The Invoicing Currency Choice in International Trade: Theory and Practice

by

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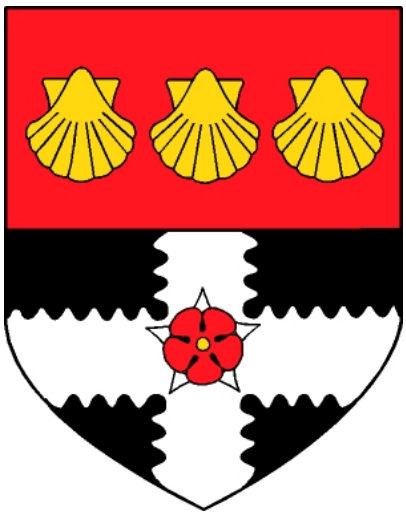

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Declaration I

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

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Declaration II

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Abstract

This PhD thesis contributes to the international trade literature, focusing on decision rules of monopolistically competitive firms in their pricing strategy, both theoretically and empirically. Chapter 1 introduces the overall setting for the thesis. Then, chapters 2 and 3 can each be read as a stand-alone paper; hence, each includes its own introduction and a review of the literature. Chapter 2 contributes to the underlying theory of currency invoicing choice, extending the model proposed by Devereux, Engel and Storgaard (2004) and developed further by Chung (2016) by the use of a more general framework, in particular a richer production function for the firms that employ intermediate goods in the production process. Chapter 3 examines empirically the theoretically derived determinants of invoicing currency in chapter 2, together with the empirically relevant ones as well, in the case of Turkish exporting firms and on the basis of a novel, firm-level micro-dataset. Chapter 4, then, provides concluding remarks to the thesis and some directions for future research.

In our theoretical chapter (chapter 2), we follow the model of Devereux, Engel and Storgaard (2004), but extending it to allow for a role of imported intermediate goods in the invoicing currency choice decisions of monopolistically competitive firms, as in Chung (2016). However, we enrich the set-up adding more realism, in particular by a more general production function featuring capital as a second factor of production, in addition to labour. Hence, we develop a two-factor of production model in the invoicing currency literature in international trade. We derive and highlight a richer cost index for monopolistically competitive firms which use imported intermediate goods in the production than the previous literature. In our model, the covariance terms involving the more realistic cost index when production involves not just labour but also capital play a critical role in decision making on pricing strategies.

In our empirical chapter (chapter 3), we examine the theoretical decision rules for Turkish exporting firms using a highly disaggregated dataset. To do this, we use multinomial

logit regression, in line with Chung (2016), but enriching the set of determinants of invoicing currency as per our theory (in chapter 2). We divide the latter into three main categories: (i) firm characteristics, including notably the physical capital share in production; (ii) macroeconomic factors; (iii) industry characteristics. We reveal that setting prices in national currency may not be a desirable pricing strategy for Turkish exporters, as there is an increase in usage of imported intermediate goods, and as firms have higher market share and more experience. However, an increase in the capital share in production leads to a rise in the setting of prices in national currency for Turkish exporters.

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List of Key Acronyms

H…….……..	Cost Index
SOE …….	Small Open Economy
VCP ……	Vehicle Currency Pricing
LCP ……..……..	Local Currency Pricing
PCP ……	Producer Currency Pricing
MNL ……..	Multinomial Logit
NOEM ……	New Open Economy Macroeconomics
CES ……	Constant Elasticity of Substitution
CRS ……	Constant Returns to Scale
CD ……..	Cobb-Douglas (production function)
DES …….	Devereux, Engel and Storgaard (2004)

List of Notation and Definitions for the Variables and Parameters in Chapter 2

i	Individual firm
k	Sector
f	Foreign
ρ	Elasticity of substitution across the varieties within sectors
η	Elasticity of substitution across sectoral aggregates
D_{ik}	Quantity demanded
p_{ik}	Firm's market price within sector
p_{kf}^{*}	Sectoral price index for all home goods sold in the foreign country
P^{*}	Foreign consumer price index
D_{k}^{*}	Sectoral foreign demand shifter that is independent of prices
K_i	Capital
L_i	Labour
X_i	Intermediate goods
Ω	Firm productivity
γ	Share of intermediate inputs
α	Capital share in output
Z_i	Quantity of domestic intermediate inputs
M_i	Imported intermediate inputs
θ	Elasticity of substitution between domestic and imported inputs
B_i	Firm efficiency in employing the inputs from abroad
P_z	Prices of the domestic inputs
P_m	Prices of the imported inputs
S	Exchange rate (units of domestic currency per unit of foreign currency)
P_m^{*}	Prices of imports denominated in foreign currency
A_i	Productivity adjusted by domestic and foreign prices of intermediate goods
f_i	Fixed cost
TC	Total cost
W	Cost of labour (nominal wage in exporter's currency)
r	Price for capital
μ_i	Marginal cost
Y	Output
τ	Productivity enhancing effect
ψ	Share of costs spent on imported inputs in total costs of intermediate goods
Π	Profit
d	Discount factor

List of Notation, Definitions and Rationale for the Variables in the Multinomial Logit Regression in Chapter 3

Variable	Description
Dependent Variable	
• icc	Invoicing currency choice of a firm (PCP, LCP or VCP)
Firm characteristics	
• importer	To express imported intermediate usage by a firm
• shareinputpcp	To capture the dependence of a firm to a certain country
• shareinputlcp	To show the effects of the total share of firm's imported inputs in domestic prices
• capitalshare	Capital share in production
• perratioik	To capture the role of firm relative size in terms of the market share of exports
• fiveyear	To capture firm's experience in the global markets
• top10	Proxy for transaction size
Macroeconomic Factors	
• CV_Euro & • CV_Dollar	To capture the role of the exchange rate volatility in Euro and US Dollar, respectively
• Epeg & • Dpeg	To capture the role of the exchange rate regime for a country which has a fixed exchange rate regime to Euro and US Dollar, respectively
• FXc	To capture the share of importer's currency in daily global foreign exchange market turnover
Industry Characteristics	
• classck & • classfk	To capture the market competition for capital goods and final goods, respectively
• rauchrcon & • rauchncon	Using Rauch's conservative classification, to capture substitutability of goods according to reference price and differentiated products, respectively
• rauchrlib & • rauchnlib	Using Rauch's liberal classification, to capture substitutability of goods according to reference price and differentiated products, respectively

Chapter 1: Introduction

Two key questions in international trade studies are: (i) what is the risk sharing between exporters and importers under incomplete asset markets; and (ii) what is the relationship between exchange rates and the relative price of goods in global markets. The answers to these major concerns in international trade are essentially based on the choice of invoicing currency, since firms in international trade highly linked through various global value chains.

Nowadays, firms usually sell final goods using imported intermediate goods. In such transactions, the natural issue is to decide which currency to be chosen as a pricing strategy between pairs of these globally linked firms: either the producer's currency or the importers' currency, or any third, internationally dominant currency.

There is a vast recent literature[1] on the choice of invoicing currency in international trade, suggesting three pricing strategies: (i) 'producer currency pricing (PCP)' strategy; (ii) 'local currency pricing (LCP)' strategy; and (iii) 'vehicle currency pricing (VCP)' strategy[2].

Whereas the previous studies analyse the choice of currency exogenously, Devereux, Engel and Storgaard (2004), DES henceforth, and then Chung (2016) investigate the issue endogenously, building theoretical models in explaining the determinants of currency choice in invoicing for exporting firms in small open economies (SOEs)[3].

DES study the consequences of nominal exchange rate changes on the choice of currency in invoicing using a partial equilibrium new open economy macroeconomics (NOEM) model. They derive a decision rule for a monopolistically competitive firm related to the currency choice of invoicing that reflects endogenous currency choice[4]. DES consider the

[1] See: Bacchetta and van Wincoop, 2005; Devereux *et al*, 2004; Goldberg and Tille, 2008; Goldberg and Tille 2016; Gopinath *et al,* 2009
[2] Detailed definitions of these pricing strategies are provided in chapter 2.
[3] Using one factor of production, labour, Devereux, Engel and Storgaard (2004) presents decision rules in pricing for final goods. This model is extended by Chung (2016) for exporting firms that use imported intermediate goods.
[4] See chapter 2 for the details of decision rules.

determinants of invoicing currency choice endogenously in a two-country framework with nominal price rigidities for final goods. Chung (2016) develops the DES model analysing the same issue but with nominal price rigidities not only for the final goods. Chung (2016) shows that exporting firms dependent on imported inputs are more likely to invoice in foreign currency. Even though Chung (2016) extended the DES theoretical model by adding imported intermediate goods, her analysis is based on one production factor only, namely labour.

In chapter 2, employing the DES theoretical framework, we allow the imported intermediate goods to play a role in the decision on invoicing currency, as in Chung (2016), but extending these two earlier models by a more general production function. In effect, we add physical capital as a second factor of production. Doing this, we develop a two-factors of production model in the invoicing currency literature. Using capital as a second factor of production, we extend Chung's (2016) model and find a richer cost index than the one she derived to matter in the decision of currency choice.

Chapter 3 examines empirically the theoretically derived decision rules in chapter 2, focussing on our contribution to the existing literature, which is the role played by physical capital in the production function in the choice of invoicing currency. We employ a multinomial logit (MNL) regression framework using highly disaggregated Turkish export transactions data. In line with Chung (2016), our empirical model allows us to examine firm characteristics, including the physical capital share in production, macroeconomic factors and industry characteristics. Our results show that Turkish firms do not tend to set their prices in national currency, Turkish Lira, in international transactions when they use more imported goods in their production and have a higher market share, and when they gain more experience. On the other hand, Turkish firms are more likely to choose LCP or VCP as pricing strategy when they have a higher share of imports denominated in domestic currency and more imported inputs denominated in a specific country's currency. In addition to this, our factor of interest,

the physical capital share in production, also contributes to increase the likelihood of a PCP strategy. With a rising capital share in production, Turkish firms are more likely to set prices according to PCP. Our empirical chapter also gives us a chance to compare a developed economy, the United Kingdom (UK), and a developing economy, Turkey. The main differences between the UK and Turkey have been observed in terms of the preferences for PCP. Namely, UK firms prefer PCP more than Turkish firms in international transaction, and this might well be due to the UK having a more stable, and international, national currency.

Each of chapters 2 and 3 of this PhD thesis can be read as a stand-alone paper. Hence, each of these chapters has its own introduction and a review of the literature. The purpose of this introductory chapter is to present the overall setting of this thesis. At the end, chapter 4 suggests overall concluding remarks to the thesis, outlining some directions for future analysis.

Chapter 2: Imported Inputs and the Optimal Choice of Export Currency Invoicing

Abstract

The currency of invoicing in international trade is a central issue in the transmission of monetary policy. Following Devereux, Engel and Storgaard's (2004) theoretical framework, this paper allows the role of imported intermediate goods in the decision of invoicing currency as in Chung (2016). However, we extend the model by a more general production function, adding capital as a second factor of production. We, thus, develop a novel model with two factors of production in the invoicing currency literature that also features imported inputs. Consequently, by deriving and highlighting a richer cost index in the invoicing decision making of a monopolistically competitive firm importing inputs, we emphasize the significance of the capital share in the production function and the resulting more general theory-based decision rules.

JEL Classifications: F1, F3, F41

Keywords: currency invoicing, intermediate inputs, two-factor production function, producer currency pricing, local currency pricing, vehicle currency pricing

2.1 Introduction

The choice of invoicing currency[5] is one of the fundamental policy issues in international trade, since it has consequences on exchange rate movements under price stickiness, answering two critical questions: i) who shares the exchange rate risk in incomplete asset markets, importer or exporter; and, ii) how movements in the exchange rate influence relative prices of goods in international markets (see, e.g., Goldberg and Tille, 2016; Gopinath *et al.*, 2010; Gopinath, 2015). These questions and answers in the international trade literature depend on the choice of invoicing currency of the firms that are selling the goods in global markets as well as buying intermediate goods from foreign suppliers.

The literature (Bacchetta and van Wincoop, 2005; Devereux, Engel and Storgaard, 2004; Goldberg and Tille, 2008; Goldberg and Tille 2016; Gopinath *et al.*, 2009) suggests three main modelling strategies in the choice of currency, namely producer currency pricing (PCP), local currency pricing (LCP) and vehicle currency pricing (VCP). Hence, a natural question question could be asked: would a firm prefer to follow PCP or LCP or VCP? In other words, what are the reasons behind each invoicing currency strategy? An increasing number of international transactions and, hence, inter-dependence across countries, make this question highly important. One reason is that the issue of invoicing currency choice not only relates to bearing an exchange rate risk but also it might increase the inflationary pressure for a small open economy (SOE) which uses a large number of imported intermediate goods in its production process. To address these issues, Devereux, Engel and Storgaard (2004), DES henceforth, and Chung (2016) developed a theoretical framework appropriate to analyse the determinants of invoicing currency decisions for exporting firms in SOEs.

[5] We use the term 'invoicing currency' and 'currency of pricing' with the same meaning following Friberg (1998) and Friberg and Wilander (2008) terminology.

DES examine the effects of nominal exchange rate changes on currency invoicing. The authors mainly explain the issue of exchange rate risk in the presence of lags between the time the international goods are ordered by the buyer and the time at which goods are transported and paid by him/her. Hence, during the period of the currency arrangements the buyer, or in other words importer, faces with the risk of exchange rate. In their framework, the two parties of the agreement, importer and exporter, have the same preference on invoicing currency, i.e., both sides of the deal prefer a unique currency in international trade. Their partial equilibrium new open economy macroeconomics (NOEM) model derives a decision rule for a monopolistically competitive firm related to the currency of invoicing that reflects endogenous currency choice[6]. The previous studies in the literature take invoicing currency choices as an exogenous variable while DES analyse the determinants of invoicing currency choice endogenously in a two-country framework with nominal price rigidities. However, their analysis is based on price rigidity only for the final goods, and the results may differ when imported intermediate goods take a role in the analysis too.

This gap in the literature is filled in by Chung (2016), exploring the effect of imported inputs in the decision on invoicing currency. Chung (2016) analyses the determinants of invoicing currency via the DES two-country model but extended to the presence of price rigidity of imported intermediate inputs. Her analysis reveals that an exporting firm dependent on imported inputs is more likely to invoice in foreign currency. Although Chung (2016) extended the DES model by adding imported intermediate goods, her extension of the framework remains based on one production factor only, namely labour.

Following the DES theoretical framework, we here allow for the role of imported

[6] For example, importers may favour an invoice in the domestic currency and exporters may set an invoice in the foreign currency. In their framework, the authors reveal that the volatility of the exchange rate surges the desirability of PCP. The reason is that, under PCP, the firm's profit function is convex in the exchange rate, whereas under LCP it is linear in the exchange rate. Then, a higher variance of the exchange rate increases expected profits under PCP relative to LCP.

intermediate goods in the decision on invoicing currency as in Chung (2016), but extending the framework by a more general production function, in particular adding capital as a second factor of production. So, in the light on the above-cited key literature, we in effect develop a novel, two-production-factor model in the invoicing currency literature.

With capital as a second factor of production, we enrich Chung's (2016) extension to the DES framework, which leads to a more complex and more realistic cost index in the decision making on currency invoicing, also emphasizing the significance of the capital share in the production function. Doing this, the covariance between the marginal cost (including this richer cost index) and the exchange rate gains importance in our theoretical framework, highlighting the following novel results. Firstly, a negative covariance leads to an optimal choice of VCP versus PCP and LCP. Secondly, a negative covariance between the exchange rate of countries A (home) and C (a third country, different from the destination market for exports whose currency serves as vehicle currency) and the marginal cost implies that firms optimally follow LCP practices. Lastly, a negative covariance between the exchange rate of countries B (export/destination market) and C and the marginal cost leads to an optimal choice of PCP in currency invoicing. These more realistic possibilities and nuances, relative to the existing literature, reveal the complicated nature of optimal invoicing currency choice for exporting firms with imported inputs and capital in the production function and justify the contribution of this theoretical chapter.

The rest of the chapter is structured as follows. Section 2.2 presents a review of the literature on the importance of invoicing currency. Section 2.3 introduces the theoretical model of optimal choice of export currency invoicing when firms employ imported inputs and benefit from the two factors of production function, labour as well as capital. Section 2.4 concludes.

2.2 Literature Review

In their seminal paper that launched the new open economy macroeconomics (NOEM) literature, Obstfeld and Rogoff (1995) assume that firms set export prices in their domestic currency when selling abroad. In fact, this is the earlier assumption of the Mundell-Fleming-Dornbusch tradition in non-microfounded open economy macroeconomics. Consequently, this conventional view with regard to the currency of invoicing in international trade mostly explains the effect of exchange rate fluctuations on the (imported and, hence final) price of globally traded goods. It is equivalent to the assumption that the price of internationally traded (final) goods is sticky in the currency of the domestic country, hence referred to as the producer currency pricing (PCP) paradigm in international trade. Allowing for a one-for-one pass-through from exchange rate changes to domestic prices, exchange rate pass-through is complete under the PCP strategy. In their model, any shock that leads to a depreciation of the domestic currency decreases the export prices of home-produced final goods and increases those of the import prices of foreign-produced final goods. This relative price change further triggers what is known as the expenditure switching effect in classical international macroeconomics, which in turn plays a critical role in the global spillover of business cycles and in the determination of optimal monetary policy (See, e.g., Obstfeld and Rogoff 1995, 1996 and 2000; Dotsey and Duarte, 2017).

Betts and Devereux (1996 and 2000) modify Obstfeld and Rogoff's (1995) model by assuming, alternatively, that firms determine prices in the currency of the importing country instead, which has become labelled as a local currency pricing (LCP) strategy. This alteration implies, by contrast, that exchange rate pass-through on prices is nil in the model with LCP only (or, more precisely from an empirical angle, incomplete, as mostly observed in the data). This extreme finding does not only highlight the differences between assumed pricing strategies, PCP versus LCP, in theoretical frameworks; it also reveals the influences on prices

of the choice of an exchange rate regime. In order to prevent domestic firms from bearing the exchange rate risks in global markets, a flexible exchange rate regime is more preferable in the Obstfeld and Rogoff's (1995) PCP model, whereas a fixed exchange rate is more favourable in the Betts and Devereux (1996 and 2000) LCP model.

Donnenfeld and Zilcha (1991) use a theoretical framework[7] looking at the conditions on how to choose invoicing currency strategy when the price is determined by combining two pricing strategies, LCP and PCP. This decision might build uncertainty in the demand of importing firms if PCP is used as an invoicing currency when there is a change in importer's currency. In their theoretical model, Donnenfeld and Zilcha (1991) show the reason of selecting LCP as an invoicing currency when there is a fall in the expected profit of exporters because of fluctuations of prices denominated according to LCP.

Friberg (1998), analyses the optimal choice of currency from the perspective of the period implementation of a typical international trade transaction. There are different episodes in an export transaction for a firm between they set prices and receive payments. The differences between these periods might lead to an uncertainty in the expected profit of firms because of different currency selection in each episode. According to Friberg (1998), there are three major episodes in international trade transactions. First, firms set prices in some currency (the currency of price-setting) when they compete in global markets. After this episode, the exchange rate takes a prominent role, since it determines the quantity demanded of imported goods in global markets. Finally, exporters receive a payment (the currency of payment) at the end of the process according to the invoicing currency (i.e., the currency of invoicing). So, this process from setting prices in some currency to receiving payment in the invoicing currency may cause uncertainty. Friberg (1998) highlights the choice of the same currency (of price-

[7] In their model, this mechanism works sequentially. In other words, output, prices, and sales are decided in order. For example, when the exporting firm prefers LCP, the quantity demanded is not affected by the change in the exchange rate. On the other hand, when the exporting firm chooses PCP, there might be a demand uncertainty, since the demand in the importing country is determined by the nominal exchange rate.

setting, invoicing, and payment) in all three episodes of the international transaction for a firm, despite this theoretical difference. The author also suggests a hedging strategy in the forward currency markets in order to protect firms from this type of uncertainty.

While Donnenfeld and Zilcha (1991) and Friberg (1998) take the decision of invoicing currency choice exogenously in their frameworks, the more recent literature (Devereux, Engel and Storgaard, 2004; Corsetti and Pesenti, 2004; Bacchetta and van Wincoop, 2005) analyses the same issue endogenously. This distinct perspective created a huge shift in the analysis of the international trade theory. The new, current paradigm in the literature became that of an endogenous decision on the choice of invoicing currency.

In order to analyse the invoicing currency choice endogenously, DES build a partial equilibrium NOEM model for a monopolistically competitive firm in a two-country framework. The authors show a high correlation between monetary policy and exchange-rate pass-through. Under the existence of differences in the money growth volatility, exporters show a preference in currency invoicing in favour of the economy that has a more stable money growth. Their fundamental result explains how a firm chooses its pricing strategy based on firm's expected profits. Expected profits of a firm are increasing in the exchange rate, since: i) a firm will face a high demand for its product in global markets in response to an increase in exchange rate when the other firms does not change their prices under PCP implying firm's profit function is strictly convex; ii) the value of sales will increase in response to a rise in the exchange rate under LCP, since a firm's profit function is linear in the exchange rate. Therefore, firms will prefer PCP when there is an exchange rate uncertainty, since profit rises in response to an increase in the variance of the exchange rate.

Bacchetta and van Wincoop (2005) analyse the optimal choice of invoicing currency adding a micro-level firm decision into the standard general equilibrium model. Pointing out the importance of competition for a firm, globally and domestically, the authors show that firms

tend to set their prices in their own currency due to the low level of competition in terms of market share and product differentiation. In other words, if an exporting economy has a higher global market share for a particular good (and/or the more differentiated its goods), it is highly possible that the firms in the destination country set their prices in their own currency.

Corsetti and Pesenti (2004) analyse whether a firm chooses LCP or PCP as an invoicing currency under the optimal exchange rate policy and the optimal monetary policy. The authors show multiple equilibria in their model: i) if firms use PCP, the law of one price holds, then prices in the destination country are determined by the exchange rate; hence, this leads to targeting of the domestic output gap with a flexible exchange rate regime as an optimal policy rule in the open economy framework; ii) if a firm prefers LCP, a monetary policy with a fixed exchange rate regime becomes the optimal policy choice.

Gopinath, Itskhoki, and Rigobon (2010) find the evidence on endogenous choice of invoicing currency rather than exogenous in the US data. Looking at the differences in price adjustment frequencies, the authors state that firms prefer PCP versus LCP if they adjust the prices less often. However, if a firm changes its prices more often, it follows LCP. Their contribution suggests that invoicing currency choice plays a significant role in medium-run exchange-rate pass through, while it has no effect on the long-run pass through.

Devereux and Shi (2013) set up a dynamic general equilibrium model of a vehicle currency as a medium of exchange. The authors claim that there is an efficiency gain from using a vehicle currency in international trade rather than exporter country's currency. Gains from vehicle currency practice depend on three features, as follows. First of all, the number of currencies and countries: transaction gains from the vehicle currency practice increase with the number of countries and currencies. Secondly, the size of the countries: issuing the vehicle currency, big economies have an obvious advantage than small economies, since they have a higher share and impact in forex markets. Lastly, the monetary policy followed by the third

country with whom the currency acts as a vehicle currency in trade: the condition for this is the existence of a stable inflationary environment for the vehicle currency economy. If there is a volatile inflation this gain may vanish.

Goldberg and Tille (2008) estimate the determinants of invoicing currency in international trade. The authors show the importance of industrial features of trading economies (price sensitivity of demand and economies of scale), the volatility in macroeconomic variables (wages and aggregate demand) and transaction cost in the foreign exchange market in determining the invoicing currency decision.

Floden and Wilander (2006) investigate the effects of invoicing currency choice on consumer prices using a dynamic model for multiple periods. The authors show that the choice of currency invoicing is highly related to price updates and profit maximization. According to Floden and Wilander (2006), if a firm selects invoicing currency to minimize price update frequency, it also maximizes its profit in the long run.

Devereux, Tomlin and Dong (2015) study the relationship between the market share and invoicing currency choice of both exporting and importing monopolistically competitive firms. Using a Canadian dataset, the authors find evidence of following theoretical assumptions: i) there is a difference in exchange rate pass-through in the market share between importing and exporting firms, monotonically declining, and non-monotonic U shaped, respectively; ii) if there is an increase in the LCP, there is a low level of exchange rate pass-through; iii) using PCP strategy implies non-monotonic and U shaped to the market share of exporting firms whereas monotonically decreasing to the market share of importing firms. Hence, they emphasize the importance of the market share in the invoicing currency analysis.

Goldberg and Tille (2013) set up a bargaining theory of invoicing currency determination in international trade. In their two-currency model negotiation between exporters and importers include the allocation of exchange rate risk via the invoicing currency choice

and the price level of the products. Goldberg and Tille (2013) show that importers who have a higher bargaining power, face a higher exchange rate risk; however, they benefit from a lower level of prices. Goldberg and Tille (2013) emphasize the role of market share in the pricing strategy of importing and exporting firms underlining the importance of the market structure.

The international trade literature suggests that imported intermediate goods have a positive impact on firms' productivity.[8] For example; Goldberg *et al.* (2010) investigate the impact of trade barrier reductions on intermediate goods imports and consequently firm product scope. Goldberg *et al*. (2010) find that 31% of the new product variety in Indian firms is attributed to lower trade barriers in the analysed period. Increased access to the new intermediate inputs is the key factor that creates productivity gains from trade. The reduction in the trade barriers leads to an increase in exports associated with an even bigger rise in imports.

Empirically, the share of the imported input content of export is 20% and this is as high as 40% in smaller countries (Hummels *et al.,* 2001). Castellani *et al.* (2010) find evidence that there is heterogeneity among firms: exporting firms are larger, more productive, and more capital intensive than non-exporting firms. Castellani and Fassio (2016) find evidence showing that, for Swedish firms, imported inputs are key determinants of the firm's export propensity and product variety. Kasahara and Lapham (2013) analyse the interaction between productivity and decisions to import and export. Imported intermediate goods give the firms the ability to become more productive compared to the other firms. More productive firms export more, and their exported goods are on average more import intensive.

[8] For empirical studies which found a positive relationship between access to imported intermediate goods and productivity gains, see, e.g.: for India - Goldberg *et al.* (2010), Indonesia - Amiti and Konings (2007), Hungary - Halpern, Koren and Szeidl (2015), Chile - Kasahara and Rodrigue (2008), Italy - Castellani *et al*. (2010), Sweden - Castellani and Fasio (2016), OECD countries - Hummels *et al.* (2001), Turkey - Akgunduz and Fendoglu (2019), Ulu (2015), France - Bas and Strauss-Kahn (2014).
In theoretical studies, the significance of imported intermediate inputs for productivity increases is found in, e.g.: Ethier (1979, 1982), Romer (1987, 1990), Markusen (1989), Grossman and Helpman (1991).

Grossman and Helpman (1991) and Feenstra *et al.* (1992) show theoretically that there is a positive effect of imported intermediary goods on firm-level productivity because of accessing better quality of inputs and technological spillovers. In another theoretical study, Melitz (2003) finds that more productive firms enter into export markets, while least productive firms exit from export markets.

2.3 Theoretical Model of Optimal Choice of Export Currency Invoicing

In this section, we extend[9] the DES-Chung (2016) theoretical framework, by also employing the modelling approaches in Gopinath and Neiman (2014) and Halpern *et al.* (2015), to examine the effect of imported inputs together with physical capital as a sector factor in the production process in the choice of invoicing currency. We begin by stating the assumptions adopted in our model extension. Then, we present expected firm profits and the profit maximising price under each alternative pricing-setting strategy, PCP, LCP, and VCP. Finally, following Devereux, Engel and Storgaard (2004)[10], we derive a decision rule on the endogenous invoicing currency choice taking into account the dependence of production of the exporting firms on intermediate imported goods and on physical capital.

2.3.1 Assumptions

Extending Chung (2016), we classify the model assumptions under four main categories: 'demand', 'production technology', 'intermediate goods', and 'total cost and import density'. We follow all model assumptions of Chung (2016) for 'demand' and 'intermediate goods';

[9] For a detailed derivation of the complete model, see Appendix A.
[10] These authors consider endogenous currency choice in the absence of intermediate imported goods for exporting firms.

however, our model is richer from her theoretical framework with regard to the assumptions on 'production technology' and 'total cost and imported density'.

2.3.1.1 Demand

Suppose that a monopolistically competitive firm i produces a differentiated good and supplies it to the destination market within a sector k. Consumers have a constant elasticity of substitution (CES) demand function over the varieties of goods. The elasticity of substitution across the varieties within sectors is ρ, with $\rho > 1$, while the elasticity of substitution across sectoral aggregates is $\eta > 0$.

Under these circumstances, a firm faces the following CES demand function:

$$D_{ik}(p_i) = \left[\frac{p_{ik}}{p^*_{kf}}\right]^{-\rho} \left[\frac{p^*_{kf}}{P^*}\right]^{-\eta} D^*_k \tag{1}$$

where D_{ik} is the quantity demanded, p_{ik} is the firm's market price within sector k, p^*_{kf} is the sectoral price index for all home goods sold in the foreign country (denominated in foreign currency), P^* is the foreign consumer price index (denominated in foreign currency), and D^*_k is the sectoral foreign demand shifter that is independent of prices and the firm takes it as given.

2.3.1.2 Production Technology

The firm i is a monopolist producer of its good and has a constant returns to scale (CRS) Cobb-Douglas (CD) production function, specified as follows,

$$Y_i = \Omega\, X_i^{\gamma} \left(K_i{}^{\alpha} L_i{}^{1-\alpha}\right)^{1-\gamma} \tag{2}$$

where, K_i is the physical capital available for production, L_i is the labour input, X_i is the intermediate good input, Ω denotes the firm's total factor productivity (TFP), $0 < \gamma < 1$ is the

share of intermediate inputs in the production process, and $0 < \alpha < 1$ is the capital share in the production technology. Chung (2016) has used a similar production function, but abstracting from physical capital. However, once we extend her model employing a richer production function, as in Gopinath and Neiman (2014) and Halpern *et al.* (2015), we are also able to analyse the role of physical capital in the endogenous choice of currency invoicing.

2.3.1.3 Intermediate Goods

Intermediate goods X_i consist of two imperfect substitute bundles, a domestic variety and a foreign variety, as follows,

$$X_i = \left[Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right]^{\frac{1+\theta}{\theta}} \tag{3}$$

Z_i is the quantity of domestic intermediate inputs, M_i is the quantity of imported intermediate inputs, and $\theta > 0$ is the elasticity of substitution between domestic and imported inputs. The firm's efficiency in employing the inputs from abroad is denoted by B_i. In the model, it may be diversified among firms showing a degree of firm dependency on imported inputs in the production process. Hence, the existence of foreign intermediate inputs in the production process may provide a productivity gain or a productivity loss to firm i according to the value of B_i. If the imported-input efficiency coefficient is greater than one ($B_i > 1$), it implies an efficient use of imported inputs, whereas when it is less than one ($B_i < 1$) the use of imported goods in the production of final goods by the firm is inefficient.

The prices of the domestic and imported inputs are denoted P_z and P_m, respectively. The imported intermediate input, M_i, is priced in foreign currency. Hence;

$$P_m = S\, P_m^* ,$$

where S is the nominal exchange rate expressed as units of domestic currency per unit of foreign currency and P_m^* is the price denominated in foreign currency.

To write down the advantage of a unit of home currency spent on the foreign good relative to the domestic good, the firm's productivity[11] adjusted by domestic and foreign prices of the intermediate good can be written as,

$$A_i = \frac{B_i}{P_m/P_z} \text{ or, alternatively, } A_i = \frac{B_i}{SP_m^*/P_z}$$

2.3.1.4 Total Cost and Import Intensity

At the beginning of importing any particular good, the adoption of new imported inputs in the production process is usually costly. For example, firms need to bear the costs of hiring new workers in addition to their wage rate (i.e., learning legal requirements, etc.). Therefore, in the model we suppose that all these expenses of firm i are captured by a need to pay a fixed cost[12] f_i in terms of labour in order to import foreign inputs. It can be thought that this fixed cost may be interpreted as a sunk cost for importing firms at the beginning of importing.

Including the sunk cost, the firm first chooses the amount of inputs to minimize its total costs subject to the production technology at a given level of output. Hence, the total cost of the firm can be written as:

$$TC_i = WL_i + rK_i + P_zZ_i + P_mM_i + f_i W \quad (4)$$

where W is the cost of labour (nominal wage in exporters currency) and r is the rental price for capital.

Equation (4) can be written as the sum of a variable cost plus a fixed cost:

[11] As Chung (2016) linked productivity with the definition of quality in Grossman and Helpman (1993), the term can be thought as a ratio of the advantages of a good to the cost of it. Hence, A_i shows an advantage preference of foreign goods in production versus domestic alternatives.

[12] The presence of fixed cost is consistent with the empirical evidence: see, e.g., Halpern *et al.* (2015) and Gopinath and Neiman (2014)

$$TC_i = \mu_i Y + f_i W \tag{5}$$

where μ_i is the firm's marginal cost.

As mentioned, Chung (2016) does not include physical capital in the production technology. However, we extend her model adding capital as a second factor of production. Hence, we obtain a richer cost index[13], H, than Chung (2016), specified as

$$H = P_Z{}^{\gamma} W^{(1-\gamma)(1-\alpha)} r^{(1-\gamma)\alpha} \gamma^{-\gamma} \alpha^{\alpha(\gamma-1)} (1-\gamma)^{(\gamma-1)} (1-\alpha)^{(\alpha-1)(1-\gamma)} \tag{6}$$

Equation (6)[14] can be reduced to Chung's (2016) analogue when the capital share, α, is equal zero[15].

The productivity-enhancing effect, τ, from using imported inputs can be specified as follows:

$$\tau = \left[1 + \left(\frac{B_i}{SP_m^*/P_Z}\right)^{\theta}\right]^{\frac{1}{\theta}} \tag{7}$$

The productivity-enhancing effect is increasing in the productivity parameter B_i.

Using equations (6) and (7), the marginal cost μ_i can be derived as,

$$\mu = \frac{H}{\Omega\ \tau^{\gamma}} \tag{8}$$

As seen, our extended model is deeper than Chung's (2016) in terms of the marginal cost, μ_i, since it includes physical capital as a second factor in the production function.

Finally, the share of costs spent on imported inputs in total costs of intermediate goods can be defined as follows,

[13] See Appendix A for a full derivation of the model.
[14] We omit the i indexing for simplicity.
[15] Zero to the zero power is taken unity for simplification (see Alfriend and Richardson, 1973).

$$\psi = \frac{SP_M^* M}{SP_M^* M + P_Z Z} = \left[1 - \tau^{-\theta}\right] \tag{9}$$

The parameter ψ_i directly captures the dependence of the firm on foreign inputs. It is increasing in the productivity-enhancing effect τ_i, which is sensitive to the elasticity of substitution between domestic and foreign inputs in production.

2.3.2 Invoicing Currency Choice

Following Devereux, Engel and Storgaard (2004), an exporting firm is supposed to predetermine the optimal price and its invoicing currency one period forward in order to maximize expected profits under exchange rate uncertainty after the firm chooses how much input is required in the production. A critical feature of the model is that the firm selects invoicing currency endogenously (as in DES and Chung, 2016).

In our model, firm i in the home country (A) has three possible pricing strategies. The first one is PCP, whereby the firm sells a differentiated good to a foreign country (B) with invoicing in its own currency. The second one is LCP, whereby firm i sells the good using the destination country's (B) currency. The last option is VCP, whereby firm i in the home country (A) trades with a foreign country (B) but choosing a third country's currency (C) as an invoicing currency (VCP).

This section deals with profit maximization of the exporting firm under the three different cases; i) PCP, ii) LCP and iii) VCP. Regardless of the pricing strategy (PCP, LCP, or VCP), a firm is maximizing its expected profits using a discount factor, d, and the expectation takes place in period $t-1$ when a firm set its price for period t.

2.3.2.1 Producer Currency Pricing

In the case of producer currency pricing (PCP), it is assumed that the price set for exported goods is denominated in the home currency. The exporting firm chooses the price P^{PCP} for sale

of its good in the foreign market to maximize its expected discounted profits, $\mathrm{E}\Pi^{PCP}$. Then, the expected discounted profits are as follows,

$$\mathrm{E}\Pi^{PCP} = \mathrm{E}\left[d(P^{PCP} - \mu)\left[\frac{P^{PCP}}{SP}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta} D^*\right] \tag{10}$$

Taking the first derivative of equation (10), the profit maximizing price under PCP is:

$$P^{PCP} = \frac{\rho}{\rho - 1}\frac{E(WS^{\rho}\kappa)}{E(S^{\rho}\kappa)} \tag{11}$$

where $\kappa = dP^{\rho-\eta}P^{*\eta}D^*$.

2.3.2.2 Local Currency Pricing

The exporting firm chooses the price P^{LCP} for sale of its good in the foreign market to maximize its expected discounted profit, $E\Pi^{LCP}$. If the firm sets its price in the foreign currency (i.e., under local currency pricing), then the expected discounted profits are:

$$E\Pi^{LCP} = E\left[d(SP_i^{LCP} - \mu)\left(\frac{P_i^{LCP}}{P}\right)^{-\rho}\left(\frac{P}{P^*}\right)^{-\eta} D^*\right] \tag{12}$$

The profit maximizing price under LCP derived from the first-order condition then is:

$$P^{LCP} = \frac{\rho}{\rho - 1}\frac{E(\mu\kappa)}{E(S\kappa)} \tag{13}$$

2.3.2.3 Vehicle Currency Pricing

Under VCP, the exporting firm which uses an imported intermediate good in its production decides on the price P^{VCP} for sale of its good in the foreign market to maximize its expected

discounted profit, $\mathrm{E}\Pi^{VCP}$. If the firm sets its price in a third currency rather than the producer or local currency, expected discounted profits are written as,

$$\mathrm{E}\Pi^{VCP} = \mathrm{E}\left[d(S_{AC}P^{VCP} - \mu)\left[\frac{P^{VCP}}{P}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta} D^*\right] \tag{14}$$

The resulting profit maximizing price under VCP is then:

$$P^{VCP} = \frac{\rho}{\rho - 1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)} \tag{15}$$

2.3.3 Firm's Decision Rule

After determining expected discounted profits under each of the above-mentioned pricing strategies - PCP, LCP and VCP, we are now able to analyse which of these strategies are more desirable for an exporting firm. In line with Devereux, Engel and Storgaard (2004) and Chung (2016), in order to get results for the firm's decision rules, we need to take a second-order approximation[16] of the expected profit functions defined above.

In our theoretical framework, the price decision of a domestic firm with two factors of production - capital and labour - using imported intermediate inputs can be shown to be, respectively, under three cases:

Case 1: A firm sets its price for the foreign market in PCP (versus LCP) if;

[16] Since the linearized system is independent of the volatility of shocks, a higher-order approximation is required. To see the effect of endogenous shocks that are related to variances of endogenous variables, we use a second-order approximation (following the literature; see, e.g., Devereux, Engel and Storgaard (2004), Engel, 2006, Gopinath *et al.* 2010, and Chung, 2016).

$$\frac{1}{2}\left(var(lnS_{AC}) + var(lnS_{BC})\right) - (cov(lnS_{AC}, ln\mu) + cov(lnS_{BC}, ln\mu)) \\ - cov(lnS_{AC}, lnS_{BC}) > 0 \tag{16}$$

Case 2: A firm set its price for the foreign market in PCP (versus VCP) if;

$$\left[\frac{1}{2} var(lnS_{AC}) - cov(lnS_{AC}, ln\mu)\right] > 0 \tag{17}$$

Case 3: A firm set its price for the foreign market in LCP (versus VCP) if;

$$\left[\frac{1}{2} var(lnS_{BC}) - cov(lnS_{BC}, ln\mu) - cov(lnS_{AC}, lnS_{BC})\right] > 0 \tag{18}$$

In line with Chung (2016), the above conditions about pricing strategies can be summarized as follows: i) exchange rate volatility, captured by high $var \ln S_{AC}$, leads the firm to set its price in PCP in equation (16) and (17); ii) in addition, a negative covariance between the log of the exchange rate (S_{AC}) and the log of marginal costs (μ) also leads the firm to set its price in PCP versus alternatives pricing strategies according to equations (16) and (17); iii) a negative covariance between the log of marginal cost and the exchange rate between countries B and C implies the choice of LCP versus PCP in equation (16) and VCP versus LCP in equation (18); iv) a negative sign of the covariance between lnS_{AC} and lnS_{BC} leads to choose LCP versus PCP in equation (16) and VCP versus LCP in equation (18).

The economic intuition behind the above-stated invoicing currency decision rules is that a highly volatile exchange rate of the home currency is one of the fundamental reasons in explaining why a firm chooses PCP as long as a flexible exchange rate regime operates, i.e., $var\ ln(S) > 0$, since the firm's concern about its expected profits dominates that about its expected costs. As in Chung (2016), we generated the importance of the exchange rate in the

cost structure of exporting firms through the existence of imported intermediate goods denominated in foreign currency. So, if a firm does not benefit from imported intermediate commodities, the covariance term between the exchange rate and the home share of inputs is neglectable.

Together with Chung (2016) and Devereux, Engel and Storgaard (2004), we underline that the existence of exchange rate risk in the decision rules for the firms, which care about expected revenues[17]. However, for the firm which chooses PCP as a pricing strategy, the price risk might be eliminated, but there is still exchange rate uncertainty for the quantity based on foreign economies' demand (Chung, 2016). Choosing LCP as a pricing strategy defines the opposite strategy. If a firm sets prices according to LCP, then it protects its quantity, but prices are risky due to the exchange rate uncertainty. On the other hand, VCP as a pricing strategy creates a wider view of pricing strategy since it takes into account the exchange rate risk between countries B and C; hence a higher variance of this exchange rate leads to choosing VCP. All these above explanations essentially reveal theoretically a trade-off between the risk of price and quantity changes for an exporting firm with imported inputs and also capital in the production function.

2.4 Concluding Remarks

This chapter explores how invoicing currency choice depends on firms' production technology. Following Devereux, Engels and Storgaard (2004) and Chung (2016), in order to show how the decision rule of domestic firms are affected by the choice of currency in invoicing, we follow a similar but a richer strategy compared to the above-stated papers. Based on Devereux, Engels and Storgaard (2004) framework, Chung (2016) explains the role of imported inputs in

[17] Devereux, Engels and Storgaard (2004) indicate that optimal currency choice can be seen from the shape of the production function utilized by a firm. They show that PCP implies a convex expected revenue function, whereas LCP implies a linear one. Therefore, a rise in the exchange rate increases expected revenue for the firms which use PCP, but falls for the firms which use LCP (*ceteris paribus*).

the choice of currency for domestic firms with a one-factor production model, solely labour. Including capital as a second factor of production, we extend her model by deriving a richer cost index, H, in the invoicing currency decision making.

Introducing this richer cost index, H, we further highlight the importance of the capital share in the production technology. Doing this, we present generalized decision rules for the three-country framework in the DES-Chung (2016), home country A, destination country B, and a third country C. In this more realistic, on the production side, three-country framework, our results support Chung's (2016) arguments in the preference on VCP versus PCP and LCP in equations (17) and (18). Furthermore, we show an added argument in the decision rule under the three-country case in equation (16). In equations (17) and (18) the covariance between the extended marginal cost including the physical capital, μ, and the exchange rate has a negative sign, which means that with an increase in this covariance firms tend to optimally choose VCP versus PCP and LCP. In equation (16), we set a decision rule for PCP versus LCP in the three-country framework. It shows the covariance between the exchange rate between countries A and C and our richer marginal cost, μ has a negative sign implying that if the covariance increases firms choose LCP. Furthermore, the covariance between the exchange rate between countries B and C and our richer marginal cost, μ, also leads to a more desirable choice of LCP in currency invoicing in equation (16).

In terms of the limitations of our theoretical model, we do not assume any bargaining power[18] between exporter and importer at the intermediate input stage. We only derived theoretical decision rules based on the exporting firm's maximization problem. However, the same problem could be analysed, including the bargaining power between home country firms

[18] Although the bargaining power does not play any role in our theoretical framework, we test it in our empirical framework. We use the transaction size of firms as a proxy for bargaining power.

and foreign trade partners. Adding the bargaining power between exporters and importers in that stage would be an interesting extension of our theoretical model.

Although our extended model reveals a richer theoretical explanation for the optimal invoicing currency choice in in the literature, it would be interesting to check its empirical implications. Therefore, in chapter 3 we test the theory proposed above against data for a developing small open economy, Turkey. Doing this, we will also compare the theoretical model of Chung (2016) and ours, since Chung's framework is tested for a developed country, the United Kingdom.

Appendix A

A.1 Derivation of Cost Minimization and the Cost Index

Recall equation (4) for the total cost function,

$$TC = WL + rK + P_z Z + P_m M + f_i W$$

Given output, the firm first chooses the amount of inputs, L, K, Z, and M to minimize its total cost. Therefore, the cost minimization problem (min{ L, K, Z, and M}) of firm can be written as,

$$WL + rK + P_z Z + P_m M + f_i W - \mu \left[\Omega X_i^{\gamma} (K^{\alpha} L^{1-\alpha})^{1-\gamma} - Y\right] - \chi \left[\left[Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}}\right]^{\frac{1+\theta}{\theta}} - X\right] \quad \text{(A1)}$$

Here, μ and χ are the Lagrange multipliers on the constraints of the production technology and intermediate goods, respectively. In other words, these are constraints on equations (2) and (3).

In order to show cost minimizing input levels, we need to take the first derivative of equation (A1) with respect to L, K, Z, M and X and derive the first order conditions.

Differentiate equation (A1) with respect to L:

$$\frac{\partial \mathcal{L}}{\partial L} = W - \mu(1-\gamma)\Omega X_i^{\gamma} (K^{\alpha} L^{1-\alpha})^{-\gamma} (1-\alpha) K^{\alpha} L^{-\alpha}$$

$$W - \mu(1-\gamma)\Omega X_i^{\gamma} (K^{\alpha} L^{1-\alpha})^{-\gamma} (1-\alpha) K^{\alpha} L^{-\alpha} \frac{(K^{\alpha} L^{1-\alpha})}{(K^{\alpha} L^{1-\alpha})}$$

$$W - \mu(1-\gamma)\Omega X_i^{\gamma} (K^{\alpha} L^{1-\alpha})^{-\gamma} \frac{(K^{\alpha} L^{1-\alpha})}{(K^{\alpha} L^{1-\alpha})} (1-\alpha) K^{\alpha} L^{-\alpha}$$

$$W - \mu(1-\gamma)\frac{\mathrm{Y}}{(K^{\alpha}L^{1-\alpha})}(1-\alpha)\,K^{\alpha}L^{-\alpha}$$

$$W = \mu(1-\gamma)(1-\alpha)\frac{Y}{L} \tag{A2}$$

Differentiate (A1) with respect to K:

$$\frac{\partial \mathcal{L}}{\partial K} = \; r - \mu(1-\gamma)\Omega\, X_i^{\gamma}\,(K^{\alpha}L^{1-\alpha})^{-\gamma}\alpha\, K^{\alpha-1}L^{-\alpha}$$

$$r - \mu(1-\gamma)\Omega\, X_i^{\gamma}\,(K^{\alpha}L^{1-\alpha})^{-\gamma}\alpha\, K^{\alpha-1}L^{-\alpha}\frac{(K^{\alpha}L^{1-\alpha})}{(K^{\alpha}L^{1-\alpha})}$$

$$r - \mu(1-\gamma)\Omega\, X_i^{\gamma}\,(K^{\alpha}L^{1-\alpha})^{-\gamma}\frac{(K^{\alpha}L^{1-\alpha})}{(K^{\alpha}L^{1-\alpha})}\alpha\, K^{\alpha-1}L^{-\alpha}$$

$$r = \mu(1-\gamma)\alpha\frac{Y}{K} \tag{A3}$$

Differentiate (A1) with respect to X:

$$\frac{\partial \mathcal{L}}{\partial X} = \; -\mu\,\Omega\,\gamma\, X_i^{\gamma-1}\,(K^{\alpha}L^{1-\alpha})^{1-\gamma} + \chi$$

$$= \; -\mu\,\Omega\,\gamma\,\frac{X^{\gamma}}{X}(K^{\alpha}L^{1-\alpha})^{1-\gamma} + \chi$$

$$\chi = \; \mu\;\gamma\,\frac{Y}{X} \tag{A4}$$

Differentiate (A1) with respect to Z:

$$\frac{\partial \mathcal{L}}{\partial Z} = P_z - \chi\left[\frac{1+\theta}{\theta}\left(Z_i^{\frac{\theta}{\theta+1}} + (B_iM_i)^{\frac{\theta}{\theta+1}}\right)^{\frac{1}{\theta}} \quad \frac{\theta}{1+\theta}Z^{\frac{-1}{1+\theta}}\right]$$

$$= P_z - \chi\left[\left(Z_i^{\frac{\theta}{\theta+1}} + (B_iM_i)^{\frac{\theta}{\theta+1}}\right)^{\frac{1}{\theta}} \quad Z^{\frac{-1}{1+\theta}}\right]$$

$$= P_z - \chi \left[\frac{\left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1}{\theta}}}{Z^{\frac{1}{1+\theta}}} \right]$$

taking both sides to the power of $\left(\frac{1+\theta}{1+\theta}\right)$ yields;

$$P_z = \chi \left[\frac{\left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1}{\theta}}}{Z^{\frac{1}{1+\theta}}} \right]^{\frac{1+\theta}{1+\theta}}$$

$$P_Z = \chi \left[\frac{\left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1+\theta}{\theta}}}{Z} \right]^{\frac{1}{1+\theta}}$$

$$P_Z = \chi \left[\frac{X}{Z} \right]^{\frac{1}{1+\theta}} \tag{A5}$$

Differentiate equation (A1) with respect to M:

$$\frac{\partial \mathcal{L}}{\partial M} = SP_m^* - \chi \left[\frac{1+\theta}{\theta} \left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1}{\theta}} \quad B^{\frac{\theta}{\theta+1}} \frac{\theta}{1+\theta} M^{\frac{-1}{1+\theta}} \right]$$

$$= SP_m^* - \chi \left[\frac{\left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1}{\theta}} \quad B^{\frac{\theta}{\theta+1}}}{M^{\frac{1}{1+\theta}}} \right]$$

$$SP_m^* = \chi \left[\frac{\left(Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}} \right)^{\frac{1}{\theta}} \quad B^{\frac{\theta}{\theta+1}}}{M^{\frac{1}{1+\theta}}} \right]$$

taking both sides to the power of $\left(\frac{1+\theta}{1+\theta}\right)$ yields;

$$SP_m^* = \chi \left[\frac{XB^{\theta}}{M} \right]^{\frac{1}{1+\theta}} \tag{A6}$$

Rearrange $\frac{\partial \mathcal{L}}{\partial Z}$ and $\frac{\partial \mathcal{L}}{\partial M}$ and divide the first equation by the second equation to get;

$$\frac{P_Z}{SP_m^*} = \frac{\chi \left[\frac{X}{Z} \right]^{\frac{1}{1+\theta}}}{\chi \left[\frac{X\, B^{\theta}}{M} \right]^{\frac{1}{1+\theta}}}$$

$$\frac{P_Z}{SP_m^*} = \left[\frac{X}{Z} \right]^{\frac{1}{1+\theta}} \left[\frac{M}{X\, B^{\theta}} \right]^{\frac{1}{1+\theta}}$$

$$\frac{P_Z}{SP_m^*} = \left[\frac{M}{ZB^{\theta}} \right]^{\frac{1}{1+\theta}}$$

$$B^{\frac{\theta}{1+\theta}} = \frac{SP_m^* M^{\frac{1}{1+\theta}}}{P_Z\, Z^{\frac{1}{1+\theta}}}$$

taking both sides to the power of $(1+\theta)$ yields;

$$B^{\theta} = \frac{(SP_m^*)^{1+\theta} M}{{P_Z}^{1+\theta}\, Z}$$

$$\frac{(SP_m^*)(SP_m^*)^\theta M}{P_Z {P_Z}^\theta Z} = B^\theta$$

$$\frac{(SP_m^*)(SP_m^*)^\theta M}{P_Z \, {P_Z}^\theta Z} = B^\theta$$

$$\frac{SP_m^* M}{P_Z Z} = \left[\frac{B}{SP_m^*/P_Z}\right]^\theta \tag{A7}$$

Alternatively, $M = \frac{P_Z Z}{SP_m^*}\left[\frac{B}{SP_m^*/P_Z}\right]^\theta$.

Substitute $M = \frac{P_Z Z}{SP_m^*}\left[\frac{B}{SP_m^*/P_Z}\right]^\theta$ into equation (3) $X_i = \left[Z_i^{\frac{\theta}{\theta+1}} + (B_i M_i)^{\frac{\theta}{\theta+1}}\right]^{\frac{1+\theta}{\theta}}$;

$$X_i = \left[Z_i^{\frac{\theta}{\theta+1}} + \left(B_i \frac{P_Z Z}{SP_m^*}\left[\frac{B}{SP_m^*/P_Z}\right]^\theta\right)^{\frac{\theta}{\theta+1}}\right]^{\frac{1+\theta}{\theta}}$$

$$X = \left[Z_i^{\frac{\theta}{\theta+1}} + \left(\frac{BP_Z}{SP_M^*}\right)^{\frac{\theta}{\theta+1}} \; Z^{\frac{\theta}{\theta+1}} \; \left[\left(\frac{B}{SP_m^*/P_Z}\right)^\theta\right]^{\frac{\theta}{1+\theta}}\right]^{\frac{1+\theta}{\theta}}$$

$$X = \left[Z_i^{\frac{\theta}{\theta+1}}\left[1 + \left(\frac{BP_Z}{SP_M^*}\right)^{\frac{\theta}{\theta+1}} \; \left[\left(\frac{B}{SP_m^*/P_Z}\right)^\theta\right]^{\frac{\theta}{1+\theta}}\right]\right]^{\frac{1+\theta}{\theta}}$$

$$X = Z\left[1 + \left(\frac{BP_Z \, B^\theta P_Z^\theta}{SP_m^* S^\theta (P_M^*)^\theta}\right)^{\frac{\theta}{1+\theta}}\right]^{\frac{1+\theta}{\theta}}$$

$$X = Z\left[1 + \left(\frac{B^{1+\theta} P_Z^{1+\theta}}{S^{1+\theta}(P_M^*)^{1+\theta}}\right)^{\frac{\theta}{1+\theta}}\right]^{\frac{1+\theta}{\theta}}$$

$$X = Z\left[1 + \left(\frac{B}{SP_m^*/P_Z}\right)^{\theta}\right]^{\frac{1+\theta}{\theta}} \quad \text{(A8)}$$

Rewrite equation (A5) $P_Z = \chi\left[\frac{X}{Z}\right]^{\frac{1}{1+\theta}}$ using (A4) $\chi = \mu\,\gamma\,\frac{Y}{X}$

$$P_Z = \mu\,\gamma\,\frac{Y}{X}\left[\frac{X}{Z}\right]^{\frac{1}{1+\theta}}$$

$$P_Z X = \mu\,\gamma\,Y\left[\frac{X}{Z}\right]^{\frac{1}{1+\theta}} \quad \text{(A9)}$$

Then rewrite equation (A9) together with equation (A8)

$$P_Z X = \mu\,\gamma\,Y\left[\frac{Z\left[1 + \left(\frac{B}{SP_m^*/P_Z}\right)^{\theta}\right]^{\frac{1+\theta}{\theta}}}{Z}\right]^{\frac{1}{1+\theta}}$$

$$P_Z X = \mu\,\gamma\,Y\left[1 + \left(\frac{B}{SP_m^*/P_Z}\right)^{\theta}\right]^{\frac{1}{\theta}}$$

here $\tau = \left[1 + \left(\frac{B}{SP_m^*/P_Z}\right)^{\theta}\right]^{\frac{1}{\theta}}$ so

$$X = \frac{\mu\,\gamma\,Y\,\tau}{P_Z} \tag{A10}$$

τ is the productivity-enhancing effect from using imported inputs (Halpern *et al.*, 2015), which is increasing in the firm's imported-inputs efficiency parameter B.

Substitute $X = \frac{\mu\,\gamma\,Y\,\tau}{P_Z}$, $K = \mu(1-\gamma)\alpha\frac{Y}{r}$ and $L = \mu(1-\gamma)(1-\alpha)\frac{Y}{W}$ into the production function, recalling equation (2)

$$Y_i = \Omega\, X_i^{\gamma}\, (K^{\alpha}L^{1-\alpha})^{1-\gamma}$$

$$Y = \Omega \left[\frac{\mu\,\gamma\,Y\,\tau}{P_Z}\right]^{\gamma} \left[\left(\mu(1-\gamma)\alpha\frac{Y}{r}\right)^{\alpha}\left(\mu(1-\gamma)(1-\alpha)\frac{Y}{W}\right)^{1-\alpha}\right]^{1-\gamma}$$

$$YP_Z{}^{\gamma}\, W^{(1-\gamma)(1-\alpha)} r^{(1-\gamma)\alpha} = \Omega\,(\mu\,\gamma\,Y\,\tau)^{\gamma}\,[(\mu(1-\gamma)\alpha Y)^{\alpha}(\mu(1-\gamma)(1-\alpha)Y)^{1-\alpha}]^{1-\gamma}$$

$$= \Omega\mu^{\gamma+\alpha(1-\gamma)+(1-\alpha)(1-\gamma)}\gamma^{\gamma}\tau^{\gamma}Y^{\gamma+\alpha(1-\gamma)+(1-\alpha)(1-\gamma)}(1-\gamma)^{\alpha(1-\gamma)+(1-\alpha)(1-\gamma)}\,\alpha^{\alpha(1-\gamma)}(1-\alpha)^{(1-\alpha)(1-\gamma)}$$

$$P_Z{}^{\gamma}\, W^{(1-\gamma)(1-\alpha)} r^{(1-\gamma)\alpha} = \Omega\mu\gamma^{\gamma}\tau^{\gamma}(1-\gamma)^{(1-\gamma)}\,\alpha^{\alpha(1-\gamma)}(1-\alpha)^{(1-\alpha)(1-\gamma)}$$

$$\mu = \frac{P_Z{}^{\gamma}\, W^{(1-\gamma)(1-\alpha)} r^{(1-\gamma)\alpha}\,\gamma^{-\gamma}\,\alpha^{\alpha(\gamma-1)}(1-\gamma)^{(\gamma-1)}(1-\alpha)^{(\alpha-1)(1-\gamma)}}{\Omega\,\tau^{\gamma}}$$

$$H = P_Z{}^{\gamma}\, W^{(1-\gamma)(1-\alpha)} r^{(1-\gamma)\alpha}\,\gamma^{-\gamma}\,\alpha^{\alpha(\gamma-1)}(1-\gamma)^{(\gamma-1)}(1-\alpha)^{(\alpha-1)(1-\gamma)}$$

$$\mu = \frac{H}{\Omega\ \tau^{\gamma}} \tag{A11}$$

Substitute (A2), (A3), (A4), (A5), (A6), (A7) into

$$\text{TC} = WL + rK + P_z Z + P_m M + f_i W;$$

we have,

$$TC = \mu(1-\gamma)(1-\alpha)\frac{Y}{L} L + \mu(1-\gamma)\alpha\frac{Y}{K}K + \frac{\mu\gamma Y}{X}\left[\frac{X}{Z}\right]^{\frac{1}{1+\theta}} Z + \frac{\mu\gamma Y}{X}\left[\frac{X}{Z}\right]^{\frac{1}{1+\theta}} Z\left[\frac{B}{SP_m^*/P_Z}\right]^{\theta} + f W$$

Then, if we substitute W from (A2), $SP_M^* M$ from (A7), P_z from (A9), and r from (A3)

$$TC = \mu(1-\gamma)(1-\alpha)Y + \mu(1-\gamma)\alpha Y + \mu\gamma Y X^{\frac{-\theta}{1+\theta}} Z^{\frac{\theta}{1+\theta}} + \mu\gamma Y X^{\frac{-\theta}{1+\theta}} Z^{\frac{\theta}{1+\theta}}\left[\frac{B}{SP_m^*/P_Z}\right]^{\theta} + f W$$

$$TC = \mu Y\left[(1-\gamma)(1-\alpha) + (1-\gamma)\alpha + \gamma\left[\frac{Z}{X}\right]^{\frac{\theta}{1+\theta}} + \gamma\left[\frac{Z}{X}\right]^{\frac{\theta}{1+\theta}}\left[\frac{B}{SP_m^*/P_Z}\right]^{\theta}\right] + f W$$

$$TC = \mu Y\left[(1-\gamma) + \gamma\left[\frac{Z}{X}\right]^{\frac{\theta}{1+\theta}}\left(1 + \left[\frac{B}{SP_m^*/P_Z}\right]^{\theta}\right)\right] + f W$$

$$TC = \mu Y\left[1 - \gamma\left(\left[\frac{Z}{X}\right]^{\frac{\theta}{1+\theta}}\left(1 + \left[\frac{B}{SP_m^*/P_Z}\right]^{\theta}\right)\right)\right] + f W$$

$\left[\frac{Z}{X}\right]^{\frac{\theta}{1+\theta}} = \left[\frac{\mu\gamma Y}{P_Z X}\right]^{\theta}$ and $\left(1 + \left[\frac{B}{SP_m^*/P_Z}\right]^{\theta}\right) = \left[\frac{P_Z X}{\mu\gamma Y}\right]^{\theta}$ so,

$$TC = \mu Y + f W \qquad \text{(A12)}$$

$\psi =$ the share of the cost spent on imported inputs in total cost of intermediate goods

$$\psi = \frac{SP_M^* M}{SP_M^* M + P_Z Z}$$

Using equation (A7)

$$\psi = \frac{P_Z Z\left[\frac{B}{SP_m^*/P_Z}\right]^{\theta}}{P_Z Z\left[\frac{B}{SP_m^*/P_Z}\right]^{\theta} + P_Z Z}$$

$$\psi = \frac{P_Z Z \left[\frac{B}{SP_m^*/P_Z}\right]^\theta}{P_Z Z \left[\left[\frac{B}{SP_m^*/P_Z}\right]^\theta + 1\right]}$$

as $\tau = \left[1 + \left(\frac{B}{SP_m^*/P_Z}\right)^\theta\right]^{\frac{1}{\theta}}$

$$\tau^\theta = 1 + \left(\frac{B}{SP_m^*/P_Z}\right)^\theta$$

$$\psi = \frac{\left[\frac{B}{SP_m^*/P_Z}\right]^\theta}{\left[\left[\frac{B}{SP_m^*/P_Z}\right]^\theta + 1\right]}$$

$$\psi = \frac{\tau^\theta - 1}{\tau^\theta}$$

$$\psi = 1 - \tau^{-\theta} \tag{A13}$$

A.2 Model Derivation of Currency Choice Decision for Each Pricing Strategy

If a firm follows PCP, then expected discounted profits are given by:

$$\mathrm{E}\Pi^{PCP} = \mathrm{E}\left[d(P^{PCP} - \mu)\left[\frac{P^{PCP}}{SP}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta} D^*\right] \tag{A14}$$

$$E\Pi^{PCP} = E\left[dP^{PCP}P^{PCP\,-\rho}S^\rho P^\rho P^{-\eta}P^{*\eta}D^* - dWP^{PCP\,-\rho}S^\rho P^\rho P^{-\eta}P^{*\eta}D^*\right]$$

Call $\kappa = dP^{\rho-\eta}P^{*\eta}D^*$

$$E\Pi^{PCP} = E\left[S^\rho \kappa P^{PCP}P^{PCP\,-\rho} - WS^\rho \kappa P^{PCP\,-\rho}\right] \tag{A15}$$

The first order condition for profit maximization under PCP is

$$\frac{\partial \Pi^{PCP}}{\partial P^{PCP}} = E\left[(1-\rho)P^{PCP^{(-\rho)}}S^{\rho}Z + \rho W S^{\rho} Z P^{PCP^{(-\rho-1)}}\right] \tag{A16}$$

$$P^{PCP^{-\rho-(-\rho-1)}} = -\frac{\rho}{1-\rho}\frac{E(WS^{\rho}\kappa)}{E(S^{\rho}\kappa)}$$

$$P^{PCP} = \frac{\rho}{\rho-1}\frac{E(WS^{\rho}\kappa)}{E(S^{\rho}\kappa)} \tag{A17}$$

If a firm sets its price according to LCP, then expected discounted profits are given by;

$$E\Pi^{LCP} = E\left[d(SP^{LCP}(i) - \mu)\left(\frac{P^{LCP}(i)}{P}\right)^{-\rho}\left(\frac{P}{P^*}\right)^{-\eta}D^*\right] \tag{A18}$$

$$E\Pi^{LCP} = E\left[dSP^{LCP}P^{LCP^{-\rho}}SP^{\rho}P^{-\eta}P^{*\eta}D^* - dWP^{LCP^{-\rho}}P^{\rho}P^{-\eta}P^{*\eta}D^*\right]$$

Use, as before, $\kappa = dP^{\rho-\eta}P^{*\eta}D^*$

$$E\Pi^{LCP} = E[S\kappa P^{LCP^{1-\rho}} - \mu\kappa P^{LCP^{-\rho}}] \tag{A19}$$

The first order condition for profit maximization is

$$\frac{\partial \Pi^{LCP}}{\partial P^{LCP}} = E\left[(1-\rho)P^{LCP^{(-\rho)}}S\kappa + \mu S\kappa\rho P^{PCP^{(-\rho-1)}}\right] \tag{A20}$$

$$P^{LCP^{-\rho-(-\rho-1)}} = -\frac{\rho}{1-\rho}\frac{E(\mu\kappa)}{E(S\kappa)}$$

$$P^{LCP} = \frac{\rho}{\rho - 1}\frac{E(\mu\kappa)}{E(S\kappa)} \tag{A21}$$

Using these solutions, the expressions for expected discounted profits are as follows.

For PCP,

$$E\Pi^{PCP} = E\left[d\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)} - \mu\right)\left(\frac{\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}}{SP}\right)^{-\rho}\left(\frac{P}{P^*}\right)^{-\eta}D^*\right] \tag{A22}$$

$$= E\left[d\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)} - \mu\right)\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\right)^{-\rho}S^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*}{}^{-}\right]$$

$$\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\right)^{-\rho}d\,S^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*} - d\mu\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\right)^{-\rho}S^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*}$$

$$\left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\right)^{1-\rho}E(S^{\rho}\kappa) - \left(\frac{\rho}{\rho-1}\frac{E(\mu S^{\rho}\kappa)}{E(S^{\rho}\kappa)}\right)^{-\rho}E(\mu S^{\rho}\kappa)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{\rho}{\rho-1}E(\mu S^{\rho}\kappa)^{1-\rho}E(S^{\rho}\kappa)^{\rho-1}E(S^{\rho}\kappa) - E(\mu S^{\rho}\kappa)^{-\rho}E(S^{\rho}\kappa)^{\rho}E(\mu S^{\rho}\kappa)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{\rho}{\rho-1}E(\mu S^{\rho}\kappa)^{1-\rho}E(S^{\rho}\kappa)^{\rho} - E(\mu S^{\rho}\kappa)^{1-\rho}E(S^{\rho}\kappa)^{\rho}\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(E(\mu S^{\rho}\kappa)^{1-\rho}E(S^{\rho}\kappa)^{\rho}\left(\frac{\rho}{\rho-1} - 1\right)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(E(\mu S^{\rho}\kappa)^{1-\rho}E(S^{\rho}\kappa)^{\rho}\left(\frac{1}{\rho-1}\right)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)[E(\mu S^{\rho}\kappa)]^{1-\rho}[E(S^{\rho}\kappa)]^{\rho}$$

If $\tilde{\rho}=\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)$ then,

$$E\Pi^{PCP}=\tilde{\rho}[E(\mu S^{\rho}\kappa)]^{1-\rho}[E(S^{\rho}\kappa)]^{\rho} \tag{A23}$$

For LCP,

$$E\Pi^{LCP}=E\left[d\left(S\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S\kappa)}-\kappa\right)\left(\frac{\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S\kappa)}}{P}\right)^{-\rho}\left(\frac{P}{P^{*}}\right)^{-\eta}D^{*}\right] \tag{A24}$$

$$=E\left[d\left(S\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S\kappa)}-\kappa\right)\left(\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S\kappa)}\right)^{-\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*}{}^{-}\right]$$

if $\tilde{\rho}=\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)$ then,

$$E\Pi^{LCP}=\tilde{\rho}[E(S\kappa)]^{\rho}[E(\kappa\mu)]^{1-\rho} \tag{A25}$$

A.3 Second-Order Approximations and Currency Choice When Only PCP and LCP are Options for the Exporting Firm

Recall the derived expressions for expected discounted profits under PCP and LCP,

$$E\Pi^{PCP} = \tilde{\rho}[E(\mu S^{\rho}\kappa)]^{1-\rho}[E(S^{\rho}\kappa)]^{\rho}$$

$$E\Pi^{LCP} = \tilde{\rho}[E(S\kappa)]^{\rho}[E(\kappa\mu)]^{1-\rho}$$

For PCP expected discounted profits can be written as:

$$\tilde{\rho}(Eexp(ln\kappa)\exp(\rho lnS))^{\rho}(Eexp(ln\kappa)\exp(\rho lnS)exp(ln\mu))^{1-\rho} \quad \text{(A26)}$$

Now use the second-order approximation,

$$(Eexp(ln\kappa)\exp(\rho lnS))$$

$$\approx \exp(Eln\kappa)\exp(\rho ElnS)$$

$$*\left(1+\frac{1}{2}var(ln\kappa)+\frac{\rho^2}{2}var(lnS)+\rho cov(ln\kappa,lnS\right)$$

$$\left(Eexp(ln\kappa)\exp(\rho lnS)\,exp(ln\mu)\right)$$

$$\approx \exp(Eln\kappa)\exp(\rho ElnS)\exp(Eln\mu)$$

$$*\left(1+\frac{1}{2}var(ln\kappa)+\frac{\rho^2}{2}var(lnS)+\frac{1}{2}var(ln\mu)+\rho cov(lnS,ln\kappa)\right.$$

$$\left.+\,cov(ln\kappa,ln\mu)+\rho cov(lnS,ln\mu)\right)$$

Using these two approximations, we can get an approximation for profits equal to

$$\tilde{\rho}(\exp(Elnκ)\exp(\rho ElnS))^{\rho} * \left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)+\rho cov(lnκ,lnS\right)^{\rho}$$
$$* (\exp(Elnκ)\exp(\rho ElnS)\exp(Elnμ))^{1-\rho}$$
$$* \left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)+\frac{1-\rho}{2}var(lnμ)+\rho cov(lnS,lnκ)\right.$$
$$\left.+cov(lnκ,lnμ)+\rho cov(lnS,lnμ)\right)^{1-\lambda}$$

If $\sum = \tilde{\rho}\exp(Elnκ)\exp(\rho ElnS)\exp((1-\rho)Elnμ)$, we can re-write the above equation as

$$\sum * \left(\left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)+\rho cov(lnκ,lnS\right)^{\rho}\left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)\right.\right.$$
$$\left.\left.+\frac{1}{2}var(lnμ)+\rho cov(lnS,lnZ)+cov(lnκ,lnμ)+\rho cov(lnS,lnμ)\right)^{1-\rho}\right)$$

Taking logs, we get expected discounted profits

$$ln\sum + lnρ+\frac{\rho}{2}var(lnκ)+\frac{\rho^3}{2}var((lnS)+\rho^2 cov(lnκ,lnS)+ln1-lnρ+\frac{1}{2}var(lnκ)$$
$$-\frac{\rho}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)-\frac{\rho^3}{2}var(lnS)+\frac{1-\rho}{2}var(lnμ)$$
$$+\rho cov(lnS,lnκ)-\rho^2 cov(lnκ,lnS)+(1-\rho)cov(lnκ,lnμ)+\rho(1$$
$$-\rho)cov(lnS,lnμ)$$

$$ln\sum + \left(\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS)+\frac{(1-\rho)}{2}var(lnμ)\right) \quad \text{(A27)}$$
$$+\rho cov(lnκ,lnS)$$
$$+\left(\rho(1-\rho)cov(lnμ,lnS)+(1-\rho)cov(lnκ,lnμ)\right)$$

For LCP expected discounted profits can be written as:

$$\tilde{\rho}(Eexp(ln\kappa)\exp(lnS))^{\rho}(Eexp(ln\kappa)exp(ln\mu))^{1-\rho} \tag{A28}$$

Now use the second-order approximation,

$$(Eexp(ln\kappa)\exp(lnS))$$

$$\approx \exp(Eln\kappa)\exp(ElnS) * \left(1+\frac{1}{2}var(ln\kappa)+\frac{1}{2}var(lnS)+cov(ln\kappa,lnS)\right)$$

$$\left(Eexp(ln\kappa)exp(ln\mu)\right)$$

$$\approx \exp(Eln\kappa)\exp(Eln\mu)$$

$$* \left(1+\frac{1}{2}var(ln\kappa)+\frac{1}{2}var(ln\mu)++cov(ln\kappa,ln\mu)\right)$$

Using these two approximations we can get an approximation for profits equal to

$$\tilde{\rho}(\exp(Eln\kappa)\exp(ElnS))^{\rho} * \left(1+\frac{1}{2}var(ln\kappa)+\frac{1}{2}var(lnS)+cov(ln\kappa,lnS)\right)^{\rho}$$

$$* (\exp(Eln\kappa)\exp(Eln\mu))^{1-\rho}$$

$$* \left(1+\frac{1}{2}var(ln\kappa)+\frac{1}{2}var(ln\mu)++cov(ln\kappa,ln\mu)\right)^{1-\rho}$$

If, again, $\sum = \tilde{\rho}\exp(Eln\kappa)\exp(\rho ElnS)\exp((1-\rho)Eln\mu)$, we can re-write the above equation as

$$\sum * \left(1 + \frac{1}{2} var(ln\kappa) + \frac{1}{2} var(lnS) + cov(ln\kappa, lnS)\right)^{\rho}$$

$$* \left(1 + \frac{1}{2} var(ln\kappa) + \frac{1}{2} var(ln\mu) + + cov(ln\kappa, ln\mu)\right)^{1-\rho}$$

Taking logs, we get expected discounted profit

$$ln \sum + ln\rho + \frac{\rho}{2} var(ln\kappa) + \frac{\rho}{2} var((lnS) + \rho cov(ln\kappa, lnS) + ln1 - ln\rho + \frac{1}{2} var(ln\kappa)$$

$$- \frac{\rho}{2} var(ln\kappa) + \frac{1-\rho}{2} var(ln\mu) + (1-\rho) cov(ln\kappa, ln\mu)$$

$$ln \sum + \left(\frac{1}{2} var(ln\kappa) + \frac{\rho}{2} var(lnS) + \frac{(1-\rho)}{2} var(ln\mu)\right) + \rho cov(ln\kappa, lnS) \quad \text{(A29)}$$

$$+ \left((1-\rho) cov(ln\kappa, ln\mu)\right)$$

Now comparing equations (A27) and (A29);

$$ln \sum + \left(\frac{1}{2} var(ln\kappa) + \frac{\rho^2}{2} var(lnS) + \frac{(1-\rho)}{2} var(ln\mu)\right) + \rho cov(ln\kappa, lnS)$$

$$+ (\rho(1-\rho) cov(ln\mu, lnS) + (1-\rho) cov(ln\kappa, ln\mu))$$

$$ln \sum - \left(\frac{1}{2} var(ln\kappa) - \frac{\rho}{2} var(lnS) - \frac{(1-\rho)}{2} var(ln\mu)\right) - \rho cov(ln\kappa, lnS)$$

$$- \left((1-\rho) cov(ln\kappa, ln\mu)\right)$$

$$\frac{\rho^2}{2} var(lnS) + \rho(1-\rho) cov(ln\mu, lnS) = \frac{\rho}{2} var(lnS)$$

$$\frac{\rho}{2} var(lnS) + (1-\rho) cov(ln\mu, lnS) = \frac{1}{2} var(lnS)$$

$$\frac{\rho}{2}var(lnS) - \rho cov(ln\mu, lnS) = \frac{1}{2}var(lnS) - cov(lnS, ln\mu) \tag{A30}$$

Our contribution consists in the re-definition of the cost index, H, hence marginal cost; then, replace μ by the term $\frac{H}{\Omega\tau^{\gamma}}$ as follows; $\mu = H\Omega^{-1}\tau^{-\gamma}$

$$ln\mu = lnH - ln\Omega - \gamma ln\tau$$

A.4 Invoicing Currency Choice When a Third Country's Currency (VCP) is an Option for the Exporting Firm

Firm i in a home country (A) sells a differentiated good to a foreign country (B), choosing a third country's (C) currency as an invoicing currency (in effect, VCP), that is neither the exporter's currency nor that of their customer.

If a firm follows VCP, then expected discounted profit as:

$$\mathrm{E}\Pi^{VCP} = \mathrm{E}\left[d(S_{AC}P^{VCP} - \mu)\left[\frac{P^{VCP}}{P}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta}D^*\right] \tag{A31}$$

$$E\Pi^{VCP} = E\left[dS_{AC}P^{VCP}P^{VCP^{-\rho}}P^{\rho}P^{-\eta}P^{*\eta}D^* - d\mu P^{VCP^{-\rho}}P^{\rho}P^{-\eta}P^{*\eta}D^*\right]$$

Call, again, $\kappa = dP_{AB}{}^{\rho-\eta}P^{*\eta}D^*$

$$E\Pi^{VCP} = E\left[S_{AC}\kappa P^{VCP}P^{VCP^{-\rho}} - \mu\kappa P^{VCP^{-\rho}}\right] \tag{A32}$$

The first order condition for profit maximization (now under VCP)

$$\frac{\partial \Pi^{VCP}}{\partial P^{VCP}} = E\left[(1-\rho)P^{VCP^{(-\rho)}} S_{AC}\kappa + \rho\mu\kappa P^{VCP^{(-\rho-1)}}\right] \tag{A33}$$

$$P^{VCP^{-\rho-(-\rho-1)}} = -\frac{\rho}{1-\rho}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}$$

$$P^{VCP} = \frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)} \tag{A34}$$

Expected discounted profits under PCP and LCP are, respectively, in the three-country model in this appendix section:

$$\mathrm{E}\Pi^{PCP} = \mathrm{E}\left[d(P^{PCP}-\mu)\left[\frac{P^{PCP}}{S_{AC}P}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta} D^*\right]$$

$$E\Pi^{LCP} = E\left[d(S_{AB}P^{LCP}-\mu)\left(\frac{P^{LCP}}{S_{BC}P}\right)^{-\rho}\left(\frac{P}{P^*}\right)^{-\eta} D^*\right]$$

$$E\Pi^{PCP} = E\left[dP^{PCP}P^{PCP^{-\rho}} S_{AC}^{\rho} P^{\rho} P^{-\eta} P^{*\eta} D^* - d\mu P^{PCP^{-\rho}} S_{AC}^{\rho} P^{\rho} P^{-\eta} P^{*\eta} D^*\right]$$

with $\kappa = dP^{\rho-\eta}P^{*\eta}D^*$, as before,

$$E\Pi^{PCP} = E\left[S_{AC}^{\rho}\kappa P^{PCP}P^{PCP^{-\rho}} - \mu S_{AC}^{\rho}\kappa P^{PCP^{-\rho}}\right] \tag{A35}$$

FOC:

$$\frac{\partial \Pi^{PCP}}{\partial P^{PCP}} = E\left[(1-\rho)P^{PCP^{(-\rho)}} S_{AC}^{\rho}\kappa + \rho\, P^{PCP^{(-\rho-1)}}\mu\, S_{AC}^{\rho}\kappa\right]$$

Optimal prices to maximize expected discounted profits under PCP are

$$P^{PCP} = \frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)} \tag{A36}$$

$$E\Pi^{LCP} = E\left[dS_{AB}P^{LCP}P^{LCP^{-\rho}}S_{AB}S_{BC}^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*} - d\mu P^{LCP^{-\rho}}S_{BC}^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*}\right]$$

$$E\Pi^{LCP} = E[S_{AB}\kappa P^{LCP^{1-\rho}} - \mu\kappa P^{LCP^{-\rho}}S_{BC}^{\rho}] \tag{A37}$$

FOC:

$$\frac{\partial\Pi^{LCP}}{\partial P^{LCP}} = E\left[(1-\rho)P^{LCP^{(-\rho)}}S_{AB}\kappa + \mu S_{BC}^{\rho}\kappa\rho P^{PCP^{(-\rho-1)}}\right]$$

Optimal prices to maximize expected discounted profits under LCP are

$$P^{LCP} = \frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)} \tag{A38}$$

Optimal prices to maximize the expected discounted profits under PCP, LCP and VCP are, respectively:

$$P^{PCP} = \frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}$$

$$P^{LCP} = \frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)}$$

$$P^{VCP} = \frac{\rho}{\rho - 1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}$$

Using these solutions, the expressions for expected discounted profits are,

for PCP,

$$E\Pi^{PCP} = E\left[d\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)} - \mu\right)\left(\frac{\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}}{S_{AC}^{\rho}P}\right)^{-\rho}\left(\frac{P}{P^*}\right)^{-\eta}D^*\right]$$

$$= E\left[d\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)} - \mu\right)\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\right)^{-\rho}S_{AC}^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^*\right]$$

$$\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\right)^{-\rho}dS_{AC}^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^* - d\mu\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\right)^{-\rho}S_{AC}^{\rho}P^{\rho}P^{-\eta}P^{*\eta}D^*$$

$$\left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\right)^{1-\rho}E(S_{AC}^{\rho}\kappa) - \left(\frac{\rho}{\rho-1}\frac{E(\mu S_{AC}^{\rho}\kappa)}{E(S_{AC}^{\rho}\kappa)}\right)^{-\rho}E(\mu S_{AC}^{\rho}\kappa)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{\rho}{\rho-1}E(\mu S_{AC}^{\rho}\kappa)^{1-\rho}E(S_{AC}^{\rho}\kappa)^{\rho-1}E(S_{AC}^{\rho}\kappa) - E(\mu S_{AC}^{\rho}\kappa)^{-\rho}E(S_{AC}^{\rho}\kappa)^{\rho}E(\mu S_{AC}^{\rho}\kappa)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{\rho}{\rho-1}E(\mu S_{AC}^{\rho}\kappa)^{1-\rho}E(S_{AC}^{\rho}\kappa)^{\rho} - E(\mu S_{AC}^{\rho}\kappa)^{1-\rho}E(S_{AC}^{\rho}\kappa)^{\rho}\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(E(\mu S_{AC}^{\rho}\kappa)^{1-\rho}E(S_{AC}^{\rho}\kappa)^{\rho}\left(\frac{\rho}{\rho-1}-1\right)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(E(\mu S_{AC}^{\rho}\kappa)^{1-\rho}E(S_{AC}^{\rho}\kappa)^{\rho}\left(\frac{1}{\rho-1}\right)\right)$$

$$\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)\left[E(\mu S_{AC}^{\rho}\kappa)\right]^{1-\rho}\left[E(S_{AC}^{\rho}\kappa)\right]^{\rho}$$

if $\tilde{\rho}=\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)$ then,

$$E\Pi^{PCP}=\tilde{\rho}\left[E(\mu S_{AC}^{\rho}\kappa)\right]^{1-\rho}\left[E(S_{AC}^{\rho}\kappa)\right]^{\rho} \tag{A39}$$

for LCP,

$$E\Pi^{LCP}=E\left[d\left(S\frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)}-\mu\right)\left(\frac{\frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)}}{P}\right)^{-\rho}\left(\frac{P}{P^{*}}\right)^{-\eta}D^{*}\right]$$

$$=E\left[d\left(S\frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)}-\mu\right)\left(\frac{\rho}{\rho-1}\frac{E(\mu\kappa S_{BC}^{\rho})}{E(S_{AC}S_{AC}^{\rho-1}\kappa)}\right)^{-\rho}P^{\rho}P^{-\eta}P^{*\eta}D^{*}\right]$$

if $\tilde{\rho}=\left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)$ then,

$$E\Pi^{LCP}=\tilde{\rho}\left[E(S_{AC}S_{BC}^{\rho-1}\kappa)\right]^{\rho}\left[E(\kappa\mu S_{BC}^{\rho})\right]^{1-\rho} \tag{A40}$$

for VCP,

$$\mathrm{E}\Pi^{VCP} = \mathrm{E}\left[d\left(S_{AC}\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}-\mu\right)\left[\frac{\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}}{P}\right]^{-\rho}\left[\frac{P}{P^*}\right]^{-\eta}D^*\right]$$

$$= E\left[d\left(S_{AC}\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}-\mu\right)\left(\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}\right)^{-\rho}P^{\rho}P^{-\eta}P^{*\eta}D^*\right]$$

$$S_{AC}\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}\left(\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}\right)^{-\rho}dP^{\rho}P^{-\eta}P^{*\eta}D^* - d\mu\left(\frac{\rho}{\rho-1}\frac{E(\mu\kappa)}{E(S_{AC}\kappa)}\right)^{-\rho}P^{\rho}P^{-\eta}P^{*\eta}D^*$$

if $\tilde{\rho} = \left(\frac{\rho}{\rho-1}\right)^{-\rho}\left(\frac{1}{\rho-1}\right)$ then,

$$E\Pi^{VCP} = \tilde{\rho}[E(S_{AC}\kappa)]^{\rho}[E(\kappa\mu)]^{1-\rho} \qquad \text{(A41)}$$

A.5 Second-Order Approximations for PCP When VCP Is Also an Option in Invoicing

Recall equations (A39), (A40) and (A41).

For PCP, equation (A39) can be written as:

$$\tilde{\rho}(Eexp(ln\kappa)\exp(\rho lnS_{AC}))^{\rho}(Eexp(ln\kappa)\exp(\rho lnS_{AC})exp(ln\mu))^{1-\rho}$$

Now use the second order approximation,

$$(Eexp(ln\kappa)\exp(\rho lnS_{AC}))^{\rho} \approx \exp(Eln\kappa)\exp(\rho ElnS)^{\rho} * \left(1+\frac{1}{2}var(ln\kappa)+\frac{\rho^2}{2}var(lnS_{AC})+\rho cov(ln\kappa, lnS\right)^{\rho}$$

$$\left(Eexp(ln\kappa)\exp(\rho lnS_{AC})\,exp(ln\mu)\right)^{1-\rho}$$

$$\approx \exp(Eln\kappa)\exp(\rho ElnS)\exp(Eln\mu)$$

$$*\left(1+\frac{1}{2}var(ln\kappa)+\frac{\rho^2}{2}var(lnS_{AC})+\frac{1}{2}var(ln\mu)+\rho cov(lnS_{AC}, ln\kappa)+cov(ln\kappa, ln\mu)+\rho cov(lnS_{AC}, ln\mu)\right)^{1-\rho}$$

Using these two approximations we can get an approximation for profits equal to

$$\tilde{\rho}(\exp(Elnκ)\exp(\rho ElnS_{AC}))^{\rho} * \left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS_{AC})+\rho cov(lnκ,lnS_{AC}\right)^{\rho}$$

$$* (\exp(Elnκ)\exp(\rho ElnS_{AC})\exp(Elnμ))^{1-\rho}$$

$$* \left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS_{AC})+\frac{1}{2}var(lnμ)+\rho cov(lnS_{AC},lnκ)\right.$$

$$\left.+cov(lnκ,lnμ)+\rho cov(lnS_{AC},lnμ)\right)^{1-\lambda}$$

If, as before, $\sum = \tilde{\rho}\exp(Elnκ)\exp(\rho ElnS)\exp($ $(1-\rho)Elnμ$, we can re-write the above equation as,

$$\sum * \left(\left(1+\frac{1}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS_{AC})+\rho cov(lnκ,lnS_{AC})\right)^{\rho}\left(1+\frac{1}{2}var(lnκ)\right.\right.$$

$$+\frac{\rho^2}{2}var(lnS_{AC})+\frac{1}{2}var(lnμ)+\rho cov(lnS_{AC},lnZ)+cov(lnκ,lnμ)$$

$$\left.\left.+\rho cov(lnS_{AC},lnμ)\right)^{1-\rho}\right)$$

Taking logs, we get expected discounted profits for PCP

$$ln\sum +lnρ+\frac{\rho}{2}var(lnκ)+\frac{\rho^3}{2}var((lnS_{AC})+\rho^2 cov(lnκ,lnS_{AC})+ln1-lnρ$$

$$+\frac{1}{2}var(lnκ)-\frac{\rho}{2}var(lnκ)+\frac{\rho^2}{2}var(lnS_{AC})-\frac{\rho^3}{2}var(lnS_{AC})$$

$$+\frac{1-\rho}{2}var(lnμ)+\rho cov(lnS_{AC},lnκ)-\rho^2 cov(lnκ,lnS_{AC})+(1$$

$$-\rho)cov(lnκ,lnμ)+\rho(1-\rho)cov(lnS_{AC},lnμ)$$

$$E\Pi^{PCP} \approx ln\sum + \left(\frac{1}{2}var(ln\kappa) + \frac{\rho^2}{2}var(lnS_{AC}) + \frac{(1-\rho)}{2}var(ln\mu)\right) + \rho cov(ln\kappa, lnS_{AC}) + \left(\rho(1-\rho)cov(ln\mu, lnS_{AC}) + (1-\rho)cov(ln\kappa, ln\mu)\right) \quad \text{(A42)}$$

For LCP, we follow the second-order approximation for equation (A40) and then, taking logs, we get the following;

$$E\Pi^{LCP} \approx \ln\Sigma + \frac{1}{2}var\,(\ln\kappa) + \frac{1-\rho}{2}\,var\,(\ln\mu) + \frac{\rho}{2}\,var\ln(S_{BC}) + \frac{\rho(1-\rho)}{2}\,\mathrm{var}\,(\ln S_{BC}) + [\,\rho\,\mathrm{cov}\,(\ln\kappa\,,\ln S_{AC}) + (1-\rho)\,cov\,(\ln\mu\,,\ln\kappa) + \rho(1-\rho)\,cov(\ln S_{BC}, \ln\mu\,, -\rho(1-\rho)cov\,(\ln S_{AC}, \ln S_{BC})\,] \quad \text{(A43)}$$

For VCP, and by analogy in the approximation steps as above for PCP and LCP, from equation (A41) we get the following;

$$E\Pi^{VCP} \approx \ln\Sigma + \frac{1}{2}var\,(\ln\kappa) + \frac{1-\rho}{2}\,var\,(\ln\mu) + \frac{\rho}{2}\,var\ln(S_{AC}) + [\,\rho\,\mathrm{cov}\,(\ln\kappa\,,\ln S_{AC}) + (1-\rho)\,cov\,(\ln\mu\,,\ln\kappa)] \quad \text{(A44)}$$

Then comparing equations (A44) with (A42) and (A43) (i.e., comparing expected profits under VCP versus PCP and LCP), we establish the respective decision rules in equations (16), (17), and (18) in the main text, to analyse which pricing strategy is more preferable for an exporting firm in this extended three-country framework allowing for VCP.

Chapter 3: The Determinants of Invoicing Currency Choice for Turkish Exporters

Abstract

At the background of the empirical implications of the theoretical framework in the preceding chapter, this chapter investigates the determinants of invoicing currency choice for Turkish firms. Although the invoicing currency choice is central for the transmission of monetary policy, empirical research on this topic is scarce due to the limited availability of data. With a new micro-level invoicing currency dataset on Turkish trade, this chapter mainly analyses the determinants of invoicing practices for Turkish exporters. Our main contributions to the international trade literature cover two principal aspects, which were the main ingredients and contributions in the theoretical chapter: (i) to show the role of imported inputs in global transactions and the choice of currency invoicing for a developing small open economy; (ii) to emphasize the role of physical capital in the production function in the choice of invoicing currency. We fill in these gaps in the literature studying a highly disaggregated firm-level dataset for Turkish firms, which have a large number of trading partners. Our main findings, in line with the underlying theoretical framework in chapter 2, reveal that a higher capital-labour ratio leads to an increase in the choice of 'producer currency pricing' relative to the alternatives of 'local currency pricing' and 'vehicle currency pricing' for Turkish firms. We also discuss the key possible explanations for this result.

JEL Classification: F1, F31, F41

Keywords: currency invoicing, vehicle currency, intermediate inputs, two-factor production function, international trade, Turkish exporters

3.1 Introduction

Invoicing currency choice is one of the important issues in open economy macroeconomics, especially with regard to international spillovers of monetary policy[19], effects on the balance of payments and international trade competitiveness. When firms sell their goods to a foreign market, exporting firms have three options to set their prices. Exporter firms prefer to set their prices either in their own currency (producer's currency pricing, PCP) or in the currency of the importer (local currency pricing, LCP), or in a third currency, which is neither domestic nor the destination country currency (vehicle currency pricing, VCP). In this chapter, using a detailed micro-level data for Turkish exporters, we analyse the determinants of invoicing currency choice for Turkish firms and investigate invoicing currency choice patterns.

While traditional macroeconomics[20] assumed that the price of exports is set in the currency of the exporter (PCP), so that exchange rate fluctuations lead to expenditure switching away from the appreciating currency's goods, the new open economy macroeconomics (NOEM) literature allows for the possibility of pricing to market, where prices are set in the local currency and do not fluctuate with the exchange rate.[21] It is also considered that low transaction costs have an important role that leads firms to invoice in vehicle currency.[22]

Because of scarce firm level data related to their pricing strategies the literature has many theoretical determinants of invoicing currency choice but limited empirical results. We

[19] Invoicing currency choice directly affects how domestic prices react to exchange rate volatility in the presence of price stickiness. The degree of exchange rate pass-through is clearly related to invoicing currency choice: see, e.g., Engel (2006), Goldberg and Tille (2008) and Gopinath, Itshoki and Rigobon (2010). Ignoring invoicing currency choice might be misleading when trying to explain the effects of changes in the exchange rate on domestic prices, so monetary policymakers should take it into account (Chen *et al.*, 2019).

[20] See Mundell (1963), Fleming (1962) and Obstfeld and Rogoff (1995): this early literature just assumed that exporters prefer to price in their own currency (PCP); with PCP, the law of one price holds.

[21] Betts and Devereux (1996, 2000) were among the first to include pricing to market into a NOEM model.

[22] Swoboda (1968, 1969) points out to the role of transaction cost related to the currency liquidity feature of international financial markets and emphasizes that currency use as a vehicle due to lower transaction cost. Krugman (1980) focuses the role of vehicle currency in international trade.

could divide empirical studies into three different categories: firstly, empirical analysis using cross-country[23] aggregate data; secondly, empirics using survey analysis[24]; and, thirdly, empirics relying on firm-level transactions[25] data obtained through the national statistical institute or customs.

In line with the previous chapter, the main contribution of this empirical study consists in testing the determinants of invoicing currency choice, adding the role of capital share in production for the exporter firms which use imported intermediate inputs in their production process. To do this, we employ a multinomial logit (MNL) model for Turkish firms using a rich dataset of Turkish exporters with 3.081.430 transactions in 2013[26]. Our model allows us to examine the issue under three subparts, namely: i) to test firm characteristics in preference on currency invoicing; ii) to study macroeconomic factors in invoicing currency choice; and iii) to highlight industry characteristics in the choice of currency of invoicing.

According to firm characteristics, our results reveal that firms prefer to follow PCP if exporter firms: i) use imported intermediate goods in production; ii) have a higher relative size in terms of the market share of exports; and iii) have higher experience in the-exporting in the sector. On the other hands, firms with i) a higher imported input denominated in the origin country currency, ii) an increasing number of the imported inputs denominated in the destination country currency, iii) a higher capital share, and iv) a greater transaction size show a decreasing preference of PCP in favour of LCP or VCP. In addition to these results, macroeconomic determinants in invoicing currency reveal that if the volatility of the euro increases, Turkish exporting firms prefer PCP, while the volatility of the US dollar decreases preferences of PCP versus LCP or VCP. As a macroeconomic determinant, exchange rate pegs do not give statistically significant results in comparison of LCP and PCP, but give statistically

[23] See, e.g., Goldberg and Tille (2008) and Kamps (2006).
[24] See, e.g., Friberg and Wilander (2008), Ito *et al.* (2010), Witte and Ventura (2016).
[25] See, e.g., Donnenfeld and Haug (2003), Goldberg and Tille (2016), Chung (2016).
[26] The most recent available data in our analysis are sourced from the Turkish Statistical Institute (TUIK).

significant results for PCP versus VCP. Euro pegs increase the usage of PCP in exports, while dollar pegs increase the usage of VCP. As a final macroeconomic determinant, transaction cost increases preference for PCP versus LCP, but decreases preference for PCP versus VCP. Our final distinction category is based on industry characteristics. We specifically consider two features of the industry, market competition and substitutability of goods. Although our results do not yield a statistically significant coefficient for the substitutability of goods, we find statistically significant results for the market competition, which show that if local competition increases, firms prefer PCP versus alternative pricing strategies.

Our paper relates to similar work by Chung (2016), who also emphasizes the role of intermediate inputs in the determinants of invoicing currency choice. However, we use a more general production function, as derived and discussed in the previous chapter. Therefore, we also could empirically check the role of the capital share in the production technology in our framework. Additionally, Chung (2016) examines the issue for a developed country, UK, which has a more stable monetary policy and a less volatile currency. By contrast, we test this issue from a developing country perspective, Turkey, which has a relatively unstable monetary policy with a high inflation environment and highly volatile currency in international money markets. Therefore, our paper also shows the main differences between exporter pricing practices for a firm which operates in a developed economy versus a developing country. To the best of our knowledge, this is the first paper that i) includes the effect of both imported inputs and the capital share in production together and ii) tests the determinants of currency invoicing in a developing country.

The rest of the paper is organized as follows: Section 3.2 literature presents a review of empirical studies on the invoicing currency choice. Section 3.3 introduces our dataset and its descriptive statistics. Section 3.4 specifies our empirical model. Section 3.5 reports our main findings from the Multinomial Logit regressions and, finally, section 3.6 concludes.

3.2 Literature Review of Empirical Studies

The determinants of currency invoicing are the object of a growing literature. In this section, we give a brief review of the main insights from empirical studies, as a background for our subsequent analysis of Turkish international trade data[27].

Invoicing currency choice practices have a significant effect on how macroeconomic shocks are transmitted among countries. Whereas this literature devotes a lot of attention in terms of theoretical perspectives, there is only a limited empirical analysis thus far. Specifically, detailed datasets on the invoicing currency choice at the firm/product level and by destination country are rarely disclosed.

The scarce empirical literature on the invoicing currency choice could be divided into three groups: i) cross-country analysis; ii) survey-based analysis; and iii) studies relying on firm/transaction-level data.

3.2.1 Cross Country Analysis

Goldberg and Tille (2008) analyse the determinants of invoicing currency choice for 24 countries with the collection of aggregate data on the share of invoicing currency choice. Industry characteristics, country size, and transaction costs are the key determinants of invoicing currency choice. Industry characteristics include price sensitivity of demand and economies of scale. To prevent firms from fluctuations in their relative prices, Goldberg and Tille (2008) highlighted the importance of following a similar pricing strategy - as a 'coalescing' effect - within firms in the sector. The coalescing effect is seen mostly in industries

[27] All the analysis in this chapter has been conducted at the Turkish Statistical Institute (TUIK) under a confidentiality agreement. The author is grateful to the Turkish Statistical Institute for granting access to their "A-Group Micro Data", which allowed us to implement the methodology of analysis outlined in this thesis.

where the substitution effect is high. They reveal that when firms do not have enough price setting power vehicle currency pricing (VCP) is widely used, specifically in the US dollar.

Kamps (2006) focuses on the role of the Euro, using an unbalanced panel dataset with 42 countries. She documented that the US dollar is the dominant currency in world trade, whereas the share of the Euro invoicing is increasing overtime. In the dataset, PCP, LCP and VCP strategies are not directly separated, therefore Kamps's (2006) analysis is primarily a comparison on the determinants of US dollar and Euro invoicing practices. Kamps (2016) finds vague evidence on the role of exchange rate risk as a driving force of invoicing currency choice. This is maybe because her dataset is at the aggregate level and does not provide a distinction between PCP, LCP and VCP. Only for the Euro invoicing estimation, a higher exchange rate risk is found to lead to invoicing in the Euro.

3.2.2 Survey Analysis

Friberg and Wilander (2008) made a survey with Swedish[28] exporting firms and analysed the determinants of invoicing currency choice. LCP is the dominant invoicing currency among Swedish exporting firms, especially, if the export market is large and the volume of trade is high. Their results show that the invoicing currency to a significant extent is determined in negotiations. These findings are mostly in line with the theoretical determinants; however, they find that transaction costs are not considered to play a significant role.

Ito *et al.* (2010) use survey data related to the Japanese firms[29] invoicing decision and find that when Japanese firms export to the developed countries, they prefer LCP. However, if Japanese firms export highly differentiated goods, they prefer PCP, even if their trade partners

[28] Grassman (1973) also made an empirical contribution in invoicing literature based on Swedish trade. His main finding is that trade in manufacturing goods between developed countries is denominated in PCP, which is known as "Grassman's Law".
[29] Ito *et al.* (2010) interview 23 Japanese firms in the automobile, electrical machinery, general machinery, and electrical component industries in order to get information related to their invoicing currency choice and their exchange rate risk management.

are in developed countries. Also, Ito *et al.* (2010) reveal that Japanese firms tend to use the US dollar as an invoicing currency in the exports to Asia. They conclude that the firms' characteristics play a significant role in invoicing decisions.

Witte and Ventura (2016) examine the invoicing currency choice of Italian external EU export and import transactions during 2010, using survey data. Their main contribution is the role of geography and of tax treaties in invoicing currency choice. If an exporter and importer are in the vicinity, they are more likely to invoice LCP or PCP than using the vehicle currency in their transactions. They find that when there is a tax treaty with Italy and its trading partner, vehicle currency is less preferred. Tax treaties lead to increased information sharing between trading partners and give rise to invoicing in LCP or PCP. Their studies do not include firm-level data so that they could not identify the firm-specific effects on invoicing currency decision.[30]

3.2.3 Firm-Level / Transaction-Level Analysis

Donnenfeld and Haug (2003) test the optimal invoicing currency choice for imports into Canada covering the period from 1989 to 1994. Their empirical results show that if the exchange rate risk increases, LCP is more preferred than PCP and VCP. Also, they find that the relative size of a country (size of GNP) has a role in the currency denomination of trade.

Goldberg and Tille (2016), using highly disaggregated data on Canadian import transactions between 2002 and 2009, analyse the determinants of invoicing currency choice. Their data[31] is very rich in terms of the information on the origin country, invoice currency and value of transactions, quantity, industry code, but does not include identifiers for firms. They analyse the determinants in three categories; macro-level determinants, micro-level

[30] Novy (2006) considers how exchange rate risk of a firm's cost structure may have an effect on the currency invoicing decision.
[31] Data is collected by the Canada Border Services Agency.

determinants and transaction-level determinants. The exchange rate has a significant role as a macro-level determinant in terms of exchange rate volatility, exchange rate regime and currency transaction volume. In Canadian import transactions, vehicle currency invoicing is the dominant invoicing practice.

Chung (2016) examines the determinants of invoicing currency choice using UK trade transaction data[32] with non-EU countries. She is specifically interested in the effects of imported inputs on the invoicing currency choice decisions. The author finds that the probability of UK exporters to prefer an invoicing practice in PCP (in GBP) increases by about 18% when there is a 1% increase in the share of imported input priced in LCP (in GBP). So, exchange rate risk via input currency denomination affects firms invoicing currency choice. Besides, she reports that firms are more likely follow PCP for differentiated goods, while firms tend to follow LCP for homogenous goods.

3.3 Dataset and Descriptive Statistics

In this section, we start by giving stylised facts and trends in Turkish international trade. Then, we describe our unique confidential dataset[33] that we used in the empirical analysis.

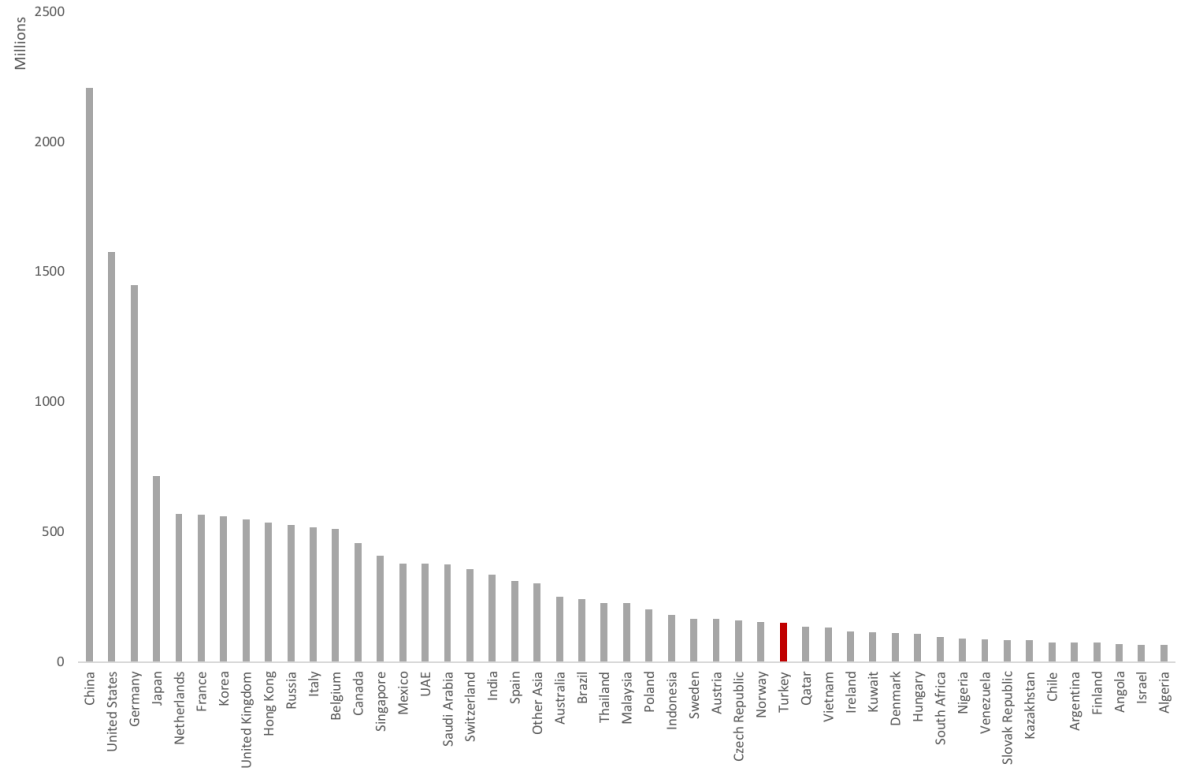
Stylized facts of our Turkish trade dataset can be expressed by the importance of Turkey in global exports, the trade partners of Turkey in terms of exporting and importing, the change in the number of Turkish firms in international trade over the years, the import content of exports for Turkish firms, and the evolution of currency shares in Turkish exports.

Figure 1 presents the rank of Turkish exports in global trade. Turkey is listed as the 32nd exporting country in 2013, and its position has increased since then. There has been a

[32] This highly disaggregated dataset is obtained from Her Majesty's Revenue and Customs (HMRC), and contains invoicing currency, firm identity, country of origin/destination, product and industry codes, trade volume and value for each transaction. Access to this dataset from HMRC is only available to approved projects. Recording invoicing currency became a requirement after 2010 for non-EU imports.

[33] All the analysis for this paper has been conducted at TUIK under a confidentiality agreement. The results and opinions shown here are the responsibility of the author and do not necessarily reflect the views of any agency.

Figure 1: List of Countries by Export, 2013



Source: United Nations International Trade Statistics Database (UN Comtrade) and author's calculation.

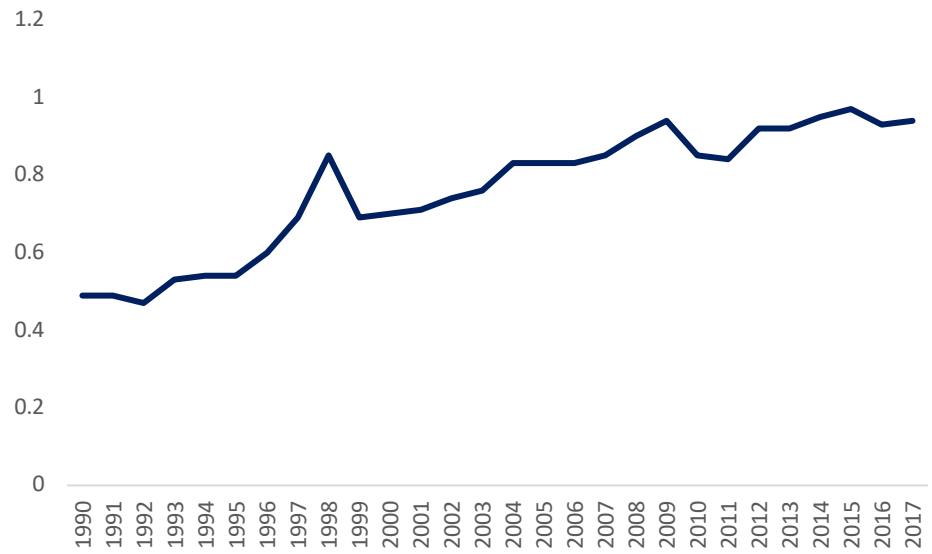
substantial increase in the export share of Turkey from 1990 to 2017 because of trade liberalization policies in this period. This movement could be seen in Figure 2.

The Turkish trade dataset employed here allows us to study a wide range of trading partners. Turkish firms have transactions with around 220 trading partners[34] for both importing and exporting firms in each year from 2000 to 2015. Figure 3 shows the top trade partners of Turkish firms in exporting and importing in 2013[35]. It can be clearly seen that Germany is the top trade partner of Turkey in exporting, and third in importing. Germany is followed by the United Kingdom, Iraq, Italy, the US and France in exporting. However, Turkish top one and two trade partners in imports are Russia and China, respectively. Besides these countries,

[34]Source: Turkish Statistical Institute, *Exports and imports by country (online*), and author's calculations.
[35]This pattern is more or less similar in the following years.

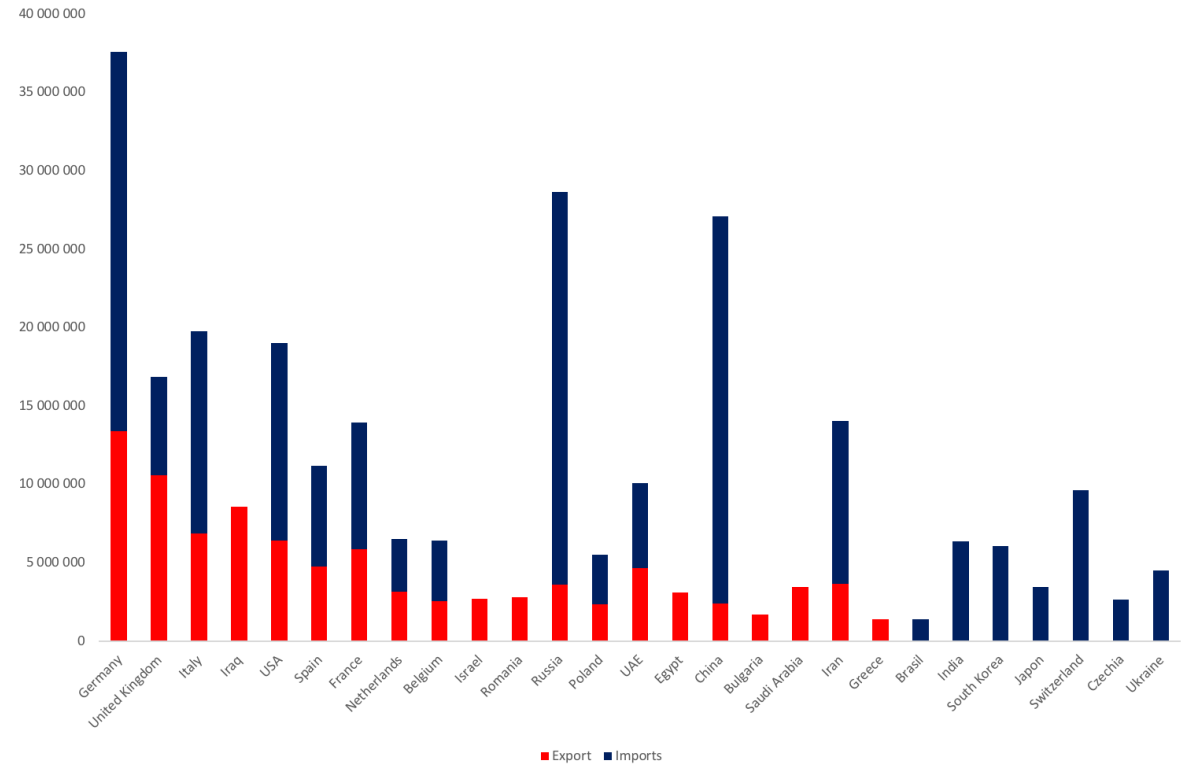
Spain, the Netherlands, Belgium, Poland, the United Arab Emirates, and Iran play important roles in Turkish bilateral trade. On the other hand, Israel, Romania, Egypt, Bulgaria, Saudi Arabia and Greece have a relatively important position in exporting, while Brasil, India, South Korea, Japan, Switzerland, Czechia, and Ukraine have importance in importing.

Figure 2: Turkey's Export Share in World Export (in %)



Source: United Nations International Trade Statistics Database (UN Comtrade) and author's calculation.

Figure 3: Top Countries in Turkish exports and imports (value: thousand US dollars),2013



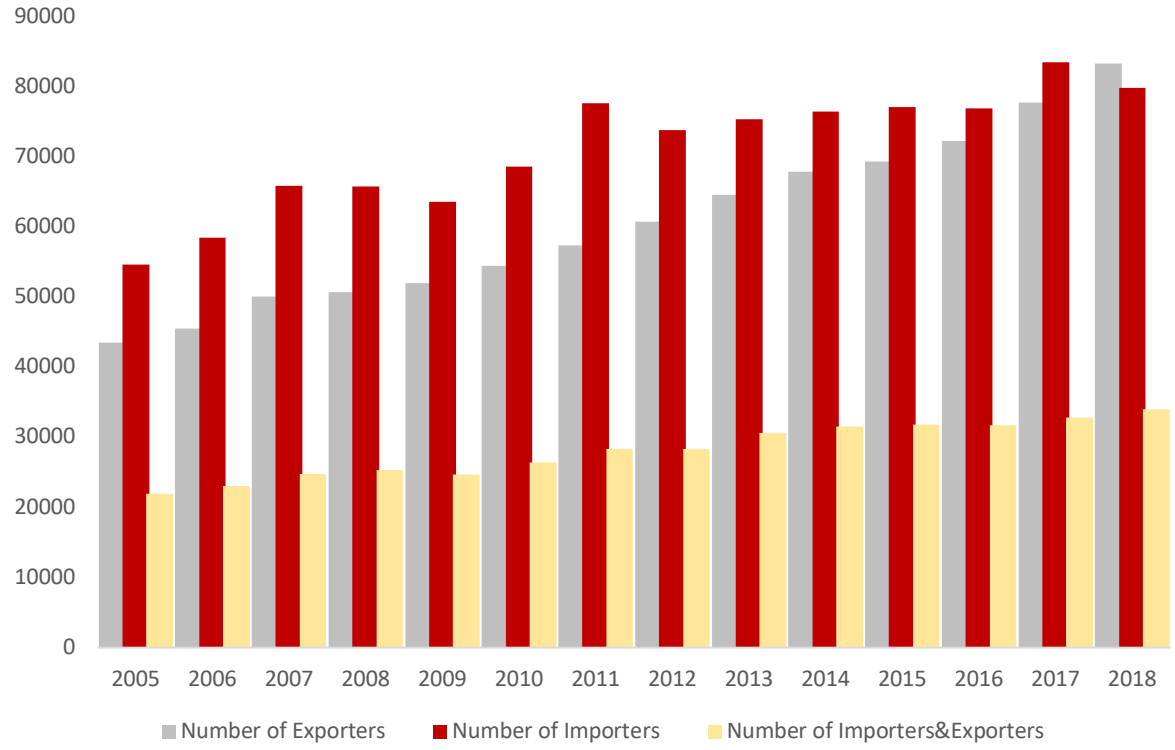
Source: Turkish Statistical Institute and author's calculation.

The increasing number of Turkish firms is also evidence of the rising role of Turkey in international trade. Figure 4 presents the changes in the number of firms in only exporting, only importing and both exporting and importing. It can be seen that the number of Turkish exporter firms has almost doubled from 2005 to 2018. Though, not as much as exporter firms, an increasing trend can be also observed by importing firms and firms doing both exports and imports.

Together with an increasing number of Turkish firms in international trade, there is an increasing trend in the import content of exports as well. Figure 5 shows a comparison of the import content of exports between Turkey and developed countries such as the US, Germany, and UK. In the mid-1990s, Turkey's import content of exports was far behind such developed

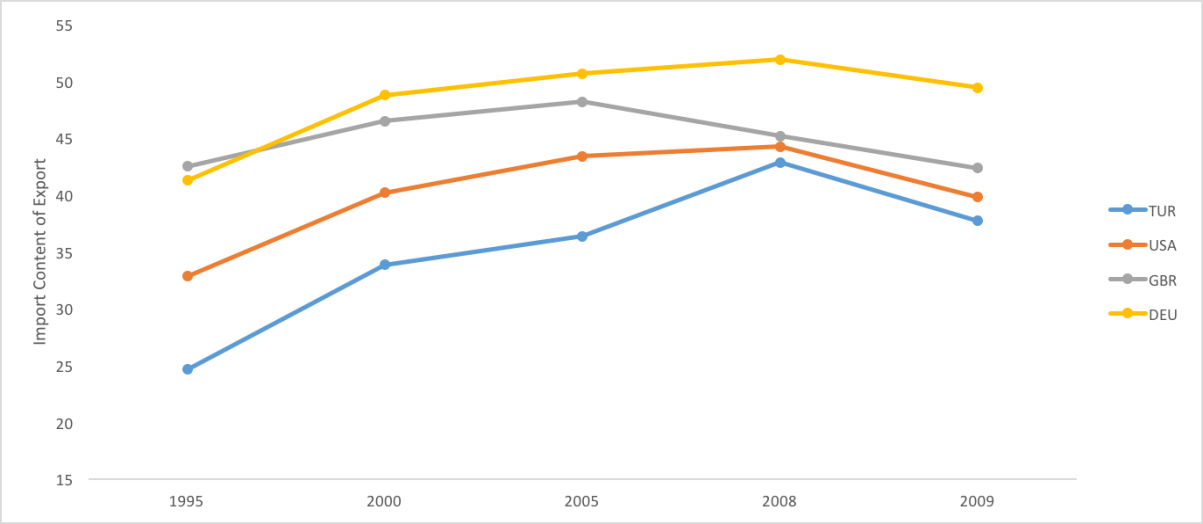
economies. However, with an increasing trade openness throughout the period, this ratio for Turkey converges to its developed counterparts.

Figure 4: Number of Firms in Export and Import



Source: Turkish Statistical Institute and author's calculation.

Figure 5: Import Content of Exports for Turkish Firms



Source: Turkish Statistical Institute and author's calculation.

Figure 6 illustrates the evolution of the currency share of exports for Turkish firms between 1996 and 2016. It can clearly be seen that the US dollar[36] is the dominant invoicing currency over the period. After the Euro was introduced, it became the second dominant invoicing currency for Turkish exports. The British pound also shows a relatively high weight in the currency decomposition of Turkish exports, comparatively to the rest of the currencies. Before the introduction of the Euro, the French franc and the German mark were considerably important in this decomposition.

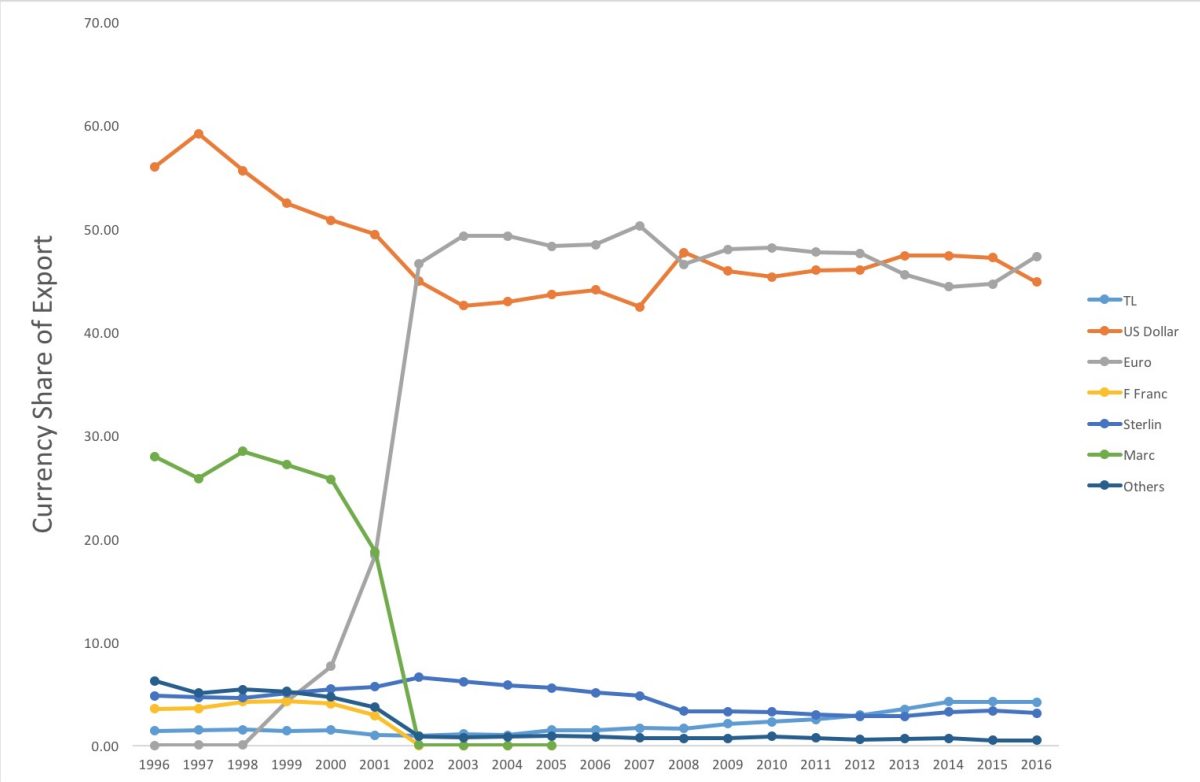
In order to compare our empirical results and measure the effectiveness of our contribution, namely the 'capital/labour' ratio and intermediate goods, we follow Chung's (2016) paper in terms of methodology related to definitions and descriptions of variables. Hence, our dataset includes the firm ID, the country of shipping for imports and/or destination

[36] See Gopinath (2015) for the discussion on dominant currency pricing for the US dollar.

country for exports, product codes, industry codes, the value of transactions, and the invoicing currency.

Table 1 shows the currency choice of Turkish firms in foreign trade. Although there are more than 200 trade partners of Turkish firms, there are just 20 currencies which were used as

Figure 6: Invoicing Currency Share of Exports for Turkish Firms



Source: Turkish Statistical Institute and author's calculation.

invoicing currencies in 2013. Furthermore, only three foreign currencies exceed 1% of total transactions. The highest one is the US dollar, which accounts for 47.51% of international transactions. As a choice of currency invoicing, the Euro follows the USD for Turkish firms. It stands for 42.86% of transactions in 2013. As a foreign currency, the GBP is the third biggest currency in international trade for Turkish firms. Yet, the British pound represents only 1.76% of all transactions for Turkish exporters and importers. A large number of different foreign currencies in the trading might be an indication of a high preference of LCP or VCP for Turkish firms, since the Turkish lira only characterizes 7.46% of the transactions in 2013. Therefore, we note the low degree of PCP usage for Turkish firms in invoicing in the dataset.

Table 1: Currency Choice for Turkish Firm in 2013

Currency	Frequency	Percent	Cumulative
GBP	55917	1.76	1.76
Iran Riyal	1	0.00	1.76
Sweden Krone	2184	0.07	1.83
Swiss Franc	2601	0.08	1.91
US Dollar	1510527	47.51	49.42
Euro	1362652	42.86	92.28
Australia Dollar	1822	0.06	92.33
UEA Dirham	2	0.00	92.33
Leva (Bulgaria)	33	0.00	92.33
Denmark Krone	409	0.01	92.35
South Africa Rand?	18	0.00	92.35
Japanese Yen	442	0.01	92.36
Canadian Dollar	843	0.03	92.39
Norway Krone	690	0.02	92.41
Polish Zloty	368	0.01	92.42
Romania Levi	12	0.00	92.42
Russian Rubble	2531	0.08	92.50
Saudi Arabia Riyal	52	0.00	92.50
Turkish Lira	238054	7.49	99.99
Czech Koruna	298	0.01	100
Total	**3179457**	**100**	

Source: Turkish Statistical Institute and author's calculation.

Table 2 also supports a low level of PCP usage for Turkish exporters and shows that VCP is used in more than half of the transactions for the Turkish firms[37]. Approximately 54% of transactions (in value) are made by using VCP practices. LCP practice is also greater than PCP for Turkish firms, which is around 27% and 18%, respectively.

Table 2: Invoicing Currency Strategy in 2013

Share of Pricing Strategy (in value in %)	
Producer Currency Pricing (PCP)	18
Local Currency Pricing (LCP)	27
Vehicle Currency Pricing (VCP	54

Source: Turkish Statistical Institute and author's calculation.

Table 3 presents the distribution of the shares of invoicing currency for Turkish firms by industry, destination and category of exporting and importing goods in 2013. According to the one-digit SITC industry classification VCP is the dominant strategy for Turkish exporters. The only exception is manufactured goods in exports, since LCP is a significantly greater choice of currency in invoicing. In imports, we can uncover a similar pattern, but PCP usage is also increasing. PCP particularly exceeds VCP in the chemicals sector, and slightly higher in manufactured goods in imports[38].

According to the destination of shipping in exports (middle panel in Table 3), Turkish firms choose LCP versus PCP and VCP for the Euro-area (in fact, EU-28) and the US market, whereas VCP has a substantially higher preference for the rest of Europe, China and the rest of the world. In imports, PCP is the preferable pricing strategy in EU-28 and the US. However,

[37] According to Chung (2016), the share of PCP as a pricing strategy covers almost 60% of transactions for the UK firms. This indicates a crucial difference in the invoicing practices between developing and developed countries' firms.
[38] PCP also exceeds VCP in miscellaneous goods.

VCP is a superior pricing strategy between Turkish importers and international firms for the rest of the world. An interesting fact is that there is also an extremely low interest in the choice of the Turkish lira as a currency of invoicing in exporting and importing. This again shows another difference across countries with less volatile versus highly volatile domestic currencies. Using a developed country dataset, Chung (2016) shows that UK firms choose PCP versus alternatives for particular destinations such as the US in exporting and importing; and China, East Asia, rest of Europe and rest of the world only in exporting. However, we cannot see a similar pattern in invoicing for Turkish firms as a developing country case in our dataset, which is another novel finding and contribution to the literature.

The bottom panel of table 3 shows the decomposition of goods using the Broad Economic Categories (BEC) classification. According to the BEC classification, we can decompose goods into final, intermediate, and capital goods. VCP is a highly used pricing strategy for Turkish exporters in all categories of goods. 75% of final goods, 76% of intermediate goods and 66% of capital goods is represented by VCP. Similar to Turkish exporters, Turkish importers mostly choose VCP as a pricing strategy for final goods (52%) and capital goods (56%). However, they use slightly higher PCP (foreign currency) for intermediate goods in importing, representing 49% of importing intermediate goods, while the share of VCP is approximately 48%.

Table 3: Pricing Strategy (%) by Industry, Destination and Classification

	Exports			Imports		
1-Digit SITC Industry	**PCP(TL)**	**LCP**	**VCP**	**LCP(TL)**	**PCP**	**VCP**
0: Food& live animals	3.13	27.17	69.70	2.89	44.46	52.64
1: Beverages & tobacco	3.52	34.41	62.07	3.04	40.79	56.17
2: Crude materials	5.02	23.02	71.96	1.14	35.81	63.05
3: Mineral fuels	5.10	9.83	85.07	2.97	38.73	58.29
4: Animal &veg. oils	2.11	16.54	81.35	1.18	28.89	69.94
5: Chemicals	6.08	14.34	79.58	4.02	55.79	40.19
6: Manufactured goods	16.41	73.78	9.80	2.93	48.86	48.22
7: Machinery	4.39	22.73	72.88	3.81	44.60	51.59
8: Miscellaneous	4.86	29.80	65.35	20.96	69.01	10.02
9:Not classified	18.24	17.20	64.56	10.57	29.94	59.48
Destination Region/Country	**PCP(TL)**	**LCP**	**VCP**	**LCP(TL)**	**PCP**	**VCP**
EU28	2.26	58.93	38.81	5.07	74.50	20.43
Other EU	5.27	4.68	90.05	4.80	20.07	75.14
US	2.32	81.77	15.91	4.49	63.87	31.64
China	3.04	0.00	96.96	4.74	0.06	95.21
Others	6.96	6.63	86.42	6.73	4.42	88.85
The BEC Category	**PCP(TL)**	**LCP**	**VCP**	**LCP(TL)**	**PCP**	**VCP**
Final Goods	6.35	18.29	75.37	3.95	44.37	51.68
Intermediate Goods	0.35	23.65	76.00	3.09	49.22	47.69
Capital Goods	5.01	29.06	65.93	13.79	30.62	55.59

Source: Turkish Statistical Institute and author's calculation.

3.4 Empirical Model

Our theoretical model in chapter 2 is based on an optimal pricing strategy for an exporting firm, which aims to maximize its profit from international transactions. Since there is no order dependency and there are three mutually exclusive pricing alternatives (as categorical dependent variables) in the theory, the MNL model is a widely used[39] approach in the empirical analysis of invoicing currency.

To estimate the pricing strategy for Turkish exporting firms, we set dummy dependent variables (PCP, LCP and VCP) as in Chung (2016). Therefore, we employ a multinomial logit (MNL) regression[40] to examine the above-mentioned pricing strategies, which are mutually exclusive and exhaustive. Statistical interpretation of the MNL estimation shows the preference of currency choice shifting from PCP (base category) to LCP and VCP, as in Chung (2016). We specify an MNL regression as follows,

$$\Pi^{i,c,k}(PCP) = MNL(Firm^{i}, Macro^{c}, Industry^{k})$$

where superscripts $i, c,$ and k denote firm, destination (country), and industry, respectively. $Firm^{i}$ is a set of factors relating to firm characteristics, including the use of imported inputs; $Macro^{c}$ is a set of macroeconomic factors relating to exchange rates; $Industry^{k}$ is a set of other measures at the industry level.

Our paper can be compared to that of Chung (2016); however, we studied a more general production function including capital in the theoretical model. Chung (2016) also examined the issue for a developed-country firms, the UK, but our analysis is for a developing-country firms, Turkey. Therefore, a comparison of the coefficients for a developed economy and developing economy provides here an interesting aspect of the studied pricing strategies.

[39] See Donnefeld and Haug, 2003; Sokolova, 2015; Goldberg and Tille, 2016.
[40] See Appendix B1 for a brief discussion on the econometrics of the MNL.

3.5 Empirical Results

In this section, we present our model results[41], decomposing our MNL regression[42] according to three main characteristics. Firstly, we present firms' characteristics using imported intermediate goods in production, the share of inputs in PCP and the share of inputs in LCP, and the capital share in production as control variables. Then, we add the relative size of firms in terms of the market share of exports, the experience of firms in the global markets and the transaction size to our control variables. Doing these in models 1 and 2, we are able to test mostly our theoretical model implications, since both models include our theoretically derived parameters in invoicing currency choice as well as other standard parameters in the literature. Secondly, we analyse the impact of macroeconomic factors such as exchange rate volatility, the exchange rate regime and transaction cost of the exchange rate. Finally, we present models including industry characteristics, i.e., market competition and the substitutability of goods.

3.5.1 Firm Characteristics (Models 1 and 2)

Models 1 and 2 barely analyse the effect of firm characteristics in currency invoicing based on the theoretically derived parameters in chapter 2 plus stylized parameters in invoicing currency choice literature, such as firm experience and firm size. In the first model, we only consider the original variables from Chung (2016) (*importer, shareinputpcp, shareinputlcp*) plus our variable of main and novel interest, the share of capital in production (*capitalshare*).

[41] In table 4 we present our findings from the MNL regression. In table 5, we also show our results from a restricted model excluding capital, for a higher comparability with the work of Chung (2016). Using the restricted model, we can better compare a developed country case (the UK) and a developing country case (Turkey) since we use the same specification of the model. Table 4 and 5 give the coefficients from the respective MNL regressions, not the marginal effect. It can be calculated from the coefficients of the regressions, but for the sake of higher tractability and comparability, we prefer Chung's (2016) specification, which allows us to compare our results with her findings.

[42] We applied the Hausman test for the Independence from Irrelevant Alternatives (IIA) assumption after each regression and found negative chi-square values, which indicates that IIA has not been violated. For a detailed discussion regarding the IIA assumptions, see Appendix B1. Witte and Ventura (2016) use a Multinomial Probit approach to avoid the IIA assumption, but they stated that either estimation quite often generated similar results.

Furthermore, in line with Chung (2016), we add other variables to model 1, such as the share of export of a firm in industry, '*perratioik',* its experience in global markets, *'fiveyear',* and the transaction size, '*top10*', in the second model in order to capture firm characteristics in a broader framework. We also add industry[43] and destination[44] fixed effects to model 1 and 2 as in Chung (2016). These variables are significant but omitted from table 4, since they do not change the empirical results.

To distinguish between importing and non-importing exporting firms, we use '*importer*' as a dummy variable. If a firm uses an imported intermediate good in production it takes the value of one, and zero otherwise. The theoretical model in the previous chapter shows that the use of imported inputs in production increases the likelihood of firms to shift away from PCP, as in Chung (2016). The coefficient is positive and highly statistically significant in the first two regressions. It shows that importing exporters use LCP and VCP more than PCP as an invoicing currency. However, our coefficients are considerably higher than those in Chung (2016). So, it can be inferred that a developing country's firms, in Turkey, might use LCP and VCP more than firms operating in a developed country, the UK. In other words, the national currency is not desirable in global transactions in developing countries, since it is unstable (relative to developed countries).

The second dummy variable is '*shareinputpcp*', meant to analyse the share of inputs that a firm imports from a specific country priced in the currency of that particular country. Thus, this dummy variable captures the dependence of a firm on a certain country. The coefficient is negative and significant in both models 1 and 2. Chung (2016) finds only a positive significant coefficient for LCP but negative significant coefficient for VCP. Our result shows another difference between a developed and developing country. In a developed country,

[43] The industry fixed effects are at the SITC-1 digit level.
[44] Destination fixed effects are for the US, China, East and South East Asia, and Europe.

firms with a high degree of dependency on imported inputs denominated in foreign currency are more likely to use LCP relative to VCP, whereas there are no significant differences between the usage of LCP and VCP in developing countries in this aspect. Moreover, this '*shareinputpcp'* increases the usage of PCP for firms in a developing country. Our "reduced" empirical model (in table 5), for the purpose to be comparable more directly to that in Chung (2016), also gives similar results: the estimated coefficients are negative and highly significant for both LCP and VCP.

In line with Chung (2016), we also consider a firm level ratio, '*shareinputlcp'*, to see the effect of the total share of firm's imported inputs in domestic prices[45]. The aim of this dummy variable is to see the effect of another source of inputs in production since the earlier variable, '*shareinputpcp*', only captures the PCP dominated inputs. Chung (2016) finds that higher '*shareinputlcp*' is expected to increase the likelihood of firms to choose PCP as an invoicing currency. Our results support her findings since the coefficient is statistically significant and negative in models 1 and 2. Our "reduced" model (in table 5) also supports this argument, since the coefficients in models 1 and 2 give statistically significant and negative results.

Our coefficient of key interest is '*capitalshare*' in production for firms which use imported inputs in their production. Once we introduce the capital share in production, we find that the coefficient is negative and statistically significant in models 1 and model 2. Thus, a higher capital share in production leads to a lower usage of LCP and VCP in invoicing.

The four variables '*importer*', '*shareinputpcp*', '*shareinputlcp*' and '*capitalshare*' are our main focus in terms of the firm characteristics. Therefore, we analysed just these 4 variables

[45] To compare our model with Chung (2016), we computed the share of '*shareinputlcp*' including all imported goods for a firm. Therefore, we calculated imported inputs for any Turkish firm, then we decompose it according to the country of origin. Then, we form this dummy variable if a country has imported goods with LCP as well as it has imported intermediate goods with PCP, then a firm sells the final product using LCP takes one, otherwise zero.

in model 1. In model 2, we employ a richer MNL regression, increasing the number of factors which are related to firm characteristics (i.e. '*perrationik*', '*fiveyear*' and '*itop10*').

To analyse the role of a firm's relative size in terms of the market share of exports, we use the variable '*perrationik*', as in Chung (2016). We use this ratio as a proxy for the share of exports of a firm into an HS4 industry. Our data support the finding of Chung (2016), i.e., firms with a higher ratio tend to choose LCP and VCP more than PCP, since big firms have more global transactions in their balance sheet and they would like to eliminate exchange rate uncertainty as much as they can. Though we have mixed findings in our regression, this argument is also supported by the "reduced" model, since the coefficients are positive and statistically significant in model 2.

The next dummy variable '*fiveyear*' captures the firm's experience in global markets. In line with Chung (2016), the dummy variable takes the value 1 if a single firm has more than 5 years of experience in the global trade, and 0 otherwise. Unlike Chung (2016), we find positive and significant coefficients for both LCP and VCP. While Chung's (2016) results for a developed economy show that more experienced firms are more likely to use PCP in global transactions, we find that more experienced firms of a developing country actually use LCP or VCP more than PCP. This novel finding highlights another distinction between developed and developing countries' firms. The result is not surprising, since the stylized facts in the Turkish dataset (as described in the previous section) show an extensive use of VCP as a dominant pricing policy for the Turkish exporters. We can see a similar pattern in our "reduced" model, with the coefficients being positive and statistically significant in model 2.

The final variable for firm characteristics is '*top10*' which is used as a proxy for transaction size. Following Chung (2016), we create a dummy variable for this aim. It takes a value of 1 if the transaction is in the top 10^{th} percentile in value within an HS4 industry, and 0 otherwise. Despite the theoretical discussion (see, e.g., Goldberg and Tille, 2008. and Chung,

2016) we find a negative and significant[46] coefficient for this variable. The applied literature[47] simply assumes that larger transactions are more likely to be priced in LCP since it shows the bargaining power of importing firms. However, this theoretical perspective is not the case for Turkish exporters, which use imported intermediate goods in their production. This is again an expected implication of studying developing economies in this framework, as the stylized facts of our Turkish dataset show a superior performance of VCP to the alternative pricing strategies.

3.5.2 Macroeconomic Factors (Model 3)

In model 3, we analyse the role of macroeconomic factors in addition to the above-mentioned firm characteristics. Following Chung (2016)[48], the macroeconomic factors are designed to capture the effects of: i) exchange rate volatility; ii) the exchange rate regime; and iii) the transaction cost of the exchange rate.

Figures 7 and 8 document the movements in the exchange rate (US dollar and Euro, respectively) in multiple periods. From the figures, it can clearly be seen that the value of the Turkish lira is highly volatile. Since exchange rate volatility plays a critical role in our theoretical framework (in chapter 2), we examine the volatility of the mostly used foreign currencies (US dollar and Euro) in Turkish exports.

To see the role of exchange rate volatility, we created two dummy variables '*CV_Euro'* and '*CV_Dollar*' using the IMF's monthly exchange rate data from 2006-2013. The literature suggests that the currency of a country with uncertain and/or volatile macroeconomic conditions may be less preferable for exporters (see Devereux, Engel and Storgaard (2004) and Chung (2016)). Exporters sell to a country with a more volatile currency against the US dollar,

[46] In the "reduced" model we only find partially significant and mixed results in models 3, 4 and 5.
[47] Chung (2016) also explains the similarity in the coefficients of 'perrationik' and 'top10' since bigger firms may do the larger transactions, Thus, these two variables may capture a similar effect. However, we found an opposite and significant relationship for Turkish firms.
[48] Chung (2016) considers the coefficient of variation of the importer's currency relative to the GBP and the US dollar. However, we only consider the coefficient of variation for the Euro and the US dollar, which are the mostly used currencies in the foreign trade of Turkish firms.

Table 4: Determinants of Currency Choice for Turkish Exporters

VARIABLES	Model 1 LCP	Model 1 VCP	Model 2 LCP	Model 2 VCP	Model 3 LCP	Model 3 VCP	Model 4 LCP	Model 4 VCP	Model 5 LCP	Model 5 VCP
importer	1.698***	2.945***	1.432***	2.666***	15.66	16.51	13.93	14.75	13.93	14.75
	(0.361)	(0.361)	(0.354)	(0.350)	(1,112)	(1,112)	(453.1)	(453.1)	(453.1)	(453.1)
shareinputpcp	-0.00701***	-0.00671***	-0.00927***	-0.00999***	0.0223***	0.00827***	0.0120***	-0.00280	0.0120***	-0.00280
	(0.000760)	(0.000733)	(0.000771)	(0.000739)	(0.00289)	(0.00227)	(0.00315)	(0.00261)	(0.00315)	(0.00261)
shareinputlcp	-0.0267***	-0.0434***	-0.0221***	-0.0385***	-0.0122***	-0.0277***	-0.0191***	-0.0369***	-0.0191***	-0.0369***
	(0.000597)	(0.000587)	(0.000611)	(0.000593)	(0.00278)	(0.00168)	(0.00303)	(0.00199)	(0.00303)	(0.00199)
capitalshare	-3.73e-06***	-3.68e-06***	-3.39e-06***	-3.37e-06***	-3.83e-07	-2.30e-07**	-4.72e-07	-2.93e-07***	-4.72e-07	-2.93e-07***
	(1.42e-07)	(1.38e-07)	(1.45e-07)	(1.44e-07)	(3.05e-07)	(9.47e-08)	(3.07e-07)	(9.34e-08)	(3.07e-07)	(9.34e-08)
perratioik			0.456***	0.510***	-0.449***	0.0191	-0.185***	0.310***	-0.185***	0.310***
			(0.0232)	(0.0228)	(0.0471)	(0.0335)	(0.0574)	(0.0462)	(0.0574)	(0.0462)
fiveyear			0.973***	0.802***	-0.713**	0.127	-0.996***	-0.164	-0.996***	-0.164
			(0.0584)	(0.0483)	(0.323)	(0.271)	(0.335)	(0.285)	(0.335)	(0.285)
top10			-0.149***	-0.110**	0.0943	-0.498***	0.407***	-0.164	0.407***	-0.164
			(0.0508)	(0.0496)	(0.135)	(0.0946)	(0.141)	(0.103)	(0.141)	(0.103)
CV_Euro					0.0699***	0.0274***	0.0516***	0.0122	0.0516***	0.0122
					(0.0193)	(0.00867)	(0.0196)	(0.00931)	(0.0196)	(0.00931)
CV_Dollar					-0.834***	-0.0648***	-0.815***	-0.0520**	-0.815***	-0.0520**
					(0.0839)	(0.0198)	(0.0842)	(0.0208)	(0.0842)	(0.0208)
Epeg					-33.27	0.577***	-32.12	0.197	-32.12	0.197
					(1.850e+06)	(0.171)	(869,014)	(0.179)	(869,014)	(0.179)
Dpeg					-37.33	-1.900***	-35.24	-1.335***	-35.24	-1.335***
					(4.916e+06)	(0.318)	(2.314e+06)	(0.325)	(2.314e+06)	(0.325)
FXc					0.187***	-0.0800***	0.197***	-0.0684***	0.197***	-0.0684***
					(0.0195)	(0.00912)	(0.0200)	(0.00989)	(0.0200)	(0.00989)
classck							-0.745***	-0.542***	-0.745***	-0.542***
							(0.249)	(0.190)	(0.249)	(0.190)
classfk							-2.395***	-2.607***	-2.395***	-2.607***
							(0.187)	(0.132)	(0.187)	(0.132)
rauchrcon							-16.33	30.10		
							(0)	(3.355e+07)		
rauchncon							-15.76	30.54		
							(0)	(1.006e+07)		
rauchrlib									-16.33	30.10
									(0)	(3.355e+07)
rauchnlib									-15.76	30.54
									(0)	(1.006e+07)
Constant	3.889***	2.875***	2.695***	1.849***	6.221***	3.955***	9.142***	7.149***	9.142***	7.149***
	(0.122)	(0.117)	(0.135)	(0.127)	(0.793)	(0.466)	(0.841)	(0.527)	(0.841)	(0.527)
Observations	59,694	59,694	59,534	59,534	14,343	14,343	14,343	14,343	14,343	14,343
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.300	0.300	0.309	0.309	0.397	0.397	0.436	0.436	0.436	0.436

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Reduced Model

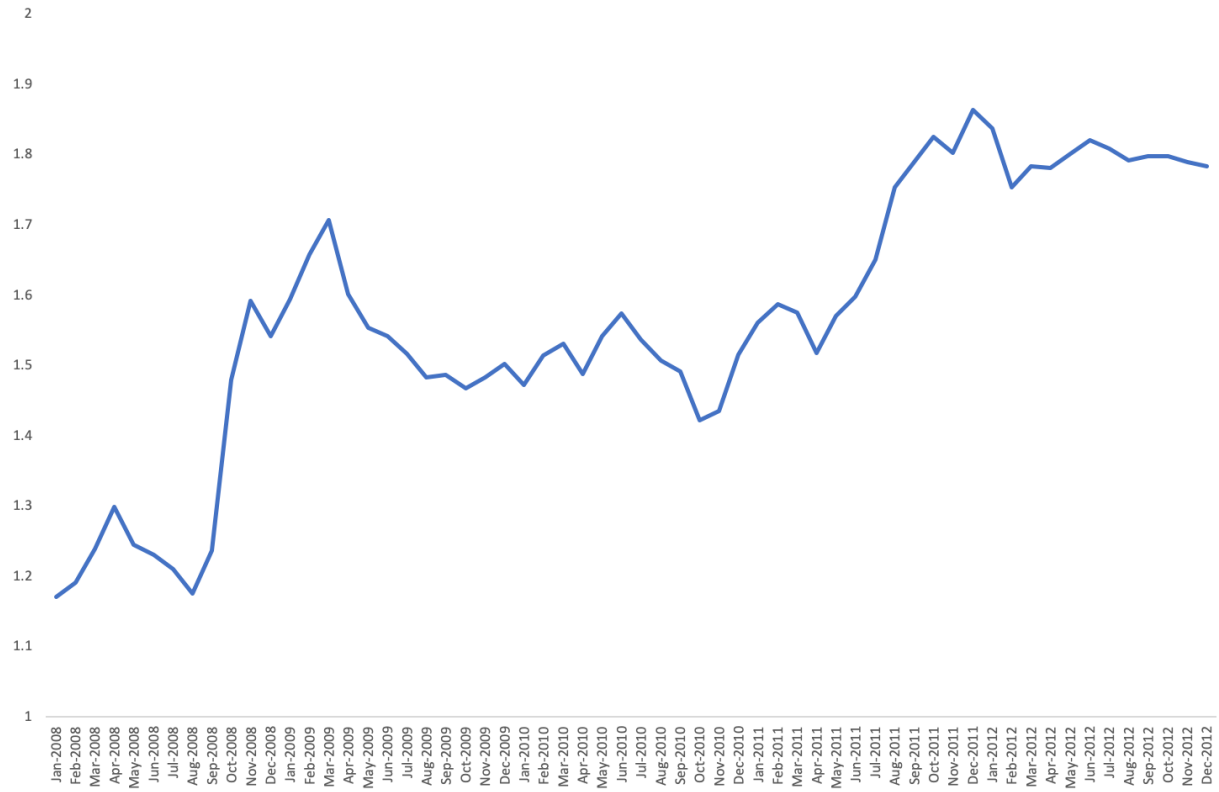
VARIABLES	Model 1 LCP	Model 1 VCP	Model 2 LCP	Model 2 VCP	Model 3 LCP	Model 3 VCP	Model 4 LCP	Model 4 VCP	Model 5 LCP	Model 5 VCP
importer	0.0778	-0.196	0.301	0.119	5.956	6.819	17.79	18.62	17.79	18.62
	(0.209)	(0.225)	(0.197)	(0.210)	(9.313)	(9.266)	(3,394)	(3,394)	(3,394)	(3,394)
shareinputpcp	-0.00653***	-0.00510***	-0.00942***	-0.00899***	0.0185***	0.00506**	0.00820***	-0.00597**	0.00820***	-0.00597**
	(0.000706)	(0.000677)	(0.000711)	(0.000678)	(0.00281)	(0.00220)	(0.00298)	(0.00243)	(0.00298)	(0.00243)
shareinputlcp	-0.0259***	-0.0420***	-0.0213***	-0.0369***	-0.0177***	-0.0298***	-0.0260***	-0.0401***	-0.0260***	-0.0401***
	(0.000558)	(0.000551)	(0.000569)	(0.000554)	(0.00264)	(0.00161)	(0.00285)	(0.00191)	(0.00285)	(0.00191)
perratioik			0.583***	0.636***	-0.445***	0.0251	-0.147***	0.345***	-0.147***	0.345***
			(0.0242)	(0.0239)	(0.0471)	(0.0337)	(0.0563)	(0.0450)	(0.0563)	(0.0450)
fiveyear			0.437***	0.486***	-0.940***	-0.176	-1.255***	-0.509**	-1.255***	-0.509**
			(0.0517)	(0.0450)	(0.290)	(0.236)	(0.301)	(0.250)	(0.301)	(0.250)
top10			-0.0217	0.0217	0.111	-0.484***	0.412***	-0.165	0.412***	-0.165
			(0.0489)	(0.0479)	(0.134)	(0.0942)	(0.141)	(0.103)	(0.141)	(0.103)
CV_Euro					0.0719***	0.0258***	0.0520***	0.00933	0.0520***	0.00933
					(0.0193)	(0.00857)	(0.0195)	(0.00916)	(0.0195)	(0.00916)
CV_Dollar					-0.818***	-0.0469**	-0.787***	-0.0334	-0.787***	-0.0334
					(0.0844)	(0.0196)	(0.0834)	(0.0207)	(0.0834)	(0.0207)
Epeg					-27.77	0.704***	-17.71	0.334*	-17.71	0.334*
					(124,819)	(0.169)	(686.1)	(0.177)	(686.1)	(0.177)
Dpeg					-31.79	-1.761***	-20.78	-1.216***	-20.78	-1.216***
					(329,961)	(0.313)	(1,842)	(0.321)	(1,842)	(0.321)
FXc					0.175***	-0.0933***	0.183***	-0.0821***	0.183***	-0.0821***
					(0.0196)	(0.00862)	(0.0196)	(0.00933)	(0.0196)	(0.00933)
classck							-0.326	-0.219	-0.326	-0.219
							(0.245)	(0.188)	(0.245)	(0.188)
classfk							-2.448***	-2.615***	-2.448***	-2.615***
							(0.187)	(0.131)	(0.187)	(0.131)
rauchrlib									0.716	16.07
									(45,545)	(32,867)
rauchnlib									1.037	16.33
									(12,894)	(8,387)
Constant	3.276***	2.249***	2.616***	1.539***	6.499***	4.234***	9.494***	7.528***	9.494***	7.528***
	(0.115)	(0.110)	(0.127)	(0.120)	(0.782)	(0.452)	(0.826)	(0.515)	(0.826)	(0.515)
Observations	61,903	61,903	61,728	61,728	14,606	14,606	14,606	14,606	14,606	14,606
Industry Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Destination Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pseudo R-squared	0.293	0.293	0.303	0.303	0.395	0.395	0.434	0.434	0.434	0.434

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

they are more likely to use PCP (Chung, 2016). Our finding supports these theoretical explanations for the US dollar but not for the Euro. This might be because of the high volatility in the Euro during this period. Chung's (2016) dataset also gives a similar result for the US dollar.

Our "reduced" model expresses matching results with our "base" model. In table 5, the coefficient of "*CV_Euro"* is positive and statistically significant for both LCP and VCP, whereas "*CV_Dollar*" has a negative sign and statistically significant coefficients for LCP and VCP cases.

Figure 7: US Dollar to Turkish Lira



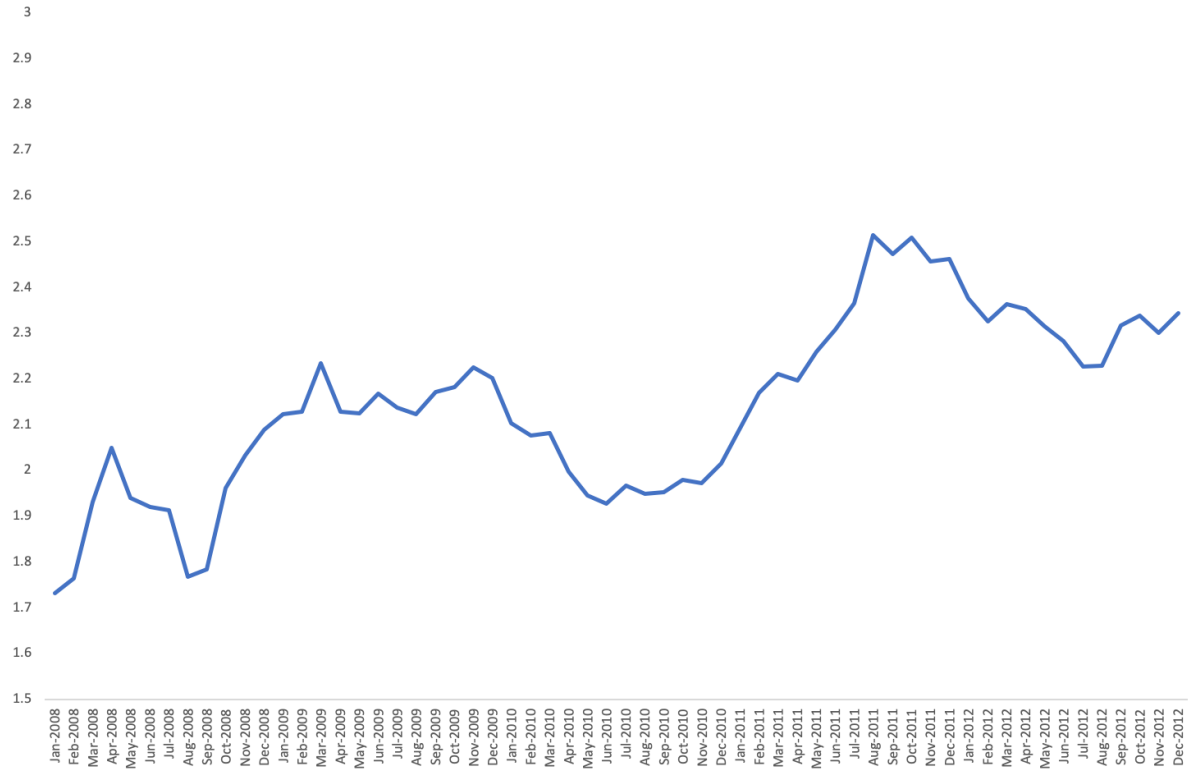
Source: IMF's International Financial Statistics.

Following the peg definition of IMF's classification in 2007[49], we consider the exchange rate regime of trade partners for Turkish firms. We use dummy variables '*Dpeg'* and

[49] The type of fixed exchange rate regimes are; (i) no separate legal tender; (ii) pre-announced peg or currency board arrangements; (iii) pre announced horizontal band narrower than or equal +/-2% and (iv) de facto peg.

'*Epeg'* to capture the role of the exchange rate regime. Goldberg and Tille (2016) explain that a fixed exchange rate regime to eliminate the exchange rate volatility, and this leads to an increase in the usage of LCP. However, LCP might be a less preferable strategy, since an exchange rate peg might be also a signal of an unstable or poor macroeconomic performance in developing countries (Chung, 2016). Although we analysed a developing country, our findings support Chung's (2016) argument for a developed country. We estimate that exporters prefer VCP (rather than PCP) when exporting countries with fixed exchange rate regime to the Euro, while they prefer PCP when exporting countries with a fixed exchange rate regime to the US dollar. These findings support the above-mentioned argument for volatility in the Euro versus the US dollar. We have similar findings in the "reduced" model.

Figure 8: Euro to Turkish Lira



Source: IMF's International Financial Statistics.

The last macroeconomic factor of the model is the '*transaction cost of exchange'*. Following Goldberg and Tille (2016) and Chung (2016), our variable '*FX*' simply shows the share of importer's currency in daily global foreign exchange market turnover. We compute this parameter using the BIS Triennial Central Bank Survey in 2007. A lower transaction cost is associated with a higher '*FX*', and this shows a high usage of LCP (Goldberg and Tille, 2016 and Chung, 2016). Our findings in model 3 support this argument for Turkish firms. The "reduced" model also shows evidence of a similar pattern for Turkish firms.

3.5.3 Industry Characteristics (Model 4 and 5)

In models 4 and 5 we add industry characteristics as explanatory variables. Following Chung (2016), we focus on the market with two critical features of the industry: i) market competition and ii) the substitutability of goods.

To analyse the market competition, we follow the BEC classification to find the end-use of goods. To classify the end-use of goods, we add variable '*classk*' consisting of three dummy variables '*classfk*' for final goods, '*classck*' for capital goods and '*classIK*' for intermediate goods. Local competition may be higher for the exporters of consumption goods in the foreign market than exporters of intermediate inputs (Chung, 2016). Hence, local competition may lead to choosing PCP for final good producers (Bachetta and van Wincoop, 2003). Our findings support this theoretical explanation since the coefficient is negative and statistically significant in models 4 and 5. Chung's (2016) model does not support this theoretical argument, since she finds a positive coefficient for the variables. Despite the different results from the theoretical discussion, Chung (2016) explains this result as the UK has more transactions in the final goods on average than transactions of intermediate goods. However, our finding is consistent with the theoretical framework and it may also show another difference between a developed economy and developing economy. In table 5, we can follow matching results for the "reduced" model.

The second aspect of industry characteristics is '*substitutability of goods'*. Since Chung (2016) follows the Rauch (1999) index to distinguish differentiated and homogenous goods[50], we follow the same strategy to compare our models. We use the 4-digit SITC level to define the Rauch variables. However, our results show insignificant coefficients for these variables. Our "reduced" model, again, finds insignificant coefficients for these variables too.

3.6 Concluding Remarks

This study particularly focuses on the role of the capital share and imported inputs in the determination of invoicing currency for Turkish firms. In line with our theoretical contribution in the previous chapter, we find that if the capital share of production increases, then the probability of choosing LCP or VCP versus PCP decreases empirically. In other words, PCP is a more preferable pricing strategy as the usage of physical capital increases in the production process of the Turkish exporting firms. We use a highly disaggregated export transaction dataset in identifying the determination of invoicing currency choice for Turkish exporting firms in 2013. We also show evidence on the importance of firms' characteristics, industry characteristics and macroeconomic stability of an economy.

We find interesting results when we compare our model with the natural benchmark of Chung's (2016) model. She presents results for the UK economy, which has relatively a stable monetary policy with low inflation environment and less volatile currency in international markets. However, our country of interest, Turkey, can be described as a relatively unstable economy with a long term high inflationary environment and its currency highly volatile in the global markets in comparison with the UK.

[50] This classification of goods is designed from Rauch (1999) and revised in 2007. Chung (2016), followed the liberal classification rather while we show both liberal classification (in model 4) and conservative classification (in model 5). However, the coefficient does not give any significant differences between the approaches.

One of the main differences between British and Turkish firms is a preference on PCP as a pricing strategy, since the UK firms use a higher share of PCP versus LCP and VCP for some sectors/destination and industry, whereas the share of PCP is always significantly lower for Turkish firms. Supporting this argument, we also find that more experienced firms in Turkey may not tend to choose PCP as a pricing strategy in export, while UK firms choose PCP as firm experience increases in the market. In other words, even the experience in the market increases, Turkish firms do not prefer the national currency as an invoicing currency, while the UK exporters do prefer.

Choice of invoicing is an important part of understanding the trade of intermediate goods, since it is highly related to exchange rate pass-through. Thus, one natural extension of our model could be the analysis of the degree of pass-through within the industries, since some sectors may have higher pass-through (see Chung, 2016, Mumtaz, Oomen, and Wang, 2006). Therefore, it would be interesting to see the heterogeneity of pass-through for Turkish firms in different industries. In line with this extension, it would also be interesting to see a comparison of industries in the developing and developed world in terms of exchange rate pass-through.

Appendix B

B.1 Econometrics of Multinomial Logit Model

The analysis of the probability of choice on categorical dependent variables based on multivariate analysis can be studied under the MNL methodology. Allowing more than two categories, this econometric method is an extension of the binary logistic regression. In order to assess the probability of each categorical association, the MNL regression uses maximum likelihood estimation, as does too the binary logit regression.

The methodology does not assume normality, linearity and homoscedasticity. These features of the MNL regression might seem as an advantage of the methodology. However, an important assumption of the MNL regression is the assumption of independent irrelevant alternatives (IRR). This assumption requires that the choice of any strategy or category is not related to the choice of remaining categories or strategies.

The attractiveness of the model comes through the probabilities Pr $(y_i = m|x_i)$ which relate to the logistic design take the form,

$$\text{Prob}(y_i = m|x_i) = \frac{\exp(x'\beta_m)}{\sum_{j=1}^{M} \exp(x'\beta_j)}$$

$$= \frac{\exp(x'\beta_m)}{1 + \sum_{j=2}^{M} \exp(x'\beta_j)}$$

where m shows choices and given the normalisation $\beta_1 = 0$.

Estimation of the MNL regression for a given sample of dataset is by Maximum Likelihood (ML), where the likelihood function is a logical extension of the likelihoods in the discrete choice models. The likelihood can be formulated via the multiplication of the probabilities of each observation, conditional on data, the modal parameters, and the assumed distribution of the disturbance term. The likelihood for the i^{th} observation in the sample,

$$I_i = \prod_{m=1}^{M} Pr(y_i = m|x_i)^{z_{im}} = \prod_{m=1}^{M} P_{im}^{z_{im}}$$

where $z_{im} = 1(y_i = m)$ for $m = 1, \dots, M$, and where P_{im} represents the probability $Pr\ (y_i = m|x_i)$. For parameters $\theta = (\beta_2, \dots, \beta_{M-1})'$. Then the full sample likelihood can be written as,

$$L(\theta) = \prod_{i=1}^{n} \prod_{m=1}^{M} P_{im}^{z_{im}}$$

It is known that maximization of the log likelihood brings an outcome that ML estimates best imitate the observed data.

The parameters related with each variable in the MNL measure the extent to which the propensities in each category change relative to the base category in response to an increase in the corresponding variable. The whole influence of a change in an individual regressor variable is hard to interpret. Marginal effects may offer clarification of the total effects of a change in an independent variable on the different category probabilities. Marginal effects for the MNL can be computed by calculating the derivatives of each probability with respect to each explanatory variable.

Calculation of these probabilities in the MNL models provides an advantage, however, there is also a major drawback regarding these probabilities. The validity of the model is simply based on the 'independence of irrelevant alternatives' assumption. If we re-write the above formula,

$$\Pr(y_i = m|x_i) = \frac{\exp(x'\beta_m)}{\sum_{j=1}^{M} \exp(x'\beta_j)}$$

for all $m = 1, \dots, M - 1$. However, if we then form the ratio of two probabilities $\Pr\ (y_i = s|x_i)$ and $\Pr\ (y_i = k|x_i)$, we find that

$$\frac{\Pr(y_i = s \mid x_i)}{\Pr(y_i = k \mid x_i)} = \frac{\exp\,(x'\beta_s)}{\exp\,(x'\beta_k)}$$

The ratio of probabilities of any two outcomes is independent of the probability of any remaining outcome. Adding an extra outcome to the range of choices, therefore, leaves this ratio of probabilities unchanged. This difficult feature is known as 'the independence of irrelevant alternatives' and forms the principal criticism of the Multinomial Logit Model. When IIA assumption has been violated then we can use alternative specifications such as the multinomial probit model and the nested logit model.

Chapter 4: Conclusion and Direction for Future Research

This PhD thesis contributed to the literature on currency invoicing in international trade addressing in more detail the issue of how firms decide on invoicing currency in global transactions. Specifically, we focus on the role of (i) the capital share and (ii) imported inputs in production, as we analyse the heterogeneous firms. Earlier studies[51] with price rigidities assume firms use either PCP or LCP, exogenously. Devereux, Engel, and Storgaard (2004) were the first to analyse the choice of invoicing currency endogenously, building a theoretical model in explaining the choice of currency in invoicing for final goods. Then, Chung (2016) extended this framework, including imported intermediate goods with one factor of production, labour. In line with this literature, we develop the framework set up in these two models by adding physical capital as a second factor of production, in chapter 2. In chapter 3, we examine the determinants of currency invoicing empirically, employing a multinomial logit regression. Using a highly disaggregated firm-level dataset for Turkish firms, we decomposed the determinants of invoicing currency choice into three different categories, such as (i) firm characteristics, (ii) macro factors, and (iii) industry characteristics. Doing this, we are also able to compare the differences and similarities between a developed economy case, the UK in Chung (2016), and our developing country case, Turkey.

In the theoretical chapter (chapter 2), we extended the DES-Chung (2016) model in order to derive more general exporting firm decision rules on invoicing currency choice. Our contribution is to add physical capital as a second factor of. Having set up this novel two-factors of production model with imported intermediate goods in the production process, we further extend the exporting firm decision rules and derive a richer cost index that matters relative to the earlier literature. Hence, in our framework the covariance term between marginal

[51] See chapter 2 for a detailed discussion of the literature.

cost (including the extended cost index) and the exchange rate plays a critical role in the decision rules, implying three fundamental results: (i) a negative covariance shows that a higher coefficient leads to a choice of VCP versus PCP and LCP; (ii) when the covariance term is between the exchange rate of countries A and C, and marginal cost has a negative sign, if it increases, exporting firms prefer LCP; (iii) when the covariance term is between the exchange rate of countries B and C, and marginal cost has a negative sign, if it increases, LCP become a more desirable pricing strategy for exporting firms. Adding physical capital in the production function, our results not only support Chung's (2016) argument in invoicing currency choice, but also highlight a decision rule on the preference of LCP, PCP or VCP. This brings motivation for our empirical study, where we test the determinants of invoicing currency in a developing country, such as Turkey. Turkish exporters with imported inputs tend to exhibit a higher preference for VCP in their transactions because an unstable domestic monetary policy, high inflationary environment and highly volatile bilateral exchange rate in the global markets.

In the empirical chapter (chapter 3), we investigate the theoretically derived decision rules (in chapter 2), concentrating on the role of the share of physical capital and imported intermediate goods as the determinants of invoicing currency choice. We use a multinomial logit regression model using a firm-level Turkish export transactions data. In line with Chung (2016), we divide the determinants of invoicing currency choice into three sub-parts: (i) firm characteristics, including our factor of interest, physical capital shares in production; (ii) macroeconomic factors; (iii) industry characteristics. Our MNL results suggest that there are substantial variations in terms of invoicing currency practices for firms in a developed country, the UK, versus a developing country, Turkey, when we compare our results with Chung (2016). We find and discuss key interpretable relationships between currency choice of invoicing decisions and its determinants.

In terms of potential implications for future research, we need to consider the relationship between exchange rate pass-through and imported intermediate goods and the choice of invoicing currency in monetary policy transmission. Therefore, it may be worth going into a richer empirical model focusing on the analysis of the heterogeneity of pass-through within sectors that use imported intermediate goods in the production process. This reveals the potential heterogeneity of pass-through for firms in different industries. Moreover, it would be interesting to expand the study into a richer, cross-country analysis, which could also highlight how different countries and/or regions follow the decision rules on currency invoicing and how this affects monetary policy.

In terms of policy implications, we think that the main intuition from this PhD thesis relates to the importance of the capital share in the production process together with the usage of imported intermediate goods and its effects on firms' decision rules on invoicing currency choice. While our theoretical chapter derives decision rules with a richer cost index for exporting firms, our empirical chapter tests these theoretically derived determinants of invoicing currency choice. Our results reveal that, in a developing country, Turkish exporting firms avoid the use of Turkish lira in their international transactions. There might be several explanations of this behaviour, such as (i) relatively unstable monetary policy, (ii) with a high inflation environment, and (iii) high volatility of the Turkish lira in global markets. However, our results show that if the physical capital share in production increases, Turkish exporting firms tend to choose the national currency in invoicing, no matter the above-mentioned instability features of a developing economy. Such a conclusion shows the importance of production structure and related costs in currency invoicing decisions for Turkish exporters.

References

Akgunduz, Y.E. and Fendoglu, S., 2019. Exports, Imported Inputs, and Domestic Supply Networks. *Research and Monetary Policy Department, Central Bank of the Republic of Turkey.* Working Papers No:1908

Amiti, M. and Konings, J., 2007. Trade Liberalization, Intermediate Inputs, and Productivity: Evidence from Indonesia. *American Economic Review*, *97* (5), 1611-1638.

Alfriend, K.T. and Richardson, D.L., 1973. Third and Fourth Order Resonances in Hamiltonian Systems. *Celestial Mechanics*, *7* (4), 408-420.

Bacchetta, P. and van Wincoop E., 2003. Why Do Consumer Prices React Less Than Import Prices to Exchange Rates? *Journal of the European Economic Association*, 1, 662-670.

Bacchetta, P. and van Wincoop, E., 2005. A Theory of the Currency Denomination of International Trade. *Journal of International Economics,* 67**,** 295-319.

Bas, M. and Strauss-Kahn, V., 2014. Does Importing More Inputs Raise Exports? Firm-level Evidence from France. *Review of World Economics*, *150* (2), 241-275.

Betts, C. and Devereux, M.B., 1996. The Exchange Rate in a Model of Pricing-to-Market. *European Economic Review*, *40* (3-5), 1007-1021.

Betts, C. and Devereux, M.B., 2000. Exchange Rate Dynamics in a Model of Pricing-to-Market. *Journal of International Economics*, *50* (1), 215-244.

Castellani, D., Serti, F. and Tomasi, C., 2010. Firms in International Trade: Importers' And Exporters' Heterogeneity in Italian Manufacturing Industry. *World Economy*, *33* (3), 424-457.

Castellani, D. and Fassio, C., 2016. Import, Export and Multinationality. Evidence from Swedish Firms. *Rivista di Politica Economica*, *7*, 129-151.

Chen, N., Chung, W. and Novy, D., 2019. Vehicle Currency Pricing and Exchange Rate Pass-Through. *Centre for Economic Performance, LSE*.

Choudhri, E. U. and Hakura, D. S., 2015. The Exchange Rate Pass-Through to Import and Export Prices: The Role of Nominal Rigidities and Currency Choice. *Journal of International Money and Finance,* 51**,** 1-25.

Chung, W., 2016. Imported Inputs and Invoicing Currency Choice: Theory and Evidence from UK Transaction Data. *Journal of International Economics*, *99*, 237-250.

Corsetti, G. and Pesenti, P., 2002. Self-Validating Optimum Currency Areas. *NBER Working Papers* No: 8783

Corsetti, G. and Pesenti, P., 2004. Endogenous Pass-Through and Optimal Monetary Policy: A Model of Self-Validating Exchange Rate Regimes. *European University Institute,* manuscript.

Corsetti, G., Crowley, M., Han, L. and Song, H., 2018. *Markets and Markups: A New Empirical Framework and Evidence on Exporters from China* (No. 87180). London School of Economics and Political Science, LSE Library.

Devereux, M.B. and Shi, S., 2013. Vehicle Currency. *International Economic Review*, *54* (1), 97-133.

Devereux, M. B., Engel, C. and Storgaard, P. E., 2004. Endogenous Exchange Rate Pass-Through When Nominal Prices Are Set in Advance. *Journal of International Economics*, 63, 263-291.

Devereux, M.B., Tomlin, B. and Dong, W., 2015. Exchange Rate Pass-Through, Currency of Invoicing and Market Share. *National Bureau of Economic Research.* Working Paper No. 21413.

Dogruel, A.S., Dogruel, F. and Izmen, U., 2010. Changes in Exchange Rates and the Performance of the Manufacturing Sectors in Turkey. *Topics in Middle Eastern and North African Economies*, *12*.

Donnenfeld, S. and Haug, A., 2003. Currency Invoicing in International Trade: An Empirical Investigation. *Review of International Economics*, *11* (2), 332-345.

Donnenfeld, S. and Zilcha, I., 1991. Pricing of Exports and Exchange Rate Uncertainty. *International Economic Review*, 1009-1022.

Dotsey, M. and Duarte, M., 2017. How Important Is The Currency Denomination of Exports in Open-Economy Models? *Review of Economic Dynamics*, 23, 1-18.

Engel, C., 2006. Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Export Pricing. *Journal of the European Economic Association*, *4*(6), 1249-1260.

Ethier, W., 1979. Internationally Decreasing Costs and World Trade. *Journal of International Economics*, *9*(1), 1-24.

Ethier, W.J., 1982. National and International Returns to Scale in the Modern Theory of International Trade. *American Economic Review*, *72*(3), 389-405.

Flodén, M. and Wilander, F., 2006. State Dependent Pricing, Invoicing Currency, and Exchange Rate Pass-Through. *Journal of International Economics*, *70*(1), 178-196.

Friberg, R., 1998. In Which Currency Should Exporters Set Their Prices? *Journal of International Economics*, *45*(1), 59-76.

Friberg, R. and Wilander, F., 2008. The Currency Denomination of Exports—A Questionnaire Study. *Journal of International Economics*, *75*(1), 54-69

Goldberg, L.S. and Tille, C., 2006. The International Role of the Dollar and Trade Balance Adjustment. *National Bureau of Economic Research* Working Paper No. 12495.

Goldberg, L. S. and Tille, C., 2008. Vehicle Currency Use in International Trade. *Journal of International Economics* 76(2): 177-192.

Goldberg, L.S. and Tille, C., 2013. A Bargaining Theory of Trade Invoicing and Pricing *National Bureau of Economic Research* Working Paper No. 18985.

Goldberg, L.S. and Tille, C., 2016. Micro, Macro, and Strategic Forces in International Trade Invoicing: Synthesis and Novel Patterns. *Journal of International Economics*, *102*, 173-187

Goldberg, P. K., Khandelwal, A. K., Pavcnik, N. and Topalova, P., 2010. Imported Intermediate Inputs and Domestic Product Growth: Evidence from India. *Quarterly Journal of Economics,* 125, 1727-1767.

Gopinath, G. and Neiman B., 2014. Trade Adjustment and Productivity in Large Crises. *American Economic Review* 104(3), 793-831.

Gopinath, G., Itskhoki, O. and Rigobon, R., 2010. Currency Choice and Exchange Eate Pass-Through. *American Economic Review*, *100*(1), 304-36.

Gopinath, G., 2015. The International Price System. *National Bureau of Economic Research* Working Paper No. 21646.

Greene, W.H., 2003. *Econometric Analysis*. 5th ed. New Jersey: Pearson Education Inc.

Grossman, G.M. and Helpman, E., 1991. *Innovation and Growth in the Global Economy*. MIT Press.

Haller, S.A., 2012. Intra-Firm Trade, Exporting, Importing, and Firm Performance. *Canadian Journal of Economics/Revue Canadienne D'économique*, *45*(4), 1397-1430.

Halpern, L., Koren, M. and Szeidl, A., 2015. Imported Inputs and Productivity. *American Economic Review*, *105*(12), 3660-3703.

Hummels, D., Ishii, J. and Yi, K.M., 2001. The Nature and Growth of Vertical Specialization in World Trade. *Journal of International Economics*, 54(1), 75-96.

Ito, T., Koibuchi, S., Sato, K. and Shimizu, J., 2016. Exchange Rate Exposure and Risk Management: The Case of Japanese Exporting Firms. *Journal of the Japanese and International Economies*, *41*, 17-29.

Ito, T., Koibuchi, S., Sato, K. and Shimizu, J., 2010. Determinants of Currency Invoicing in Japanese Exports: A Firm-Level Analysis. *RIETI* Discussion Paper No. 10034.

Kamps, A., (2006), The Euro as Invoicing Currency in International Trade, *European Central Bank* Working Paper No. 665.

Kasahara, H. and Rodrigue, J., 2008. Does the Use of Imported Intermediates Increase Productivity? Plant-Level Evidence. *Journal of Development Economics,* 87**,** 106-118.

Kasahara, H. and Lapham, B., 2013. Productivity and the Decision to Import and Export: Theory and Evidence. *Journal of International Economics,* 89**,** 297-316.

Krugman, P., 1980. Vehicle Currencies and the Structure of International Exchange. *Journal of Money, Credit and Banking,* 12 (3), 513-526.

Langedijk, S., Karagiannis, S. and Papanagiotou, E., 2016. Invoicing Currencies in International Trade - Drivers and Obstacles to the Use of the Euro. *European Commision,* JRC Scientific and Policy Report No. 11.

Lyonnet, V., Martin, J. and Méjean, I., 2019. Invoicing Currency and Financial Hedging. *CEPR* Discussion Paper No. 11700.

Lu, D. and Ulu, M. F., 2014. Firm Size, and Import Content of Production. *CBRT* Working Paper

Markusen, J.R., 1989. Trade in Producer Services and in Other Specialized Intermediate Inputs. *American Economic Review*, 85-95.

Mumtaz, H., Ö. Oomen and J. Wang., 2006. Exchange Rate Pass-Through into UK Import Prices. *Bank of England* Working Paper no. 312.

Muûls, M. and Pisu, M., 2009. Imports and Exports at the Level of the Firm: Evidence from Belgium. *World Economy*, *32*(5), 692-734.

Obstfeld, M. and Rogoff, K., 1995. Exchange Rate Dynamics Redux. *Journal of Political Economy* 103, 624–660.

Obstfeld, M. and Rogoff, K., 1996. *Foundations of International Macroeconomics*. Cambridge, MA: MIT press.

Obstfeld, M. and Rogoff, K., 2000. New Directions for Stochastic Open Economy Models. *Journal of International Economics* 50, 117–153.

Rauch, J. E., 1999. Networks Versus Markets in International Trade. *Journal of International Economics* 48(1): 7-35.

Romer, P.M., 1987. Growth Based on Increasing Returns Due to Specialization. *American Economic Review*, *7* (2), 56-62.

Romer, P.M., 1990. Endogenous Technological Change. *Journal of Political Economy*, *98* (5, Part 2), S71-S102.

Sokolova, M.V., 2015. Strategic Currency Choice in International Trade . *CESifo* Group Munich Working Paper No. 5574.

Swoboda, A., 1968. The Euro-Dollar Market: An Interpretation. Essays in International Finance 64. Princeton, NJ: Princeton University.

Witte, M.D. and Ventura, L., 2016. An Empirical Examination of the Currency Denomination of Trade. *International Economic Journal*, *30* (1), 87-107.