

Research Article / Araştırma Makalesi

**THE OPTIMAL CHOICE OF EXPORT CURRENCY:
A THEORETICAL APPROACH***

Asst. Prof. Seyhan AYGÜL 

Zonguldak Bülent Ecevit University, FEAS, Zonguldak, Türkiye, (seyhanaygul@gmail.com)

ABSTRACT

The invoicing currency choice in international trade is a vital issue for the spread of business cycles and monetary policy. Following Devereux et al., (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 the 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. 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.

Keywords: Currency Invoicing, Intermediate Goods, Vehicle Currency Pricing, Local Currency Pricing, Producer Currency Pricing.

OPTİMAL İHRACAT PARA BİRİMİ SEÇİMİ: TEORİK BİR YAKLAŞIM

ÖZET

Uluslararası ticarete kullanılan faturalama para birimi para politikasının aktarım mekanizması açısından oldukça önemli bir konudur. Devereux vd., (2004) teorik çerçevesini takip eden bu çalışma, Chung'da (2016) olduğu gibi ithal ara malların faturalandırma para birimi kararındaki rolünü analiz etmektedir. Bununla birlikte, ikinci üretim faktörü olarak sermayenin, emeğin tek üretim faktörü olduğu modele eklenmesiyle, teorik model daha kapsayıcı bir üretim fonksiyonuyla geliştirilmektedir. Böylece, faturalama para birimi literatüründe ithal girdileri de içeren iki üretim faktörlü yeni bir teorik model ortaya konmuştur. Modelimizde, üretimin sadece emeği değil aynı zamanda sermayeyi de içerdiği durumlarda daha gerçekçi maliyet endeksini içeren kovaryans terimleri, fiyatlandırma stratejilerine ilişkin karar vermede kritik bir rol oynamaktadır.

Anahtar Kelimeler: Faturalandırma Para Birimi, Ara Malları, Araç Döviz Fiyatlandırması, Yerel Döviz Fiyatlandırması, Üretici Döviz Fiyatlandırması.

* This study was based on the Phd Thesis under the title "The Invoicing Currency Choice in International Trade: Theory and Practice" in University of Reading, 2020.

1. Introduction

The choice of invoicing currency¹ is one of the fundamental policy issues in international trade since it has consequences on exchange rate movements under the price stickiness. In international trade studies, the risk sharing between importers and exporters in incomplete markets and the connection between exchange rates and the relative price of goods in global markets relates to the currency invoicing choice since firms in international trade are highly linked with global value chains (Gopinath et al., 2010; Gopinath, 2015; Goldberg & Tille, 2016). This research contributes to the international trade literature focussing on decision rules of monopolistically competitive firms' pricing strategy theoretically extending Devereux et al. (2004) and Chung (2016) models using a more general production function for the firms that use intermediate goods in the production process.

The literature (Bacchetta & van Wincoop, 2005; Devereux et al. 2004; Goldberg & Tille, 2008; Goldberg & Tille 2016; Gopinath et al, 2010) suggests three main modelling strategies in the choice of invoicing currency, namely PCP producer currency pricing and LCP local currency pricing and VCP vehicle currency pricing. Hence, a natural question could be asked: would a firm prefer to follow PCP or LCP or VCP? An increasing number of international transactions and, hence, the interdependence of each country, 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 et al. (2004), DES henceforth, and Chung (2016) developed a theoretical framework appropriate to explore the determinants of invoicing currency decisions for exporting firms in SOEs.

DES examine the impact of nominal exchange rate variations on invoicing currency. The authors mainly analyse the issue of the exchange rate risk in the presence of lags between the moment when the international goods are ordered by the importer and the time when the goods are transported and paid by him/her. Hence, during the period of the currency arrangements the buyer, or in other words importer, faces the risk of the exchange rate. In their framework, two parties of the agreement, importer, and exporter, have the same preference on invoicing currency, i.e., both sides of the deal prefer unique currency in the international trade. Their partial equilibrium new open economy macroeconomics (NOEM) model derives a decision rule for a monopolistically competitive firm related to the invoicing currency choice that reflects endogenous currency choice². 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 the 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.

1 We use the term 'invoicing currency' and 'currency of pricing' with the same meaning following Freiberg (1998) and Freiberg & Willander (2008) terminology.

2 For example, importers may have a favour of invoice in the domestic currency and exporter may set its invoice in the foreign currency. According to their framework, the authors reveals that volatility of exchange rate surges the desirability of PCP. The reason of that, the firm's profit function is convex function of the exchange rate when firm prefer PCP strategy, while with local currency pricing the function is linear within the exchange rate. Then, the exchange rate volatility raises expected profits with PCP compared to LCP.

This gap in the literature is filled 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 model reveals that exporting firm dependent on imported inputs is highly possible 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 DES theoretical framework, we here allow for the role of imported 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 shed light on the above-cited key literature, we develop a novel two factor of production model in the invoicing currency literature.

With capital as a second factor of production, we enrich Chung's (2016) extensions to the DES framework, which leads to a more complex and more realistic as cost index, H , in the decision making on invoicing currency, 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 paper.

The paper is structured as follows. Section 2 gives a review of the literature on the importance of invoicing currency. The third section introduces the theoretical model of optimal choice of export currency invoicing when firms employ imported inputs benefiting the two factors of production function. Section 4 concludes.

2. Literature Review

In their seminal paper that launched the new open economy macroeconomics literature, Obstfeld & Rogoff (1995:631) assume that firms set export prices in their domestic currency when selling abroad. Thus, this view mainly explains the effect of exchange rate fluctuations on the (imported and, hence final) price of globally traded goods. Because it is assuming that the price of internationally traded (final) goods is sticky in the domestic currency. This is called as producer currency pricing (PCP) paradigm in international trade. It is known that exchange rate pass-through (ERPT) is complete under the PCP strategy. In their model, any shock that leads to a depreciation of the domestic currency decreases the export prices whereas increases the import prices. This is known as the expenditure switching effect. This effect plays an important role in the global spread of business cycles and optimal monetary policy determination (See-Obstfeld & Rogoff, 1996; 2000; Dotsey & Duarte, 2017).

Betts & Devereux (1996; 2000) modify Obstfeld & Rogoff (1995) model, allowing a fraction of firms to determine prices in the currency of the destination country, which has become labelled local currency pricing (LCP). So, this extension underlines that exchange rate pass-through on prices is incomplete. This alteration implies, by contrast, that exchange rate pass-through 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. To prevent domestic firms from bearing the exchange rate risks in global markets, a flexible exchange rate regime is more preferable in Obstfeld & Rogoff's (1995) PCP model, whereas a fixed exchange rate is more favourable in the Betts & Devereux (1996; 2000) LCP model.

Donnenfeld & Zilcha (1991) use a theoretical framework³ 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 the importer's currency. In their theoretical model, Donnenfeld & Zilcha (1991:1014) show the reason for 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 perception 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 uncertainty in the expected profit of firms because of different currency selections in each episode. According to Friberg (1998:60), 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 (1998:60) highlights the choice of the same currency (of price-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 Friberg (1998) and Donnenfeld & Zilcha (1991) take the decision of currency invoicing choice exogenously in their frameworks, the more recent literature (see Devereux et al. 2004; Corsetti & Pesenti, 2004; Bacchetta & 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.

³ In their model, this mechanism works sequentially. In other words, output, prices, and sales are decided in order. For example, the quantity demanded is not affected by the exchange rate change if the exporting firm prefers LCP. However, if the exporting firm selects PCP, there might be a demand uncertainty, since the demand in the importing country is determined by the nominal exchange rate.

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 ERPT. Under the existence of distinctions 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 the firm's expected profits. The expected profits are rising with the exchange rate, since: i) a firm will face a high demand for its product in global markets in response to an increase in the exchange rate when the other firms do not change their prices in PCP, implying the profit function of firms is strictly convex; ii) sales value will increase in response to a rise in the exchange rate under LCP since the 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 & van Wincoop (2005) analyse the optimal choice of currency invoicing 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 market share for a particular good (and/or the more differentiated its goods), it is highly possible that the firms in the destination country determine their prices in their national currency.

Corsetti & Pesenti (2004) analyse whether a firm chooses LCP or PCP as a currency invoicing under the optimal exchange rate policy and the optimal monetary policy. The authors show multiple equilibria in their model i) if firms use PCP 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 turn into an optimal policy choice.

Gopinath et al. (2010) find evidence on endogenous choice of invoicing currency rather than exogenous in the US data. Looking at 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 long run pass-through is not affected.

Devereux & 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 the exporter country's currency. Gains from vehicle currency practice depend on three features, as follows. First, the number of currencies and countries: transaction gains from vehicle currency practice are high with the number of countries and currencies. Secondly, the size of the countries: issuing the vehicle currency, big economies have an obvious advantage over small economies, since they have a higher share and impact in forex markets. Lastly, the monetary policy followed by the third country whose currency act 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 volatile inflation this gain may vanish.

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

Floden & 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 & Wilander (2006:192), if a firm selects invoicing currency to minimize price updates frequency, it also maximizes its profit in the long run.

Devereux et al. (2015) study the relationship between the market share and invoicing currency choice of monopolistically competitive exporting and importing firms. Using the Canadian dataset, the authors find evidence of the following theoretical assumptions. First, 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. Secondly, if there is an increase in the LCP, there is a low level of exchange rate pass-through. Lastly, using PCP strategy implies non-monotonic 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.

The international trade literature suggests that imported intermediate goods have a positive impact on firms' productivity.⁴ For example; Goldberg et al. (2010:1728) assess the impact of reducing trade barriers on intermediate goods import and, therefore, on the firm product scope. Goldberg et al. (2010) find that 31% of the new product variety in Indian firms is attributed to the 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 trade barrier reduction leads to an increase in exports associated with an even bigger increase in imports.

Empirically, the share of imported input content of export is 20% and this is as high as 40% in smaller countries (Hummels et al. 2001:83-86). Castellani et al. (2010:425-430) find evidence that there is heterogeneity among firms, exporting firms are larger, more productive, and more capital intensive than non-exporting firms. Castellani & Fasio (2016:140-142) find evidence showing that, for Swedish firms, imported inputs are key determinants of a firm's export propensity and product variety. Kasahara & Lapham (2013) analyse the relationship with productivity and import and export decisions. Imported intermediate goods improve firms' productivity compared to the other firms. High productive firms export increase, and their goods are on average more intensive in import.

4 For empirical studies which found a positive relationship between access to imported intermediate goods and productivity gain see: for India - Goldberg et al. (2010), Indonesia - Amiti & Konings (2007), Hungary - Halpern, Koren & Szeidl (2015), Chile- Kasahara & Rodrigue (2008), Italy - Castellani et al. (2010), Sweden - Castellani & Fasio (2016), OECD countries Hummels et al. (2001), Turkey - Akgunduz & Fendoglu (2019), Turkey - Lu & Ulu (2014), France - Bas & Strauss-Kahn (2014) For theoretical studies: Theoretical literature states significance of imported intermediate input for productivity increase see: Ethier (1979; 1982), Romer (1987; 1990), Markusen (1989), Grossman & Helpman (1991)

Grossman & Helpman (1991) and Feenstra et al. (1992) theoretically show that there is a positive effect on firm level productivity because of accessing the better quality of inputs and technological spillovers. Melitz (2003) theoretically show that more productive firms enter into the export markets whereas least productive firms exit from export markets.

3. Theoretical Model of Optimal Choice of Export Currency Invoicing

In this section, we extend the DES-Chung (2016) theoretical framework, by also employing a modelling approach in Gopinath & Neiman (2014) and Halpern et al. (2015), to examine the effect of imported inputs together with physical capital 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 profit maximising price in each alternative price setting strategy, PCP, LCP, and VCP. Finally, following the Devereux et al. (2004)⁵, we develop 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.

3.1. Assumptions

Extending Chung (2016), we classify the model assumptions under the 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’ however, our model is richer from her theoretical framework with regard to the assumptions on ‘production technology’ and ‘total cost and imported density’.

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 CES demand function over the varieties of goods. p represent the elasticity of substitution across the varieties within sectors and is $p > 1$, whereas η represent the elasticity of substitution across sectoral aggregates and is $\eta > 0$.

Under these conditions, the exporting firm faces the following CES demand function:

$$D_{ik}(p_i) = \left[\frac{p_{ik}}{p_{kf}^*} \right]^{-\rho} \left[\frac{p_{kf}^*}{p^*} \right]^{-\eta} D_k^* \quad (1)$$

where D_{ik} indicate the quantity demanded, p_{ik} is the firm’s market price within sector k , p_{kf}^* show the sectoral price index for all domestic products sold in abroad (denominated foreign currency), denoted the foreign consumer price index (set in destination currency), and D_k^* show sectoral demand shifter that the firm takes it as given and it is not dependent of prices.

⁵ The authors consider endogenous currency choice without considering the presence of intermediate imported goods for the exporter firms.

3.1.2. Production Technology

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

$$Y_i = \Omega X_i^\gamma (K_i^\alpha L_i^{1-\alpha})^{1-\gamma} \quad (2)$$

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 firm's total factor productivity, γ is the share of intermediate inputs that lies between 'zero' and 'one' ($0 < \gamma < 1$), and α 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 see the role of physical capital in the endogenous choice of currency invoicing.

3.1.3. Intermediate Goods

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

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

Z_i is the quantity of domestic intermediate inputs, M_i is the quantity of imported intermediate inputs, θ 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 amongst 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 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 it is less than one ($B_i < 1$) the use of imported inputs 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;

$$P_m = SP_m^*,$$

where S is the foreign exchange rate which can be stated as units of domestic currency per unit of foreign currency and P_m^* is the price set in foreign currency.

To indicate the benefit of one unit of domestic money spent on the imported good compared to the domestic good, the productivity⁶ that adjusted by domestic and foreign prices of intermediate goods can be written as

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

⁶ As Chung (2016) linked productivity with the definition of quality in Grossman & Helpman (1991), the term can be thought of 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.

3.1.4. Total Cost and Import Intensity

At the beginning of importing any particular good, the adoption of new imported inputs into the manufacturing process is usually costly. For example, firms need to accept the costs of appointing new workers in addition to their wage rate (i.e. learning legal requirements, etc.) Therefore, in the model, we suppose all these expenses of firm i are captured by a requirement to pay a fixed cost⁷ 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 selects the quantity of inputs in order to minimize total costs at a given level of output. Hence, the total cost of the firm can be written as:

$$TC = WL + rK + P_z Z + P_m M + f_i W \quad (4)$$

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

Equation (4) can be represented by the total of a variable cost and a fixed cost:

$$TC_i = \mu_i Y + f_i W \quad (5)$$

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

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

Equation (6)⁸ can be reduced to Chung's (2016) analogue when the capital share of income, α , is equal to zero.

τ represent the productivity-enhancing effect gaining from using imported inputs can be specified as follows:

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

The productivity-enhancing effect is rising with the parameter B_i .

We can write marginal cost μ_i using equations (6) and (7) as:

$$\mu = \frac{H}{\Omega \tau^\gamma} \quad (8)$$

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

⁷ The presence of fixed cost is consistent with the empirical evidence, see Halpern et al. (2015) and Gopinath & Neiman (2014)

⁸ We omit the i indexing for simplicity.

Finally, the cost of imported input as a percentage of total costs of intermediate goods can be defined as follows:

$$\psi = \frac{SP_M^* M}{SP_M^* M + P_z Z} = [1 - \tau^{-\theta}] \quad (9)$$

The parameter ψ_i directly catch the reliance of the firm on foreign varieties. 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.

3.2. Invoicing Currency Choice

Following Devereux et al. (2004), an exporter firm is supposed to predetermine optimal price and its currency of invoicing one period forward to maximize expected discounted profits with exchange rate uncertainty after the firm chooses how much input is required in the production. A critical part of the model is that the firms' currency invoicing selection endogenous (as Devereux et al., 2004; 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 product to a destination 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 operating in the country A (home country) trades with a destination country (B) but choosing a third country's currency (C) as an invoicing currency (VCP).

This part considers profit maximization of the exporting firm under three different cases: i) PCP, ii) LCP and iii) VCP. Regardless of the pricing strategy a firm is maximizing its expected profits using a discount factor, δ , and firms look on period ahead.

3.2.1. Producer Currency Pricing (PCP)

In the case of PCP, it is assumed that the price determined for exported goods is set in the national currency in order to maximize profit, Π .

If the company determines its price in its home currency PCP, so the expected discounted profit as follows:

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

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

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

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

3.2.2. Local Currency Pricing (LCP)

In the case of LCP the exporting firm prefer to follow the price P^{LCP} for the sale of its product in the international market to maximize its profit Π . If the firm determines its price in the destination currency (local currency pricing) LCP, then the expected discounted profits as follows:

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

The profit maximizing prices under LCP derived from the first condition as follows:

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

3.2.3. Vehicle Currency Pricing (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 international market for profit Π maximization. If the exporting firm determine its price in a third country currency rather than the producer or local currency, expected discounted profit could be written as follows:

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

The resulting profit maximizing price under VCP as follows:

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

3.3. Firm's Decision Rule

After determining expected discounted profits under each of the above-mentioned pricing strategies -PCP, LCP and VCP-, now we are able to analyse which of these strategies are more desirable for an exporting firm. In line with Devereux et al. (2004) and Chung (2016), so as to get results for firm's decision rules, we need to derive a second-order approximation⁹.

In our theoretical framework¹⁰, 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;

9 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 literature; see, e.g., Devereux et al. (2004), Engel, 2006; Gopinath et al. 2010; Chung, 2016).

10 Golddberg & Tille (2013) develop a theoretical model of price determination in international trade through the lens of bargaining between exporter and importer. While their model considers only PCP and LCP, they ignore VCP. Adding the bargaining between exporter and importer would be a valuable extension of our theoretical model. Goldberg & Tille (2016) express that if invoicing currency choice modelled taking bargaining between exporter and importer into account, it is expected that importers characteristics influence the decision.

Case 1: A firm denominated its price in PCP (versus LCP) if;

$$\frac{1}{2}(var(\ln S_{AC}) + var(\ln S_{BC})) - (\text{cov}(\ln S_{AC}, \ln \mu) + \text{cov}(\ln S_{BC}, \ln \mu)) - \text{cov}(\ln S_{AC}, \ln S_{BC}) > 0 \quad (16)$$

Case 2: A firm denominated its price PCP (versus VCP) if;

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

Case 3: A firm denominated its price in LCP (versus VCP) if;

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

In line with Chung (2016), the above conditions about pricing strategies can be summarized as follows: i) exchange rate fluctuations, denoted by high $var \ln S$ forces the firm to determine its price in PCP in equation (16) and (17); ii) in addition, a negative covariance term between the exchange rate (S_{AC}) and the marginal costs (μ) also makes the firm to determine its price in PCP versus alternatives pricing strategies according to equations (16) and (17); iii) a negative covariance between the 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 $\ln S_{AC}$ and $\ln S_{BC}$ 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 via the existence of imported intermediate goods which is priced 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 et al. (2004), we underline that the existence of exchange rate risk in the decision rules for the firms, which care about expected revenues¹¹. 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. Besides, VCP as a pricing strategy creates a wider view of pricing strategy since it takes into account the exchange rate risk between destination country B

¹¹ Devereux et al. (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, the expected revenue is increasing with exchange rate increase for the firms which use PCP but falls for the firms which use LCP (ceteris paribus).

and third country 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 capital in the production function.¹²

4. Concluding Remarks

This paper explores how invoicing currency choice depends on firms' production technology. Following Devereux et al. (2004) and Chung (2016), 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. Constructed on Devereux et al. (2004) framework, Chung (2016) explains the part of imported inputs in the choice of invoicing currency for domestic firms with one-factor production model, solely labour. Including capital as a second factor of production, we extend her model since we derive a deeper 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 Home country and third country 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 destination country and third country and our richer marginal cost, μ , also leads to a more desirable choice of LCP in currency invoicing in equation (16). Finally, our theoretical contribution could be empirically examined using firm level transaction data on invoicing currency choice as in Aygul (2020).

Author's Contribution Statement

The author contributed to all phases of the study.

Conflict of Interest

The author has no conflict of interest to declare.

¹² For the detailed mathematical derivations of models see Aygul (2020).

References

- Akgunduz, Y. E. & 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
- Aygul S. (2020). The invoicing currency choice in international trade: Theory and practice (PhD Thesis, University of Reading)
- Amiti, M. & Konings, J. (2007). Trade liberalization, intermediate inputs, and productivity: Evidence from Indonesia. *American Economic Review*, 97(5), 1611-1638.
- Bacchetta, P. & van Wincoop, E. (2005). A theory of the currency denomination of international trade. *Journal of International Economics*, 67, 295-319.
- Bas, M. & 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. & Devereux, M. B. (1996). The exchange rate in a model of pricing-to-market. *European Economic Review*, 40(3-5), 1007-1021.
- Betts, C. & 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. & Tomasi, C. (2010). Firms in international trade: Importers' and exporters' heterogeneity in Italian manufacturing industry. *World Economy*, 33(3), 424-457.
- Castellani, D. & Fassio, C. (2016). Import, export and multinationality evidence from Swedish firms. *Rivista di Politica Economica*, 7, 129-151.
- 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. & Pesenti, P. (2004). Endogenous pass-through and optimal monetary policy: A model of self-validating exchange rate regimes. European University Institute, Manuscript.
- Devereux, M. B. & Shi, S. (2013). Vehicle currency. *International Economic Review*, 54(1), 97-133.
- Devereux, M. B., Engel, C. & 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. & Dong, W. (2015). Exchange rate pass-through, currency of invoicing and market share (No. w21413). National Bureau of Economic Research.
- Donnenfeld, S. & Zilcha, I. (1991). Pricing of exports and exchange rate uncertainty. *International Economic Review*, 1009-1022.
- Dotsey, M. & 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. *The American Economic Review*, 72(3), 389-405.
- Feenstra, R. C., Markusen, J. R. & Zeile, W. (1992). Accounting for growth with new inputs: Theory and evidence. *The American Economic Review*, 82(2), 415.
- Flodén, M. & 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. & Wilander, F. (2008). The currency denomination of exports—a questionnaire study. *Journal of International Economics*, 75(1), 54-69
- Goldberg, L. S. & Tille, C. (2008). Vehicle currency use in international trade. *Journal of International Economics* 76(2), 177-192.
- Goldberg, L. S. & Tille, C. (2013). A bargaining theory of trade invoicing and pricing (No. w18985). National Bureau of Economic Research.
- Goldberg, L. S. & 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. & Topalova, P. (2010). Imported intermediate inputs and domestic product growth: Evidence from India. *The Quarterly Journal of Economics*, 125, 1727-1767.
- Gopinath, G. & Neiman B. (2014). Trade adjustment and productivity in large crises. *The American Economic Review*, 104(3), 793-831.
- Gopinath, G., Itskhoki, O. & Rigobon, R. (2010). Currency choice and exchange rate pass-through. *American Economic Review*, 100(1), 304-36.
- Gopinath, G. (2015). The international price system. National Bureau of Economic Research Working Paper No:w21646
- Grossman, G. M. & Helpman, E. (1991). *Innovation and growth in the global economy*. MIT press.
- Halpern, L., Koren, M. & Szeidl, A. (2015). Imported inputs and productivity. *American Economic Review*, 105(12), 3660-3703.
- Hummels, D., Ishii, J. & Yi, K. M., (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics*, 54(1), 75-96.
- Kasahara, H. & Rodrigue, J. (2008). Does the use of imported intermediates increase productivity? Plant-level evidence. *Journal of Development Economics*, 87, 106-118.
- Kasahara, H. & Lapham, B. (2013). Productivity and the decision to import and export: Theory and evidence. *Journal of International Economics*, 89, 297-316.
- Lu, D. & Ulu, M. F. (2014). Firm size, and import content of production. Working paper, CBRT.
- Markusen, J. R. (1989). Trade in producer services and in other specialized intermediate inputs. *The American Economic Review*, 85-95.
- Melitz, M. J. (2003). The impact of trade on intra-industry reallocations and aggregate industry productivity. *Econometrica*, 71(6), 1695-1725.
- Obstfeld, M. & Rogoff, K. (1995). Exchange rate dynamics redux. *Journal of Political Economy* 103, 624–660
- Obstfeld, M., Rogoff, K. S. & Wren-Lewis, S. (1996). *Foundations of international macroeconomics*. Cambridge, MA: MIT Press.
- Obstfeld, M. & Rogoff, K. (2000). New directions for stochastic open economy models. *Journal of International Economics* 50, 117–153.
- Romer, P. M. (1987). Growth based on increasing returns due to specialization. *The American Economic Review*, 77(2), 56-62.
- Romer, P.M. (1990). Endogenous technological change. *Journal of Political Economy*, 98(5, Part 2), 71-102.