estimates of time-varying exchange rate pass-through coefficients across industries worldwide. This implies that the Armington view of competition prevails in the following empirical analysis<sup>10</sup>. Let  $P_{iglt}$  be the import price index of a good  $g$  exported from any country  $i$  to destination  $l$ , and defined in the case of Atkeson and Burstein [2008]'s demand function as  $P_{iglt} = \left[ \sum_{f_i \in \mathcal{C}} \epsilon_{f_i glt} P_{f_i glt}^{1-\theta_{glt}} \right]^{\frac{1}{1-\theta_{glt}}}$  with  $f_i \in \mathcal{C} = \{2, \dots, N_{iglt}\}$  denoting the set of firms exporting from  $i$  to  $l$  in this industry. The zero-profit condition of Melitz [2003] implies that an exporter's profits must cover its fixed cost of exporting. Using the markup definition in (2.3), this is formally expressed by:  $P_{f_i glt} Q_{f_i glt} = \sigma_{f_i glt} E_{ilt} F_{f_i glt}$ . Let a firm's fixed cost of exporting be a flexible specification of its own marginal cost [Bilbiie et al., 2012], real expenditures in the destination economy  $Y_{lt} P_{lt}^{-1}$  [Arkolakis], and a set of bilateral variable between  $i$  and  $l$  that influence fixed costs in the industry  $F_{iglt}$  [Feenstra and Romalis, 2014]:  $F_{f_i glt} = C_{f_i glt}^{\beta_1} Y_{lt} P_{lt}^{-1} F_{iglt}^{\beta_2}$ . Combining the last three equations, assuming that firms are heterogeneous in terms of productivity and denoting  $M_{iglt}$  as the mass of exporters, the following econometric specification for changes in the import price index of any good  $g$  exported from  $i$  to  $l$  is obtained:

$$\Delta p_{iglt} = \beta_1 \Delta c_{iglt} / \beta_2 \Delta y_{lt} - \beta_3 \Delta f_{iglt} / \beta_5 \Delta q_{iglt} / \beta_4 \Delta m_{iglt} / \beta_0 / \prod_{gl} \prod_t \beta_{glt} \delta_{glt} \left[ \Delta e_{ilt} / \prod_{gl} \prod_t \delta_{glt} / \epsilon_{iglt} \right] \quad (2.30)$$

with  $c_{iglt}$  and  $q_{iglt}$  representing the sectoral cost index and total quantity of  $g$  exports from  $i$  to  $l$ , respectively, and  $\delta_{glt}$  denoting industry-destination-year fixed effects. The focus of this empirical exercise is to estimate how changes in the exchange rate between the euro and the currency of a trade partner affect import price indices within each industry at home and at this destination, such that  $e_{ilt}$  only takes values of bilateral exchange rates between the euro and the currency of the corresponding trade partner. In addition, to allow for heterogeneity of the exchange rate

<sup>9</sup>A positive elasticity of marginal costs with respect to the home currency can occur notably because of increasing returns to scale, no imported input, or zero productivity enhancement

<sup>10</sup>In any export markets, the Armington view implies that foreign firms compete with other importers, but not with domestic firms, so that domestic prices can be omitted from the analysis. While this assumption may seem strong, it has been found to be approximately accurate. Auer and Schoenle [2016] for instance find that individual import prices are not correlated with the index of domestic competitors prices, but that they are highly correlated with the index of import competitor prices. In addition, the econometric specification used in this study controls for changes in sectoral and destination-specific domestic price changes by including destination-industry-year fixed effects.

pass-through coefficients along any destination, year, or sectoral-specific dimension, equation (2.30) includes interaction terms between destination-industry-year fixed effects and bilateral exchange rate.

Trade data are provided by the UN Comtrade database, which reports information on bilateral sales values and export quantities between any pair of trade partners worldwide at the four-digit industry level. Information on the mass of exporters and the fixed costs of exporting from  $i$  to  $l$  within each one of the four-digit industries are extracted from the incredible rich database made available by Feenstra and Romalis [2014]. Finally, sectoral cost indices at the four-digit level are proxied by unit labor cost indices extracted from the INDSTAT database provided by UNIDO. Estimations are run at the two-digit level to obtain measures of competitors' prices responses to euro shocks as fine-grained as possible. The latter are given for any 4-digit industry-destination-year triplet  $glt$  by:  $\xi_{P-fglt} [\beta_0 / \beta_{glt}]$ . Note that the exchange rate elasticities of import prices estimated by this empirical framework cover nine years, 412 four-digit industries, and 125 destinations worldwide.

The results are reported separately for the French domestic market and for all export destinations in the first two rows of Table 2.3. On average, a 1% appreciation of the euro entails a -0.21% decrease into French import prices and a 0.18% increase of foreign import prices worldwide. The medians are -0.23% and 0.10 %, respectively. On the domestic market side, these estimates are in line with previous estimates of the import pass-through literature, e.g., Burstein et al. [2014], who find that overall, the medium-run pass-through to U.S import prices is 20% and the life-long pass-through is 28%.<sup>11</sup> On the export markets side, the values of the exchange rate pass-through coefficients are slightly lower than usual, but this can be easily explained. In particular, the coefficients are estimated for each industry-destination pair over worldwide imports in a given year. Thus, the average price of some third trade partners' imports can possibly not be affected (or only slightly) by changes in the bilateral value of the euro with respect to the currency of the destination country.

### 2.3.5 Firms' Exchange Rate Exposure and Testable Predictions

The responses of a firm's product- and destination-specific marginal cost  $\xi_{C-fglt}$  and its competitors' prices to exchange rate shocks  $\xi_{P-fglt}$ , as well as its markup in levels,  $\mu_{fglt}$ , are used to calibrate the exchange rate elasticities of its markup  $\xi_{\mu-fglt}$  and its (local currency) price  $\xi_{P-fglt}$ ,

<sup>11</sup>There is, however, a significant difference with the result of Campa et al. [2005], who estimate coefficients of exchange rate pass-through into aggregate French manufacturing import prices, which range from 0.63 in the short run (one quarter) and 0.80 in the long run (the sum of the contemporaneous quarter coefficients and its four lags) over the period 1989–2001. However, this difference can be explained by the period covered, as France has adopted the euro since 1999. Conditional on changing, prices in their currency of pricing respond less to exchange rate shocks than prices set in the local currency. Thus, differences in the prevalence of local currency pricing (LCP) versus producer currency pricing (PCP) under the euro and the french franc areas probably explain why pass-through into French import prices has declined between the two periods.

using equations (2.21) and (2.22), respectively. This ultimately allows measuring the profit margin effect,  $\xi_{ma_{fglt}}$ , and the volume effect,  $\xi_{vo_{fglt}}$ , defined by (2.24) and (2.25), which combine to form the variety-specific exchange rate operating profits exposure  $\xi_{\pi_{fglt}}$  specified in (2.16).

While markups shape the response of prices and profits to currency fluctuations, the whole calibration is performed without the need of any market share calculation. Indeed, in equation (2.22), the cost pass-through coefficients  $\kappa_{fglt}$  are expressed as a function of the variety-specific perceived demand elasticities  $\sigma_{fglt}$  and the elasticities of substitution across products within each industry-destination pair,  $\rho_{glt}$ . The former are obtained thanks to markups estimates in level and the use of equation (2.3), and the latter are extracted at the four-digit industry level from the database provided by Feenstra and Romalis [2014]. The theoretical predictions of Section 2.2 are, however, empirically tested using firms' market shares,  $s_{fglt}$ . These are calculated by aggregating firms' sales on each four-digit industry-destination pair over a year and dividing it by total (world) imports of the corresponding industry-destination pair over the same year. In addition, since (i) marginal costs responses to currency shocks particularly depend on a firm's productivity and its share of imported inputs, and (ii) the average competitor prices' responses to currency changes depend on a set of industry- and destination-specific features, the theoretical predictions are tested using the following econometric specification:

$$\xi_{X_{fglt}} \left[ \gamma_0 / \gamma_1 s_{fglt} / \gamma_2 s_{fglt}^2 / \gamma_3 \tilde{\pi}_{ft} / \gamma_4 I_{ft} / \prod_{gl} \prod_t \delta_{glt} / v_{fglt} \right] \quad (2.31)$$

where  $\tilde{\pi}_{ft}$  and  $I_{ft}$  are the firm-specific (log) productivity and share of imported inputs in total input expenditures, and  $\delta_{glt}$  are industry-destination-year fixed effects. The dependent variable of the model,  $\xi_{X_{fglt}}$  will alternatively be the calibrated variety-specific exchange rate elasticities of prices  $\xi_{P_{fglt}}$ , markups,  $\xi_{\mu_{fglt}}$ , profit margins,  $\xi_{ma_{fglt}}$ , volume of sales,  $\xi_{vo_{fglt}}$ , and profits,  $\xi_{\Pi_{fglt}}$ .

## 2.4 Results

### 2.4.1 Prices and Markups

The first testable prediction is that the exchange rate elasticities of firms' markups and prices are U-shaped in market shares. The last four rows of Table 2.3 report the calibrated exchange rate elasticities of markups and local currency prices separately for the varieties sold in the French domestic market and those sold in export markets worldwide. Tables 2.10 and 2.11 in Appendix 2.C report summary statistics on these calibrated elasticities broken down by two-digit industry level. These provide some useful insights.

First, the transmission of exchange rate shocks to traded prices is incomplete. This implies that French manufacturing firms incur a substantial loss of unit revenues expressed in terms of the domestic currency (euro). In addition, the mean and median exchange rate elasticities of French firms' prices, expressed in terms of local currency, are higher than those of their competitors in both the domestic market and export market. This implies a strong reduction of their price competitiveness worldwide. Thus, the average and median French firms' operating profit diminish because of both a negative valuation effect and a negative volume effect.

Second, the extent of these adjustments varies significantly both across and within sectors. The mean and median exchange rate pass-through rate into local currency prices are 39% and 21%, respectively, but the mean varies from 9% in the industry of wearing apparel, fur and leather to 77% in the industry of fabricated metal products. Note that the magnitude of these values is in line with previous estimates reported in the literature. [Garetto \[2016\]](#), for instance, find an average pass-through rate of 39% to 43% to local currency selling prices into the car industry across 14 origin countries<sup>12</sup>. On the domestic side, the mean and median decline in French manufacturing firms' domestic prices induced by a 1% appreciation of the euro are -0.18% and -0.20%, respectively, while the mean varies from -0.09% in the industry of basic metals to -0.33% in the industry of pulp and paper products. The heterogeneity of domestic and export prices' responses to currency shock within sectors is highlighted by the high standard deviation values of exchange rate pass-through coefficients displayed in [Table 2.11](#).

Third, the decline in export and domestic prices expressed in terms of euros—which follow an appreciation—is coupled with a decrease in domestic and export markups. The mean and median fall in export markups caused by a 1% domestic currency appreciation are respectively -0.34% and -0.33%, but again, the extent of markup adjustments across varieties between and within sectors is large. The upper tail of the distribution even exhibits positive values. This implies that, while the average and median French export markups fell during the appreciation of the euro between 1999 and 2007, some French firms have benefitted from this appreciation by substantially increasing their markups. An interesting fact is that the calibrated fall in domestic markups is

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<sup>12</sup>The magnitude of this exchange rate pass-through rate into local currency selling prices is, however, lower than the one estimated in the case of domestic currency f.o.b. prices by [Berman et al. \[2012\]](#). The latter find that the average French exporter increased its export price in euro from 0.8% to 13.5% depending on the sample (single-product firms, core competency products, firm-product level, etc.) in response to a 10% appreciation of the euro over the period 1995–2005. This corresponds to an exchange rate pass-through coefficient of around 0.9. This difference has at least two explanations. First, the shift from the French franc to the euro over this period has probably increased the share of PCP (euro pricing) behavior, so that French exporters now adjust more their price expressed in terms of domestic currency (euros) than prices expressed in terms of local currency. Second, lower exchange rate pass-through for consumer prices than for border prices of exported goods can be mechanically explained by the presence of significant local costs that are insensitive to exchange rate movements. Several studies document the higher degree of stickiness in border prices in comparison to consumer prices, as producer/border prices include many business-to-business transactions and contracts that may incorporate non-price features, while consumer good prices cover mostly list (spot) price [[Burstein et al., 2014](#)]. [Friberg and Wilander \[2008\]](#) use survey data for Swedish exporters and find that even exporters list a price the median price adjustment is once per year.

lower than the fall in export markups, with an average of -0.6% and a median of -0.4%, whereas its heterogeneity is larger. More specifically, almost 30% of French firms in the sample appears to have responded to the euro appreciation by increasing domestic markup (16% of the varieties within the sample for export markups). In sum, domestic and export markups can increase or decrease in response to an exchange rate shock, depending on the cost structure of firms and the competition structure of the industry.

**Table 2.3: Exchange rate elasticities of firms' own markups, marginal costs and prices, and competitors' prices**

variable	obs.	mean	p5	p25	p50	p75	p95	sd.
$\xi_{P_{-fgdt}}$	2,849	-0.21	-0.67	-0.39	-0.23	-0.11	-0.03	0.21
$\xi_{P_{-fglt}}$	351,405	0.18	-0.02	0.02	0.10	0.17	0.24	0.07
$\xi_{C_{fgdt}}$	151,972	-0.13	-0.39	-0.23	-0.16	-0.01	0.13	0.35
$\xi_{C_{fglt}}$	5,799,703	-0.18	-1.05	-0.49	-0.18	0.30	0.86	0.39
$\xi_{\mu_{fgdt}}$	102,312	-0.04	-0.41	-0.18	-0.06	0.04	0.11	0.32
$\xi_{\mu_{fglt}}$	4,082,091	-0.34	-0.91	-0.50	-0.33	-0.24	0.22	0.29
$\xi_{P_{fgdt}}$	102,312	-0.18	-0.54	-0.30	-0.20	-0.11	0.17	0.25
$\xi_{P_{fglt}}$	3,909,382	0.39	-0.05	0.06	0.21	0.45	0.97	0.29

This heterogeneity of pass-through rates and markup reactions to currency shocks across varieties is explored using the econometric specification (2.31). The results are reported in Table 2.4 below. Columns (1) and (4) regress the variety-specific exchange rate elasticities of local currency selling prices and markups, respectively, on market shares and their square; columns (2) and (5) report the results of the baseline equation (2.31); and finally, columns (3) and (6) add the square of (log) firms' productivity to the baseline equation. In all specifications, the coefficients associated with the market share and its square are strongly significant, negative and positive respectively, and of comparable magnitude. The baseline specifications imply that a 10% increase in a variety's market share increases the variety's price and markup in response to an exchange rate shock by  $1.45 / 1.88 s_{fglt}\%$  and  $1.82 / 2.2; s_{fglt}\%$ , respectively. Thus, consistent with Proposition 1, the response of local currency selling prices and markups to exchange rate changes are U-shaped in market shares.

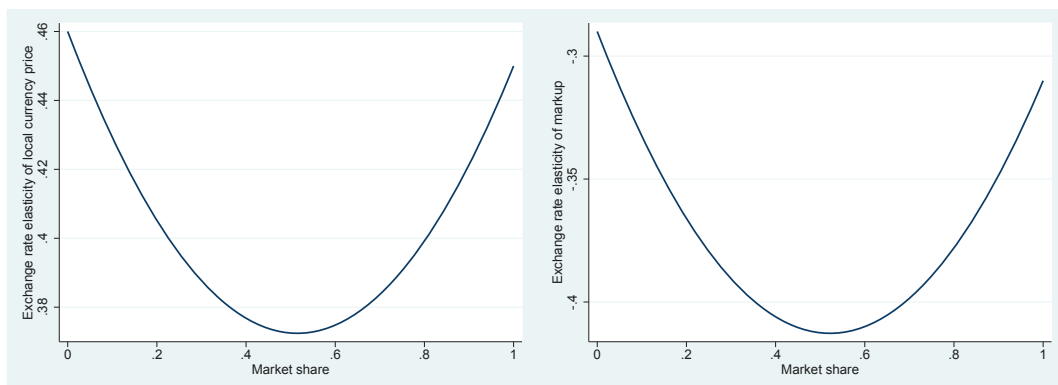
Figure 2.1 plots the values of  $\dot{\xi}_{P_{fglt}}$  and  $\dot{\xi}_{\mu_{fglt}}$  estimated by the baseline specifications reported in columns (2) and (5), respectively. The first subfigure on the left emphasizes that, all other things being equal,  $\dot{\xi}_{P_{fglt}}$  is decreasing in the interval  $s_{fglt} \in ]1 \Leftrightarrow 1.63[$ , ranging from 0.46 to 0.37; and increasing in the interval  $s_{fglt} \in ]1.63 \Leftrightarrow 2[$ , ranging from 0.37 to -0.45. The second subfigure on the right highlights that the value of  $\dot{\xi}_{\mu_{fglt}}$  decreases from -0.29 to -0.41 in the same first interval and then increases until -0.31 for a firm in monopoly. Thus, the smallest firms and largest firms—for different reasons—exhibit higher pass-through rates than medium-sized firms do and tend to shrink their markup to a lesser extent in response to a domestic currency appreciation.

Table 2.4: Heterogeneity of exchange rate elasticities of markups and local currency prices along market shares, French manufacturing industries, 1999-2007

	$\zeta_{P_{fglt}}$			$\zeta_{\mu_{fglt}}$		
	(1)	(2)	(3)	(4)	(5)	(6)
$S_{fglt}$	-0.47*** (0.01)	-0.34*** (0.01)	-0.31*** (0.01)	-0.53*** (0.01)	-0.47*** (0.01)	-0.44*** (0.01)
$S_{fglt}^2$	0.45*** (0.01)	0.33*** (0.01)	0.30*** (0.01)	0.51*** (0.01)	0.45*** (0.01)	0.41*** (0.01)
$\tilde{v}_{ft}$		0.02*** (0.00)	0.01*** (0.00)		0.10*** (0.00)	0.12*** (0.00)
$\tilde{v}_{ft}^2$			0.00*** (0.00)			0.01 (0.00)
$I_{ft}$		0.01*** (0.00)	0.01*** (0.00)		0.13*** (0.00)	0.13*** (0.00)
$\_cons$	0.41*** (0.00)	0.46*** (0.00)	0.46*** (0.00)	-0.34*** (0.00)	-0.29*** (0.00)	-0.30*** (0.00)
N	3,909,382	3,026,006	3,026,006	3,182,091	3,169,582	3,159,582
R sq Adj.	0.32	0.34	0.34	0.36	0.44	0.45

Note: Standard errors in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All regressions include industry-destination fixed effects and year dummies.

Figure 2.1: Exchange rate elasticity of local currency prices and markups along market share





Finally, note that conditional on market shares and the shares of imported intermediate inputs, a raise in a firm's productivity monotonically and significantly reduces the shrink in markup required to remain competitive after an appreciation of the home currency, and thus, monotonically increases local currency price adjustment. Finally, conditional on a firm's productivity and market share, a rise in the share of imported inputs into the firm's expenditures substantially increases the exchange rate elasticity of markup (i.e., the firm shrinks its markup "less" following an appreciation of the home currency), so that the adjustment of its local currency price is larger. This is coherent with recent empirical findings in the literature emphasizing imperfect pass-through of marginal cost shocks into prices<sup>13</sup> [e.g. De Loecker et al., 2012].

#### 2.4.2 Profit Margin Effect and Volume Effect

The second testable prediction is that the volume effect and the profit margin effect are hump-shaped and U-shaped, respectively, in market shares. Table 2.5 below reports descriptive statistics on the calibrated profit margin effect, volume effect, and total exposure for the varieties sold in the domestic market and those sold in export markets separately. Tables 2.12, 2.13, and 2.14 in Appendix 2.C report these elasticities broken down by two-digit industries. This allows drawing the following stylized facts. First, the average decrease in French domestic and export profit margins induced by a 1% appreciation of the euro are -0.05% and -0.36%. The medians are -0.04% and -0.40%, respectively. Thus, an increase in the value of the home currency diminishes the average and median profit margin made by firms in domestic and export markets, consistent with the conventional view. In addition, the decline in export profit margins is substantially larger than that in domestic profit margins.

Second, the mean of the calibrated exchange rate elasticities of domestic and export volumes is -0.05% and -0.32%, respectively. Their median are -0.13% and -0.24%, respectively. These values correspond to the real exchange rate elasticity of French firms' export volume found in Berman et al. [2012], which ranges from -0.25% to -0.43% over the period 1995–2005 according to firms' decile of productivity. Thus, an appreciation of the home currency substantially decreases domestic firms' sales volumes—for a given profit margin—in both the domestic market and export markets. Note that as one could have expected, the decline in export volumes is substantially larger than that in domestic sales volumes.

Third, the heterogeneity of the profit margin effect and the volume effect is large both across and within industries. Across industries, the mean of the export profit margin effect varies from -0.71% in the machinery and equipment industry to -0.03% in the wearing apparel, fur, and leather industry. The mean of the export volume effect varies from -0.69% in the fabricated metal prod-

<sup>13</sup>The greater a firm's share of imported inputs, the more an appreciation of the domestic currency reduces its marginal cost. Hence, the firm absorbs this "additional" fall in marginal costs into a rise in markup, and thus a rise in its price.

ucts industry to -0.18% in the machinery and equipment industry. Within industries, this heterogeneity is highlighted by the high value of standard deviations reported in Tables 2.12 and 2.13. Overall, while an appreciation of the euro appears to reduce both the profit margin and the volume of sales for most varieties in the sample, some varieties exhibit a zero or positive coefficient of either the profit margin effect or the volume effect. This is shown in Table 2.5, which clearly indicates that, when the home currency appreciates, the profit margin or the sales volume of some varieties are constant or increase.

Fourth, consistent with the theoretical model presented in Section 2.2, there is a significant trade-off between the profit margin effect and the volume effect. This is shown by Figure 2.5 in Appendix 2.C, which plots the valuation effect against the volume effect estimated for each one of the varieties exported within the sample. The negative trend between both elasticities within each industry clearly emphasized that the higher the volume effect, the lower the profit margin effect. In other words, whereas some firms absorb a negative currency shock into profit margins, others choose to keep their profit margin constant at the cost of a loss in their sales volume.

Table 2.5: Profit margin effect, volume effect, and operating exchange rate exposure

variable	obs.	mean	p5	p25	p50	p75	p95	sd.
$\xi_{ma_{fgdt}}$	100,266	-0.05	-0.31	-0.13	-0.04	0.02	0.18	0.15
$\xi_{ma_{fglt}}$	3,374,420	-0.36	-1.09	-0.62	-0.40	-0.13	0.55	0.59
$\xi_{vo_{fgdt}}$	98,262	-0.05	-0.66	-0.29	-0.13	0.05	0.58	0.31
$\xi_{vo_{fglt}}$	3,918,823	-0.32	-1.05	-0.51	-0.24	-0.08	0.00	0.22
$\xi_{\bar{m}_{fgdt}}$	100,266	-0.21	-1.14	-0.47	-0.11	-0.11	0.31	0.31
$\xi_{\bar{m}_{fglt}}$	3,942,733	-0.27	-1.15	-0.29	-0.21	0.06	0.34	0.44

The role of the market share in this trade-off is tested using the econometric specification (2.31). The results are reported in Table 2.6 below. Columns (1) and (4) regress the profit margin effect and the volume effect, respectively, on market share and its square; columns (2) and (5) report the results of the baseline specification (2.31); and finally, columns (3) and (6) add the square of (log) firms' productivity to the baseline equation. In all specifications, the coefficients associated with the variety's market share and its square clearly appear significant, and their sign in the case of the profit margin effect is negatively correlated with those of the volume effect. Thus, whereas the profit margin effect is significantly U-shaped in market share, the volume effect is clearly hump-shaped. Figure 2.2 plots the predicted values of  $\dot{\xi}_{ma_{fglt}}$  and  $\dot{\xi}_{vo_{fglt}}$  by the baseline specifications. The subfigure on the left emphasizes that the profit margin of varieties with a market share close to 0 or 1 is almost non-responsive to currency shocks ( $\dot{\xi}_{ma_{fglt}} \Leftrightarrow 1$ ). In other words, the smallest and largest firms incur no loss of profit margin when the domestic currency appreciates. However, an appreciation of the home currency substantially reduces the profit margin of medium-sized firms.  $\dot{\xi}_{ma_{fglt}}$  tends to be -0.4 for varieties with a market share close

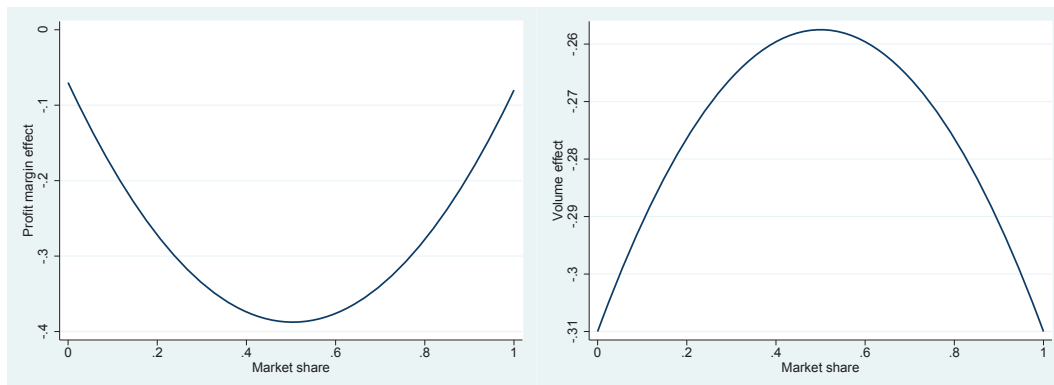
to 0.5. Conversely, the second subfigure on the right emphasizes that, thanks to a significant decline in their profit margin, medium-sized firms limit the fall of their sales volume. However, the smallest and largest firms incur a significant loss in their volume of sales, with a value of  $\hat{\xi}_{vo_{fglt}}$ , which tends to -0.31.

Table 2.6: Heterogeneity of exchange rate elasticities of profit margins, sale volumes and profits along market shares, French manufacturing industries, 1999-2007

	$\xi_{ma_{fglt}}$			$\xi_{vo_{fglt}}$			$\xi_{\pi_{fglt}}$		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$S_{fglt}$	-0.59*** (0.02)	-1.26*** (0.03)	-1.57*** (0.03)	0.39*** (0.01)	0.21*** (0.01)	0.16*** (0.01)	0.20*** (0.01)	0.07*** (0.01)	0.07*** (0.01)
$S_{fglt}^2$	0.56*** (0.01)	1.25*** (0.01)	1.55*** (0.01)	-0.38*** (0.01)	-0.20*** (0.01)	-0.16*** (0.01)	-0.07 (0.01)	-0.02* (0.01)	-0.02 (0.01)
$\sim f_{jt}$		0.17*** (0.00)	0.11*** (0.00)		-0.03*** (0.00)	-0.03*** (0.00)		0.02*** (0.00)	0.03*** (0.00)
$\sim^2 f_{jt}$			-0.02 (0.00)			0.01*** (0.02)			0.01 (0.01)
$I_{ft}$		0.22*** (0.01)	0.23*** (0.01)		0.01*** (0.00)	0.01*** (0.00)		0.02*** (0.00)	0.03*** (0.00)
cons	-0.39*** (0.00)	-0.07*** (0.00)	-0.02*** (0.00)	-0.24*** (0.00)	-0.31*** (0.00)	-0.32*** (0.00)	-0.23*** (0.00)	-0.30*** (0.00)	-0.30*** (0.00)
N	3,749,356	2,904,995	2,904,995	3,091,823	3,041,926	3,041,926	3,0942,733	3,058,978	3,058,978
R sq Adj.	0.05	0.09	0.10	0.23	0.24	0.24	0.20	0.21	0.21

Note: Standard errors in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All regressions include industry-destination fixed effects and year dummies.

Figure 2.2: Exchange rate elasticity of profit margins and sales volumes along market share



### 2.4.3 Operating Profits Exposure to Exchange Rate Changes

The last testable prediction of the theoretical model is that, despite its non-monotonic effect on profit margins and sales volumes, an exchange rate appreciation monotonically decreases operating profits as a firm's market share gets closer to 0. In other words, the larger a firm's market share, the less an increase in the value of the domestic currency diminishes its domestic and export operating profits. The last two rows of [Table 2.5](#) indicate that the heterogeneity of the variety-specific exchange rate exposures is large. On average, a 1% appreciation of the euro diminishes profits made by French manufacturing firms by -0.21% in the domestic market and -0.27% in export markets. The medians are respectively -0.11% and -0.21%, respectively. While many varieties exhibit a negative exchange rate exposure coefficient, some varieties appear to have benefitted from the euro appreciation, as they are associated with a positive exchange rate exposure. This arises because, whereas some firms suffer from a strong loss of price competitiveness and/or from a significant decrease in their profit margins, other benefit from significant marginal costs reduction and/or from reallocation of market shares.

The variety-specific exchange rate exposures are aggregated at the firm level for each year<sup>14</sup>, and the distribution of the French manufacturing firms' exchange rate exposure coefficient is plotted in [Figure 2.6](#) below. This clearly highlights the heterogeneity effects of a currency shock on firms' profit. It is obvious that some firms exhibit positive exchange rate exposure, i.e., they benefit from an appreciation of the home currency, while others incur substantial loss in domestic, export, and total profits.

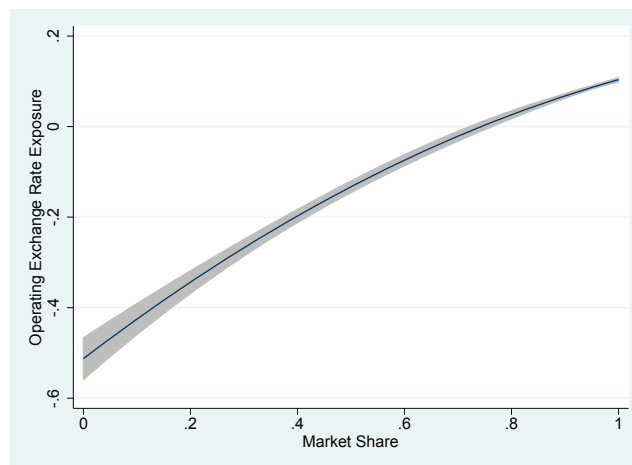
This heterogeneity is explored using once more the econometric baseline specification (2.31). The results are reported in the last three columns of [Table 2.5](#). An increase in market share significantly reduces the exposure of French manufacturing firms' operating profits to negative exchange rate shocks. The coefficient associated with the square of firms' market share is significant, but implies that the relationship between a firm's market share is monotonically increasing and concave as long as  $s_{fglt} \in ]1; 2[$ . Thus, as a variety's market share gets larger, its profit becomes less and less negatively exposed to domestic currency appreciations. [Figure 2.3](#) below plots the quadratic prediction of a variety's exchange rate exposure according to its market share. This emphasizes that while the varieties associated with the lowest market shares ( $s_{fglt} \Leftrightarrow 1$ ) or those associated with average market shares ( $s_{fglt} \Leftrightarrow 1.6$ ) exhibit, respectively, a high and a moderate negative exchange rate exposure coefficient ( $\xi_{\Pi_{fglt}} \Leftrightarrow -0.5$  and  $-0.2$ ), the largest firms ( $s_{fglt} \Leftrightarrow 2$ ) exhibit a positive exposure coefficient ( $\xi_{\Pi_{fglt}} \Leftrightarrow 1.2$ ). In other words, an appreciation of the home currency increases (or does not affect) profits for the largest firms, but reduces

<sup>14</sup>Formally, a firm-specific exchange rate exposure is defined by:

$$\xi_{\Pi_{ft}} = \sum_g \sum_l \frac{\Pi_{fglt}}{\Pi_{ft}} \times \xi_{\Pi_{fglt}}$$

profits for the smallest firms and medium-sized firms. This stylized fact is robust to including productivity and share of imported controls. Since large firms account for a substantial amount of total sectoral profits, this finding provides a significant explanation for the low level of exchange rate exposure coefficient found in previous studies using stock market data or aggregate industry-level data.

Figure 2.3: Operating exchange rate exposure along market share



## 2.5 Conclusion

This study provides a theoretical and an empirical framework that help to explain how and to what extent exchange rate fluctuations affect the profitability of heterogeneous import-competing and exporting firms. The general accounting framework allows the exposure of a firm's profit to currency shocks to be decomposed into two components: an effect on profit margin for a given sales volume, and an effect on sales volume for a given profit margin. Both effects are inversely correlated with the firm's pass-through rate, which is itself decomposed into two components: the response of its own marginal cost and the response of its competitors' prices to currency changes. The extent of both responses depends on the firm's markup level and on the convexity of the firm's residual demand curve. In this framework, the pass-through rate is shown to be U-shaped in firms' market power, and thus, the exchange rate elasticity of profit margin and the exchange rate elasticity of sales volume are U-shaped and hump-shaped in market share, respectively. In other words, the smallest and largest firm—not for the same reason—incur no loss of profit margin when the domestic currency appreciates, at the cost of a fall in their sales volume. Conversely, medium-sized firms shrink their profit margin significantly to keep their market share constant.

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Despite this non-monotonic effect, the exchange rate exposure of profits is shown to be linear on the whole. Using French firm-level data over the period 1999–2007, the empirical framework concludes that the appreciation of the euro during this period slightly increased or had no effect on profits made by the largest firms, but significantly reduced profits made by the smallest and medium-sized firms. Since large firms account for a substantial amount of total sectoral profits, this finding helps to explain "the exchange rate exposure puzzle", that is, the low value of exposure to exchange rate shocks reported in previous empirical studies based on stock market data or on industry-level data.



# Appendix

## 2.A Derivations and Proofs

### 2.A.1 General case

#### 2.A.1.1 Derivation and Proof of Proposition 1

Time, sectoral and destination subscripts are omitted for clarity. Consider the domestic and foreign exchange exposures defined in (2.6) and (2.7). Since the ratio of profits to export volume is equal to the unit profit margin,  $\Upsilon_f = \frac{P_f E^{-1} C_f}{Q_f}$ , the share of export revenues into profits equals the perceived demand elasticity:  $P_f E^{-1} Q_f \Upsilon_f = \sigma_f$ . Using the price specification (3.13), a firm's exchange rate pass-through can be expressed by

$$\xi_{P_f} = \frac{2}{\xi_{\mu_f} / \xi_{C_f}} \quad (2.32)$$

where the exchange rate elasticity of the firm's marginal cost,  $\xi_{C_f}$ , is given by (3.9), and the exchange rate elasticity of markup equals

$$\xi_{\mu_f} = (\xi_{\sigma_f} - \sigma_f) \sigma_f^{-2} \quad (2.33)$$

The sensitivity of the price elasticity of demand with respect to the exchange rate,  $\xi_{\sigma_f}$ , can be rewritten as the product of the sensitivity of the price elasticity of demand with respect to a change in the market share times the exchange rate elasticity of the market share, that is

$$\xi_{\sigma_f} = \theta_f * \xi_{s_f} \quad (2.34)$$

Given that firms are large enough to affect the price index but not large enough to affect the economy-wide aggregates that shift the demand expenditure,  $Y$ , the exchange rate elasticity of a firm's market share is

$$\xi_{s_f} = \frac{2}{s_f + 1} \left( \xi_{P_f Q_f} - \xi_{P_{-f} Q_{-f}} \right) \quad (2.35)$$



with  $P_{-f}Q_{-f} = \sum_{i \neq f} P_i Q_i / Y - P_f Q_f$ . Using this definition, the exchange rate elasticity of the firm's competitors' prices is then given by  $\xi_{P_{-f}Q_{-f}} = \sigma_f - 2 - \sigma_f^{-1} \xi_{P_f Q_f}$ , so that the exchange rate elasticity of the firm's market share can be rewritten as

$$\xi_{s_f} = \xi_{P_f Q_f} - 2 - \sigma_f \xi_{P_f} / \sigma_f \xi_{P_{-f}} \quad (2.36)$$

Combining (2.34), (2.36) and (2.32) and substituting back into (2.33) yields the exchange rate elasticity of the firm's markup expressed in (2.11). The substitution of (2.11) into (2.32) then yields the specification for the firm's exchange rate pass-through (2.12).

The derivative of equations (2.11) and (2.12) with respect to the perceived price elasticity of demand,  $\sigma_f$ , have the exact same discriminant,  $\Lambda = \theta_f - 2 \left[ \frac{\xi_f}{\sigma_f} \right]^2 \approx 1$ , associated with two similar roots:  $\phi_{f1} = 2$  and  $\phi_{f2} = \frac{\xi_f}{\theta_f} \left[ \frac{\xi_f}{\sigma_f} - 2 \right] > 1$ , where  $\frac{\xi_f}{\sigma_f} \left[ \frac{\xi_f}{\sigma_f} - 2 \right] / \xi_{C_f} \left( 0 \xi_{P_{-f}} \approx 2 \right)$ . The exchange rate pass-through and markup's elasticity thus decrease in the interval  $\sigma_f \in ]2, \phi_{f2}[$  and then increase for firms with  $\sigma_f \approx \phi_{f2}$  (Proposition 1).

### 2.A.1.2 Derivation and Proof of Proposition 2

The volume effect as specified in (2.14) is obtained by substituting the firm's exchange rate pass-through (2.12) into its simplified expression (2.7.(b)). The derivative of (2.14) with respect to the perceived price elasticity of demand,  $\sigma_f$ , can be expressed by  $\partial \xi_{vo_f} / \partial \sigma_f = 3 - \sigma_f - 2 \left[ \frac{\xi_f}{\sigma_f} - 2 \right] / \sigma_f - 2 \left[ \theta_f \right]$ . The latter expression has a positive discriminant,  $\Lambda = 2 / \theta_f - 2 \left[ \frac{\xi_f}{\sigma_f} - 2 \right] \geq 2$ , which is associated with two roots:  $\phi_{1f} = 2 / \frac{(1-\sqrt{\Delta})}{4 \bar{\xi}_f - 1} \geq 2$  and  $\phi_{2f} = 2 / \frac{(1+\sqrt{\Delta})}{4 \bar{\xi}_f - 1} \approx 2$ . The exchange rate elasticity of sales volume thus increases with the perceived demand elasticity in the interval  $\sigma_f \in ]2, \phi_{2f}[$  and then decreases for firms with  $\sigma_f \approx \phi_{2f}$  (Proposition 2).

### 2.A.1.3 Derivation and Proof of Proposition 3

Finally, the domestic and foreign operating exposures defined in (2.15) and (2.16) are obtained by substituting the expression for a firm's exchange rate pass-through (2.12) into (2.6) and (2.7). The former are clearly monotonically increasing in a firm's perceived demand elasticity,  $\sigma_f$  (Proposition 3).

## 2.A.2 Atkeson and Burstein [2008]'s settings

### 2.A.2.1 Proof of Proposition 1.bis

Consider the exchange rate elasticities of markups and (foreign currency) prices defined by (2.21) and (2.22), respectively. For each firm-product-destination-year quadruplet, their derivative with respect to the perceived demand elasticity have a similar discriminant,  $\Delta = (5\xi - 2)\varrho - 2 + \approx 1$ , with two similar roots, but only one superior to 1:  $\xi = 2 / \left( \frac{\varrho - 1}{\xi - 1} \right)$ . Thus, the exchange rate elasticities of markups and (foreign currency) prices both decrease with the market share in the interval  $]1 - \hat{\xi}$ , and then increase in the interval  $]\hat{\xi} - 2$  (Proposition 1.bis) with

$$\xi \left[ \frac{\varrho - 2}{\varrho - \eta} \right] \varrho - 2 + \xi - 2 + \left( -\frac{1}{2} \right) \left[ \right]$$

### 2.A.2.2 Proof of Proposition 2.bis

The derivative of the volume effect (2.25) with respect to the demand elasticity is strictly decreasing in the interval  $]1 - \hat{\xi}$  and can take values ranging from  $\varrho - 2 + \approx 1$  for  $s \in ]2$  to  $\in$  for  $s \in ]1$  to. In other words, the derivative changes sign in the interval  $]1 - \hat{\xi}$ , taking first positive and then negative values. Thus, the volume effect increases (that is, becomes less and less "negative") until a given market share  $s$ , and then decreases as the market share gets closer to 1 (Proposition 2.bis).

## 2.B Marginal Costs and Markups Measures

Recovering markups and marginal costs requires estimates of two crucial parameters: (i) the output elasticities with respect to at least one variable input, which is assumed in our setting to be materials  $\psi_{fgt}^m$ ; and (ii) the share of input expenditures allocated within a firm to each product-destination output pair  $\rho_{fglt}$ . The first parameter is associated with three challenges traditionally related to the estimates of the production function coefficients: “input price” bias, “input allocation” bias and “unobserved productivity”. The first section of this appendix discusses these issues and details the strategies selected to tackle each one of these challenges. The second section describes their practical implementation in a unified framework. The second parameter is clearly equal to 1 in the case of firms that manufacture only one product for one destination. The last section of this appendix explains how this parameter is recovered in the case of multi-product and multi-destination firms.

### 2.B.1 Production Function Estimates

Since the production technology is assumed to be product specific but not destination specific within plants, production function estimates can be implemented at the firm-product-year level by aggregating yearly quantities and sales across markets for each firm and product. In order to get rid of unanticipated shocks and/or measurement errors in the estimation of the production function parameters, log of equation (2.3) is taken, defining log output as  $q_{fgt} = \ln Q_{fgt} \exp \nu_{fgt}$ , the vector of log physical inputs as  $x_{fgt} = \ln \{v_{fgt} \cdot k_{fgt}\}$  and the log of unobserved productivity  $\tilde{\nu}_{fgt} = \ln A_{fgt}$ :

$$q_{fgt} = \beta_0 + \beta_1 x_{fgt} + \tilde{\nu}_{fgt} \quad (2.1)$$

As noted by [De Loecker et al. \[2012\]](#), several identification issues that could result in biased estimates of the production function parameters (the vector  $\beta$ ) can be distinguished in equation (2.1). The first arises because most empirical applications observe both sales and input uses in monetary terms instead of output and input physical quantities. If one does not control for either output or input price variations, there is no apparent problem as the two price biases tend to work in opposite directions, so that the estimated parameters may exhibit plausible values. However, this does not mean that the two biases exactly cancel each other out [see [De Loecker and Koujianou, 2014](#)]. In this paper, the database used reports information on export quantities and sales for each firm-product-destination triplet, so that equation (2.1) is estimated in terms of physical output at the firm-product level. Hence, the output price bias is directly resolved. However, the EAE survey provides information on wages, workers and material expenditures for each French manufacturing firm but does not report information on prices nor quantities of materials purchased, while the price of capital is as typically not available. If the input price variations are not control for, the production function coefficients estimated from equation (2.1) will

be biased, in particular because the estimates do not take into account quality changes. Consider for instance the case of two firms that produce exactly the same quantity of a given product, but not the same quality. If one does not control for the fact that the firm that manufactures the highest output quality is also facing higher material prices, the estimate of the elasticity of physical output with respect to material expenditures will probably be negative. Furthermore, controlling for unobserved input prices is not only important to recover consistent estimates of the production parameters, but also to control for unobserved productivity  $\tilde{\nu}_{ft}$ , which naturally depends on input prices.

Unobserved productivity is of course the second typical key challenge in the literature concerned with production function estimates, since it leads to both the simultaneity and the selection biases. As pointed out by [Olley and Pakes \[1996\]](#), [Levinsohn and Petrin \[2003\]](#) and [Akerberg et al. \[2006\]](#), the simultaneity bias between unobserved productivity shocks and inputs can be handled by a control function based on a static input demand equation. In particular, our work follows [Akerberg et al. \[2006\]](#) which use material as a perfectly variable input to proxy for unobserved productivity, and hence assumes (i) that material is perfectly invertible in productivity, i.e. that the demand for material is strictly monotonic in productivity and productivity is the only unobservable entering the demand for material, and (ii) that material is chosen when the plant learns its productivity, while capital and labor are chosen before to the productivity shock<sup>15</sup>. In addition, following [De Loecker et al. \[2012\]](#), the selection bias is addressed with a selection correction closely related to the third key challenge associated with the estimate of equation (2.1): the identification problem due to the existence of multi-product firms.

The existence of multi-product firms indeed generates an “input allocation” bias which arises because multi-product plants do not report how inputs are allocated across products. To remove this bias, [De Loecker et al. \[2012\]](#) proposed an identification strategy that uses an unbalanced sample of single-product plants at a given point of time, since by definition, the input allocation problem does not exist in their case ( $\rho_{fgt} = 2$ ). This unbalanced panel at a given time  $t$  contains both firms that always remain single-producers and those that manufacture a single product at  $t$  but add additional products at a later date. While the exclusion of multi-product plants may lead to a sample selection problem, the unbalanced sample improves the selection problem by including the plants that switch from single- to multi-producers in response to productivity shocks. Moreover, to account for the fact that the productivity threshold that determines a firm’s decision to switch from single- to multi-manufacturer (and vice versa) may be correlated with the inputs, a correction for sample selection is also implemented. This consists in two steps: (i) estimating the predicted probability that plants are single-product manufacturers, and (ii) including this predicted probability among the controls for productivity.

<sup>15</sup>In contrast, [Olley and Pakes \[1996\]](#) and [Levinsohn and Petrin \[2003\]](#) assume that the choice of labour is made when the plant learns its productivity, which creates a colinearity problem according to [Akerberg et al. \[2006\]](#).

These three challenges - namely the “input prices” bias, the “unobserved productivity” and the “input allocation” bias - can be formalized in the production function equation (2.1). Let's  $\bar{x}_{ft}$  denote the (unobserved) vector of deflated - by a sector specific price index - input expenditures;  $\bar{w}_{f_{gt}}^x$  the (unobserved) vector of the firm-product-specific input prices;  $w_{f_{gt}}^x$  the deviations of the firm-product-specific input prices from the industry input price indexes  $\psi_{gt}^x$ <sup>16</sup> and  $\rho_{f_{gt}}$  [  $\ln \rho_{f_{gt}}$  the share of the firm's input expenditures allocated to product  $g$ , all these variables being defined in log. As a result, the vector of input quantities for each firm-product pair in log is defined as  $x_{f_{gt}}$  [  $\rho_{f_{gt}} / \bar{x}_{ft} \bar{w}_{f_{gt}}^x$ . Substituting this expression for physical inputs into the equation (2.1), the log of physical output can be expressed as follows:

$$q_{f_{gt}} [ f_{gt} \bar{x}_{ft} = \beta [ / G \rho_{f_{gt}}, \bar{x}_{ft}, \beta [ / H ) w_{f_{gt}}^x, \rho_{f_{gt}}, \bar{x}_{ft}, \beta ( / \omega_{ft} \bar{x}_{ft}, r_{f_{gt}} [ / \epsilon_{f_{gt}} \quad (2.2)$$

The three biases clearly appear in this expression. Firstly, the term  $G$  captures the “input allocation” bias which results from the unobserved input allocation across products within a firm. By definition,  $G$  is equal to 1 for single-product firms. Hence, since the technology for a given product  $g$  is assumed to be identical across firms, this bias can be addressed by running the estimates on the sample of single-product firms such as defined above. This however calls for a sample selection correction which is implemented when controlling for unobserved productivity.

Secondly, the term  $H$  captures the “input price” bias resulting from unobserved firm and product-specific input prices. In order to address this bias, De Loecker et al. [2012] assumed that the vector of variable input prices depends on the quality  $z_{f_{gt}}$  of product  $g$ , exogenous factors  $L_f$  (e.g geography) and firm/product-level actions  $a_{f_{gt-1}}$  taken prior to time  $t$ <sup>17</sup>:  $W_{f_{gt}}^v [ W_{f_{gt}}^v z_{f_{gt}}, L_f, a_{f_{gt-1}} [$ . As a result, firm-specific input price variations can arise through exogenous changes in input prices across local input markets ( $L_f$ ) and/or through variations in input quality ( $z_{f_{gt}}$ ). This implies that two firms competing in the same industry and producing at the same location only face the exact same input prices if they buy exactly the same input quality<sup>18</sup>.

This paper follows the methodology proposed by De Loecker et al. [2012] to address the “input price” bias, but the approach is characterized by two crucial differences. First, the EAE survey provides information on wages and quantities of workers at the firm level, so that only capital and material prices are unobserved. On this aspect, our approach is thus more closely related

<sup>16</sup>Formally,  $w_{f_{gt}}^x = \bar{w}_{f_{gt}}^x - \bar{w}_{gt}^x$  such that  $w_{f_{gt}}^x = 0$  for the producer paying exactly the (weighted) average  $\bar{w}_{gt}^x$ .

<sup>17</sup> $a_{f_{gt-1}}$  can capture pre-negotiated input prices through contracts, for example, as long as the contracts do not specify that input price does not depend on input quantity.

<sup>18</sup>This specification of input price variation thus allows to partially address the strong assumptions made in almost all production function studies - using deflated input expenditures - that firms in a given industry face the same input prices. However, this framework rules out static sources of market power in input markets by assuming that a firm's variable input price does not depend on input quantity. While restrictive, this assumption is however only violated if firms have monopsony power in input markets. In addition, even in that case, this approach would understate the level of markup but not changes in markups, as long as there are no contemporaneous changes in firms' monopsony power.

to [Katayama et al. \[2009\]](#) who nevertheless presume that all input price variations can be controlled by wage changes. This assumption remains strong, especially when considering that the input demand equation for material is also used to control for unobserved productivity. In order to implement a consistent control for unobserved material and capital prices, the EAE survey and trade data are coupled with another database provided by the French Ministry of Higher Education and Research which contains information on firms' resources used in research and development (R&D). These data include in particular the number of patent applications, general expenses in R&D excluding remuneration and capital, R&D expenditures in remuneration, R&D expenditures in capital and the share of high-skilled workers in total employment. The logs of all of these variables are collected into the vector  $z_{fgt}$  which is used as a proxy for quality, instead of the output price and the market share used in [De Loecker et al. \[2012\]](#)<sup>19</sup>. This is the second crucial difference with their study<sup>20</sup>. Hence, under the assumption of complementary input quality - i.e. that manufacturing high quality products requires combining high quality materials with high quality labor and capital, so that all input prices can be expressed as a function of a single index of product quality<sup>21</sup> - the vector of log input prices can be formally re-written as a function of both the vector containing R&D variables and the firm location:

$$w_{fgt}^x = w_{fgt}^x(z_{fgt}, L_f) \quad (2.3)$$

Substituting this input price control function into the expression of  $H$  in (2.2), a new expression for  $H$  that allows to capture the input prices bias is obtained. The latter is expressed for single-product firms ( $G$ ) constituting the sample as follows<sup>22</sup>:

$$H = w_{fgt}^x(\bar{x}_{ft}, \beta) \left( z_{ft}, L_f \right) \equiv \bar{x}_{ft}, z_{ft}, L_f, \beta, \delta \quad (2.4)$$

where we reiterate that  $\bar{x}_{ft}$  denotes the log vector of deflated input expenditures. Note that the input prices term enters both alone and in interactions with the vector of deflated input expenditures, such that the input price control function requires to estimate both the vector of coefficients  $\delta$  associated with the former and the production function coefficients  $\beta$ .

<sup>19</sup>In their approach, [De Loecker et al. \[2012\]](#) show that firm-product quality can be proxied – and thus input price variation resulting from variation in input quality can be proxied - by its corresponding output price. This is based on the intuition that output prices contain information on input prices since the main premise is that manufacturing high quality products requires high quality inputs, and that high quality inputs are expensive.

<sup>20</sup>Since (i) our sample includes not only multi-product firms but also multi-destination firms, and (ii) the production function estimates are runned at the firm-product-level but not at the firm-product-destination level, it would have been inappropriate to proxy for a firm's product quality by using a weighted price index and a weighted market share average of this product across all the destinations to which it is shipped. Another alternative would be to reduce the sample to both single-product and single-destination firms (that is, domestic single-producers). However, this would (i) considerably restrict the sample and (ii) call for another sample correction procedure, especially when controlling for the selection bias in the estimation of unobserved productivity.

<sup>21</sup>This is a common assumption in the literature and underlies « O-Ring » -type theories of production (e.g., [Kremer \[1993\]](#), [Verhoogen \[2008\]](#) and [Kugler and Verhoogen \[2012\]](#)).

<sup>22</sup>The term  $\rho_{fgt}$  thus disappears from  $H(\cdot)$  and the product subscript  $g$  can then be omitted.

Finally, the last source of potential bias in (2.2), namely the unobserved firm-level productivity  $\tilde{y}_{ft}$  is controlled using a static input demand equation for materials [Akerberg et al., 2006] and a sample selection correction. The (log) materials expenditure function,  $\bar{m}_{fgt}$ , takes two arguments. The first argument includes all the state variables of the firm  $s_{ft}$  that affects its physical material demand. These include the discrete number of products manufactured by the firm  $G_{ft}$ , the dynamic input for all products  $K_{ft}$ , productivity  $A_{ft}$ , location information  $L_f$  and all payoff relevant serially correlated variables such as trade and distribution costs, the firm's export status and its market destination, which are collected in the vector  $r_{ft} : s_{ft} [G_{ft} = K_{fg=1t}, \dots, K_{fG_{ft}t} = A_{ft} = L_f = r_{ft}]$ . The second argument is the input (material) price equation  $w_{fgt}^m$  expressed in (2.3).

Alongside this correction for the simultaneity bias, the selection bias, which stems from the composition of the unbalanced panel of firms and which arises if a single-producer's choice to add a second product depends on its unobserved productivity and/or its input use, also need to be controlled for. The decision to add a product is assumed to be made during the previous period, implying that the firm makes this decision based on a forecast of some variables in the future as required by the selection rule. The cutoff point associated with the introduction of a second product, denoted  $\zeta_{ft}$ , is therefore a function of the state variables of the firm  $s_{ft}$  and its information set at time  $t - 2$ . As a result, the probability for a firm to remain single-producer  $SP_{ft}$ , which depends on both the firm's productivity in  $t - 2$  and this productivity cutoff, is estimated using

$$\begin{aligned} SP_{ft} \leq \Pr \left[ \tilde{y}_{ft} \geq \zeta_{ft} \mid s_{ft} [ \tilde{y}_{ft-1}, \zeta_{ft} \mid s_{ft} [ \{ \right. \\ \leq \omega_{t-1} \} \tilde{y}_{ft-1}, \zeta_{ft} \mid s_{ft} [ \left( \right. \\ \left. \leq \omega_{t-1} \mid \bar{x}_{ft-1}, r_{ft-1}, z_{ft-1}, L_f, D_{i=f} [ \right. \end{aligned}$$

and will as such be included in the law of motion for productivity used to estimate the vectors of parameters  $\beta$  and  $\delta$  [Akerberg et al., 2006, De Loecker, 2013]. In principle, one could run the estimation separately for each good  $g$ . In practice, our sample size is too small to allow estimates at the product level, so that estimates are runned at the two-digit sector level. This follows the standard practice in the literature where the production function parameters are measured at the industry level [e.g. Levinsohn and Petrin, 2003]. Furthermore, the entire procedure requires choosing a functional form for the production function  $f_{gt}$ . We adopt a translog specification<sup>23</sup> because of its flexibility. Specifically, the translog offers the advantage that it generates output elasticities that are not constant over time and across firms (though the production coefficients

<sup>23</sup> The translog production function associated with four inputs, labor  $L$ , capital  $K$ , material  $M$  and energy  $E$ , is:  
 $q_{fgt} = \beta_{l,g} l_{fgt} + \beta_{ll,g} l_{fgt}^2 + \beta_{k,g} k_{fgt} + \beta_{kk,g} k_{fgt}^2 + \beta_{m,g} m_{fgt} + \beta_{mm,g} m_{fgt}^2 + \beta_{e,g} e_{fgt} + \beta_{ee,g} e_{fgt}^2 + \beta_{lk,g} l_{fgt} k_{fgt}$   
 $+ \beta_{lm,g} l_{fgt} m_{fgt} + \beta_{le,g} l_{fgt} e_{fgt} + \beta_{km,g} k_{fgt} m_{fgt} + \beta_{ke,g} k_{fgt} e_{fgt} + \beta_{me,g} m_{fgt} e_{fgt} + \beta_{lkm,g} l_{fgt} k_{fgt} m_{fgt}$   
 $+ \beta_{lke,g} l_{fgt} k_{fgt} e_{fgt} + \beta_{lme,g} l_{fgt} m_{fgt} e_{fgt} + \beta_{kme,g} k_{fgt} m_{fgt} e_{fgt} + \beta_{lkme,g} l_{fgt} k_{fgt} m_{fgt} e_{fgt} + \Omega_{ft}$

are constrained to be the same across years and firms). Hence, large firms can have different elasticities than small firms. Note however that the exact functional form chosen for  $f(\cdot)$  does not generate any identification results. The only crucial assumption is that productivity enters in a log-additive fashion.

The next section details this two-step methodology, based on the moment conditions and implemented on a sample of single-product firms. This allows us to obtain consistent estimates of the production function coefficients  $\beta$  by tackling the three challenges just presented above. Estimates of  $\hat{\beta}$  ultimately allows to recover the yearly product-specific output elasticities on materials,  $\psi_{fgt}^m$ <sup>24</sup>.

### 2.B.2 Practical Implementation

Following [Akerberg et al. \[2006\]](#) and [De Loecker et al. \[2012\]](#), estimates of the production function parameters in equation (2.1) are runned using a consistent two-step methodology. In the first stage, the sample is restricted to single-product plants observed for at least three consecutive years. Three years are chosen as the moment conditions require at least two years of data because of the lagged values, and an additional (third) year to allow for potential measurement error in the precise timing of a new product introduction. For each single-producer, yearly quantities and sales across destinations are aggregated. This results from the assumptions that production technology is identical across products between plants and across markets within plants. A consistent estimate of expected output is then obtained by plugging the expression for the “input price” correction from (2.4) into the production function (2.2):

$$\hat{q}_{ft} = \zeta_t \bar{x}_{ft}, z_{ft}, L_f, r_{ft}, D_{g=f} / \epsilon_{ft} \quad (2.5)$$

This first stage estimation allows purging output quantities from unanticipated shocks and/or measurement error  $\epsilon_{ft}$  and yields estimates of predicted output  $\hat{q}_{ft}$ . The function  $\zeta_t$  is approximated by a third-order polynomial in all its elements, with the exception of product dummies. Note that the variables entering this equation are thus those (i) affecting the demand for physical material, (ii) proxying for unobserved input price (i.e. in particular controlling for quality differences), and (iii) controlling for unobserved productivity. As a result, some of the variables proxying for input prices also enter the input demand equation. However, this has no implications for the identification of the production function parameters. Indeed, we do not distinguish between these when forecasting output since the only purpose of this first stage is to get rid of

<sup>24</sup>In the case of a translog production function, the output elasticities for materials are given for each firm-product-year triplet by:

$$\begin{aligned} \hat{\psi}_{fgt}^m = & \hat{\beta}_{m,g} + 2\hat{\beta}_{mm,g}\tilde{m}_{fgt} + \hat{\beta}_{lm,g}\tilde{l}_{fgt} + \hat{\beta}_{km,g}\tilde{k}_{fgt} + \hat{\beta}_{me,g}\tilde{e}_{fgt} + \hat{\beta}_{lkm,g}\tilde{l}_{fgt}\tilde{k}_{fgt} + \hat{\beta}_{lme,g}\tilde{l}_{fgt}\tilde{e}_{fgt} \\ & + \hat{\beta}_{kme,g}\tilde{k}_{fgt}\tilde{e}_{fgt} + \hat{\beta}_{lkme,g}\tilde{l}_{fgt}\tilde{k}_{fgt}\tilde{e}_{fgt} \end{aligned}$$



unanticipated shocks/measurement errors. After the first stage, productivity can be expressed as a function of data and parameters using equation (2.2) – with  $G$  – and the input price correction in (2.4), which yields:

$$\tilde{y}_{ft} = \zeta_{ft} \dot{f}_t \bar{x}_{ft} \tilde{\beta} \left( \dot{H} \right) z_{ft}, L_f \left[ * \bar{x}_{ft}, z_{ft}, L_f \left[ \tilde{\delta} \left( \right) \right. \right] \quad (2.6)$$

where the function  $\dot{f}_t$  is the estimate of the production function without correction for input price nor unanticipated shock/measurement error, and the input price control function  $\dot{H}$  is approximated with a third order polynomial. As pointed out by De Loecker et al. [2012], it is important to note that even though the input expenditures enter both the production function  $f$  and the input price control function  $H$ , the coefficients of the production function are identified because they enter the input price control function interacted simply with input prices. In other words, the input expenditures do not enter the input price function. This identification insight does not rest on any functional form assumptions. It results from the fact that the control function for quality, and hence input prices, rests on the demand side alone and hence does not include input expenditures.

In order to obtain estimates of the parameter vectors  $\beta$  and  $\delta$ , moments are formed on innovation in the productivity shocks, so that the law of motion for productivity is estimated in the second stage. The fact that current shocks on productivity have a contemporaneous effect on firms' material choices while labor and capital do not immediately respond to these shocks is exploited, and the possibility that the degree of such adjustments is heterogeneous across firms and over time is also taken into account. In other words, materials are considered as the flexible input and their lags are thus used to build moments. Since the (log) materials expenditure  $\bar{m}_{ft}$  is a function of the state variables of the firm  $s_{ft}$ , product dummies  $D_g$  and the input (material) price equation  $w_{fgt}^m$  – expressed in (2.4), the materials demand equation can be inverted to obtain a control function for productivity. Taking into account the sample correction, the law of motion of productivity is:

$$\tilde{y}_{ft} = g \tilde{y}_{ft-1} + \vartheta_{ft-1}^{output} + \vartheta_{ft-1}^{input} + EXP_{t-1} + IMP_{t-1} + SP_{ft} \left( \xi_{ft} \right) \quad (2.7)$$

where  $SP_{ft} = \Pr \left[ \tilde{y}_{ft} \leq \left( \tilde{y}_{ft} \right) s_{ft} + \tilde{y}_{ft-1}, \left( \tilde{y}_{ft-1} \right) s_{ft-1} \right] \left[ \omega_{t-1} \bar{x}_{ft-1}, r_{ft-1}, z_{ft-1}, L_f, D_g \right]$ . This predicted probability of remaining a single-producer is estimated through a probit that regresses a dummy variable equal to 1 if a plant remains single-manufacturer and 0 if it switches to multi-producer.  $\vartheta_{ft-1}^{output}$  and  $\vartheta_{ft-1}^{input}$  are input and output tariffs, while  $EXP_{t-1}$  and  $IMP_{t-1}$  are respectively export and import dummies. All of these four variables are included in the law motion of productivity to account for the fact that trade policy and export/import status may affect productivity, so that their omission may lead to biased production function coefficients. Finally, the innovations in the productivity shock  $\xi_{ft}$  are obtained as the residuals of equation (2.7), implying that they are functions of the vector parameters  $\xi_{ft} \beta, \delta$

The production functions are then estimated using the moment conditions standard in the input control literature:

$$E(\xi_{ft})\beta, \delta - Y_{ft} + [1$$

where  $Y_{ft}$  contains lagged materials, current capital and labor, and their higher order and interaction terms, as well as additional variables controlling for input prices differences, that is quality, and their appropriate interactions with the inputs.

### 2.B.3 Input Allocations

Recovering markups and marginal costs also required measures of the time varying share of material into revenue for each firm-product-destination triplet,  $\alpha_{fglt}^m$ . This requires in turn recovering input allocations across products within plants  $\rho_{fgt}$ , which are unknown in the case of multi-product firms. To estimate  $\rho_{fgt}$ , we follow [De Loecker et al. \[2012\]](#) and solve for each plant-year pair a system of  $G_{ft} / 2$  equations, with  $G_{ft}$  the number of products manufactured by the firm at  $t$ , made up of (i)  $G_{ft}$  equations for the bias in the error term of the production function, which stems from missing information on input allocation shares across products, and (ii) one equation stating that the sum of input cost shares at the plant-year level is 1. Formally, the  $G_{ft}$  equations are obtained for each product manufactured by a plant from the previous assumptions that productivity is firm-specific and log-additive and that inputs are divisible across products. As a result, the output - cleared from any measurement error and unanticipated shocks - can be decomposed into two components,  $f_1$  and  $f_2$ , the former capturing all terms that do not depend on  $\rho_{fgt}$  and the latter collecting all terms involving  $\rho_{fgt}$ :

$$\begin{aligned} \dot{q}_{fgt} \leq E) q_{fgt} \phi_t \bar{x}_{ft}, r_{ft} [ & \left( \right. \\ & \leq f) \bar{x}_{ft}, \dot{\beta}, \dot{w}_{fgt}, \dot{\rho}_{fgt} \left( / \sim_{ft} \right. \\ & \leq f_1) \bar{x}_{ft}, \dot{\beta}, \dot{w}_{fgt} \left( / f_2 \bar{x}_{ft}, \dot{w}_{fgt}, \dot{\rho}_{fgt} [ / \sim_{ft} \right. \end{aligned}$$

$f_1$  and  $f_2$  depend upon the functional form of the production function, while input prices  $\dot{w}_{fgt}$  are calculated through the input price function (2.4). Furthermore, because the input allocation shares have to sum up to 1 across all products, the system of  $G_{ft+1}$  equations to be solved can be expressed as follows:

$$\begin{aligned} & \left. \begin{aligned} & \dot{q}_{f1t} \quad f_1) \bar{x}_{ft}, \dot{\beta}, \dot{w}_{f1t} \left( \leq f_2 \bar{x}_{ft}, \dot{w}_{f1t}, \dot{\rho}_{f1t} [ / \sim_{ft} \right. \\ & \times \times \times \\ & \dot{q}_{fG_{ft}t} \quad f_1) \bar{x}_{ft}, \dot{\beta}, \dot{w}_{fG_{ft}t} \left( \leq f_2) \bar{x}_{ft}, \dot{w}_{fG_{ft}t}, \dot{\rho}_{fG_{ft}t} \left( / \sim_{ft} \right. \right. \\ & \left. \left. \sum_{g \in G_{ft}} \rho_{fgt} [ 2 \right. \right. \end{aligned} \right. \end{aligned}$$

where  $\left. \right\} \rho_{fgt} \left( \begin{matrix} G_{ft} \\ g=1 \end{matrix}, \sim_{ft} \right) \sqrt{\quad}$  are the  $G_{ft} / 2$  unknowns.

In the case of the translog production function, the system yields:

$$\left\{ \begin{array}{l} \dot{\omega}_{f1t} [ \omega_{ft} / \dot{a}_{f1t} \rho_{f1t} / \dot{b}_{f1t} \rho_{f1t}^2 / \dot{c}_{f1t} \rho_{f1t}^3 \\ \times \times \times \\ \dot{\omega}_{fG_{ftt}} [ \omega_{ft} / \dot{a}_{fG_{ftt}} \rho_{fG_{ftt}} / \dot{b}_{fG_{ftt}} \rho_{fG_{ftt}}^2 / \dot{c}_{fG_{ftt}} \rho_{fG_{ftt}}^3 \\ \sum_{g \in G_{ft}} \rho_{fgt} [ 2 \end{array} \right.$$

where the parameters  $\dot{a}_{fgt}$   $\dot{b}_{fgt}$   $\dot{c}_{fgt}$  are given by:

$$\begin{aligned} \dot{a}_{fgt} [ & \dot{\beta}_{k,g} / \dot{\beta}_{k,g} / \dot{\beta}_{m,g} / \bar{l}_{ft} ) \dot{\beta}_{lk,g} / \dot{\beta}_{lm,g} / 3\dot{\beta}_{ll,g} / \dot{\beta}_{lkm,g} \bar{k}_{ft} / \dot{\beta}_{lkm,g} \bar{m}_{ft} \quad 3\dot{\beta}_{lkm,g} \dot{\omega}_{fgt} ( \\ & / \bar{k}_{ft} ) \dot{\beta}_{lk,g} / \dot{\beta}_{km,g} / 3\dot{\beta}_{kk,g} / \dot{\beta}_{lkm,g} \bar{m}_{ft} \quad 3\dot{\beta}_{lkm,g} \dot{\omega}_{fgt} ( / \bar{m}_{ft} ) \dot{\beta}_{lm,g} / \dot{\beta}_{km,g} / 3\dot{\beta}_{mm,g} \quad 3\dot{\beta}_{lkm,g} \dot{\omega}_{fgt} ( \\ & 3\dot{\omega}_{fgt} ) \dot{\beta}_{ll,g} / \dot{\beta}_{kk,g} / \dot{\beta}_{mm,g} / \dot{\beta}_{lk,g} / \dot{\beta}_{lm,g} / \dot{\beta}_{km,g} ( / 4\dot{\omega}_{fgt}^2 \dot{\beta}_{lkm,g} \\ \dot{b}_{fgt} [ & \dot{\beta}_{ll,g} / \dot{\beta}_{kk,g} / \dot{\beta}_{mm,g} / \dot{\beta}_{lk,g} / \dot{\beta}_{lm,g} / \dot{\beta}_{km,g} / \dot{\beta}_{lkm,g} \bar{l}_{ft} / \dot{\beta}_{lkm,g} \bar{k}_{ft} / \dot{\beta}_{lkm,g} \bar{m}_{ft} \\ \dot{c}_{fgt} [ & \dot{\beta}_{lkm,g} \end{aligned}$$

## 2.C Figures and Tables

Table 2.7: Median output elasticities by sector, French manufacturing industry, 1999-2007

Industry	Labor	Capital	Material	Energy	Returns to scale
Textiles	0.29	0.15	0.30	0.26	1.01
Wearing apparel, fur, leather	0.46	0.07	0.39	0.11	1.02
Wood and products of wood and cork	0.19	0.17	0.37	0.26	0.99
Pulp, paper and paper products	0.24	0.09	0.33	0.35	1.01
Publishing, printing and recorded media	0.29	0.11	0.45	0.25	1.10
Chemicals and chemical products	0.12	0.21	0.45	0.22	0.99
Rubber and plastic products	0.32	0.15	0.21	0.33	1.00
Other non-metallic mineral products	0.23	0.15	0.33	0.33	1.04
Basic metals	0.20	0.12	0.36	0.30	0.98
Fabricated metal products	0.25	0.10	0.34	0.29	0.97
Machinery and equipment nec	0.25	0.09	0.35	0.28	0.97
Electrical machinery and apparatus nec	0.30	0.07	0.28	0.35	0.99
Radio, TV and comm. equipment	0.30	0.09	0.34	0.32	1.03
Motor vehicles, trailers and semi-trailers	0.27	0.14	0.35	0.37	1.12
Other transport equipment	0.21	0.12	0.34	0.39	1.06
Furniture, manufacturing nec, recycling	0.24	0.13	0.31	0.34	1.02

Note: The table reports the median output elasticities with respect to each factor of production estimated from the translog production function and for all firm-product-year triplet observations. The last column reports the median return to scale.

Table 2.8: Domestic and export markups by sector, French manufacturing industry, 1999-2007

Industry	Domestic Markups			Export Markups		
	mean	p50	sd	mean	p50	sd
Textiles	1.71	1.48	1.35	2.61	1.56	2.95
Wearing apparel, fur, leather	1.72	1.37	1.49	2.43	1.54	3.14
Wood and products of wood and cork	2.00	1.82	1.39	1.92	1.30	2.04
Pulp, paper and paper products	1.43	1.34	1.03	1.40	1.35	1.44
Publishing, printing and recorded medias	1.63	1.48	1.21	1.77	1.23	1.75
Chemicals and chemical products	2.59	2.26	1.79	3.15	1.67	3.88
Rubber and plastic products	1.38	1.28	1.03	2.28	1.31	2.67
Other non-metallic mineral products	1.56	1.43	1.13	2.84	1.80	3.26
Basic metals	2.62	2.23	1.92	2.84	1.37	4.36
Fabricated metal products	1.84	1.67	1.27	2.35	1.73	2.90
Machinery and equipment nec	2.05	1.84	1.50	2.43	1.86	3.60
Electrical machinery and apparatus nec	1.73	1.59	1.31	3.82	2.14	4.64
Radio, TV and communication equipment	1.36	1.19	1.19	3.26	1.25	5.80
Motor vehicles, trailers and semi-trailers	2.03	1.75	1.62	3.32	1.02	5.22
Other transport equipement	1.98	1.73	1.57	5.66	1.88	8.76
Furniture, manufacturing nec, recycling	2.27	2.02	1.68	3.02	2.30	3.12
<b>Total manufacturing sector</b>	<b>1.87</b>	<b>1.46</b>	<b>1.41</b>	<b>2.82</b>	<b>1.65</b>	<b>3.72</b>

Note: The table displays the mean, median and markup by sector by sector for the 1999-2007 period. Export markups are reported at the firm-product-destination-year level while domestic markups are computed at the firm-year level. The table trims observations with markups that are above and below the 98th and 2nd percentiles within each sector and in both domestic and export markets.

Figure 2.4: Marginal costs and output quantities by sector, French manufacturing industry, 1999-2007

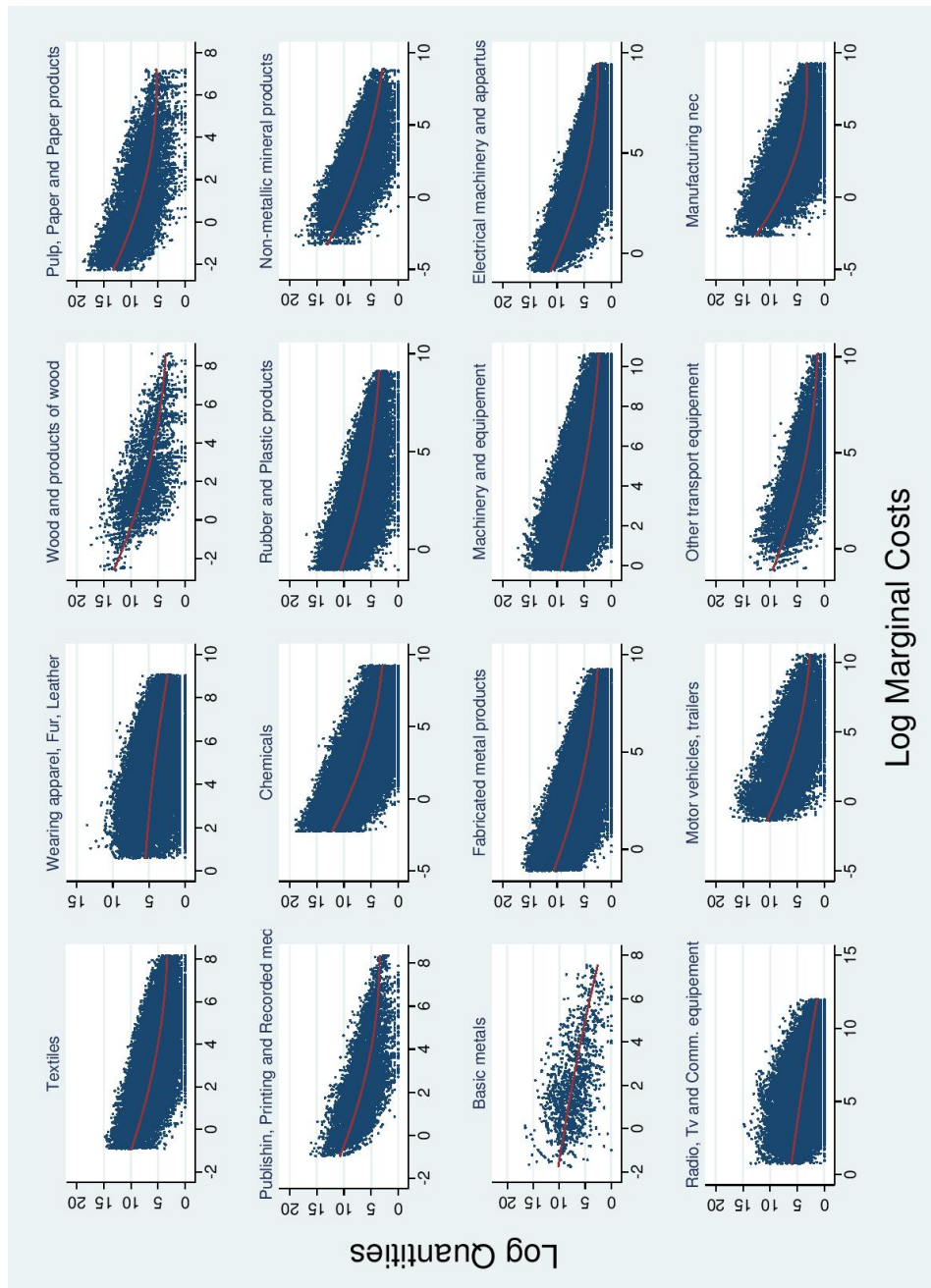


Table 2.9: Exchange rate elasticities of marginal costs by sector, French manufacturing industry, 1999-2007

Industry	Export markets $\xi_{C_{fglt}}$				Domestic market $\xi_{C_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	459,163	-0.02	-0.06	0.45	8,649	-0.08	-0.07	0.40
Wearing apparel, fur, leather	767,783	-0.19	-0.11	0.32	9,485	-0.18	-0.18	0.28
Wood and products of wood and cork	15,332	-0.67	-0.57	0.27	5,228	0.02	-0.06	0.33
Pulp, paper and paper products	112,637	-0.26	-0.27	0.27	4,734	-0.20	-0.18	0.03
Publishing, printing and recorded medias	104,025	-0.44	-0.37	0.18	13,350	-0.14	-0.23	0.14
Chemicals and chemical products	887,301	0.08	0.09	0.18	9,718	-0.24	-0.33	0.14
Rubber and plastic products	329,597	-0.08	-0.12	0.33	12,500	-0.14	-0.23	0.29
Other non-metallic mineral products	170,366	-0.09	-0.13	0.39	7,046	-0.18	-0.26	0.35
Basic metals	128,383	-0.29	-0.28	0.53	3,518	-0.06	-0.09	0.49
Fabricated metal products	443,568	-0.03	0.00	0.27	36,262	-0.12	-0.20	0.23
Machinery and equipment nec	786,084	-0.03	-0.11	0.52	17,960	-0.21	-0.20	0.48
Electrical machinery and apparatus nec	331,501	0.02	-0.06	0.50	5,695	-0.17	-0.15	0.46
Radio, TV and comm. equipment	564,981	-0.42	-0.48	0.59	10,915	0.06	0.14	0.55
Motor vehicles, trailers and semi-trailers	197,183	-0.12	-0.12	0.05	4,370	-0.11	-0.10	0.01
Other transport equipment	186,341	-0.12	-0.07	0.14	2,542	-0.21	-0.29	0.10
Furniture, manufacturing nec, recycling	315,458	-0.18	-0.25	0.27				0.23
<b>Total manufacturing sector</b>	<b>5,799,703</b>	<b>-0.18</b>	<b>-0.18</b>	<b>0.39</b>	<b>151,972</b>	<b>-0.13</b>	<b>-0.16</b>	<b>0.35</b>

Table 2.10: Exchange rate elasticities of markups by sector, French manufacturing industry, 1999-2007

Industry	Export markets $\xi_{\mu_{fglt}}$				Domestic market $\xi_{\mu_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	355,744	-0.45	-0.40	0.34	6,719	-0.10	-0.12	0.30
Wearing apparel, fur, leather	491,455	-0.54	-0.49	0.31	4,681	0.01	0.03	0.21
Wood and products of wood and cork	11,952	-0.06	-0.11	0.23	2,827	0.09	-0.10	0.34
Pulp, paper and paper products	88,070	-0.24	-0.22	0.19	3,741	-0.13	-0.13	0.50
Publishing, printing and recorded medias	72,091	-0.19	-0.23	0.23	7,955	-0.02	-0.02	0.24
Chemicals and chemical products	683,771	-0.29	-0.31	0.24	8,227	-0.07	-0.03	0.38
Rubber and plastic products	256,689	-0.39	-0.35	0.29	9,675	0.02	0.00	0.35
Other non-metallic mineral products	132,443	-0.30	-0.29	0.24	3,824	-0.06	-0.06	0.30
Basic metals	13,891	-0.32	-0.25	0.28	3,053	-0.03	-0.16	0.45
Fabricated metal products	338,619	-0.06	-0.11	0.33	22,370	0.00	0.00	0.26
Machinery and equipment nec	616,888	-0.55	-0.35	0.20	14,067	-0.05	-0.03	0.31
Electrical machinery and apparatus nec	241,743	-0.60	-0.41	0.29	4,253	0.00	0.01	0.22
Radio, TV and comm. equipment	325,842	-0.01	-0.10	0.34	5,625	-0.18	-0.17	0.37
Motor vehicles, trailers and semi-trailers	149,768	-0.20	-0.27	0.29	3,383	-0.12	-0.10	0.23
Other transport equipment	70,006	-0.34	-0.37	0.28	1,912	-0.03	-0.02	0.34
Furniture, manufacturing nec, recycling	225,859	-0.32	-0.35	0.25				
<b>Total manufacturing sector</b>	<b>4,082,091</b>	<b>-0.34</b>	<b>-0.33</b>	<b>0.29</b>	<b>102,312</b>	<b>-0.04</b>	<b>-0.06</b>	<b>0.32</b>

Table 2.11: Exchange rate elasticities of prices by sector, French manufacturing industry, 1999-2007

Industry	Export markets $\xi_{P_{fglt}}$				Domestic market $\xi_{P_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	355,744	0.71	0.66	0.29	6,719	-0.19	-0.22	0.30
Wearing apparel, fur, leather	491,455	0.09	0.05	0.33	4,681	-0.18	-0.16	0.21
Wood and products of wood and cork	11,952	0.13	0.13	0.29	2,827	-0.12	-0.13	0.34
Pulp, paper and paper products	88,070	0.30	0.28	0.21	3,741	-0.33	-0.33	0.50
Publishing, printing and recorded medias	72,091	0.16	0.10	0.33	7,955	-0.16	-0.16	0.24
Chemicals and chemical products	683,771	0.42	0.36	0.23	8,227	-0.31	-0.29	0.38
Rubber and plastic products	256,689	0.35	0.29	0.32	9,675	-0.12	-0.16	0.35
Other non-metallic mineral products	132,443	0.43	0.36	0.35	3,824	-0.23	-0.26	0.30
Basic metals	13,891	0.43	0.30	0.21	3,053	-0.09	-0.25	0.45
Fabricated metal products	338,619	0.77	0.47	0.41	22,370	-0.12	-0.11	0.26
Machinery and equipment nec	616,888	0.25	0.17	0.32	14,067	-0.26	-0.26	0.31
Electrical machinery and apparatus nec	241,743	0.25	0.19	0.27	4,253	-0.17	-0.14	0.22
Radio, TV and comm. equipment	325,842	0.48	0.19	0.24	5,625	-0.19	-0.19	0.37
Motor vehicles, trailers and semi-trailers	149,768	0.48	0.13	0.32	3,383	-0.23	-0.20	0.23
Other transport equipment	70,006	0.24	0.14	0.29	1,912	-0.23	-0.21	0.34
Furniture, manufacturing nec, recycling	225,859	0.47	0.32	0.20				
<b>Total manufacturing sector</b>	<b>4,082,091</b>	<b>0.39</b>	<b>0.21</b>	<b>0.22</b>	<b>102,312</b>	<b>-0.18</b>	<b>-0.20</b>	<b>0.32</b>

Table 2.12: Exchange rate elasticities of profit margins by sector, French manufacturing industry, 1999-2007

Industry	Export markets $\xi_{ma_{fglt}}$				Domestic market $\xi_{ma_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	179,017	-0.25	-0.22	2.19	6616	-0.09	-0.06	0.16
Wearing apparel, fur, leather	471,797	-0.03	-0.57	2.48	4,681	-0.03	-0.02	0.06
Wood and products of wood and cork	11,474	-0.12	-0.26	0.61	2,807	-0.08	-0.04	0.14
Pulp, paper and paper products	84,548	-0.05	-0.39	1.35	3,504	-0.14	-0.10	0.14
Publishing, printing and recorded medias	69,209	-0.05	-0.30	0.93	7,917	0.00	-0.01	0.13
Chemicals and chemical products	656,421	-0.52	-0.40	1.20	8,109	-0.09	-0.06	0.14
Rubber and plastic products	246,423	-0.40	-0.41	1.49	9,522	0.02	0.00	0.16
Other non-metallic mineral products	127,147	-0.68	-0.35	3.50	3,809	-0.08	-0.04	0.12
Basic metals	13,337	-0.42	-0.35	1.14	2,963	-0.11	-0.08	0.16
Fabricated metal products	325,075	-0.11	-0.23	1.16	22,003	0.02	0.00	0.16
Machinery and equipment nec	592,214	-0.71	-0.42	3.74	13,958	-0.04	-0.04	0.13
Electrical machinery and apparatus nec	232,075	-0.68	-0.63	1.43	4,202	0.01	-0.02	0.12
Radio, TV and comm. equipment	312,810	-0.10	-0.10	1.74	5,071	-0.11	-0.09	0.19
Motor vehicles, trailers and semi-trailers	143,778	-0.26	-0.19	2.01	3,322	-0.07	-0.05	0.18
Other transport equipment	67,206	-0.37	-0.78	2.01	1,782	-0.01	-0.02	0.19
Furniture, manufacturing nec, recycling	216,825	-0.15	-0.64	3.37				
<b>Total manufacturing sector</b>	<b>3,374,420</b>	<b>-0.36</b>	<b>-0.40</b>	<b>0.59</b>	<b>100,266</b>	<b>-0.05</b>	<b>-0.04</b>	<b>0.15</b>



**Table 2.13: Exchange rate elasticities of export volumes by sector, French manufacturing industry, 1999-2007**

Industry	Export markets $\xi_{vo_{fglt}}$				Domestic market $\xi_{vo_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	348,484	-0.38	-0.33	0.42	6,457	-0.17	-0.18	0.51
Wearing apparel, fur, leather	471,797	-0.15	-0.08	0.50	4,478	-0.30	-0.20	0.06
Wood and products of wood and cork	11,474	-0.13	-0.14	0.30	2,543	-0.51	-0.30	0.35
Pulp, paper and paper products	84,548	-0.28	-0.33	0.17	3,709	-0.24	-0.30	0.22
Publishing, printing and recorded medias	69,209	-0.18	-0.11	0.47	7,614	0.02	-0.14	0.36
Chemicals and chemical products	656,421	-0.42	-0.42	0.31	8,046	-0.26	-0.27	0.08
Rubber and plastic products	246,423	-0.37	-0.31	0.41	9,282	0.13	-0.14	0.43
Other non-metallic mineral products	127,147	-0.43	-0.39	0.37	3,700	0.05	-0.18	0.46
Basic metals	13,337	-0.55	-0.34	0.50	2,796	-0.09	-0.19	0.42
Fabricated metal products	325,075	-0.69	-0.49	0.37	21,449	0.00	-0.11	0.40
Machinery and equipment nec	592,214	-0.18	-0.18	0.14	13,590	-0.19	-0.25	0.27
Electrical machinery and apparatus nec	232,075	-0.26	-0.22	0.37	4,036	-0.16	-0.12	0.14
Radio, TV and comm. equipment	312,810	-0.31	-0.21	0.38	5,411	-0.01	-0.16	0.48
Motor vehicles, trailers and semi-trailers	143,778	-0.33	-0.13	0.39	3,316	-0.01	-0.17	0.44
Other transport equipment	67,206	-0.12	-0.05	0.27	1,835	-0.03	-0.18	0.37
Furniture, manufacturing nec, recycling	216,825	-0.01	-0.02	0.12				
<b>Total manufacturing sector</b>	<b>3,918,823</b>	<b>-0.32</b>	<b>-0.24</b>	<b>0.22</b>	<b>98262</b>	<b>-0.05</b>	<b>-0.19</b>	<b>0.31</b>

**Table 2.14: Exchange rate elasticities of profits by sector, French manufacturing industry, 1999-2007**

Industry	Export markets $\xi_{\Pi_{fglt}}$				Domestic market $\xi_{\Pi_{fgdt}}$			
	N	mean	p50	sd	N	mean	p50	sd
Textiles	348,489	-0.34	-0.05	0.46	6,575	-0.48	-0.35	0.45
Wearing apparel, fur, leather	478,487	-0.50	-0.13	0.30	4,592	-0.41	-0.10	0.01
Wood and products of wood and cork	11,482	-0.18	0.00	0.19	2,683	-0.22	-0.18	0.50
Pulp, paper and paper products	84,774	-0.23	-0.08	0.19	3,730	-0.04	-0.15	0.11
Publishing, printing and recorded medias	69,209	-0.37	-0.01	0.50	7,797	-0.05	-0.15	0.31
Chemicals and chemical products	660,501	-0.28	-0.04	0.37	8,149	-0.16	-0.09	0.03
Rubber and plastic products	251,115	-0.27	-0.01	0.36	9,511	-0.19	-0.24	0.30
Other non-metallic mineral products	127,147	-0.22	0.01	0.28	3,774	-0.15	-0.30	0.34
Basic metals	13369	-0.47	-0.02	0.85	2901	-0.45	-0.40	0.55
Fabricated metal products	325,075	-0.54	-0.44	0.45	21,951	-0.01	-0.14	0.28
Machinery and equipment nec	592,218	-0.26	-0.02	0.39	13,809	-0.06	-0.15	0.23
Electrical machinery and apparatus nec	235,683	-0.34	-0.08	0.40	4,141	-0.23	-0.07	0.10
Radio, TV and comm. equipment	312,810	-0.26	-0.13	0.26	5,427	-0.31	-0.22	0.53
Motor vehicles, trailers and semi-trailers	146,773	-0.26	-0.13	0.16	3,344	-0.26	-0.25	0.24
Other transport equipment	67,247	-0.27	-0.10	0.16	1,882	-0.18	-0.25	0.32
Furniture, manufacturing nec, recycling	218,354	-0.35	-0.15	0.29				
<b>Total manufacturing sector</b>	<b>3,942,733</b>	<b>-0.27</b>	<b>-0.21</b>	<b>0.44</b>	<b>100,266</b>	<b>-0.21</b>	<b>-0.11</b>	<b>0.31</b>

Figure 2.5: The valuation/volume effect trade-off in export markets, French manufacturing industry, 1999-2007

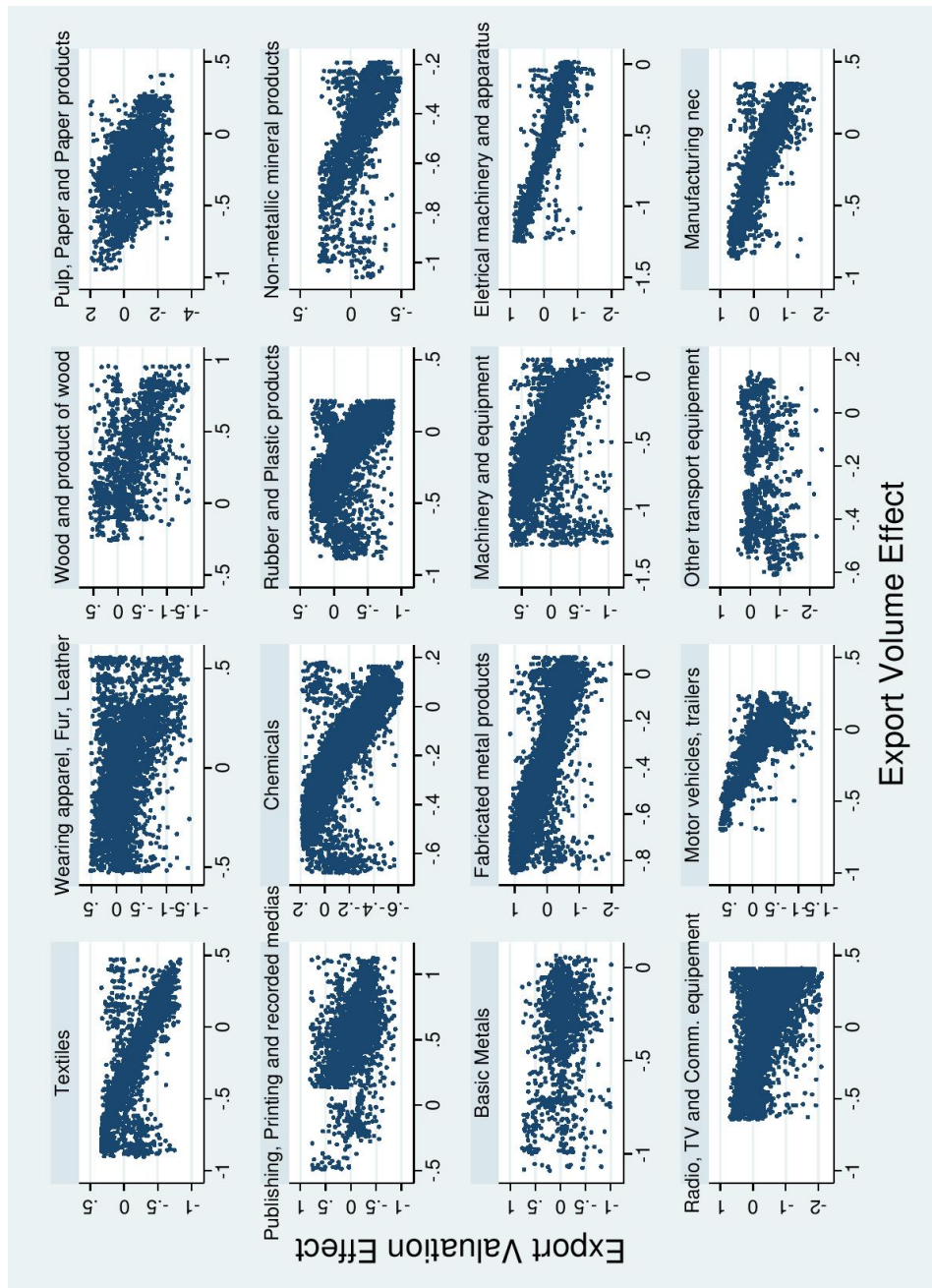
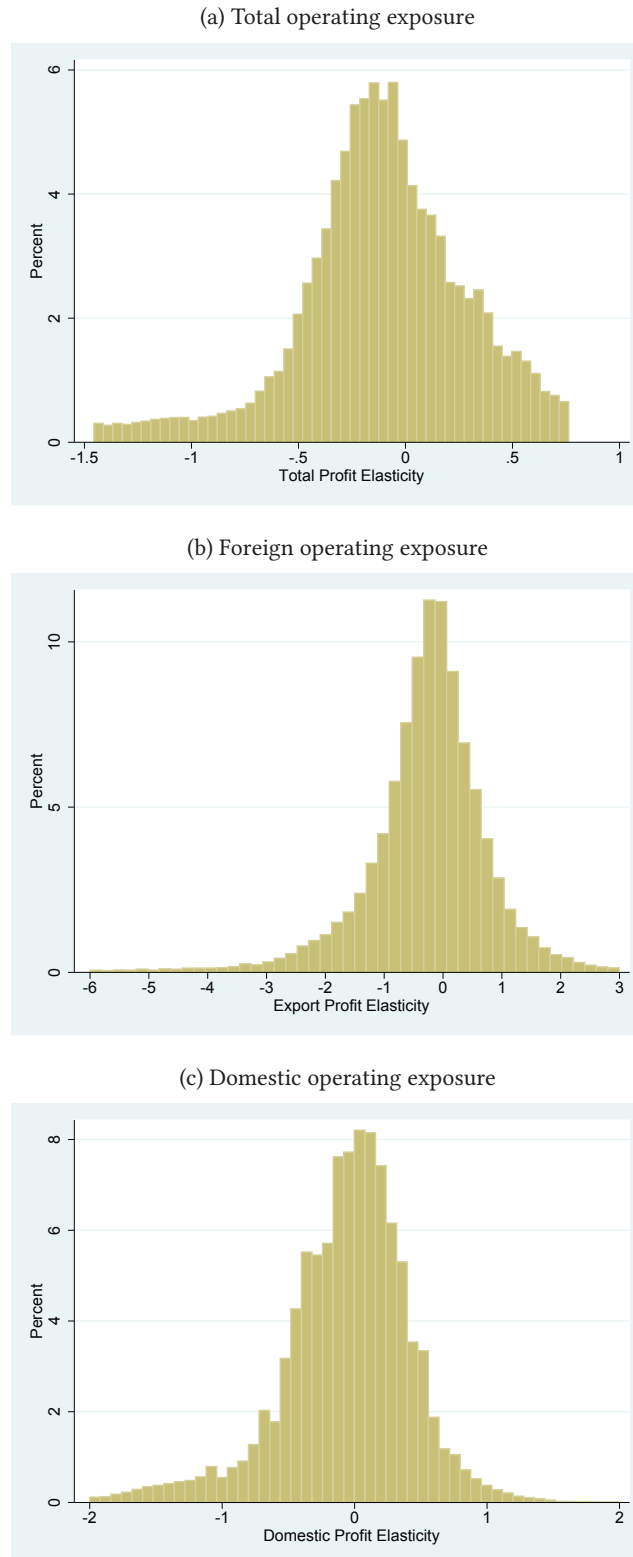


Figure 2.6: Distribution of operating exchange rate exposures, French manufacturing firms, 1999-2007







## Chapter 3

# Competitive Exposure and Quality Upgrading

*Ce chapitre est le premier à fournir des preuves théoriques et empiriques de l'existence d'une des stratégies compétitives mises en oeuvre par les entreprises pour se prémunir contre le risque de change à long-terme: la stratégie de montée en gamme. Plus spécifiquement, il met en évidence trois raisons pour lesquelles une appréciation de la monnaie domestique entraîne une amélioration de la qualité des produits nationaux au niveau des entreprises et des industries. Premièrement, en tant que choc de demande négatif, une appréciation de change encourage les entreprises à se positionner sur un segment de marché de gamme supérieure, afin de compenser leur perte de compétitivité-prix vis-à-vis de leurs concurrentes étrangères. Deuxièmement, cette stratégie de montée en gamme est facilitée par l'accès à de nouveaux biens intermédiaires importés, moins onéreux et eux-mêmes de plus grande qualité, permis simultanément par l'appréciation de change en tant que choc d'offre positif. Néanmoins, l'amélioration de la qualité demeure un processus coûteux, de telle sorte que les entreprises les moins compétitives, qui sont notamment celles produisant les produits de moins bonne qualité, sont évincées du marché. En conséquence, la qualité moyenne des biens au niveau de l'industrie augmente également, toutes choses égales par ailleurs, de par ce simple effet de réallocation.*

*Par ailleurs, ce chapitre montre qu'une appréciation de la monnaie domestique augmente également le rapport qualité/prix des produits domestiques, du moment que le champs de différenciation verticale sur le marché demeure suffisamment ouvert, c'est à dire: (i) sur les marchés avec une élasticité-prix de la demande modérée; (ii) au sein des industries où les entreprises sont en mesure d'augmenter la qualité au prix d'une faible augmentation du coût marginal; (iii) vers des destinations où les consommateurs ont une forte préférence pour la qualité, notamment les économies émergentes, qui offrent les meilleurs environnements pour ouvrir de nouveaux segments de marchés.*

### 3.1 Introduction

Chapter 1 emphasizes that, whereas firms can easily hedge transaction exposures through financial instruments, competitive exposures are longer term and require making longer-term operating adjustments. In particular, companies often respond to exchange risk by altering their product strategy, which deals with areas such as new-product introduction, product line decisions, and product innovation. This chapter is the first to provide theoretical and empirical evidence on the existence of one of these product strategies related to the management of competitive exchange rate exposure, namely the strategy of up-market positioning<sup>1</sup>.

The chapter begins by providing a theoretical background that helps to explain how currency appreciations lead to an enhancement of product quality within firms and industries. This is done by combining the new theoretical works on the endogenous modelling of firms' quality choice [e.g. Feenstra and Romalis, 2014, Hallak and Sivadasan, 2013, Kugler and Verhoogen, 2012] with the Melitz [2003]'s model of firms' heterogeneity, in order to explain in a unified framework how changes in the exchange rate (i) encourage firm to endogeneously upgrade product quality; and (ii) generate market share reallocations towards firms producing the highest quality varieties. It then takes advantage of these theoretical results to develop a new measure of product quality at the industry-level, which takes into account both the supply and demand market conditions, and uses the ProdCom database to test empirically the predictions of the model over a large range of member countries from the Euro Area over the period 1999-2007.

The model builds on Kugler and Verhoogen [2012] and Feenstra and Romalis [2014] to allow choices made by individual firms in terms of price, input and output quality to be endogenous, and then analyzes the impact of a currency shock on these choices and on the subsequent changes in the industry's equilibrium. Following Hallak and Sivadasan [2013], firms in each industry are assumed to be heterogeneous in two dimensions. The first dimension is "process productivity" as the ability to produce output using few variable inputs. The second dimension is "product productivity" as the ability to produce quality incurring low fixed outlays. Producing higher quality output requires both higher quality inputs, and so higher marginal costs, and higher distribution costs. On the demand side, quality acts like a shift parameter in the utility function allowing increasing the demand for a variety conditional on its price. In addition, preferences for quality are assumed to be heterogeneous across destination countries.

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<sup>1</sup>Feenstra [1989] was among the first to argue that enduring exchange rate movements lead to persistent shifts in the behavior of plants and entail irreversible real reallocation effects. This chapter provides evidence on such exchange rate-induced persistent shift of product management strategy, precisely a quality upgrading, and irreversible reallocation effects, specifically across varieties heterogeneous along the quality dimension.

In this framework, this chapter shows that, as a simultaneous negative demand rotator and positive demand shock, a domestic currency appreciation enhances both the quality and the quality/price ratio of products sold worldwide at both the firm level and the industry level. Specifically, the pass-through is shown to be incomplete, so that the foreign demand for domestic exports falls when the domestic currency appreciates. As a consequence, exporters from the home country upgrade the quality of their product to compensate for the loss in their price competitiveness, and so prevent their market shares abroad and their export revenues from falling. This quality-enhancing process is made easier by the access to cheaper and higher quality inputs simultaneously allowed by the appreciation of the home currency. However, enhancing output quality is still costly, so that not all firms can afford such a strategic move. In the model, the zero-profit condition of Melitz [2003] therefore implies that the less competitive firms, which notably produce the lowest quality goods, are driven out of the market. This entails a reallocation of market shares towards the highest quality varieties, so that the average quality of exports at the industry level increases *ceteris paribus*. Interestingly, the magnitude of this effect is shown to be larger in industries with a high price elasticity of demand, as the latter experience the largest reallocation movements.

The model also predicts that exchange rate appreciations increase the quality/price ratio of exported goods. This arises at both the firm level and the industry level as long as the scope for product differentiation is positive, that is (i) in markets where the intensity of preferences for quality is high, (ii) in industries where firms can achieve a higher level of output quality at the expense of a small marginal costs increase and (iii) in markets with moderate price elasticity of demand (i.e. not perfectly vertically differentiated, neither horizontally organized).

The equilibrium quality and adjusted-quality price equations drawn from the theoretical model are then used to perform two alternative measures of quality at the industry-level. The first measure follows the work of Khandelwal [2010], Khandelwal et al. [2011] and Hallak and Schott [2011] among others, and assigns a higher quality to varieties with a higher market share conditional on their relative price as compared to the market average. The second measure is on the contrary new, and adds to this demand-side intuition some supply-side aspects which, in particular, allow solving for the equilibrium mass of exporters. Therefore, the former is referred as a "demand-side" based estimate, while the latter is referred as an "equilibrium" based estimate. Both of them are implemented on a detailed database on goods traded by the euro area member countries worldwide, named ComExt, over the period 1999-2007. The long and large nominal (and real) appreciation of the euro during this period provides a good example of a persistent currency shock which allows testing this theory, and which is therefore chosen to form the historical framework of this paper.



The model is also used to derive the econometric specifications implemented in order to test empirically whether a domestic currency appreciation does genuinely increase the quality and the quality/price ratio of domestic exports. All the conclusions of the theoretical model are empirically verified and significant, both in terms of sign and magnitude. Their robustness is also confirmed with additional 2SLS regressions. While the nature of the data does not allow analysing the channels mentioned above at the firm level, the last section of this paper tests the "reallocation" effect and the "input effect" at the industry level. This last exercise leads to the following conclusion: currency appreciations diminish the mass of exporters and increase the share of the imported value added content of domestic industries' gross exports, and these two effects, in turn, increase the quality and the quality/price ratio of the goods exported abroad.

The subject and the main conclusions of this chapter are directly related to several streams of the international economics literature. First, this analysis is close to the research field that has focused on the relationship between international competition and the extensive margins of trade [e.g. [Aw and Lee, 2009](#), [Bernard et al., 2011](#), [Berthou and Fontagné, 2013](#), [Iacovone and Javorcik, 2010](#)]. This paper is also related to the literature pioneered by [Amiti and Konings \[2007\]](#) which has studied the relationship between trade liberalization episodes, imported intermediate inputs, and changes in firms' product scope [e.g. [Goldberg et al., 2009, 2010](#), [Kugler and Verhoogen, 2009](#), [Manova and Zhang, 2012b](#)]. This study is also somewhat related to the empirical studies providing evidence that firms, particularly from developed countries, rely more on innovation and employ more skilled workers when international competition increases [e.g. [Bloom et al., 2011](#), [Bugamelli et al., 2008](#), [Mion and Zhu, 2012](#)]. Finally, this analysis is closed to the theoretical works that have followed the model of [Melitz \[2003\]](#) and have studied the relationship between trade liberalization and reallocation effects [e.g. [Crozet et al., 2012](#), [Martin and Mejean, 2012](#), [Schott, 2004, 2008](#)].

[Section 3.2](#) introduces the theoretical model. It first presents the basic setup and assumptions, and then analyses the impact of a currency shock on firms' optimal choices and the subsequent changes in industry's equilibrium. [Section 3.3](#) presents the empirical framework implemented to measure quality and the data used, and then highlights some stylized facts about the estimated qualities. [Section 3.4](#) describes and implements the econometric specifications used to test all the theoretical conclusions. Then, it empirically explores the channels through which exchange rate fluctuations affect quality and quality adjusted prices. [Section 3.5](#) concludes.

## 3.2 Model

### 3.2.1 Setup

#### 3.2.1.1 Demand

The world consists of many countries, such that the home country, indexed by  $i$ , trades with  $j \approx 2$  foreign partners. Each final-good sector  $g \in \mathcal{G}$  is characterized by imperfect competition with constant-elasticity of substitution (CES) demand, augmented to account for product quality. The representative agent in destination country  $j$  has preferences over the consumption of a continuum of differentiated domestic and foreign varieties:

$$U_j = \left[ \prod_g s_{gj} \ln \int_{\omega \in \Omega_{gj}} q_j(\omega)^{\eta_{gj}} x_j(\omega)^{\frac{\sigma_g - 1}{\sigma_g}} d\omega \right]^{\frac{\sigma_g}{\sigma_g - 1}} \quad (3.1)$$

where  $s_{gj}$  is the share of final-good sector  $g$  in total expenditure in country  $j$ , and  $x_j(\omega)$  and  $q_j(\omega)$  denote respectively the quantity and quality of variety  $\omega$  consumed in country  $j$ . The set of available varieties of type  $g$  in country  $j$  is  $\Omega_{gj}$ ,  $\sigma_g > 2$  is the price-elasticity of substitution across variety of type  $g$ , and  $\eta_{gj} > 1$  captures the country-specific intensity of preference for quality for each type of good. Output quality can be interpreted as any product tangible (e.g, durability) or intangible (e.g product image due to advertising) attribute that consumers value, that is, for which they are willing to pay more [Hallak and Sivadasan, 2013]. Thus,  $q_j(\omega)$  enters equation (3.1) as a utility shifter, while there is still a horizontal dimension of product differentiation. This captures the fact that consumers appreciate both variety and quality [Chen and Juvenal, 2014]. The greater is  $\eta_{gj}$ , the greater are the perceived differences among the varieties. It is typically the case that higher-quality products embody richer sets of product characteristics, which expands the scope for horizontal differentiation, and that richer countries (higher utility) enjoy higher quality products [Feenstra and Romalis, 2014, Hallak, 2006]. If so, the varieties of a lower-quality good are closer substitutes for one another than the varieties of a higher-quality good.  $\eta_{gj}$  is therefore a measure of the scope for quality differentiation in the destination market. Consumer optimization yields the following demand for a particular variety  $\omega_i$  exported from  $i$  to destination  $j$ :

$$x_j(\omega_i) = \left[ \lambda_j^c(\omega_i)^{-\sigma_g} q_j(\omega_i)^{\eta_{gj}} E_{gj} \Pi_{gj}^{\sigma_g - 1} \right]^{-1} \quad (3.2)$$

with  $\Pi_{gj}$  the industry level quality-adjusted price index in country  $j$ <sup>2</sup>, and  $E_{gj} = \int_{\omega \in \Omega_{gj}} s_{gj} x_j(\omega) d\omega$  the total expenditure on all varieties  $\omega \in \Omega_{gj}$ , both exogenous from the point of view of individual firms.  $\lambda_j^c(\omega_i)$  is the quality-adjusted selling price of variety  $\omega_i$ , which is expressed in terms of the local currency  $j$  as follows:

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<sup>2</sup> $\Pi_{gj} = \left[ \int_{\omega \in \Omega_{gj}} \lambda_j^c(\omega)^{1 - \sigma_g} d\omega \right]^{\frac{1}{1 - \sigma_g}}$

$$\lambda_j^c \omega_i \leq \frac{p_j^c \omega_i}{q_j \omega_i^{\eta_{gj}}} \left[ \frac{e_{ij} \tau_{gij} p_j \omega_i / T_j \omega_i}{q_j \omega_i^{\eta_{gj}}} \right] e_{ij} \tau_{gij} \lambda_j \omega_i / \frac{T_j \omega_i}{q_j \omega_i^{\eta_{gj}}} \quad (3.3)$$

where  $p_j^c \omega_i$  is the local currency selling price of variety  $\omega_i$ , while  $p_j \omega_i$  and  $\lambda_j \omega_i$  are the f.o.b price and quality-adjusted export price of this variety, both expressed in the currency of the exporter. Foreign demand is adjusted both by  $\tau_{gij}$ , which is one plus the ad valorem trade costs, including one plus the ad valorem tariff (denoted below  $tar_{ij}$ ); and by  $T_j \omega_i$  which is a variety-specific additive (per unit) distribution cost in country  $j$ . Finally,  $e_{ij}$  is the nominal exchange rate between home and country  $j$ , defined such that an increase in  $e_{ij}$  means an appreciation of the home currency.

Equations (3.2) and (3.3) together simply state that the foreign demand is increasing in the quality and decreasing in the local currency selling price of a particular variety. In other words, an increase in the quality-adjusted price,  $\lambda_j \omega_i$  which is equivalent to a decrease in the quality/price ratio of variety  $\omega_i$ , reduces the demand for this variety. As long as the exchange rate pass-through rate is not zero, an appreciation of the home currency increases the local currency selling price of the varieties exported from home, so that the quality/price ratio faced by foreign consumers, and therefore the foreign demand for domestic exports, fall. Equation (3.2) makes clear that the only way for an exporter to prevent its export revenues from declining is to enhance the quality it offers to consumers. Formally, the exchange rate elasticity of output quality required to maintain export revenue (expressed in terms of the domestic currency) constant is defined by:

$$\frac{\partial r_j \omega_i}{\partial e_{ij}} \frac{e_{ij}}{r_j \omega_i} \left[ 1 - \xi_{q_j(\omega_i)}^j \left( \eta_{gj}^{-1} \right) \frac{\sigma_g}{2} / \xi_{p_j(\omega_i)}^j \right] > 1$$

and is therefore always positive, ranging between  $(\eta_{gj}) \sigma_g - 2 + 1$  and  $\sigma_g - (\eta_{gj}) \sigma_g - 2 + 1$  depending on the extent of the exchange-rate pass-through. This is the first channel emphasized in this paper through which a domestic currency appreciation, as a *negative demand rotator*, encourages domestic exporters to enhance output quality. Obviously, since there is a trade-off between quality and price adjustments, the magnitude of the quality upgrading entailed by an appreciation of the home currency is closely related to the pass-through rate,  $2 / \xi_{p_j(\omega_i)}^j$ . Thus, this magnitude depends on some firm-specific and market-specific features. In particular, since higher quality output raises a firm's sales but simultaneously increases its manufacturing and/or distribution costs, the least competitive firms might be unable to invest in such a quality-enhancing process. This should generate reallocation effects *within* industries. In addition, in line with [Kugler and Verhoogen \[2012\]](#) and [Fan et al. \[2015\]](#), evidence is provided below demonstrating that quality and price adjustments vary *between* industries according to their scope of product differentiation.

### 3.2.1.2 Firms' costs, product and process productivity

The production side of the model is an extension of Melitz [2003] and Feenstra and Romalis [2014] to allow for endogenous quality choice by heterogeneous firms. The origin of the movements in the bilateral exchange rates is considered as exogenous to individual firms' strategies in terms of prices, qualities and shipments. Firms are profit maximizing and follow a two stage cost-scale decision. In the first stage, firms located in country  $i$  simultaneously determine the amount and the quality of each input to employ in order to produce a given quality-adjusted amount of variety  $\omega_i$  in the least costly way. In the second stage, they simultaneously choose the quality,  $q_j$  and price,  $p_j$  of this final output for each market  $j$  to which it is intended for export. Producing  $\omega_i$  entails four types of costs: an iceberg trade cost between the home country  $i$  and destination  $j$ ,  $\tau_{ij}$ , a fixed cost of exporting,  $F_{ij}$ , an additive (per unit) distribution cost,  $T_j$  and a traditional marginal manufacturing cost,  $c_j$ . For the moment, the former two are assumed to be identical across varieties exported from the same country, and to vary only across destination  $j$ . In contrast, the latter two are assumed to be contingent on two different types of firms' characteristics defined below.

**Process Productivity and Product Productivity** As in Hallak and Sivadasan [2013], firms from country  $i$  are heterogeneous in two dimensions within each industry: "process productivity" and "product productivity". "Process productivity" ( $\varphi_i$ ) is the ability for a firm to produce output using few variable inputs. In the traditional literature, it refers to "plant capability" or "productivity". "Product productivity" ( $\vartheta_i$ ) is the ability to deliver high quality products to consumers incurring low expenses for distribution and marketing within each export destination. This encompasses expenses associated with activities such as advertising, downstream designing activities, networking or quality control. While some firms may succeed by rolling out an efficient management of the production process (high  $\varphi_i$ ), others may thrive based on their ability to create goods that consumers value through product differentiation (high  $\vartheta_i$ ).

"Process productivity" and "product productivity" are both exogenously drawn from two Pareto distributions, respectively  $G_i(\varphi) = \frac{1}{\varphi} \left( \frac{\varphi}{\varphi_i} \right)^{-\mu}$  and  $H_i(\vartheta) = \frac{1}{\vartheta} \left( \frac{\vartheta}{\vartheta_i} \right)^{-\nu}$ , where the location parameters  $\varphi_i \geq \varphi$  and  $\vartheta_i \geq \vartheta$  are the lower bounds to the process and product productivities for firms in country  $i$ . The distributions are assumed to be independent to each other. "Process productivity" and "product productivity" together indicate how efficient a firm is at producing a given variety, so that each variety exported from country  $i$  is represented by a combination  $\omega_i = \varphi_i \vartheta_i$ . By varying the lower bounds, differences in average process and product productivities across countries can be achieved. However, following Eaton and Kortum [2002] and Feenstra and Romalis [2014], it is assumed for analytical convenience that the dispersion parameters  $\mu$  and  $\nu$  are identical across countries, while they still vary across industries. For the moment, the sectoral subscript  $g$  are omitted in the interests of simplifying notation. As it

is standard in the literature, firms with higher "process productivity" incur lower marginal costs  $c_j)\omega_i$  while firms with higher "product productivity" incur lower (per unit) distribution costs  $T_j)\omega_i$

**Product Productivity and Distribution costs** Following [Burstein et al. \[2003\]](#), [Corsetti and Dedola \[2005\]](#) and [Berman et al. \[2012\]](#), production and wholesaling/retailing are complements, and distribution costs have to be paid in the destination country. However, the model considers two alternative scenarios: a centralized and a decentralized downstream supply chain. In a centralized structure, the manufacturer-exporter is responsible for all inventory and distribution decision-makings, whereas in a decentralized structure, the distribution is outsourced to local wholesalers and retailers<sup>3</sup>. As in [Berman et al. \[2012\]](#) and [Chen and Juvenal \[2014\]](#), a higher output quality implies higher distribution costs in both scenarios. However, in the centralized scheme, distribution costs depend on "product productivity"  $\vartheta_i$ , so that firms with higher skills for product differentiation incur lower per unit distribution costs. In contrast, in the decentralized scheme, distribution costs are independent from any firm-specific attribute. In this case, the distribution made by local wholesalers in country  $j$  is simply assumed to require  $l_j$  units of labor per unit sold, remunerated at a  $w_j$  wage rate, as in [Burstein et al. \[2003\]](#) and [Corsetti and Dedola \[2005\]](#). Distribution costs in the centralized scenario  $T_j^c)\omega_i$  and in the decentralized scenario  $T_j^d)\omega_i$  are therefore respectively given by:

$$T_j^c)\omega_i = \frac{f_j q_j)\omega_i^{\beta_{gj}}}{\vartheta_i} \quad (3.4)$$

$$T_j^d)\omega_i = w_j l_j q_j)\omega_i^{\beta_{gj}} \quad (3.5)$$

with  $\beta_{gj} > 1$  the industry and destination-specific quality elasticity of distribution costs, and  $f_j > 1$ . The higher is  $\beta_{gj}$  the more it is difficult to reach consumers in the destination market, given the nature of goods in some industries. Thus, a large value of  $\beta_{gj}$ , as a low value of  $\eta_{gj}$ , indicates that the scope for quality differentiation is limited. In addition, as  $\eta_{gj}$ ,  $\beta_{gj}$  is likely to vary over time, a fact that will be recognized in the empirical analysis. Note finally that distribution costs are variety and destination-specific in both scenarios, and that they are paid in local currency, so that they are directly unaffected by changes in the exchange rate.

**Process Productivity, Inputs Quality and Marginal Costs** The final output of variety  $\omega_i$  is produced using bundles of primary factors  $L_j)\omega_i$  and a composite of intermediate inputs  $M_j)\omega_i$ . Both are indexed by destination  $j$ , which indicates that  $L_j)\omega_i$  and  $M_j)\omega_i$  are referred to as the amount of primary and intermediate factors allocated within a firm for producing the variety  $\omega_i$  that is shipped to market  $j$ . As in [Feenstra and Hanson \[1996\]](#) and [Grossman and Rossi-Hansberg \[2008\]](#), the composite intermediate,  $M_j)\omega_i$  is costless assembled from a continuum

<sup>3</sup>In practice no supply chain can be completely centralized or decentralized, so that both approaches have their advantages and disadvantages

of intermediates indexed by  $z \in Z_{\omega_i}$ , with  $Z_{\omega_i}$  denoting the set of materials used to produce  $\omega_i$  (e.g. wood, steel, cotton etc). Intermediate input sectors are assumed to be perfectly competitive but quality-differentiated, and final-good producers are price-takers in all intermediate input markets. Each intermediate good  $z$  is formed by a combination of a domestic and some foreign varieties (e.g. french and foreign wood), and  $K_{\omega_i}^z$  denotes the set of foreign countries from where the intermediate  $z$  is imported in order to conceive the output variety  $\omega_i$ . The quantities of each type of domestic and imported inputs  $z$  are denoted  $m_{zji}(\omega_i)$  and  $m_{zjk}(\omega_i)$  respectively.

The price of these domestic and imported varieties,  $p_{zji}^m$  and  $p_{zjk}^m$ , are exogenously given. However, in each source country, plants are assumed to choose the input variety with the lower quality-adjusted price (that is the greater quality/price ratio),  $\lambda_{zji}^m(\omega_i)$  and  $\lambda_{zjk}^m(\omega_i)$ . Consequently, domestic and imported input qualities, denoted  $a_{zji}^m(\omega_i)$  and  $a_{zjk}^m(\omega_i)$  respectively, result from an endogenous choice made by firms, and are bounded by  $p_{zji}^m \left[ \lambda_{zji}^m(\omega_i) a_{zji}^m(\omega_i) \right]^{\psi_z}$  and  $p_{zjk}^m \left[ \lambda_{zjk}^m(\omega_i) a_{zjk}^m(\omega_i) \right]^{\psi_z}$ . Alternatively, one might think of  $\lambda_{zji}^m(\omega_i)$  and  $\lambda_{zjk}^m(\omega_i)$  as the share of domestic and foreign input prices that is not related to their quality component, and that firms try to minimize<sup>4</sup>.

In the first-stage of their profit-maximization problem, firms therefore simultaneously choose the quantity,  $m_{zji}(\omega_i)$  and  $m_{zjk}(\omega_i)$  and the quality,  $a_{zji}(\omega_i)$  and  $a_{zjk}(\omega_i)$  of each input in order to produce a quality-adjusted amount of output variety  $\omega_i$  in the least costly way. As in [Kugler and Verhoogen \[2012\]](#), production in the final-good sector is therefore described by two functions: one describing the production of physical units of output and another one describing the production of quality. The production of physical units is assumed to be:

$$Y_j(\omega_i) = \left( \varphi_i L_j(\omega_i) \right)^{\alpha_l} \left( \frac{M_j(\omega_i)}{q_j(\omega_i)} \right)^{\alpha_g} \left[ \int_{z \in Z_{\omega_i}} m_{zji}(\omega_i)^{\rho_z} / \prod_{k \in K_{\omega_i}} m_{zjk}(\omega_i)^{\rho_z} \right]^{\frac{\alpha_z}{\rho_z}} \quad (3.6)$$

where factor shares  $\alpha_l / \alpha_g \left[ \alpha_l / \sum_{z \in Z_{\omega_i}} \alpha_z \right] \leq 2$ , and  $\alpha_g > 1$  implies that higher quality varieties, i.e. those with a wide range of attributes, require more physical inputs to produce a given level of physical output. As in [Halpern et al. \[2011\]](#), equation (3.6) implies that domestic and foreign intermediates inputs of type  $z$  enter a firm's technology as a CES aggregate in its production function, while the assumption of  $\rho_z \in [1, 2]$  allows the elasticity of substitution between them,  $\rho_z^{-1}$ , to be constant and greater than one but less than infinity.

<sup>4</sup>[Demir et al. \[2011\]](#) use a modelisation close to this one. They consider  $a_{zjk}^m$  to be the skill requirement associated with each intermediate, and  $\lambda_{zjk}^m$  to be the price of this skill, such that the price of each intermediate is given by  $p_{zjk}^m = \lambda_{zjk}^m \times a_{zjk}^m$ .

In a similar spirit, the production of output quality is assumed to be a CES combination of inputs qualities:

$$q_j) \omega_i^{-\alpha_g} \left[ \int_{z \in Z_{\omega_i}} a_{zj}^m) \omega_i^{-\alpha_z} \text{ with } a_{zj}^m) \omega_i + \left[ \int_{z \in Z_{\omega_i}} a_{zji}^m) \omega_i^{-\chi_z} / \prod_{k \in K_{\omega_i}} a_{zjk}^m) \omega_i^{-\chi_z} \right]^{\frac{1}{\chi_z}} \right] \quad (3.7)$$

with  $\sum \chi_z \in [1, 2]$  guarantying that output quality is an increase function of input quality. Higher input quality is also more expensive for firms, which face the following total manufacturing cost:

$$C_j) \omega_i + \left[ w_i L_j) \omega_i + \prod_{z \in Z_{\omega_i}} \lambda_{zji}^m) \omega_i + a_{zji}^m) \omega_i + \psi_z m_{zji} \omega_i + \prod_{k \in K_{\omega_i}^z} \frac{\lambda_{zjk}^m) \omega_i +}{e_{ik}} a_{zjk}^m) \omega_i + \psi_z m_{zjk} \omega_i + \right] \quad (3.8)$$

where  $w_i$  is the price of one unit of labor in the Home country, and  $\sum_{z \in Z_{\omega_i}} \psi_z \in [\psi_g \in [1, 2]]$  indicates that input prices increase less than proportionally with quality. Given (3.6) and (3.7), firms choose which quality-differentiated input varieties to employ and their respective amount in order to minimize the cost function (3.8) for a given quality-adjusted amount of variety  $\omega_i$ ,  $q_j) \omega_i^{-\alpha_g} Y_j) \omega_i^{-\alpha}$ . To ensure an interior solution in firm's input and output quality choices, the extent to which marginal costs rise with quality is bounded from above  $\alpha_{gj} < \eta_{gj}$ . The marginal cost function associated with the production of one unit of variety  $\omega_i$ , in unit of the domestic currency  $i$ , that results from this cost-minimization problem is then given by:

$$c_j) \omega_i + \left[ \frac{w_i \lambda_j^m) \omega_i +}{\varphi_i} a_j^m) \omega_i + \psi_g + \alpha_g \left[ \frac{w_i p_m} \varphi_i} a_j^m) \omega_i + \alpha_g \left[ \frac{w_i p_m}{\varphi_i} q_j) \omega_i + \alpha_g \right] \right] \quad (3.9)$$

where  $w_i \in (0, \infty)$ , and  $p_m$  and  $a_j^m) \omega_i +$  denote the effective price and the optimal quality of one unit of the composite good  $M_j) \omega_i +$  respectively<sup>6</sup>.

<sup>5</sup>The cost minimization problem is therefore:

$$\min_{m_{zjk}, a_{zjk}} C_j(\omega_i) = w_i L_j(\omega_i) + \sum_{z \in Z_{\omega_i}} \left[ \lambda_{zji}^m(\omega_i) a_{zji}^m(\omega_i)^{\psi_z} m_{zji}(\omega_i) + \sum_{k \in K_{\omega_i}^z} \frac{\lambda_{zjk}^m(\omega_i)}{e_{ik}} a_{zjk}^m(\omega_i)^{\psi_z} m_{zjk}(\omega_i) \right]$$

$$\text{s.t. } q_j(\omega_i)^{\eta_{gj}} Y_j(\omega_i) = \varphi_i q_j(\omega_i)^{\eta_{gj} - \alpha_g} L_j(\omega_i)^{\alpha_l} M_j(\omega_i)^{\alpha_g}$$

where  $M_j(\omega_i)$  and  $q_j(\omega_i)$  are respectively defined by (3.6) and (3.7).

<sup>6</sup>Formally, they are defined by:

$$\tilde{p}_m = \prod_{z \in Z_{\omega_i}} \frac{1}{\alpha_z^{\alpha_z}} \left[ p_{zji}^m)^{\frac{\rho_z}{\rho_z - 1}} + \sum_{k \in K_{\omega_i}^z} \left( \frac{p_{zjk}^m}{e_{ik}} \right)^{\frac{\rho_z}{\rho_z - 1}} \right]^{\frac{\rho_z - 1}{\rho_z} \alpha_z} = \prod_{z \in Z_{\omega_i}} \left( \frac{p_{mz}}{\alpha_z} \right)^{\alpha_z} \quad \text{with } l_z = \chi_z(\rho_z - 1) - \psi_z \rho_z < 0$$

$$\tilde{\lambda}_j^m(\omega_i) = \prod_{z \in Z_{\omega_i}} \frac{1}{\alpha_z^{\alpha_z}} \left[ \left( \frac{p_{mz}}{p_{zji}^m} \right)^{\frac{l_z}{\chi_z(\rho_z - 1)}} \lambda_{zji}^m(\omega_i) \right]^{\alpha_z}; \quad a_j^m(\omega_i)^{\psi_g + \alpha_g} = \prod_{z \in Z_{\omega_i}} \left[ \left( \frac{p_{mz}}{p_{zji}^m} \right)^{\frac{\rho_z}{\chi_z(\rho_z - 1)}} a_{zji}^m(\omega_i) \right]^{\psi_z + \alpha_z}$$

When a firm chooses input quality, it faces a trade-off between two opposing effects. On one hand, a higher  $a_j^m \omega_i$  increases the firm's marginal cost. On the other hand, a higher  $a_j^m \omega_i$  enhances output quality, and thus the demand for its good. Consequently, the choice of output quality, input quality and marginal cost are closely related. More specifically, equation (3.9) indicates that manufacturing a good of higher quality is associated with a higher marginal cost because it requires the use of more sophisticated - and thus more expensive - inputs and assembly technologies [Manova and Zhang, 2012b]. Marginal costs are therefore an increasing function of both the quality-adjusted price,  $\lambda_{jz}^m \omega_i$  and the quality,  $a_{jz}^m \omega_i$  of intermediate inputs selected to design  $\omega_i$ .

An appreciating domestic currency, which reduces the price of imported inputs expressed in terms of the home currency, encourages firms to expand the set of imported inputs toward higher quality varieties, and thus to upgrade the quality of their output. Formally:

$$\xi_{q_j(\omega_i)}^k \left[ \xi_{a_j^m(\omega_i)}^k \left[ \frac{\partial a_j^m \omega_i}{\partial e_{ik}} \frac{e_{ik}}{a_j^m \omega_i} \left[ \prod_{z \in Z_{\omega_i}^k} \alpha_z \frac{\rho_z}{\chi_z} \frac{\tilde{s}_{zjk}^m}{\rho_z} \right] \right] \right] > 1 \quad (3.10)$$

where  $Z_{\omega_i}^k$  is the set of intermediates imported from country  $k$ , and  $\tilde{s}_{zjk}^m \left[ \right] p_{zjk}^m e_{ik} p_{mz}^{-1} \left( \frac{\rho_z}{\rho_z - 1} \right)$  refers to the weighted price share of each one of these imported inputs from  $k$  in the price of one unit of type  $z$ -intermediate. Equation (3.10) makes clear that an appreciation of the home currency increases the quality component of imported inputs,  $a_j^m \omega_i$  which in turn encourages firms to enhance output quality. This is the second channel emphasized in this paper through which an appreciation, as a *positive supply shock*, is likely to stimulate product quality upgrading. Note finally that, if an appreciation obviously entails a decline in the price of intermediate inputs  $p_m$ , this effect can be broken down into two components as follows:

$$\begin{aligned} \xi_{\tilde{p}_m} \left[ \frac{\partial p_m}{\partial e_{ik}} \frac{e_{ik}}{p_m} \left[ \prod_{z \in Z_{\omega_i}^k} \right] \frac{\partial \lambda_j^m \omega_i}{\partial e_{ik}} \frac{e_{ik}}{\lambda_j^m \omega_i} / \frac{\partial a_j^m \omega_i}{\partial e_{ik}} \frac{e_{ik}}{a_j^m \omega_i} \right] & \\ \left[ \prod_{z \in Z_{\omega_i}^k} \right] \frac{\alpha_z \rho_z}{\chi_z} \frac{1}{\rho_z} / \frac{\alpha_z \rho_z}{\chi_z} \frac{\rho_z}{\rho_z} \left( \tilde{s}_{zjk}^m \right) & \\ \left[ \prod_{z \in Z_{\omega_i}^k} \alpha_z \tilde{p}_{jkz}^m \right] & \left[ 2, 1 \right] \quad (3.11) \end{aligned}$$

intensive margin < 0                      extensive margin > 0

In words, equation (3.11) indicates that an appreciation of the home currency against currency  $k$  (i) induces a decrease in marginal costs by lowering the quality-adjusted price of their existing set of imported intermediates from  $k$  (intensive margin), but also (ii) encourages firms to modify their set of imported varieties from  $k$  towards higher quality intermediates, which partly offsets this decrease in marginal costs (extensive margin). In sum, intermediate inputs appear cheaper in terms of the domestic currency, while being of higher quality at the same time.



### 3.2.2 Firms' optimal choices

In the final-good sector  $g$ , a profit-maximizing firm with process productivity  $\varphi_i$  and expertise draw  $\vartheta_i$ , which considers exporting to destination  $j$ , chooses the export price and quality of variety  $\omega_i$  by solving:

$$\begin{aligned} \max_{p_j(\omega_i), q_j(\omega_i)} \quad & \pi_j(\omega_i) = \left[ p_j(\omega_i) - \frac{w_i p_m}{\varphi_i} q_j(\omega_i)^{\alpha_g} \right] \left( x_j(\omega_i) - F_{ij} \right) \\ \text{s.t.} \quad & x_j(\omega_i) = \left[ e_{ij} \tau_{gij} \lambda_j(\omega_i) / \frac{T_j(\omega_i)}{q_j(\omega_i)^{\eta_{gj}}} \int^{-\sigma_g} q_j(\omega_i)^{-\eta_{gj}} E_{gj} \Pi_{gj}^{\sigma_g - 1} \right] \end{aligned} \quad (3.12)$$

In the centralized downstream supply chain scenario, the first-order conditions for each final-good producer's optimization problem yield the following optimal price, quality and quality-adjusted price:

$$p_j(\omega_i) = \left[ \frac{\sigma_g}{\sigma_g - 2} \kappa_2 \right] \kappa_1 \frac{e_{ij} \tau_{gij} \vartheta_i}{f_j} \left[ \frac{w_i p_m}{\varphi_i} \right]^{\beta_{gj}} \left[ \frac{1}{\beta_{gj} - \alpha_g} \right] \quad (3.13)$$

$$q_j(\omega_i) = \left[ \kappa_1 \frac{e_{ij} \tau_{gij} \vartheta_i}{f_j} \right] \frac{w_i p_m}{\varphi_i} \left[ \frac{1}{\beta_{gj} - \alpha_g} \right] \quad (3.14)$$

$$\lambda_j(\omega_i) = \left[ \frac{\sigma_g}{\sigma_g - 2} \kappa_2 \right] \kappa_1 \frac{e_{ij} \tau_{gij} \vartheta_i}{f_j} \left[ \frac{w_i p_m}{\varphi_i} \right]^{\beta_{gj} - \eta_{gj}} \left[ \frac{1}{\beta_{gj} - \alpha_g} \right] \quad (3.15)$$

with  $\kappa_1 = \left[ \frac{\eta_{gj} - \alpha_g}{\beta_{gj} - \eta_{gj}} \right]$  and  $\kappa_2 = \left[ 2 / \frac{\kappa_1}{\sigma_g} \right]$  two positive factors, implying  $\beta_{gj} > \eta_{gj} > 1$ . As in [Feenstra and Romalis \[2014\]](#), these equations show that firms not only mark up over marginal costs,  $c_j(\omega_i)$  in the usual manner, they also mark up over specific distribution and trade costs, as well as over the nominal exchange rate between the home country and the export destination. Furthermore, in line with the seminal work of [Melitz \[2003\]](#), firms with higher "process productivity",  $\varphi_i$ , have lower costs and charge lower output prices. However, they also design lower output quality. As surprising as it may sound, this outcome might be easily interpreted as indicating that high "process productivity" plants compete in price, while high "product productivity" plants stand out in terms of quality [[Hallak and Sivadasan, 2013](#)]. This statement is supported by equations (3.13) and (3.14), which indicate that firms with higher quality expertise (higher  $\vartheta_i$ ) design higher output quality, and therefore charge higher output price. Note that quality can also be expressed conditional on price as follows<sup>7</sup>:

<sup>7</sup>Price can also be expressed as a function of quality, that is:

$$p_j(\omega_i) = m_j(\omega_i) \left[ \left( \kappa_1 \frac{e_{ij} \tau_{gij} \vartheta_i}{f_j} \right)^{\alpha_g - \eta_{gj}} \left( \frac{\tilde{w}_i \lambda_m}{\varphi_i} \right)^{\beta_{gj} - \eta_{gj}} \right]^{\frac{1}{\beta_{gj} - \alpha_g}}$$

where the variety-specific markup  $m_j(\omega_i) = \frac{\sigma_g}{\sigma_g - 1} \kappa_2 q_j(\omega_i)^{\eta_{gj}}$  is an increasing function of product quality. In that case, the variety and destination-specific elasticity of export price to a change in the exchange rate increases with

$$q_j)\omega_i + \left[ \frac{p_j)\omega_i + \sigma_g}{\kappa_2} \frac{2}{\sigma_g} \left( \frac{1}{\eta_{gj}} \right) \right] \kappa_1 \frac{e_{ij} \tau_{gij} \vartheta_i}{f_j} \left[ \frac{\eta_{gj} - \alpha_g}{\beta_{gj} - \eta_{gj}} \right] \frac{\varphi_i}{w_i p_m} \left[ \frac{1}{\eta_{gj} (\beta_{gj} - \alpha_g)} \right] \quad (3.16)$$

so that it is clear from (3.16) that conditional on price, both higher process productivity and higher product productivity are coupled with higher output quality. Finally, equation (3.15) stresses that, as long as there is a positive scope for product differentiation, i.e. as long as the destination-specific intensity of preferences for quality is high enough to compensate the raise in marginal costs induced by an increase in quality ( $\eta_{gj} > \alpha_g$ ), the quality-adjusted price  $\lambda_j)\omega_i +$  declines with both an increase in higher process productivity and an increase in product productivity. In other words, the quality/price ratio of a variety raise with both of these firms' abilities. Similar to Hallak and Sivadasan [2013], this implies that  $\omega_i)\varphi_i, \vartheta_i + [ \ ] \vartheta_i^{\kappa_1} \varphi_i +$  is therefore a measure of "combined productivity", defined such as firms with a higher  $\omega_i)\varphi_i, \vartheta_i$  offer a higher quality/price ratio to consumers in export markets.

Using (3.14) and (3.15), it is straightforward to see that any change in the exchange rate entails both price and quality adjustments of the varieties exported from the home country. Precisely, the variety specific exchange rate elasticities of quality and quality-adjusted price are given by:

$$\xi_{q_j(\omega_i)}^j \left[ \frac{\partial q_j)\omega_i +}{\partial e_{ij}} \frac{e_{ij}}{q_j)\omega_i +} \left[ \frac{2}{\beta_{gj}} \frac{\xi_{p_m}^j}{\alpha_g} \right] \right] \quad (3.17)$$

$$\xi_{\lambda_j(\omega_i)}^j \left[ \frac{\lambda_j)\omega_i +}{\partial e_{ij}} \frac{e_{ij}}{\lambda_j)\omega_i +} \left[ \frac{\eta_{gj} - \alpha_g}{\beta_{gj}} \right] \frac{\beta_{gj}}{\eta_{gj}} \frac{\eta_{gj}}{\alpha_g} \xi_{p_m}^j \right] \quad (3.18)$$

when the home currency  $i$  appreciates against currency  $j$ . The exchange-rate elasticity of input prices,  $\xi_{p_m}^j$ , ranges between -1 and 0, and is defined by (3.11). Equation (3.17) indicates that, following an appreciation of the domestic currency, exporters from the home country upgrade the quality of exports to  $j$  in order to compensate for the loss in their price-competitiveness, and so keep their market share and export revenue constant (see Section 3.2.1.1). Therefore, the exchange rate elasticity of quality is inversely correlated with the pass-through rate to local currency selling prices, which is given by:  $\xi_{p_m}^j \left[ \frac{\beta_{gj}}{\beta_{gj} - \alpha_g} \right] \frac{2}{\xi_{p_m}^j}$ . In addition, since according to (3.11), the decrease in inputs' price is broken down into a fall in the non-quality component of inputs (intensive margin) but a rise in their quality component (extensive margin), equation (3.17) also indicates that this quality-enhancing process is facilitated by the easier access to higher quality inputs simultaneously allowed by the domestic currency appreciation (see Section 3.2.1.2). Note that these effects are larger for firms with a high capability to upgrade quality at the expense of small marginal costs increase (low value of  $\alpha_g$ ).

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the quality of the good exported and the intensity of preferences for quality in the destination country. This outcome is perfectly in line with prior studies on the heterogeneity of exchange-rate pass-through between firms such as in Berman et al. [2012], Auer et al. [2014] or Chen and Juvenal [2014] who emphasized that the exchange-rate pass-through is higher for firms with higher-efficiency or higher-quality.

Equation (3.18) illustrates that, as long as there is positive scope for product differentiation - i.e. the intensity of preferences for quality  $\eta_{gj}$  is high enough, and the quality-elasticity of marginal costs  $\alpha_g$  is low enough - an appreciating domestic currency decreases the quality-adjusted export price, or in other words, enhances the quality/price ratio of the varieties exported from the home country. This arises through two channels: (i) the direct effect of an appreciation which strengthens the competition faced by domestic exporters in the destination market  $j$  - appearing in the first term on the right of equation (3.18), and emphasized in Section 3.2.1.1 -; and (ii) the increase in the quality/price ratio of intermediate inputs - appearing in the second term on the right of equation (3.18), and stressed out in Section 3.2.1.2.

### 3.2.3 Industry Equilibrium

#### 3.2.3.1 Process Productivity, Product Productivity and the Zero-Cutoff-Profit Condition

Following Feenstra and Romalis [2014], the model relies on the zero-cutoff-profit condition of Melitz [2003] to solve for the productivity-adjusted wage of the marginal exporter, and thereby obtain sectoral average quality and quality-adjusted prices of domestic exports. The sectoral subscript  $g$  are omitted in the interests of simplifying notation. Substituting the pricing and quality rules (3.13) and (3.14) into firms' revenue and profit (3.12), the following expressions for export revenues and profits made in destination  $j$  in terms of the home currency are obtained:

$$r_j)\omega_i+[ \kappa_3\tau_{ij}^{1-\sigma} \left) \frac{\lambda_j)\omega_i+}{\Pi_j} \left[^{1-\sigma} E_j ; \quad \pi_j)\omega_i+[ \frac{r_j)\omega_i+}{\sigma} F_{ij} \quad (3.19)$$

where  $\kappa_3 [ \left) 2 / \frac{\sigma-1}{\sigma} \frac{\kappa_1}{\kappa_2} \left( > 1 \right)$  indicates the gap between the domestic and foreign demand induced by the destination-specific distribution and trade costs, and  $\Pi_j$  and  $E_j$  are the quality-adjusted price index and the foreign demand for varieties  $\omega \in \mathcal{C}^j$ , respectively, both expressed in terms of the domestic currency. Note that revenues and profits appeared in (3.19) as an increasing function of the quality/price ratio offered by firms. The fixed exporting costs,  $F_{ij}$ , imply that there is an exporting cutoff "combined productivity",  $\omega_i$ , above which exporters make non-negative profits, and thus, decide to remain in the foreign market  $j$ :

$$r_j)\omega_i+[ \sigma F_{ij} \quad (3.20)$$

Hence, a critical value  $\omega_i$  determines firm survival, and establishes a survival cut-off function in

the  $\varphi_i$ – $\vartheta_i$  space:

$$\psi_i \varphi_i + \left[ \frac{w_i p_m e_{ij} \tau_{ij}}{\varphi_i} \left( \frac{1}{\kappa_1} \right) \left[ \frac{f_j}{\kappa_1} \left( \kappa_4 \right) \frac{E_j \Pi_j}{\sigma F_{ij}} \left[ \frac{1}{\sigma-1} \right]^{\frac{\beta_j - \alpha}{\alpha - \eta_j}} \right] \right] \quad (3.21)$$

$$\phi_i \vartheta_i + \left[ \frac{w_i p_m e_{ij} \tau_{ij}}{\vartheta_i^{\kappa_1}} \left( \frac{1}{\kappa_1} \right) \left[ \frac{f_j}{\kappa_1} \left( \frac{\eta_j - \alpha}{\eta_j - \beta_j} \right) \kappa_4 \right] \frac{E_{gj} \Pi_j}{\sigma F_{ij}} \left[ \frac{1}{\sigma-1} \right]^{\frac{\beta_j - \alpha}{\eta_j - \beta_j}} \right] \quad (3.22)$$

$$\omega_i \left[ w_i p_m e_{ij} \tau_{ij} \left\{ \frac{f_j}{\kappa_1} \left( \frac{\eta_j - \alpha}{\eta_j - \beta_j} \right) \kappa_4 \right\} \frac{E_j \Pi_j}{\sigma F_{ij}} \left[ \frac{1}{\sigma-1} \right]^{\frac{\beta_j - \alpha}{\eta_j - \beta_j}} \right] \quad (3.23)$$

where  $\kappa_4 \left[ \left( \frac{\sigma}{\sigma-1} \right)^2 / \kappa_1 \right]$  is a positive destination and sector-specific factor, and the combined productivity cutoff is defined in the previous subsection by  $\omega_i \left( \vartheta_i^{\kappa_1} \varphi_i \right)$ . In line with [Hallak and Sivadasan \[2013\]](#), equation (3.21) shows that for each value of "process productivity",  $\varphi_i$ , there is a minimum level of expertise draw in designing high quality,  $\psi_i$ , such that only firms above this minimum earn non-negative profits. The same reasoning applies to (3.22), which indicates that for each value of "product productivity",  $\vartheta_i$ , there is a minimum value of "process productivity",  $\phi_i$ , defined such that only exporters above this minimum make positive profits. The negative slopes of  $\psi_i \varphi_i$  and  $\phi_i \vartheta_i$  highlight a trade-off between process productivity and product productivity. For example, while some firms might base their success in exporting on an efficient management of the production process, others might thrive in making appealing designs, or building on the success of their brand and networking. Under this framework, exporting firms can thus achieve the same size with different combinations of  $\varphi_i$  and  $\vartheta_i$ , and different choices of quality-price combinations.

Equation (3.21) further suggests that, for a given value of "process productivity", an appreciating domestic currency enhances the minimum level of "product productivity" required to ensure non-negative profits in foreign markets. Similarly, equation (3.22) states that for a given value of "product productivity", an appreciating domestic currency enhances the minimum level of "process productivity" required to satisfy the zero-cut-off profit condition (3.20). Consistently, equation (3.23) therefore suggests that the minimum level of "combined productivity" required to ensure non-negative export profits rises with an increase in the value of the domestic currency. Thus, since (i) the combined productivity,  $\omega_i$ , is a summary statistic for export revenue and profits, and (ii)  $\psi_i \varphi_i$  and  $\phi_i \vartheta_i$  both increase with an appreciation of the home currency, the model can collapse into a one-dimensional model isomorphic, similar to [Melitz \[2003\]](#). This should simplify the analysis of the industry equilibrium.

### 3.2.3.2 The isomorphic case

Under such an isomorphic framework, the model considers from now on the decentralized downstream supply chain scenario, as defined in Section 3.2.1.2. Distribution costs no longer depend on  $\vartheta_i$ , but still remain an increasing function of product quality, and are defined by (3.5). Each variety exported from the home country is therefore hereinafter referred to as the single productivity dimension of the model,  $\varphi_i$ . In addition, following Feenstra and Romalis [2014], a flexible specification for variety-specific fixed costs is adopted. For the firm with productivity  $\varphi_i$ , the fixed cost of exporting from country  $i$  to  $j$  is assumed to be:

$$F_{ij} = \frac{w_i p_m}{\varphi_i} \left[ e^{\zeta' F_{ij}} \right] \quad (3.24)$$

This specification implies that an exporting firm's productivity applies equally well to variable and fixed costs, and that more productive marginal exporters have lower fixed costs, and thus charge lower quality-adjusted prices. In addition, the fixed cost of exporting depends on a vector of bilateral variables between home and country  $j$ ,  $F_{ij}$ , which influence trade between these countries (e.g. language, common border, colonial history etc.).

Having specified the fixed costs of exporting, the next step is to use the zero-cutoff profit condition (3.20) to solve for the productivity-adjusted costs of the marginal exporter,  $w_i p_m \phi_i$ , among each final good sector. This solution is then substituted into the demand side and supply side equations of the model to obtain the sectoral average f.o.b price,  $P_{ij}$ , quality,  $Q_{ij}$ , and quality-adjusted price,  $\Pi_{ij}$ , of the varieties exported from the home country  $i$  to destination  $j$ . More specifically, with the assumption of firm heterogeneity, total sectoral export sales from  $i$  to  $j$  in value of the home currency,  $R_{ij}$ , is found by integrating the individual sales of domestic exporters with a productivity above the marginal exporter:

$$R_{ij} = \int_{\varphi_i}^{\infty} r_j(\varphi_i) \varphi_i^\alpha d\varphi \quad (3.25)$$

$$= \kappa_5 M_{ij} r_j(\phi_i) \frac{\phi_i}{\varphi_i} \left[ \frac{\mu}{\mu - (\sigma - 1)(\eta_j - \beta_j)} \right]^{-\mu}, \quad \kappa_5 = \left[ \frac{\mu}{(\sigma - 1)(\eta_j - \beta_j)} \right]^{-\mu} \frac{\mu}{(\beta_j - \alpha)}$$

with  $M_{ij}$  the mass of exporters, and  $r_j(\phi_i)$  the revenue of the marginal exporters. Substituting this expression into the zero-cutoff-profit condition (3.20), the relative cutoff productivity is solved:

$$\left[ \frac{w_i p_m}{\phi_i} \right] \left[ \frac{R_{ij}}{M_{ij} \varphi_i^\alpha} \right]^{-\frac{1}{1+\mu}} = \frac{\kappa_5^{-1}}{\sigma e^{\zeta' F_{ij}}} \quad (3.26)$$

Substituting back this productivity cutoff into the zero-profit-condition (3.20), and using the CES demand for  $r_j$   $\phi_i$  expressed in (3.19), the demand side of the model can be expressed in a form that is closed to the gravity equation:

$$\frac{R_{ij}}{M_{ij}} \varphi_i \theta_{w_i} \left( \sigma \kappa_5 e^{\zeta' F_{ij}} \left\{ \frac{\Pi_{ij}}{\Pi_j} \left[ \frac{E_j \kappa_3 \tau_{ij}}{\kappa_5} \right]^{1-\sigma} \right\}^{-\mu} \right) \quad (3.27)$$

$$\text{with } \left[ \frac{\Pi_{ij}}{\Pi_j} \right] \left[ \frac{E_j \kappa_3 \tau_{ij}}{\kappa_5} \right]^{1-\sigma} \left\{ \frac{\Pi_{ij}}{\Pi_j} \left[ \frac{E_j \kappa_3 \tau_{ij}}{\kappa_5} \right]^{1-\sigma} \right\}^{-\mu} \quad (3.28)$$

with  $\Pi_{ij}$  defined as in Melitz [2003] and Feenstra and Romalis [2014] as the CES average of the quality-adjusted prices of domestic exporters with a productivity above the productivity cutoff of the marginal exporter,  $\phi_i$ , specified in (3.26). The demand side of the model (3.27) is directly related to the measure of quality used by the "demand-side approach" literature, which includes Schott [2008], Hallak [2006], Hallak and Schott [2011], Khandelwal [2010], Martin and Mejean [2012] and Amiti and Khandelwal [2013]. Higher exports on the left imply a higher quality/price ratio – i.e. a lower quality-adjusted prices average  $\Pi_{ij}$  – on the right. In other words, conditional on prices, a higher demand for a set of varieties implies that they are of higher quality.<sup>8</sup>

The supply-side of the model is simply obtained by substituting the quality-adjusted price of the marginal exporter given by (3.15) and (3.26) into the sectoral quality-adjusted price average (3.28). This allows expressing the average quality-adjusted export price as a function of total exports:

$$\left[ \frac{\Pi_{ij}}{\Pi_j} \left[ \frac{E_j \kappa_3 \tau_{ij}}{\kappa_5} \right]^{1-\sigma} \right] \frac{\sigma}{\sigma-2} \kappa_2 \left[ \frac{\beta_j - \alpha}{\beta_j - \alpha} \right] \frac{\kappa_1 e_{ij} \tau_{ij}}{w_j l_j} \left[ \frac{\alpha - \eta_j}{\beta_j - \alpha} \right] \frac{R_{ij}}{M_{ij}} \varphi_i \theta_{w_i} \left( \sigma e^{\zeta' F_{ij}} \left[ \frac{\beta_j - \eta_j}{1 + \mu} \right] \right)^{\frac{1}{\beta_j - \alpha}} \quad (3.29)$$

In contrast to the demand-side intuition in (3.27), this supply-side equation implies that higher exports on the right, *ceteris paribus*, are associated with a lower quality/price ratio on the left – i.e. a higher quality-adjusted price average  $\Pi_{ij}$ ). This arises because, given the mass of potential exporters, an increase in export revenues means that lower efficient firms export, so that the average price rises, and the average quality falls.

<sup>8</sup>Note that in (3.27) total exports from  $i$  to  $j$  are divided by the mass of potential exporters which would have been equivalent to dividing total exports by the number of exporters if we had hypothesized a case of homogeneous firms. In addition, as in Feenstra and Romalis [2014], the extensive margin of substitution is reflected by the exponent  $-(1 - \sigma)(1 + \mu)$  which appears on the relative price terms.

Combining the supply and demand equations (3.27) and (3.29) gives the equilibrium sectoral f.o.b price, quality and quality-adjusted prices<sup>9</sup>:

$$P_{ij} \left[ \kappa_5^{\frac{1}{1-\sigma}} \right] \left( \frac{\sigma}{\sigma-1} \kappa_2 \left[ \gamma_1 - \beta_j(\sigma-1) \right] \frac{\kappa_1 e_{ij} \tau_{ij}}{w_j l_j} \left[ \eta_j(\sigma-1) + \alpha \right] \frac{\Pi_j^{\sigma-1} E_j}{\sigma e^{\zeta' F_{ij}} \kappa_3 \tau_{ij}^{\sigma-1}} \right)^{\frac{1}{\gamma_1}} \beta_j \left. \vphantom{\frac{\sigma}{\sigma-1}} \right\} \quad (3.30)$$

$$Q_{ij} \left[ \kappa_5^{\frac{1}{1-\sigma}} \right] \left( \frac{\sigma}{\sigma-1} \kappa_2 \left[ 1 - \sigma \right] \frac{\kappa_1 e_{ij}}{w_j l_j} \left[ \sigma \right] \frac{\tau_{ij} \Pi_j^{\sigma-1} E_j}{\sigma e^{\zeta' F_{ij}} \kappa_3^{\sigma-1}} \right)^{\frac{1}{\gamma_1}} \quad (3.31)$$

$$H_{ij} \left[ \kappa_5^{\frac{1}{1-\sigma}} \right] \left( \frac{\sigma}{\sigma-1} \kappa_2 \left[ \beta_j - \alpha \right] \frac{\kappa_1 e_{ij} \tau_{ij}}{w_j l_j} \left[ \alpha - \eta_j \right] \frac{\Pi_j^{\sigma-1} E_j}{\sigma e^{\zeta' F_{ij}} \kappa_3 \tau_{ij}^{\sigma-1}} \right)^{\frac{1}{\gamma_1}} \beta_j - \eta_j \left. \vphantom{\frac{\sigma}{\sigma-1}} \right\} \quad (3.32)$$

with  $\gamma_1 \left[ \beta_j - \alpha \right] / (\sigma - 1) > 1$ . Equations (3.31) and (3.32) indicates that, by undermining the price competitiveness of exporters in foreign markets, an appreciating currency increases the minimum level of productivity required to become a successful exporter (see Section 3.2.3.1), which in turn enhances the average quality and quality/price ratio of the varieties exported from the home country<sup>10</sup>. In other words, an appreciation of the domestic currency drives the lowest qualities out of the market, so that the average quality of the varieties exported from home improves<sup>11</sup>. More precisely, the exchange rate elasticities of the average quality and quality-adjusted price of the varieties exported to  $j$  within each final-good sector  $g$  are given by:

$$\xi_{Q_{gij}}^j \left[ \frac{\partial Q_{gij}}{\partial e_{ij}} \frac{e_{ij}}{Q_{gij}} \right] \left[ \frac{\sigma_g}{\gamma_1} \right] > 1 \quad (3.33)$$

$$\xi_{\Lambda_{gij}}^j \left[ \frac{\partial H_{gij}}{\partial e_{ij}} \frac{e_{ij}}{H_{gij}} \right] \left[ \frac{\alpha_g - \eta_{gj}}{\gamma_1} \right] < 1 \quad (3.34)$$

<sup>9</sup>In the same spirit of (3.28), the CES average f.o.b prices is:

$$\tilde{P}_{ij} = \left[ \int_{\tilde{\varphi}_i}^{\infty} p_j(\varphi_i) \frac{g_i(\varphi)}{1 - G(\tilde{\varphi}_i)} \right]^{\frac{1}{1-\sigma}} = \kappa_5^{\frac{1}{1-\sigma}} p_j(\tilde{\varphi}_i)$$

The average quality is then given by:  $\tilde{Q}_{ij} = \left( \tilde{P}_{ij} / \tilde{\Lambda}_{ij} \right)^{\frac{1}{\eta_j}}$ .

<sup>10</sup>Note that the mass of exporter  $M_{ij}$  does not enter equations (3.30), (3.31) and (3.32) because the zero cut-off profit condition is solved for the per firm export, which also appears in the demand equation, so that these supply and demand conditions together eliminate the unobserved mass of firms at the equilibrium. Eliminating this variable is a key simplification that is obtained by using the supply side of a model with endogenous price and quality choice [Feenstra and Romalis, 2014].

<sup>11</sup>Combining the demand side equation (3.27), the zero-cutoff profit condition (3.19), and the equilibrium quality-adjusted prices (3.32), it can be shown that the equilibrium mass of exporters is given by:

$$M_{ij} \left( \varphi_i / \tilde{w}_i \right) = \kappa_5^{\frac{\sigma}{(1-\sigma)\mu}} \left[ \left( \frac{\sigma}{\sigma-1} \kappa_2 \right)^{\beta_j - \alpha} \left( \frac{\kappa_1 e_{ij} \tau_{ij}}{w_j l_j} \right)^{\alpha - \eta_j} \left( \frac{\tilde{\Lambda}_j^{\sigma-1} \tilde{E}_j}{\sigma e^{\zeta' F_{ij}} (\kappa_3 \tau_{ij})^{\sigma-1}} \right)^{\frac{\beta_j - \alpha}{\sigma-1}} \right]^{\frac{\sigma-1}{\gamma_1}}$$

Therefore, it is clear that an appreciation of the home currency diminishes the mass of exporters, and the corresponding elasticity is given by  $\xi_{M_{gij}}^j = \frac{(\alpha - \eta_j)(\sigma-1)}{\gamma_1} < 0$

when the home currency appreciates against currency  $j$ . Equation (3.33) therefore clearly emphasizes an increase in the average sectoral quality of the varieties exported to  $j$  following a domestic currency appreciation. Interestingly, the higher the price-elasticity of substitution between the varieties in the final good sector,  $\sigma_g$ , the higher is the quality-enhancing effect of an appreciating domestic currency. Indeed, when the home currency appreciates, the fiercer price-competition faced by exporters generates larger market share reallocations in final markets where the varieties are closer substitutes. Thus, the average quality upgrading is larger. In addition, equation (3.33) also highlights that an appreciation of the home currency involves a larger quality upgrading in industries close to the "quality-technology" frontier, i.e. in industries where firms are able to increase product quality with a high cost-efficiency (low  $\alpha_g$ ).

An interesting result also appears in (3.34) where an increase in the value of the domestic currency clearly entails a larger increase in the average quality-price ratio in industries where the scope for quality differentiation is large (a greater  $\eta_{gj}$  relative to  $\alpha_g$ ). This occurs because for high values of  $\alpha_g$ , or for small values of  $\eta_{gj}$ , a rise in quality induces a large increase in marginal costs, and thus in prices, so that the quality/price ratio of the varieties exported to  $j$  remains nearly the same. Conversely, for high values of  $\eta_{gj}$ , or for small values of  $\alpha_g$ , a rise in quality induces a large increase in firms' sales at the expense of a small increase in marginal costs. In this case, the corresponding prices rise only slightly, so that exporters in this final-good sector are able to enhance more widely their quality/price ratio.

To summarize, the theoretical framework emphasizes that an appreciating domestic currency enhances the individual and average quality of the varieties exported from the home country through at least three channels. First, the loss of price competitiveness abroad entailed by an appreciation (i.e. negative demand shock) constrains firms from enhancing the quality of their products in order to keep their quality/price ratio perceived by consumers constant, and so maintain their level of sales and revenue. At the same time, the simultaneous decline in imported input prices triggered by an exchange rate appreciation (i.e positive supply shock) encourages firms to modify their set of imported varieties towards higher quality intermediates, which facilitates this quality-enhancing process. However, quality upgrading is still costly, so that only a fraction of exporters can afford such a strategic move. Therefore, at the industry level, an appreciating domestic currency drives the lowest qualities out of the market, so that the average quality increases *ceteris paribus*. Note that this average quality upgrading occurs partly at the expense of market concentration. Interestingly, this effect should be more intense (i) in industries close to the "quality-technology" frontier (i.e. in industries with low  $\alpha_g$  value) and, (ii) in industries where the varieties are closer substitutes (i.e. high price elasticity of demand  $\sigma_g$ ).



### 3.3 Measuring Quality

In a seminal paper, Garvin [1987] emphasized eight attributes, which allow assessing and measuring quality: performance, features, reliability, conformance, durability, serviceability, aesthetics and perceived quality. In principle, economists with an interest on a specific product category should use these characteristics in order to establish a rating scale to measure its quality. Crozet et al. [2012], for instance, use such quality ratings of champagne producers in order to empirically investigate the quality interpretation of the Melitz [2003] model of firm heterogeneity within this specific product category. In practice however, such a measure based on objective and/or subjective attributes is almost impossible to implement the moment one considers a larger set of product varieties. While some economists have tried to address this issue using relative unit values as proxies for relative qualities, two recent streams of the literature have developed more refined quality measures limiting the biases associated with the latter<sup>12</sup>. Both explicitly disentangle quality from unit values<sup>13</sup>, but they rely on a different approach of the quality concept. In what follows, two alternative measures of quality, based on these two streams of the literature, are implemented.

In the theoretical model, the analysis at the firm-product level has been explicitly distinguished from the analysis at the industry level. Because of the nature of the data used, the empirical study implemented below is exclusively focused on the latter. Consequently, the term "variety" hereinafter refers to any exporting country-industry-destination triplet, and the analysis prevails at the aggregated industry level. This section first describes the two measures of quality implemented for each variety within the sample. Then, it presents the data and parameters used in the empirical part. Finally, this section gives some main stylized facts about the estimated qualities.

#### 3.3.1 Equilibrium and Demand Approaches of Quality

**Demand-side approach** The first measure of quality can be considered as relying on a "demand-side" approach, as it is based on a definition of quality exclusively related to the consumer's valuation and demand for highest-quality products, conditionally on their price. Based on this conception, Schott [2008], Hallak [2006], Hallak and Schott [2011], Khandelwal [2010], Martin

<sup>12</sup>The intuition behind the use of unit values as measure for quality is straightforward: the higher the price of a variety with respect to the related market average, the higher the estimated quality. However, differences in unit values reveal much more than differences in quality. They may, in particular, also indicate disparities in factor costs or in productivity. This is why this "gross" measure has been found to be inappropriate.

<sup>13</sup>Actually, there is a third approach which relies on quality changes *between* categories of product. The latter, initiated by Aw and Roberts [1986], and Boorstein and Feenstra [1987] and developed by Martin and Mejean [2012], is here voluntarily neglected since it consists of aggregating the price of distinct varieties within each industry and defining an increase in quality such as a reallocation of demand towards products holding the highest unit values. More specifically, this approach considers a quality upgrading as an increase in the difference between a price-weighted price index (defined as an "ideal price index") and a quantity-weighted price index (the weighted mean unit value), both computed over all the goods the sector includes. Note that the ideal price index is the Sato-Varia-Feenstra index in the case of a CES demand curve, or the Feenstra and Weinstein [2010] index in the case of a translog demand curve. Whereas seducing, this approach neglects however *within*-variety quality upgrading [Khandelwal et al., 2011]).

and Mejean [2012] and Amiti and Khandelwal [2013] use an empirical procedure perfectly summarized by Khandelwal [2010]: “The procedure utilizes both unit value and quantity information to infer quality and has a straightforward intuition: conditional on price, imports with higher market shares are assigned higher quality.” In other words, holding prices constant, the higher the demand for a variety, the higher the estimated quality. Using the demand side equation of the model in (3.27), the relative quality of varieties exported from  $i$  to  $j$  as compared to the market average at each period  $t$  can be expressed as follows:

$$\left( \frac{Q_{gijt}}{Q_{gjt}} \right)^{\eta_{gjt}(\sigma_g - 1)} \left[ \frac{P_{gijt}}{P_{gjt}} \right]^{(\sigma_g - 1)} \frac{R_{gijt}}{M_{gijt}} \varphi_i \theta_{w_i} \left( \frac{1}{1 + \mu_g} \right) \sigma \kappa_5 e^{\zeta' F_{ij}} \left\{ \frac{\mu_g}{1 + \mu_g} \frac{\kappa_3 \tau_{gijt} [(\sigma_g - 1)]}{E_{gjt}} \right. \quad (3.35)$$

As indicated in Section 3.2.3.2, equation (3.35) implies that conditional on (i) relative prices<sup>14</sup>, (ii) the fixed costs of exporting, (iii) the mass of exporters from home and (iv) the extensive margin of substitution between the varieties, a higher demand for a set of varieties exported from home on the right implies a higher measured relative quality on the left.

**Equilibrium approach** To this demand-side intuition, the model has added some supply-side aspects that allow getting a tighter solution for the equilibrium quality-adjusted prices and qualities expressed in (3.31) and (3.32). Combining both of them, the equilibrium average quality of varieties exported from  $i$  to  $j$  can also be expressed as a function of average f.o.b prices:

$$Q_{gijt} \left[ \frac{P_{gijt}^{1 - \sigma_g}}{P_{gjt}^{1 - \sigma_g}} \frac{\kappa_1 \tau_{gijt}}{\sigma_g \kappa_5 e^{\zeta' F_{ij}}} \right] \frac{\Pi_{gjt}^{\sigma_g - 1} E_{gjt}}{w_{jt} l_{jt} \kappa_3 \tau_{gijt} [(\sigma_g - 1)]} \left[ \frac{-1}{\gamma_2} \right] \quad (3.36)$$

with  $\gamma_2 [ \eta_{gjt} \sigma_g - 2 + \alpha_g - \beta_{gjt} ] > 1$ , as long as the scope for product differentiation is positive. Using (3.36) as a theoretical definition of the average equilibrium qualities, the relative quality of the varieties exported from  $i$  to  $j$  as compared to the destination market average can be expressed for each period as follows:

$$\left( \frac{Q_{gijt}}{Q_{gjt}} \right)^{\gamma_2} \left[ \frac{P_{gijt}}{P_{gjt}} \right]^{(\sigma_g - 1)} \frac{\sigma_g \kappa_5 e^{\zeta' F_{ij}}}{\kappa_1 \tau_{gijt}} \left[ \frac{w_{jt} l_{jt} \kappa_3 \tau_{gijt} [(\sigma_g - 1)]}{E_{gjt} Q_{gjt}^{\beta_{gjt} - \alpha_g}} \right] \quad (3.37)$$

Comparing (3.35) and (3.37), it is clear that a different measure of the relative average quality is obtained when the supply side of the model is also used. A higher relative price on the right still implies a higher relative measured quality on the left, but the use of the zero profit condition allows solving for the equilibrium mass of exporters and export revenues, which is a key simplification of this model as in Feenstra and Romalis [2014].

<sup>14</sup>Note that  $\tilde{P}_{gijt}$  indicates the average f.o.b price of the variety  $g$  exported from  $i$  to  $j$ , so that  $\kappa_3 \tau_{gijt} \tilde{P}_{gijt}$  is the average c.i.f price.

**Empirical Implementation** In practice, both (3.35) and (3.37) are used to develop two alternative measures of quality and to ensure this way the robustness of the empirical results. While, as explained just above, these quality measures are not based on the same theoretical definition of quality, they can however be estimated using a similar empirical framework. Both imply that using information on unit values, trade and fixed costs of exporting and some parameter estimates, a measure of the relative quality of each variety exported from  $i$  to  $j$ , as compared to that average in the destination market, can be built. In the demand-side approach case, the relative qualities are estimated using the logarithm of equation (3.35), which results in the following econometric specification:

$$regDmd_{gijt} [ \delta_{gjt} / v_{gijt} \quad (3.38)$$

where the dependent variable of this regression,  $regDmd_{gijt}$ , is defined by:

$$regDmd_{gijt} [ \ln R_{gijt} - \ln R_{gjt} \left\{ / \ln \right\} \kappa_3 \tau_{gijt} + / \frac{\ln R_{gijt}}{2 / \mu_g [ ] \sigma_g - 2 +} \\ \frac{\mu_g}{2 / \mu_g [ ] \sigma_g - 2 +} \ln \sigma_g \kappa_5 / \zeta' F_{ijt} - \ln M_{gijt} \left. \right) \varphi_i 0_{w_i} \left( \left( \right.$$

and where the yearly destination-industry fixed effects  $\delta_{gjt}$  capture, according to the theoretical model, the size of this destination market adjusted for the price elasticity of substitution between the varieties:  $\delta_{gjt} [ \ln E_{gjt} 0 ) \sigma_g - 2 +$ . The residuals of this econometric specification  $v_{gijt}$  provide the first measure of the individual relative qualities:

$$\ln \text{QualityDmd}_{gijt} [ \frac{v_{gijt}}{\eta_{gjt}} [ \ln Q_{gijt} - \ln Q_{gjt} \left\{ \quad (3.39)$$

Through the equilibrium approach, an alternative measure of quality is derived by exploiting the logarithm of equation (3.37) which results in the following empirical specification:

$$regEqu_{gijt} [ \delta_{gjt} / \epsilon_{gijt} \quad (3.40)$$

where the dependent variable of this regression,  $regEqu_{gijt}$ , is defined by:

$$regEqu_{gijt} [ \sigma_g - 2 + \ln R_{gijt} - \ln R_{gjt} \left\{ / \sigma_g - 2 + \ln \right\} \kappa_3 \tau_{gijt} [ / \ln \left. \right) \frac{\sigma_g \kappa_5}{\kappa_1 \tau_{gijt}} [ / \zeta' F_{ijt}$$

and where the yearly destination-industry-fixed effects  $\delta_{gjt}$  still capture the size of the corresponding destination market, but this time adjusted for its specific distribution costs and the average level of quality to satisfy:  $\delta_{gjt} [ \ln ) E_{gjt} Q_{gjt}^{\alpha_g - \beta_{gjt}} w_{jt} l_{jt}^{-1} \left( \right.$ . The residuals of this econometric specification,  $\epsilon_{gijt}$ , provide the second measure of the individual relative qualities:

$$\ln \text{QualityEqu}_{gijt} [ \frac{\epsilon_{gijt}}{\gamma_2} [ \ln Q_{gijt} - \ln Q_{gjt} \left\{ \quad (3.41)$$

### 3.3.2 Data and Parameters

The quality measures are based on a detailed dataset on goods traded by European Union (EU) member states, known as ComExt, and provided by Eurostat, the statistical office of the European Commission. Based on Customs (extra-EU) and Intrastat (intra-EU) declarations, ComExt reports annual export flows disaggregated by reporting economy, industry (defined at the 4-digit level of the Harmonized System) and destination since 1999. The entire procedure relies on the data reported by member states that have adopted the euro (€) as common currency in the very first years of its creation, namely Austria, Belgium, Finland, France, Germany, Greece (since 2001), Ireland, Italy, Luxembourg, Netherlands, Spain and Portugal. In addition, to reduce the statistical issues related to the shift of the harmonized classification system, the sample is limited to the period 1999-2007. Within each industry, the empirical analysis is restricted to the sub-sample of partner countries that represent at least 1% of European exports and served by at least three euro area members. This restriction ensures that the sample covers market destinations that are served by a number of exporting industries large enough. Finally, the empirical exercise neglects non-manufacturing industries, mainly agricultural goods in the customs data, since they are less likely to be vertically differentiated. These restrictions leave us with a sample of 5,393,749 observations, covering 229 trade partners worldwide, 1146 4-digit industries and 85% of the selected European countries' export value over this period.

In this sample, observations are identified by a reporter ( $i$ ), an industry ( $g$ ), a destination market ( $j$ ) and a time period ( $t$ ). As a result, the term “variety” refers to any reporter-industry-destination triplet. The f.o.b. unit value of each variety is computed using reports from the selected exporting countries, so that these unit values are calculated prior to the inclusion of any costs of shipping the product. Trade and fixed costs of exporting, the mass of exporters as well as the parameters needed to implement the quality measures at the variety level are extracted from the incredibly rich dataset made available by Feenstra and Romalis [2014] following their work on “International Prices and Endogenous Quality”. Note that this covers notably time-varying destination-industry-specific demand elasticity estimates. The only parameter required by the empirical analysis that is not included in this dataset is the industry- and destination-specific quality elasticity of distribution costs,  $\beta_{gjt}$ . However, using the fact that the ratio of c.i.f to f.o.b prices for each variety is proportional to the *ad valorem* trade costs, and that the coefficient of proportionality,  $\kappa_3$ , depends on all known parameters with the exception of  $\beta_{gjt}$ ,  $\kappa_3 \left[ \frac{\sigma_g(\beta_{gjt} - \eta_{gjt})}{(\beta_{gjt} - \eta_{gjt})(\sigma_g - 1) + (\beta_{gjt} - \alpha_g)} \right]$  (see (3.19)),  $\beta_{gjt}$  can be easily recovered using  $\beta_{gjt} \left[ \frac{\alpha_g + \eta_{gjt}(\sigma_g - 1) \hat{\kappa}_3 - \sigma_g \alpha_g}{\sigma_g(\kappa_3 - 1)} \right]$ . Table 3.1 displays descriptive statistics on all these parameters required to both (i) estimate the two quality measures through equations (3.39) and (3.41) and (ii) perform the empirical analysis on the relationship between exchange rate changes and these quality measures in the next section. Note that using this methodology to recover the  $\beta_{gjt}$ , only 0.47% appear to be inadmissible according to the previous assumptions (i.e negative). These parameters are also used to compute two addi-

tional key parameters of the theoretical model, namely  $\gamma_1$  and  $\gamma_2$ , which determine both quality estimates and the predicted effect of exchange rates changes on qualities and quality-adjusted prices according to equation (3.33) and (3.34). Over more than 510,000 calculations, only 7.94% of the former and 0.44% of the latter turn out to be negative.

Table 3.1: Parameters

	obs.	p5	p25	p50	p75	p95
$\sigma_g$	824	3.46	4.69	6.22	10.15	35.38
$\alpha_g$	850	0.37	0.54	0.62	0.69	0.84
$\mu_g$	850	4.98	6.61	9.12	13.01	25.89
$\eta_{gjt}$	899,127	1.34	2.18	2.59	3.82	6.30
$\beta_{gjt}$	587,451	1.76	2.98	3.66	5.25	11.59
$\kappa_1$	589,038	0.18	0.49	0.68	0.95	1.68
$\kappa_2$	511,435	1.01	1.06	1.11	1.17	1.35
$\kappa_3$	480,124	1.14	1.37	1.52	1.72	2.15
$\kappa_5$	569,807	1.20	1.50	1.66	1.77	3.02
$\gamma_1$	566,640	0.09	5.36	10.18	20.87	116.78
$\gamma_2$	582,564	0.00	7.10	10.53	17.38	307.27

Note: This table displays descriptive statistics on the parameters used to estimate the annual relative quality and quality adjusted price of each variety within the sample, that is each exporting country-industry-destination  $igj$  triplet. Note that this sample covers 11 euro area member states, 9 years (1999-2007), 1146 4-digit industries and 229 trade partners worldwide.

With respect to the variables used in all econometric specifications, the data on trade and fixed costs and on the mass of exporters provided by Feenstra and Romalis [2014] are completed with calculations of the annual variety-specific real exchange rate changes. This is done using the basic formula:  $q_{gijt} = \frac{e_{ijt} P_{gijt}^0}{P_{gjt}}$ . Note that an increase in  $q_{gijt}$  means an appreciation of the variety-specific real exchange rate. The bilateral nominal exchange rates,  $e_{ijt}$ , are extracted from the statistical database provided by the Bank for International Settlement. When direct bilateral exchange rates between the euro and the currency of some trade partners are not available, the cross rates are used, that is, the euro is first converted into U.S dollars, and the resulting amount is then converted into the desired currency. The average f.o.b prices and foreign price index,  $P_{gijt}$  and  $P_{gjt}$ , are computed using the unit values provided by the ComExt Database. Note that this implies that the Armington view of competition prevails in the following empirical analysis<sup>15</sup>. Table 3.2 reports some descriptive statistics on trade costs and fixed costs of exporting, as well as on annual changes in bilateral nominal and real exchange rates. Unsurprisingly, the average of both exchange rates, nominal and real, appreciated over this period, and the real magnitude of

<sup>15</sup>In any export markets, the Armington view implies that foreign firms compete with other importers but not with domestic firms, so that domestic prices can be omitted from the analysis. While it may seem strong, this assumption has been found to be approximately correct. Auer and Schoenle [2016] for instance find that individual import prices are not correlated with the index of domestic competitors prices but that they are highly correlated with the index of import competitor prices. In addition, the econometric specification used in this paper controls for changes in sectoral and destination-specific domestic price changes by including destination-industry-year fixed effects.

the variety-specific changes in exchange rates is larger than its nominal magnitude. In the next subsection, we ask how these changes in exchange rates correlate with quality adjustments in international markets.

**Table 3.2: Trade costs, fixed costs of exporting and exchange rates**

	obs.	mean	min	p25	p50	p75	max	sd.
<b>Fixed costs</b>	4,054,257	2.44	0.00	0.74	1.03	1.50	118.64	7.84
<b>Trade costs</b>	4,618,769	1.31	0.00	1.01	1.09	1.26	6.24	0.73
<b>Trade cost changes</b>	3,822,933	1.7%	-8.6%	-1.3%	-0.0%	1.1%	129.4%	26.35
<b>NER changes</b>	8,852	2.6%	-15.9%	-0.2%	0.8%	8.8%	68.4%	30.5
<b>RER changes</b>	3,559,978	1.8%	-89.2%	-29.1%	1.6%	32.9%	132.1%	51.6

### 3.3.3 Quality Patterns of Exports from the Euro Area

Table 3.3 and Table 3.4 give summary statistics on the quality estimates for all the varieties within the sample. The "equilibrium" panel displayed in Table 3.3 corresponds to quality indices as measured by the equilibrium formula (3.41), while the "demand" panel in Table 3.4 is obtained using the demand formula (3.39). Comparing these quality measures allows getting a better sense of the plausibility of the theoretical results and the empirical quality estimates.

Comparing these two panels, it is visually apparent that the demand-side quality estimates are more dispersed than the equilibrium quality estimates. Fortunately, this comparison also illustrates the robustness of the quality indices to the definition of quality, as it suggests that these two panels clearly have key features in common. In particular, it indicates that four group of countries can be distinguished in both cases. On average, Luxembourg and Austria clearly tend to export the highest quality goods as compared to their European partners, while Portugal, Greece and Spain are ranked at the bottom of the quality indices in both panels<sup>16</sup>. In the upper middle range, we find Finland, France and Germany whose ranking vary according to the selected quality indices. Finally, Italy, Belgium and the Netherlands always are in the lower middle range.

For the referenced period 1999-2007, the variety-specific quality adjustments were substantially different both between and within countries. Figure 3.1 below corroborates this fact. It plots the distribution of three variety-specific indices at the corresponding end period for each one of the euro area member countries in the sample: (i) an index of changes in "equilibrium" quality estimates, (ii) an index of changes in "demand" quality estimates, and (iii) an index of changes in real exchange rates. The index base values are set at 100 in 1999, so that only varieties that can be

<sup>16</sup>Note that the leadership of Luxembourg in terms of quality is driven by some specific "top quality" industries. This fact is illustrated both by the high standard deviations of the quality indices within this country and by their medians that are closed to that of its followers.

observed throughout the whole referenced period are plotted. The relative magnitude of quality adjustments, measured by both quality indices, was clearly larger in Luxembourg, France and Italy which also have experienced the largest real exchange rate appreciations. Conversely, this magnitude is lower in Germany and Austria, where the variety-specific changes in real exchange rate have also been low as compared to their European partners. To get an overview of the extent of the relationship between changes in quality and real exchange rate adjustments, [Table 3.5](#) below displays the simple correlations between the growth rates of the individual quality measures and real exchange rate indices for the referenced period. It illustrates two facts. First, changes in both quality indices are closely correlated but not strictly similar. Second, the correlation between quality and real exchange rate adjustments is higher when quality is measured by the "equilibrium" approach.

Finally, an interesting fact emerging from this analysis is that quality and real exchange rate variations, as well as the magnitude of their relationship, seem higher in vertically differentiated industries, or in other words, in industries where the scope for quality differentiation is large. To illustrate this point, [Figure 3.2](#) plots the same indices of quality and real exchange rate changes but only for the sub-sample of differentiated industries as classified by [Rauch \[1999\]](#)<sup>17</sup>. It is apparent that quality changes of differentiated industries were significantly larger than those of the whole sample, and it also appears that real exchange changes were substantially larger in those industries. This corroborates one of the main theoretical results of [Section 3.2](#) according to which, the quality-enhancing effect of an appreciating currency is larger in markets where the scope for differentiation is large. In the next section, the significance of this relationship between quality and real exchange adjustments is econometrically tested.

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<sup>17</sup>To be more specific, [Rauch \[1999\]](#) establishes a categorization of SITC Rev.2 industries according to three possible types: differentiated products, reference priced, or homogeneous goods.

Table 3.3: Quality indices: Equilibrium approach

	N. of obs.	Mean	Min	p25	p50	p75	Max	Sd.
Luxembourg	36,014	1.32	0.19	0.82	1.07	1.53	6.01	0.84
Austria	212,227	1.24	0.19	0.86	1.07	1.40	6.01	0.68
Finland	119,725	1.20	0.19	0.82	1.03	1.35	6.01	0.69
France	408,773	1.16	0.19	0.86	1.02	1.27	6.01	0.59
Germany	476,500	1.11	0.19	0.85	1.01	1.23	6.01	0.51
Belgium	308,113	1.08	0.19	0.78	0.97	1.20	6.00	0.57
Italy	464,028	1.08	0.19	0.78	0.97	1.19	6.01	0.58
Netherlands	343,563	1.07	0.19	0.76	0.96	1.19	6.01	0.59
Greece	58,050	1.01	0.19	0.71	0.90	1.13	6.01	0.58
Spain	305,343	1.01	0.19	0.73	0.91	1.11	6.01	0.56
Portugal	87,805	0.97	0.19	0.70	0.89	1.09	6.00	0.51
<b>Total Sample</b>	<b>2,820,141</b>	<b>1.10</b>	<b>0.19</b>	<b>0.80</b>	<b>0.99</b>	<b>1.22</b>	<b>6.01</b>	<b>0.59</b>

Table 3.4: Quality indices: Demand approach

	N. of obs.	Mean	Min	p25	p50	p75	Max	Sd.
Luxembourg	36,667	1.32	0.00	0.71	1.00	1.51	10.41	1.15
Austria	207,694	1.23	0.00	0.82	1.04	1.38	10.42	0.91
France	398,335	1.21	0.00	0.88	1.07	1.35	10.42	0.81
Germany	466,783	1.18	0.00	0.88	1.07	1.31	10.42	0.75
Finland	117,479	1.18	0.00	0.75	0.99	1.34	10.42	0.92
Belgium	302,274	1.06	0.00	0.74	0.94	1.18	10.42	0.77
Netherlands	336,126	1.06	0.00	0.72	0.95	1.18	10.42	0.78
Italy	453,964	1.06	0.00	0.79	0.96	1.15	10.42	0.64
Spain	298,690	0.96	0.00	0.65	0.85	1.06	10.42	0.75
Greece	56,502	0.90	0.00	0.57	0.79	1.01	10.41	0.76
Portugal	85,659	0.89	0.00	0.57	0.80	1.00	10.36	0.75
<b>Total Sample</b>	<b>2,760,173</b>	<b>1.10</b>	<b>0.00</b>	<b>0.77</b>	<b>0.98</b>	<b>1.23</b>	<b>10.42</b>	<b>0.78</b>

Note: The tables trim observations associated with relative qualities that are above and below the 99th and 1st percentiles within the sample.

Table 3.5: Correlations between quality index adjustments and RER movements

	$\Delta \ln \text{QualityEqu}_{gijt}$	$\Delta \ln \text{QualityDmd}_{gijt}$
$\Delta \ln \text{QualityDmd}_{gijt}$	0.399***	
$\Delta \ln q_{gijt}$	0.664***	0.277***

Note: The growth rates of equilibrium quality indices, demand quality indices, and real exchange rates are variety-specific and computed between the first year and the last year of observation of the corresponding variety. \*\*\* indicates coefficients significantly different from zero at the 1% level.



Figure 3.1: Distribution of quality and real exchange rate indices in 2007 (base 100 = 1999) by country, All industries combined

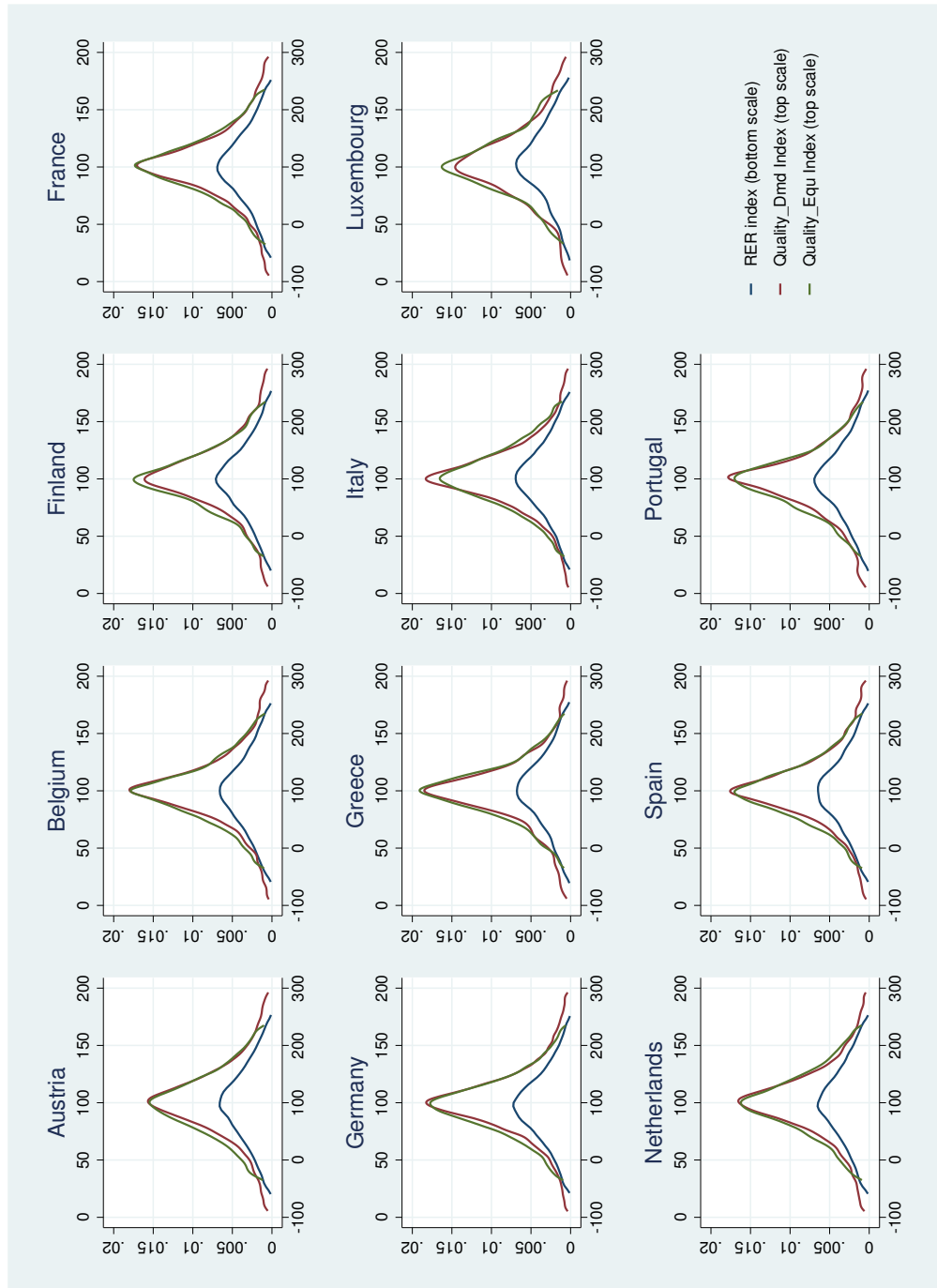
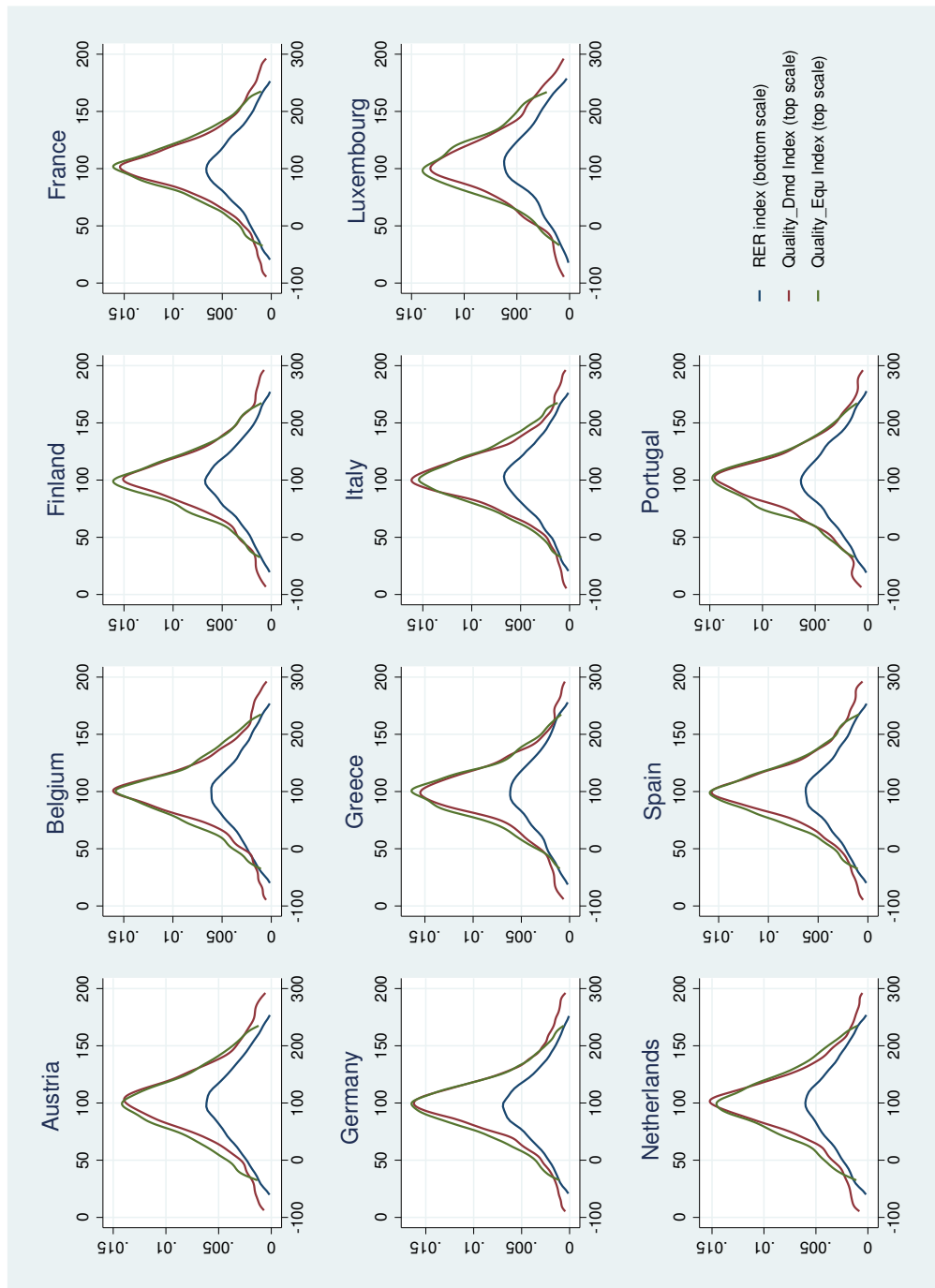


Figure 3.2: Distribution of quality and real exchange rate indices in 2007 (base 100 = 1999) by country, Vertical Differentiated Industries



### 3.4 Currency shocks and Quality Changes

#### 3.4.1 Predicted Effects and Econometric Specifications

An econometric model is now used to ask whether the predictions of the theoretical model and the previous correlations reflect a real impact of real exchange rate adjustments on the quality of euro area member countries' exports in each destination market. Taking the log of the theoretical equilibrium quality and quality-adjusted price expressed by equations (3.31) and (3.32), respectively, using the real exchange rate definition and rearranging terms, the relative quality and quality-adjusted price of a given variety can be expressed as a function of the real exchange rate and other variables of the model as follows:

$$\eta_{gjt} \gamma_1 \ln Q_{gijt} - \ln Q_{gjt} \left\{ \left[ \frac{\gamma_1}{\sigma_g} \ln \kappa_5 / \alpha_g \beta_{gjt} \right] \frac{\sigma_g}{2} \kappa_2 \left[ \frac{\eta_{gjt} \alpha_g \ln \kappa_1}{\beta_{gjt} \eta_{gjt}} \right] \ln \sigma_g / \zeta' F_{ijt} / \sigma_g \right. \\ \left. + \ln \kappa_3 \tau_{gijt} \left[ \frac{\gamma_1 \ln q_{gijt}}{\beta_{gjt} \alpha_g \ln \lambda_{gjt} / \eta_{gjt} \beta_{gjt} \ln E_{gjt} / \alpha_g \eta_{gjt} \ln w_{jt} l_{jt}} \right] \right\} \quad (3.42)$$

$$\frac{\gamma_2}{\eta_{gj}} \ln \lambda_{gijt} - \ln \lambda_{gjt} \left\{ \left[ \ln \right] \frac{\kappa_1}{\kappa_5 \sigma_g} \left[ \zeta' F_{ijt} / \frac{\alpha_g \beta_{gjt}}{\eta_{gjt}} \ln q_{gijt} \right] \sigma_g \right. \\ \left. + \ln \kappa_3 \tau_{gijt} \left[ \frac{E_{gjt}}{w_{jt} l_{jt}} \right] / \alpha_g \beta_{gjt} \ln Q_{gjt} \right\} \quad (3.43)$$

These equations imply two things. First, the effect of real exchange rate changes on the relative qualities and quality adjusted prices can be theoretically predicted. According to equation (3.42), a 1% real appreciation entails a  $\eta_{gjt}^{-1}$  % increase in the relative quality indexes. According to equation (3.43), a 1% real appreciation causes a  $\beta_{gjt} \alpha_g [\gamma_2^{-1}]$  % decrease in the relative quality adjusted f.o.b prices (equivalent to an increase in the quality/price ratio). Using the parameter estimates presented in Section 3.3.2, these predictions can be calculated. Descriptive statistics on these predictions are summarized in Table 3.6 below. On average, a 10% real appreciation of the euro should induce a 4% increase in the relative qualities, and a 3.1% decrease in the relative quality adjusted f.o.b prices of the varieties within the sample. Comparing these predictions with the empirical results shall give us an idea of the theoretical model's empirical relevance.

Table 3.6: Predicted effects of real exchange rate changes on quality

Effect on:	Obs.	Mean	Min	p25	p50	p75	Max	Sd.
Relative qualities	899,127	0.40	0.09	0.39	0.42	0.42	0.93	0.11
Relative quality adjusted prices	582,564	-0.31	-3.26	-0.40	-0.18	-0.07	1.82	0.50

Note: This table displays summary statistics on the (theoretical) predicted effect of real exchange rate changes on the relative quality and quality adjusted price estimates. Since these predicted effects are computed using the parameters of our model, the prediction are unique for each industry-destination-year triplet ( $gjt$ ), but similar for all the exporting countries within this triplet.

Equations (3.42) and (3.43) also allow establishing the baseline estimated equations:

$$\Lambda \left] \ln Q_{gijt} \right] - \ln Q_{gjt} \left\{ \left[ \begin{array}{l} \Gamma_1 \Lambda \ln \kappa_5 / \Gamma_2 \Lambda \ln \kappa_2 / \Gamma_3 \Lambda \ln \kappa_1 / \Gamma_4 \Lambda F_{ijt} \\ / \Gamma_5 \Lambda \ln \kappa_3 \tau_{gijt} \left[ / \Gamma_6 \Lambda \ln q_{gijt} / \delta_{jgt} / \varepsilon_{gijt} \right] \end{array} \right. \right. \quad (3.44)$$

$$\Lambda \left] \ln \lambda_{gijt} \right] - \ln \lambda_{gjt} \left\{ \left[ \begin{array}{l} \Omega_1 \Lambda \ln \left( \frac{\kappa_1}{\kappa_5} \right) \left[ / \Omega_2 \Lambda F_{ijt} / \Omega_3 \Lambda \ln q_{gijt} \right. \right. \\ / \Omega_4 \Lambda \ln \kappa_3 \tau_{gijt} \left[ / \delta'_{jgt} / \varepsilon'_{gijt} \right] \end{array} \right. \right. \quad (3.45)$$

where  $\left] \ln Q_{gijt} \right] - \ln Q_{gjt}$  in (3.44) are alternatively the (log) relative qualities estimated by the equilibrium approach and the demand approach,  $\ln \text{QualityEq}_{gijt}$  and  $\ln \text{QualityDmd}_{gijt}$ , respectively.  $\left] \ln \lambda_{gijt} \right] - \ln \lambda_{gjt}$  in (3.45) are the (log) relative quality-adjusted prices, which are simply given by the (log) ratio of the relative unit values to the estimated relative qualities raised to the power  $\eta_{gjt}$ . These relative quality-adjusted prices are thereafter referred to as  $\ln \text{PadjQEq}_{gijt}$  and  $\ln \text{PadjQDmd}_{gijt}$ , respectively. Finally,  $\delta_{jgt}$  in (3.44) and  $\delta'_{jgt}$  in (3.45) are both partner-industry-year fixed effects<sup>18</sup>.

A potential shortcoming of the previous regression framework is that changes in real exchange rates may be endogenous to the evolution of quality because of reverse causality or omitted variables. Reverse causality may arise if positive changes in the quality of exports are translated into a partial increase of export prices abroad. For their part, omitted variables may create endogeneity if they determine simultaneously quality and real exchange rate adjustments. To reduce the risk of reverse causality, a set of 2SLS estimations are runned. The selected instruments below are discussed in more details in [Martin and Mejean \[2012\]](#), who study how competition from low-wage countries in international markets affects the quality content of high-wage country exports using French-firm level data. First, the predicted values of real exchange rate changes are estimated (i.e.  $\Lambda \ln q_{gijt}$  is instrumented) using three instruments. The first one measures average changes in real exchange rates in other destinations (i.e. it averages  $\Lambda q_{gilt}$  across all destinations  $l$  except  $j$ ). Since the variable does not use information on the bilateral exchange rate changes between home and country  $j$ , it is independent from changes affecting the adjustment of relative prices in this country. The second instrument measures the initial real exchange rate of the exporting country-industry  $gi$  pair in the destination market, which is negatively

<sup>18</sup>Note that theoretically we should have  $\Gamma_1 = \frac{1}{\eta_{gjt}(\sigma_g - 1)}$ ,  $\Gamma_2 = \frac{\alpha_g - \beta_{gjt}}{\eta_{gjt}\gamma_1}$ ,  $\Gamma_3 = \frac{\eta_{gjt} - \alpha_g}{\eta_{gjt}\gamma_1}$ ,  $\Gamma_4 = \frac{\zeta'(\beta_{gjt} - \eta_{gjt})}{\eta_{gjt}\gamma_1}$ ,  $\Gamma_5 = \frac{(\beta_{gjt} - \eta_{gjt})(\sigma_g - 1)}{\eta_{gjt}\gamma_1}$ ,  $\Gamma_6 = \frac{1}{\eta_{gjt}}$  and the fixed effects  $\delta_{gjt} = \frac{1}{\gamma_1 \eta_{gjt}} \ln \left( \frac{E_{gjt}^{(\eta_{gjt} - \beta_{gjt})}}{(w_{jt} l_{jt})^{(\alpha_g - \eta_{gjt})}} \tilde{\lambda}_{gjt}^{(\beta_{gjt} - \alpha_g)} \right)$  in equation (3.44); and  $\Upsilon_1 = \frac{\eta_{gjt}}{\gamma_2}$ ,  $\Upsilon_2 = \frac{-\zeta' \eta_{gjt}}{\gamma_2}$ ,  $\Upsilon_3 = \frac{\alpha_g - \beta_{gjt}}{\gamma_2}$ ,  $\Upsilon_4 = \frac{(1 - \sigma_g) \eta_{gjt}}{\gamma_2}$  and the fixed effects  $\delta'_{gjt} = \frac{\eta_{gjt}}{\gamma_2} \ln \left( \frac{E_{gjt}}{(w_{jt} l_{jt})} \tilde{Q}_{gjt}^{(\alpha_g - \beta_{gjt})} \right)$  in equation (3.45).

correlated in the data with real exchange rate changes. Lastly, the third instrument makes the previous two variables interact.

Finally, in order to explore the heterogeneous dimension of the relationship between quality and real exchange rate movements, and to check the pertinence of the theoretical conclusions in [Section 3.2](#), additional non-parametric specifications are used where interactions between changes in real exchange rates and different bins constructed from percentiles of industry-specific parameters are added to the baseline equations. Specifically, the non-parametric specification first tests whether the quality-enhancing effect of real appreciations is genuinely larger (i) in industries where varieties are closer substitutes (high  $\sigma_g$  values) and (ii) in industries where the cost-efficiency of upgrading quality is high (low  $\alpha_g$  values). For this purpose, dummy variables for industries belonging to each percentile category are constructed, based on the deciles of the parameters  $\alpha_g$  and  $\sigma_g$ . Then, these dummies and their interactions with the real exchange rate variable are included in the baseline equations. The same methodology is used to test whether quality-adjusted prices diminish more (i.e. quality/price ratios increase more) in industries with low  $\alpha_g$  (high cost-efficiency of upgrading quality). Finally, the heterogeneity of exchange rate elasticities of quality across destination economies is tested. For this purpose, the trade partners of the euro area member countries are classified into five groups: High income OECD, High income non OECD, Upper middle income, Lower middle income and Low income economies using the World Bank's classification. Dummies for each one of these trade partner groups and their interaction with changes in real exchange rates are added to the baseline equations. All results are presented in the next subsection.

### 3.4.2 Results

Columns (1) and (4) of [Table 3.7](#) report the results of the baseline regression equation [\(3.44\)](#) using, respectively, the relative qualities estimated through the "equilibrium" approach and the relative qualities estimates through the "demand-side" approach as dependent variables. The positive and statistically significant coefficients of the real exchange rate in both cases clearly indicate that a real domestic currency appreciation leads to a rise in the relative quality of the varieties exported from home. This result is consistent with the theoretical expectations in terms of sign, but also in terms of magnitude. Column (1) indicates that a 1% real appreciation increases the "equilibrium" quality index by 0.5%, while column (4) shows that a 1% real appreciation enhances the "demand-side" quality index by 0.39%. This corresponds to the average 0.4% quality upgrading expected in the previous subsection. More generally, [Table 3.7](#) emphasizes that all trade barriers in export markets are associated with an enhancement of the average sectoral quality of domestic exports since, along with the real exchange rate, trade costs and fixed costs of exporting appear to have a positive and significant effect on the quality of exported varieties.

Columns (2) and (5) test the robustness of these results using lagged real exchange rates, which are still associated with significant and positive coefficients for the two quality indices. Finally, the 2SLS regressions of columns (3) and (6) do not alter these conclusions, neither in terms of sign nor in terms of magnitude. Note that the 2SLS post-estimation tests confirm that these robustness checks are valid, as the instruments used are manifestly exogenous and not weak.

Table 3.7: Quality and real exchange rate adjustments

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Lambda \ln \text{QualityEqu}_{gijt}$			$\Lambda \ln \text{QualityDmd}_{gijt}$		
$\Lambda \ln \kappa_5$	-0.01 (0.01)	-0.02 (0.02)	-0.04 (0.02)	-0.04 (0.07)	-0.21* (0.09)	-0.23 (0.26)
$\Lambda \ln \kappa_2$	-0.23*** (0.02)	-0.23*** (0.05)	-0.26*** (0.03)	-0.18 (0.15)	-0.15 (0.17)	-0.29 (0.26)
$\Lambda \ln \kappa_1$	-0.12*** (0.01)	-0.10*** (0.02)	-0.11*** (-0.01)	-0.03 (0.05)	0.02 (0.07)	-0.15 (0.13)
$\Lambda F_{ijt}$	0.03*** (0.00)	0.03*** (0.00)	0.04*** (0.00)	0.10*** (0.00)	0.10*** (0.00)	0.10*** (0.00)
$\Lambda \ln \kappa_3$	0.66*** (0.03)	0.60*** (0.07)	0.56*** (0.07)	0.49* (0.20)	0.42* (0.25)	0.25 (0.21)
$\Lambda \ln \tau_{gijt}$	0.39*** (0.00)	0.38*** (0.00)	0.43*** (0.00)	0.38*** (0.01)	0.37*** (0.01)	0.41*** (0.05)
$\Lambda \ln q_{gijt}$	0.50*** (0.00)			0.39*** (0.00)		
lag $\Lambda \ln q_{gijt}$		0.30*** (0.00)			0.25*** (0.00)	
Predicted $\Lambda \ln \tilde{q}_{gijt}$			0.49*** (0.00)			0.39*** (0.02)
_cons	-1.40*** (0.01)	-0.95*** (0.03)		-1.59*** (0.09)	-1.40*** (0.12)	
N	2,720,280	2,119,570	1,487,359	2,648,308	2,065,207	1,418,585
R sq Adj.	0.77	0.41	0.78	0.92	0.92	0.07
Sargan p-value			0.57			0.67
Hausman p-value			0.08			0.09
R sq first stage			0.13			0.13

Note: Standard errors in parentheses. \* p<0.05, \*\* p<0.01, \*\*\* p<0.001. All regressions include sector-destination fixed effects and year dummies.

Columns (1) and (4) of Table 3.8 report the results of the second baseline regression (3.45), which uses relative quality-adjusted price indices as dependent variables. Column (1) displays the results in the case where qualities are measured through the equilibrium approach, while column (4) shows the results when qualities are estimated by the "demand-side" approach. Both columns corroborate the theoretical expectations, as the coefficients of the real exchange rate are robustly significant and negative. However, while column (1) indicates that a 1% real appreciation comes

with a -0.27% decrease in the "equilibrium" quality-adjusted prices, this coefficient falls close to zero (but is still negative) in the case of the "demand-side" quality adjusted prices. In the previous subsection, an average of -0.31% decrease in quality-adjusted export prices was expected.

Theoretically, one could easily demonstrate that these results are paradoxically coherent<sup>19</sup>. The "demand-side" measure of quality does not consider the cost for firms to enhance output quality. As a result, the zero-profit condition simply requires a raise in quality that corresponds exactly to the fall in the marginal exporter's export price to maintain positive export revenues and profits. The "equilibrium" quality takes into account the fact that a higher quality also implies a raise in marginal costs, and consequently, a raise in price. The level of quality/price ratio offered by the marginal exporter thus needs to be even higher. In other words, the equilibrium analysis involves larger reallocation effects, so that the maximum level of the quality adjusted export price (the minimum quality/price ratio) required to earn non-zero export profits further decreases (increases) when the domestic currency appreciates.

Again, the robustness checks implemented using lagged real exchange rates and 2SLS instrumentations, presented in columns (2) and (3) of Table 3.8 for the "equilibrium" quality adjusted prices and in columns (5) and (6) for the "demand-side" quality adjusted prices, do not change these results. In these cases too, the instruments used in both 2SLS regressions appear robust and significant.

The heterogeneous dimension of the relationship between quality adjustments and changes in real exchange rate along some market- or destination-specific characteristics is then explored. As explained in the previous subsection, interaction variables between the real exchange rate and different bins constructed from deciles of the industry-specific parameters  $\sigma_g$  and  $\alpha_g$  are added to the baseline equations (3.44) and (3.45) for this purpose. The quality-enhancing effect of real appreciations implied by the theoretical model in Section 3.2 was expected to be larger in industries where varieties are closer substitutes (higher  $\sigma_g$ ), and in industries able to upgrade quality with a greater efficiency (low  $\alpha_g$ ). Figure 3.3 presents the full set of estimated real exchange rate elasticities of quality and quality adjusted price for each decile of  $\sigma_g$  and  $\alpha_g$ , together with a 5% confidence band. The negative trends as a function of  $\alpha_g$  for the real exchange rate elasticity of quality is clear. Interestingly, the exchange rate elasticity of quality with respect to the deciles of  $\sigma_g$  seems quadratic. In other words, the quality-enhancing effect of a real do-

<sup>19</sup>A quick look at the "demand-side" quality equation (3.35) reveals that no effect of real exchange rate changes on the estimated "demand-side" quality adjusted prices should have been expected. Indeed, rearranging its terms and using the definition of the marginal exporter's revenue to solve for total export revenue yield the following quality adjusted prices equation:

$$\left( \frac{\tilde{\lambda}_{gijt}}{\tilde{\lambda}_{gjt}} \right)^{(1-\sigma_g)} = \frac{\sigma_g e^{\zeta' F_{ij}} (\kappa_3 \tau_{gijt})^{\sigma_g - 1}}{M_{gijt} (\varphi_i / \tilde{w}_i) \tilde{E}_{gjt}^{\mu_g}}$$

Table 3.8: Quality adjusted prices and real exchange rate adjustments

	$\Lambda \ln \text{PAdjQEqu}_{gijt}$			$\Lambda \ln \text{PAdjQDmd}_{gijt}$		
$\Lambda \ln \frac{\kappa_1}{\kappa_5}$	0.10*** (0.02)	0.05 (0.03)	0.08*** (0.02)	0.12*** (0.05)	0.00 (0.06)	0.02 (0.03)
$\Lambda F_{ijt}$	-0.08*** (0.00)	-0.07*** (0.00)	-0.08*** (0.00)	-0.08*** (0.00)	-0.17*** (0.00)	-0.18*** (0.00)
$\Lambda \ln \kappa_3$	-0.75*** (0.09)	-0.60*** (0.10)	-0.67*** (0.08)	-0.66*** (0.18)	-1.41*** (0.21)	-0.94*** (0.32)
$\Lambda \ln \tau_{gijt}$	-0.97*** (0.01)	-0.96*** (0.01)	-0.97*** (0.01)	-0.96*** (0.01)	-0.94*** (0.01)	-0.82*** (0.08)
$\Lambda \ln q_{gijt}$	-0.27*** (0.00)			-0.01*** (0.00)		
$\text{lag } \Lambda \ln q_{gijt}$		-0.17*** (0.00)			-0.03*** (0.00)	
Predicted $\Lambda \ln \tilde{q}_{gijt}$			-0.28*** (0.02)			-0.02 (0.01)
_cons	1.22*** (0.10)	0.80*** (0.12)		1.56*** (0.21)	1.77*** (0.26)	
N	2,720,280	2,119,570	1,487,359	2,637,354	2,056,496	1,411,032
R sq Adj.	0.17	0.17	0.14	0.86	0.87	0.13
Sargan p-value			0.72			0.49
Haussman p-value			0.09			0.09
R sq first stage			0.12			0.12

Note: Standard errors in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All regressions include sector-destination fixed effects and year dummies.

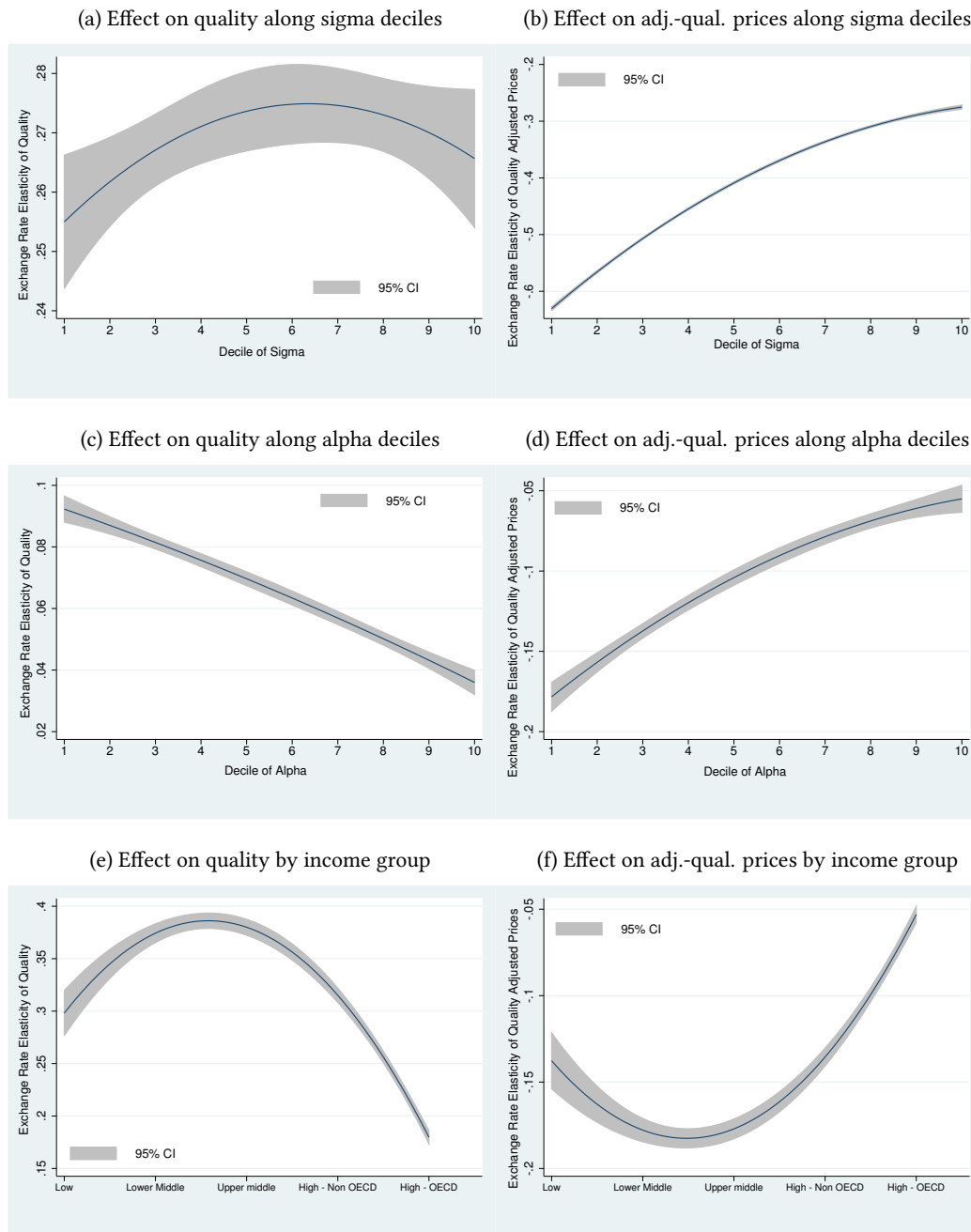
mestic appreciation is the highest in industries with middle values of price elasticity of demand, while this effect is (slightly) lower in industries horizontally organized and in highly vertically differentiated industries. With respect to quality adjusted prices, the effect of real exchange rate variations diminishes manifestly as both  $\alpha_g$  and  $\sigma_g$  get higher. In other words, the quality/price ratio of the varieties exported from home increases more in industries with a high quality-cost efficiency (low  $\alpha_g$ ) and in vertically differentiated industries.

Finally, we ask whether real exchange rate elasticities of quality and quality adjusted prices differ according to the income group of trade partners using a similar non-parametric approach. The resulting elasticities along income groups are also plotted in the last two subgraphics of Figure 3.3. Interestingly, the exchange rate elasticities of quality and quality adjusted prices follow a U-shape curve. This means that real appreciations enhance both the average quality and the average quality/price ratio of varieties exported from a given economy especially when the market targeted is a middle income economy, notably an upper middle income economy. This result corresponds to the theoretical intuition mentioned in Section 3.2, according to which these effects of real appreciations on exported products' quality and quality/price ratio are greater in indus-



tries where the scope of differentiation is large. Clearly, middle income economies are buoyant markets where the appetite for quality gets larger as these countries get richer.

**Figure 3.3: Estimated RER elasticities of quality and quality-adjusted prices along sigma and alpha deciles and income group of partners**



In sum, a real domestic appreciation enhances both the quality and the quality/price ratio of the varieties exported from a given economy. These effects are larger in markets where the scope for

quality differentiation is large, that is, (i) in markets with moderate price elasticity of demand (i.e. not perfectly vertically differentiated, neither horizontally organized), (ii) in industries where a higher level of output quality can significantly stimulate firms' sales at the expense of a small marginal cost increase, and (iii) when the destination targeted is a middle income economy, which clearly offers the most appropriate environment for new market segments.

### 3.4.3 Channels

The theoretical model showed in [Section 3.2](#) argues that the positive effect of real appreciations on quality occurs for at least three reasons. Firstly, at the firm-level, a real appreciation is perceived as a negative demand rotator, which undermines domestic exporters' price competitiveness in international markets. Seeking to preserve their market share, exporting firms are therefore likely to upgrade output quality to enter a new market niche, and so to prevent export revenues from declining. Secondly, this quality upgrading process is facilitated by the simultaneous fall in imported input prices induced by real appreciations, which as positive supply shock, should encourage firms to modify their set of imported varieties towards higher quality intermediates. The enhancement of output quality is however still costly, so that not all firms can afford such an investment, and that the least competitive ones are driven out of the market. The third effect thus appears at the industry-level, the appreciating domestic currency entailing a reallocation of market shares towards highest quality varieties, increasing *ceteris paribus* the average quality of exports. In sum, both input and output quality of the varieties exported from home are expected to increase at the firm level and at the industry level. In this section, the validity of these channels is empirically tested.

The relative qualities are estimated at the 4-digit industry level, so that the first channel cannot be investigated. However, the second and third effects, namely the "input" effect and the "reallocation" effect, are tested below. The share of imported inputs by industry are approximated by using the OECD – WTO Trade in Value-Added (TiVA) database. The latter provides information on the share of the foreign value added content of gross exports for each exporting industry-country pair and each destination  $j$  covered by the sample are collected. These shares measure the value of imported intermediate goods and services that are embodied in a given domestic industry's exports and cover 62 destinations worldwide. The richness of these data however is limited in terms of years and industries covered. The industry list includes sixteen 2-digit manufacturing industries<sup>20</sup> and the years covered that can be exploited in this analysis are 2000, 2005 and 2007.

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<sup>20</sup>The industry list is the following: Agriculture, hunting, forestry and fishing; Mining and quarrying; Food products, beverages and tobacco; Textiles, textile products, leather and footwear; Wood and products of wood and cork; Pulp, paper, paper products, printing and publishing; Coke, refined petroleum products and nuclear fuel; Chemicals and chemical products; Rubber and plastics products; Other non-metallic mineral products; Basic metals; Fabricated metal products; Computer, Electronic and optical equipment; Electrical machinery and apparatus, nec; Motor vehicles, trailers and semi-trailers; Other transport equipment; Manufacturing nec; recycling.

To address the first issue, the quality estimates and quality-adjusted price measures are aggregated at the 2-digit industry level, using the share of each variety in the corresponding 2-digit industry's total exports as weight. These weights are calculated over the whole referenced period to avoid any endogenous issue between changes in real exchange rate and export flows. In addition, the weighted average of each variable used in the econometric specifications is calculated at this same level of aggregation, using the same varieties' shares as weight. To address the second issue, the econometric estimations are performed in logarithms, since the use of first differences would cost this analysis some precious observations.

The baseline equations performed remain (3.44) for the quality indices, and (3.45) for the quality-adjusted price indices. In order to test the "input" channel, the (log) shares of the imported value added content of gross exports,  $\ln IVA_{k2ijt}$ , are added to these baseline specifications, as well as their interactions with the (log) real exchange rates. The assumption is the following: if real appreciations induce a raise in the imported value added content of exports, and the latter enhances in turn the quality of exports, then the coefficient of their interaction should be positive with respect to quality. In addition, since real appreciations should also reduce imported input prices, the coefficient of the interaction term is expected to be negative with respect to quality-adjusted prices.

Finally, in order to test the "reallocation" channel, the (log) mass of exporters,  $\ln M_{k2ijt}$ , and its interaction term with the (log) real exchange rate are also added to the baseline equations. The assumption is that a real appreciation reduces the mass of exporters, which in turn enhances the average quality of the varieties exported by a given industry, and decreases its average f.o.b price. These results come directly from the theoretical model in Section 3.2. Therefore, both the coefficient of the (log) mass of exporters and the coefficient of its interaction term with the real exchange rate are expected to be, respectively, negative and positive with respect to quality, and positive and negative with respect to the quality-adjusted prices.

Columns (1) and (4) of Table 3.9 performs the baseline equation for, respectively, the "equilibrium" and "demand" quality indices at the 2-digit level. It is apparent that the conclusion in Section 3.4.2 still holds at this level of aggregation, even though the coefficient associated with the real exchange rate is slightly lower. For instance, column (1) indicates that a 1% real appreciation is significantly associated with a rise of 0.25% in the "equilibrium" quality index. Columns (2) and (4) of Table 3.9 adds to these baseline specifications the (log) share of the imported value added content of gross exports  $\ln IVA_{ik2jt}$ , and the (log) mass of exporters,  $\ln M_{ik2jt}$ . As expected, a larger share of imported value added content of exports significantly increases the quality of exports. Conversely, a larger mass of exporters significantly diminishes the quality of exports.

Finally, columns (3) and (6) add the interaction terms between the real exchange rate and the two latter variables. For both quality measures, the interaction term between changes in the real exchange rate and the share of imported value added is robustly positive and significant. However, the coefficient of the interaction term between the mass of exporters and the real exchange rate is (significantly) very close to zero for the “equilibrium” quality measure, while as expected, it is robustly positive for the “demand-side” measure of quality. In other words, the results confirm that the increase in the imported value added content of exports, which follows an appreciation of the domestic currency, significantly improves the quality of those exports. The reduction of the mass of exporters induced by an appreciating domestic currency appears to have no effect on the quality of exports, when the latter is measured by the “equilibrium” approach, but to significantly improve export quality, when the latter is measured by the “demand” approach. While surprising, this result may be easily explained – as mentioned in the previous section – by the way through which these quality measures are performed. The “equilibrium” measure of quality is indeed achieved while solving for the mass of exporters (see equation (3.37)), so that when all explanatory variables are added, the effect of the mass of exporters on quality, alone or interacted with the exchange rate, must be very close to zero. Conversely, the “demand side” measure of quality primarily rely on the mass of exporters<sup>21</sup>, so that it is more responsive to this variable, alone or interacted with the exchange rate.

Columns (1) and (4) of Table 3.10 implement the baseline equation for, respectively, the “equilibrium” and “demand” quality-adjusted prices at the 2-digit level. Again, the results of Section 3.4.2 hold at this level of aggregation, even though the effect of the real exchange rate appears lower. A real domestic currency appreciation still significantly diminishes quality-adjusted prices. Columns (2) and (5) of Table 3.10 adds the (log) mass of exporters and the (log) share of imported value added of gross exports. As expected, a larger value of the latter enhances the average “equilibrium” quality/price ratio of the varieties exported from the home country (i.e. diminishes the quality-adjusted prices). Note that the coefficient of  $\ln IVA_{ik2jt}$  is however not significant for the quality-adjusted prices as measure by the “demand-side” approach. As mentioned in the previous section, this result is nevertheless coherent if one considers the way through which the “demand side” quality-adjusted prices are estimated (see footnote 19). Finally, both columns (2) and (5) confirm that a reduction of the mass of exporters significantly increases the quality/price ratio of domestic exports.

Columns (3) and (6) both confirm the “input” channel and the “reallocation” channel hypothesis. Firstly, a real appreciation coupled with a larger share of imported value added content of exports significantly diminishes the quality-adjusted export prices, i.e. increases the average quality/price ratio of the varieties exported from home. The coefficient of the interaction term

<sup>21</sup>As described in the theoretical section, the “demand-side” approach implies that for a given amount of export revenues, a larger number of exporters means that the quality of products has fallen.

Table 3.9: Quality, imported value added, competition and real exchange rate adjustments

	(1)	(2)	(3)	(4)	(5)	(6)
	ln QualityEqu <sub>k2ijt</sub>			ln QualityDmd <sub>k2ijt</sub>		
ln $\kappa_5$	-0.02** (0.01)	-0.02** (0.00)	-0.02** (0.01)	-1.96*** (0.08)	-1.98*** (0.0833)	-1.98*** (0.08)
ln $\kappa_1$	-0.03*** (0.01)	-0.03*** (0.01)	-0.03*** (0.01)	-0.24** (0.08)	-0.3** (0.08)	-0.25** (0.08)
ln $\kappa_2$	-0.07* (0.03)	-0.07* (0.03)	-0.07* (0.03)	0.68 (0.41)	0.57 (0.41)	0.57 (0.41)
$F_{ijt}$	0.02*** (0.00)	0.02*** (0.00)	0.02*** (0.00)	0.06*** (0.00)	0.07*** (0.00)	0.07*** (0.00)
ln $\kappa_3$	0.08** (0.03)	0.08** (0.03)	0.09*** (0.03)	-0.33 (0.30)	-0.24 (0.30)	-0.24 (0.29)
ln $\tau_{k2ijt}$	-0.00 (0.00)	-0.01 (0.00)	-0.00 (0.00)	0.02 (0.02)	0.02 (0.02)	0.02 (0.02)
ln $q_{k2ijt}$	0.25*** (0.00)	0.25*** (0.00)	0.11** (0.03)	0.22*** (0.02)	0.22*** (0.02)	0.04 (0.04)
ln IV $A_{k2ijt}$		0.23*** (0.02)	0.18*** (0.02)		0.18* (0.10)	0.01 (0.24)
ln IV $A_{k2ijt}$ * ln $q_{k2ijt}$			0.03*** (0.00)			0.04*** (0.01)
ln $M_{k2ijt}$		-0.02*** (0.00)	-0.04*** (0.00)		-0.25** (0.09)	-0.39*** (0.10)
ln $M_{k2ijt}$ * ln $q_{k2ijt}$			0.00* (0.00)			0.10** (0.03)
_cons	-0.67*** (0.01)	-1.716*** (0.0986)	-1.48*** (0.11)	-0.10 (0.18)	-0.93 (1.13)	-0.58 (1.13)
N	71,222	71,222	71,222	70,926	70,484	70,484
R sq Adj.	0.34	0.34	0.34	0.42	0.42	0.42

Note: Standard errors in parentheses. \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$ . All regressions include sector-destination fixed effects and year dummies.

between the mass of exporters and the real exchange rate is negative, indicating that a domestic currency appreciation significantly reduces the mass of exporters, which in turn decreases the quality-adjusted export prices, i.e. improve the quality/price ratio of the varieties exported from home<sup>22</sup>.

In short, both channels emphasized by the theoretical model in Section 3.2 at the industry level are empirically verified. By encouraging firms to expand their set of inputs towards higher quality intermediates ("input" effect) and by driving out the lowest quality varieties from export

<sup>22</sup>As in the case of quality, the coefficient associated with the interaction term between the mass of exporters and the real exchange rate is very close to zero for quality-adjusted export price. This is related to the fact that the "equilibrium" measures are performed while solving for the mass of exporters.

markets ("reallocation" effect), an appreciating domestic currency enhances both the average sectorial quality and the average quality/price ratio of the varieties exported from home.

Table 3.10: Quality-adjusted prices, imported value added, competition and real exchange rate adjustments.

	(1)	(2)	(3)	(4)	(5)	(6)
	ln PadjQEqu <sub>k2ijt</sub>			ln PadjQDmd <sub>k2ijt</sub>		
$\ln \frac{\kappa_1}{\kappa_5}$	0.01 (0.00)	0.02* (0.00)	0.02* (0.01)	-0.99*** (0.05)	-1.00*** (0.05)	-0.99*** (0.05)
$F_{ijt}$	-0.06*** (0.00)	-0.05*** (0.00)	-0.06*** (0.00)	-0.11*** (0.00)	-0.10*** (0.00)	-0.11*** (0.00)
$\ln \kappa_3$	-0.06 (0.04)	-0.07 (0.04)	-0.07 (0.04)	1.50*** (0.25)	1.64*** (0.25)	1.50*** (0.25)
$\ln \tau_{k2ijt}$	-0.02*** (0.00)	-0.02*** (0.00)	-0.02*** (0.00)	-0.03* (0.02)	-0.04* (0.02)	-0.04* (0.02)
$\ln q_{k2ijt}$	-0.03*** (0.00)	-0.03*** (0.00)	-0.02* (0.00)	-0.03* (0.01)	-0.06*** (0.02)	-0.06* (0.04)
$\ln IVA_{k2ijt}$		-0.26*** (0.04)	-0.25*** (0.04)		-0.34 (0.26)	-0.29 (0.25)
$\ln IVA_{k2ijt} * \ln q_{k2ijt}$			-0.02* (0.01)			-0.03** (0.01)
$\ln M_{k2ijt}$		0.03* (0.01)	0.03 (0.02)		0.18* (0.09)	0.13 (0.12)
$\ln M_{k2ijt} * \ln q_{k2ijt}$			-0.01 (0.01)			-0.09* (0.04)
_cons	-0.15*** (0.03)	1.04*** (0.20)	1.00*** (0.20)	-1.40 (1.15)	-1.28 (1.17)	-1.41 (1.17)
N	71,222	70,484	70,484	70,484	70,926	70,484
R sq Adj.	0.24	0.23	0.23	0.38	0.38	0.38

Note: Standard errors in parentheses. \* p<0.05, \*\* p<0.01, \*\*\* p<0.001. All regressions include sector-destination fixed effects and year dummies.

### 3.5 Conclusion

This chapter provides theoretical and empirical evidence demonstrating the existence of a positive relationship between real exchange rate appreciations and quality adjustments of products exported from a given economy. In order to test this hypothesis, two alternative measures of quality are derived from a theoretical model close to those of Melitz [2003], Hallak and Sivadasan [2013] and Feenstra and Romalis [2014], where firms' choices in terms of price, input and output quality are endogenous and simultaneously determined. This allows concluding both theoretically and empirically that this relationship occurs through at least three channels.

Firstly, as a negative demand rotator, a real domestic currency appreciation encourages exporters to establish their position in a higher-quality segment of markets in order to compensate for the loss in their price competitiveness, and so prevent their market share and export revenue from falling. However, this strategy of up-market positioning is costly, so that only a small fraction of firms can afford such an investment. As a result, the least competitive firms, which produce notably the lowest quality goods, are driven out of the market, so that the average quality of exports increases *ceteris paribus*. Finally, as a positive supply shock, a real appreciation reduces the prices of imported inputs and consequently, encourages firms to modify their set of imported intermediates towards higher quality inputs. This also further raises the quality of exports at both the firm level and the industry level. Note that this quality-enhancing process occurs partly at the expense of a concentration in export markets (i.e. a decrease in the mass of exporters from the home country).

In addition, real appreciations are also shown to entail larger quality upgrading (i) in industries where the varieties are closer substitutes (higher price elasticity of demand), as reallocation effects are larger within them, and (ii) in industries where firms can significantly increase sales at the expense of a small increase in marginal costs.

Finally, a real appreciation of the domestic currency not only enhances the quality, but also the quality/price ratio of domestic exports. This arises as long as the scope for product differentiation is positive, that is, (i) in markets with moderate price elasticity of demand (i.e. not perfectly vertically differentiated, neither horizontally organized); (ii) in industries with low "quality-elasticity" of marginal costs and (iii) in destinations with high preferences for quality, notably upper middle income economies, which offer the most appropriate environment to create new market segments.

# General Conclusion

This thesis first summarized previous evidence on exchange rate economic exposure for non-financial firms, and provided new highlights on the heterogeneity of this exposure across firms and industries. In particular, by taking into account heterogeneous pricing strategies between firms in a very general theoretical and empirical setting, this thesis found that, since the exchange rate pass-through is a U-shaped function of firms' market power, the elasticity of profits margins and that of sales volumes are U-shaped and hump-shaped, respectively. Despite these non-linear relationships, the effect of exchange rate fluctuations on profits is found to be strictly linear with respect to firm's size: the largest (smallest) firms have low (high) elasticity of demand and experience the smallest (largest) profit reduction following an appreciation of the domestic currency.

These predicted relationships between exchange rate fluctuations and firm exposure were then carefully empirically verified using French firm-level data over the period 1999-2007. This data confirmed that the appreciation of the euro during this period slightly increased or had no effect on profits made by the largest firms, but significantly reduced profits made by the smallest and medium-sized firms. Since large firms account for a substantial amount of total sectoral profits, this finding helps to explain "the exchange rate exposure puzzle", that is, the low value of exposure to exchange rate shocks reported in previous empirical studies based on stock market data or industry-level data.

Secondly, this thesis investigated the product and production strategies that are appropriate for coping with the economic consequences of exchange rate changes on firms' operating profits. The focus was particularly on providing theoretical and empirical existing evidence on strategies of up-market positioning induced by currency appreciations. Theoretically, this was accomplished by presenting a unified framework, which combines the new theoretical works on the endogenous modelling of firms' quality choice with the [Melitz \[2003\]](#) model of firm heterogeneity. This has allowed to show how currency appreciation (i) encourage firm to endogenously upgrade the quality and quality/price ratio of their products; and (ii) generate market share reallocations towards firms producing the highest quality varieties, and/or offering the best quality/price ratio to consumers. These theoretical findings were empirically supported using a large



database of industry-level production data from member countries of the Euro area, with the euro appreciation over the period 1999-2007 as historical background.

More generally speaking, this thesis contributes to the literature pioneered by [Feenstra \[1989\]](#) by emphasizing that enduring exchange rate movements lead to persistent shifts in the behaviour of plants and entail irreversible real reallocation effects. Besides new proofs on competitive exchange rate exposures and the existence of an associated product strategy, the analysis as a whole indeed implicitly highlights anti-competitive effects of currency appreciations: the first part implies a reallocation of profits towards the largest firms; while the second part further implies not only a reduction of the mass of exporters within domestic industries as in [Melitz \[2003\]](#), but also a reallocation of market shares towards firms that produce the highest quality varieties.

Behind these reallocation effects, there is thus a story of structural changes that can strengthen or dampen sectors, and of a changing pattern of specialization, which may then have persistent long term effects on growth. This allows understanding why the impact of the exchange rate on economic activity is a central question of macroeconomics and economic policy in general.

The policy-relevance of this thesis also lies in its historical background, the start of the euro area construction, which helps to understand how the optimal size of currency area crucially depends on the degree of heterogeneity of economic structures, i.e., how different real exchange rate appreciations and depreciations affect the heterogeneous sectors of the economy. This topic was always of high interest, but it has obviously gained relevance in the years following the financial and debt crisis, and this thesis highlights it more than ever.

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## Résumé

L'objectif de cette thèse est double. Premièrement, elle vise à proposer une revue de la littérature économique s'intéressant à l'exposition au taux de change de la profitabilité des entreprises non-financières, et à fournir de nouveaux enseignements sur son hétérogénéité intra et inter-sectorielle. Deuxièmement, cette thèse analyse les stratégies de production et de produits mises en oeuvre par les firmes pour se prémunir des effets de ces variations de change. Puisque l'éventail de telles stratégies est large, le dernier chapitre se concentre sur la stratégie de montée en gamme.

## Abstract

This thesis follows a dual objective. First, it aims to summarize previous evidence on the magnitude and channels underpinning a non-financial firm's operating exposure, i.e. the extent to which currency fluctuations can alter a company's future operating cash flow, and to provide new highlights on the heterogeneity of this exposure across firms. Second, this thesis investigates the product and production strategies that are appropriate for coping with the economic consequences of exchange rate changes on firms' operating profits. Since the range of these strategies is large, it focuses on providing theoretical and empirical evidence for the strategy of up-market positioning.

## Mots Clés

Taux de Change; Entreprises Hétérogènes; Différenciation Verticale; Exposition Economique; Stratégies d'Entreprises; Management du Risque de Change.

## Keywords

Exchange Rate; Heterogeneous Firms; Vertical Differentiation; Economic Exposure; Exchange Rate Risk Management; Firms' Strategies.