Iranian Economic Review 2021, 25(3): 419-435
DOI: 10.22059/ier.2020.75698

RESEARCH PAPER

# The Choice Theory of Vehicle Currency in International Trade: An Application for Iran

**Mina Shafieizadeh[a,*], Seyed Komail Tayebi[b], Rahman Saadat[c]**

a, c. Department of Economics, Semnan University, Semnan, Iran
b. Department of Economics, University of Isfahan, Isfahan, Iran

Received: 15 January 2019, Revised: 5 November 2019, Accepted: 19 December 2019


**Abstract**
In international trade relations, the US dollar is prominently used for invoicing, and not only for a trade involving the United States but also for other countries, it is so-called vehicle currency. This paper analytically explores the optimal policy and its implications for welfare in a two-country general equilibrium model with non-tradable goods, considering various assumptions about export invoicing currency. Fixing invoicing currency for one country's exports, compared to the other country's welfare under the two possible invoicing currencies, is this paper's main analysis. This paper derives an analytical condition under which both vehicle currency country and the non-vehicle currency country prefer vehicle currency pricing over producer currency pricing. Finally, this paper uses the choice theory of vehicle currency to explore its role in Iran's international trade. The Empirical findings show that for each value of tradable goods weight, if the bias parameter toward domestically-produced goods for foreign households equals 0.33, then Rial (home country currency) is used as a vehicle currency.
**Keywords:** Producer Currency (PCP), Vehicle Currency (VCP), Welfare Function.
**JEL Classification:** F13, F40, F41.

## Introduction

The international economic system has usually had a predominant currency to facilitate international trade. Since the mid-twentieth century, the US dollar has mostly facilitated international trade. In this sense, the dollar acts as a "vehicle currency" that is a medium of exchange between currencies. The vehicle currency has important implications for assessing macroeconomic variables. In a large class of models used to assess macroeconomic variables, prices are predetermined exogenously in producer currency (PCP), local currency (LCP), or in-vehicle currency (VCP).

According to the literature, Obstfeld and Rogoff (1995) assume that firms price their products in the currency of the country where they are located, the process that is called producer currency pricing (PCP). If prices are set in producer currency, the law of one price is held that is prices in different markets are linked to the nominal exchange rates. On the other hand, Devereux and Engel (2003), Canzoneri et al. (2005), and Duarte and Obstfeld (2008) studied the cases, in which products were priced in currency of the consumers. That is goods are priced in domestic currency for domestic sales, while they are priced in importer currency for international sales, which is called local currency pricing (LCP). Gopinath and Itskhoki (2010) studied a case, wherein the short-run, when prices were rigid, pass-through into import

* Corresponding author email: minashafieizadeh@semnan.ac.ir

prices of goods priced in producer currency was 100 percent that was zero for goods priced in local currency. Yet, when prices were adjusted, there was no difference in pass-through.

This paper, analytically studies an optimal currency policy and its implications for welfare in a two-country general equilibrium model including tradable and non-tradable goods, considering various assumptions about the export invoicing currency. Exports are assumed to be priced either in domestic currency or in the other country's currency. Specifically, it is crucial to fix the invoicing currency for one country's exports and to compare the other country's welfare under the two possible invoicing currencies. This paper derives an analytical condition, under which the non-vehicle currency country prefers VCP to PCP that is this paper's main analysis.

As it will be explained in Section 2, the main question of this paper is that if there is an analytic condition under which the non-vehicle currency country prefers VCP over PCP currency pricing. Here, we answer this question both theoretically and empirically.

The rest of this paper is organized as follows. In Section 2, the related literature and studies in this regard are reviewed. Sections 3 and 4 study the details of the currency model. Section 5 discusses the choice of vehicle currency, and Section 6 applies the calibration parameters for Iran. Finally, Section 7 concludes the paper. All proofs are relegated to the Appendix.

## Literature Review

An invoicing currency could be either exporter currency, importer currency, or vehicle currency (a third currency). The related literature has been focusing on bargaining power, industry characteristics, macroeconomic conditions, and transaction costs as the key factors of currency invoicing. Krugman (1980) found that if transaction costs decreased along with an increase in the volume of transactions, the most important currency in world payments could serve as a key currency. Once a certain currency becomes a dominant vehicle currency, the status hardly changes because of its self-reinforcing characteristic. Donnenfeld and Zilcha (1991) developed a theoretical model and found that exporters would choose the importer currency as an invoicing currency under the condition that their expected profits decrease with the rise in the volatility of prices denominated in importer currency. Viaene and Vries (1992) analyzed the currency invoicing choice in terms of strategic negotiation between trading partners. Friberg (1998) studied the invoicing currency choice including the third currency and forward currency markets. Bacchetta and van Wincoop (2005) concluded that the more is the market-share of exporters and the more differentiated are their goods, the higher is priced the exporter currency. Devereux et al. (2004) showed that in general if the exchange rate volatility was high, the exporters would choose their currencies in invoicing because the expected profit is greater in such circumstances. Engel (2006) presented the result of equivalence between the currencies of pricing and pass through. Rey (2001) showed that trading patterns affected the rise and fall of vehicle currencies by changing their transaction costs under the assumption of thick market externalities: The cost of currency exchange decreases as the volume of transactions increases. In this regard, Rey (2001) explained the historical fact that international currency shifted from the British pound to the US dollar after World War II.

Other papers include Donnenfeld and Haug (2003) and Kamps (2006). Donnenfeld and Haug (2003) found that there was a positive correlation between the exchange rate risk and the ratio of importers' currency invoicing by using Canadian import data, which supports the model developed by Donnenfeld and Zilcha (1991). They also found that the fraction of transactions invoiced in exporter currency increased with the economic size of the exporting country rather than the importing country. Kamps (2006) discovered that the existing and prospective members of the EU preferred the euro as an invoicing currency, indicating that the role of the euro, as a substitute vehicle currency of the US dollar, had increased along with the extension of its market share. Goldberg and Tille (2008) studied the coalescing effect and verified that the coalescing effect was more remarkable when the elasticity of substitution was high, and the change in demand increased the average production costs. They also found it was more likely that a single currency took a dominant role when the coalescing effect was stronger. Furthermore, they showed that hedging considerations and transaction costs played an important role in determining the invoicing currency. Goldberg and Tille (2016) also analyzed the Canadian import data by industry and partner country. They showed that the exporter with a high market share usually chose their home currency as an invoicing currency. It was also verified that exporters in the industries with greater use of raw materials were more likely to invoice in US dollars since the US dollar was a usual invoicing currency for these inputs. This finding is consistent with Chung (2016), who showed that the exporters that use more foreign currency-denominated inputs were less inclined to price in their home currency by using UK trade transaction data. According to Chung (2016), VCP is more likely for exporters who use a higher share of VCP inputs. Ligthart and da Silva (2007) analyzed the determinants of currency invoicing in Dutch goods trade with thirty OECD countries from 1987 to 1998 (before introducing the euro). They included some macroeconomic variables such as projected inflation rate, price fluctuations, the rate of improvement of the banking sector, and the unemployment rate. Results indicated that firms were less likely to invoice their home currency when the partner country had a high improvement rate of the financial sector and its share in world trade was big, and when their home currency was expected to decline. On the other hand, high expected inflation and price fluctuations in partner countries increase the home currency invoicing. Sokolova (2015) found that bargaining powers had a different impact on currency choice at the industry and firm levels.

Our research has many different aspects from the previous studies. First, in methodology, we focus on Iran's trading relations by using the general equilibrium trade model. Second, in the presented model, we use the welfare function in closed form, and compare it under different pricing schemes to write the analytical proposition of "choice theory".

We adopt these rules for two main reasons: to describe the other determinant factors of choosing the currency invoicing, and to define the choice theory of vehicle currency in international trade.

## The Model

The model is similar to the two-country model developed by Corsetti and Pesenti (2005). We modify the model by introducing a non-tradable goods sector. There are two groups of countries: home and foreign. Each country produces one tradable good and one non-tradable good. Each good is produced in a continuum of brands that are indexed over an interval [*0, 1*]. The brands of the home and foreign tradable goods are indexed by $h$ and $f$, respectively. Similarly, $n$ and $n^*$ are indices for the brands of home and foreign non-tradable goods, respectively. Households are immobile across countries and defined over a unit mass. They are indexed by $j$ in the home country and by $j^*$ in a foreign country.

### *Preferences and Constraints*

Home household $j$'s lifetime utility is assumed to depend on consumption $C(j)$, real balances ($M(j)/P$), and labor effort ($L(j)$):

$$u_t(j) = E_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \left[ \ln C_\tau(j) + \chi \ln \frac{M_\tau(j)}{P_\tau} - \kappa L_\tau(j) \right], \chi, \kappa > 0, \quad (1)$$

Where $\beta<1$ is the intertemporal discount rate. Foreign household *j**'s utility is similarly defined, with identical parameters $\chi$ and $\kappa$. For each household j, the consumption indices of home tradable brands, foreign tradable brands, and home non-tradable brands are assigned as follows respectively:

$$C_{H,t}(j)=\left[\int_0^1 C_t(h,j)^{\frac{\theta-1}{\theta}}dh\right]^{\theta/(\theta-1)}, \tag{2}$$

$$C_{F,t}(j)=\left[\int_0^1 C_t(f,j)^{\frac{\theta-1}{\theta}}df\right]^{\theta/(\theta-1)}, \tag{3}$$

$$C_{N,t}(j)=\left[\int_0^1 C_t(n,j)^{\frac{\theta-1}{\theta}}dn\right]^{\theta/(\theta-1)}, \tag{4}$$

where $\theta$ (>1) is the elasticity of substitution between brands, and $C_t(h,j)$ is the consumption of home tradable brand *h* by home agent *j* at time *t*. Here $C_t(f,j)$ and $C_t(n,j)$ are defined analogously. Consumption indices for the foreign country are similarly defined with the same constant elasticity of substitution $\theta$.

The prices of brands *h*, *f*, and *n* in the home market are assigned as *P*(*h*), *P*(*f*), and *P*(*n*), respectively. They are denominated in home currency. The prices of brands *h*, *f*, and *n** in the foreign market are *P**(*h*), *P**(*f*), and *P**(*n**), respectively. These prices are denominated in foreign currency. In addition, the price of a home tradable good in the home country, $P_H$, is defined as the lowest expenditure per unit of consumption of the home tradable good. That is the price of a home tradable good is given by:

$$P_{H,t}=\left[\int_0^1 P_t(h)^{1-\theta}dh\right]^{\theta/(\theta-1)}, \tag{5}$$

And that the demand for brand *h* by agent *j* is a function of the relative price of brand *h* to the home tradable good and consumption of home tradable good, described as:

$$C_t(h,j)=\left(\frac{P_t(h)}{P_{H,t}}\right)^{-\theta}C_{H,t}(j). \tag{6}$$

Similar expressions are obtained for the prices of tradable and non-tradable goods in each market and the demand functions for each brand.

In addition, we assume the unit elasticity of substitution between the home tradable good and the foreign tradable good, which is smaller than the elasticity of substitution between brands in each sector of $\theta$. That is each country's production sector specializes in producing one type of good. Unit elasticity assumption suggests that home household *j*'s consumption index for tradable goods ($C_{T,t}(j)$) is a Cobb–Douglas function of the consumption of a home and foreign tradable goods:

$$C_{T,t}(j)=C_{H,t}(j)^{\gamma}C_{F,t}(j)^{1-\gamma},0<\gamma<1. \tag{7}$$

where $\gamma$ is bias parameter toward domestically-produced goods for foreign households.

The price index for the tradable goods in the home market, $P_{T,t}$, which is denominated in home currency, is the lowest expenditure on one unit of the tradable goods. That is the price is a Cobb–Douglas function of home and foreign tradable goods, and that the demand for home and foreign tradable goods is a constant fraction of household *j*'s expenditure on the consumption of the tradable goods:

$$P_{T,t} = \frac{P_{H,t}^{\gamma} P_{F,t}^{1-\gamma}}{\gamma^{\gamma}(1-\gamma)^{1-\gamma}} \tag{8}$$

$$P_{T,t}C_{T,t}(j) = \frac{1}{\gamma} P_{H,t}C_{F,t}(j) = \frac{1}{1-\gamma} P_{F,t}C_{F,t}(j). \tag{9}$$

The consumption basket for home agent *j*, *C*(*j*) is assumed to consist of the consumption indices of the tradable and non-tradable goods with unit elasticity of substitution. Then the consumption basket is a Cobb–Douglas function of these goods:

$$C_t(j) = C_{T,t}(j)^{\varphi} C_{N,t}(j)^{1-\varphi}, 0 < \varphi < 1. \tag{10}$$

Then, by the same reasoning as for the price index of tradable goods in the home market, the Equations 11 and 12 are obtained:

$$P_t = \frac{P_{T,t}^{\varphi} P_{N.t}^{1-\varphi}}{\varphi^{\varphi}(1-\varphi)^{1-\varphi}}. \tag{11}$$

$$P_t C_t(j) = \frac{1}{\varphi} P_{T,t}C_{T,t}(j) = \frac{1}{1-\varphi} P_{N,t}C_{N,t}(j). \tag{12}$$

Foreign agent *j** consumptions and prices are similar to the home counterparts of (2)-(12).

Households in the home country hold a portfolio of home tradable goods firms and non-tradable goods firms, home money $M_t$, and two bonds (the home country bond $B_t$ and the foreign country bond $B_t^*$ denominated in home and foreign currencies, respectively). They receive wages and profits from the firms, while lump-sum taxes *T* (denominated in home currency) are imposed on them. Assume $i_t$ and $i_t^*$ to be the nominal interest rates on the home and foreign bonds, respectively. We assume that $i_t$ and $i_t^*$ are paid at the beginning of the period $t$, and are known as $t-1$. The home household *j*'s period-by-period budget constraint is summarized as:

$$M_t(j) + B_{t+1}(j) + \varepsilon_t B_{t+1}^*(j) \le M_{t-1}(j) + \left(1+i_t\right)B_t(j) + \left(1+i_t^*\right)\varepsilon_t B_t^*(j) + W_t L_t(j) +$$
$$\int_0^1 \Pi_t(h)dh + \int_0^1 \Pi_t(n)dn - T_t(j) - \int_0^1 P_t(h)C_t(h,j)dh - \int_0^1 P_t(f)C_t(f,j)df - \int_0^1 P_t(n)C_t(n,j)dn. \tag{13}$$

Since there is no government expenditure, and home money is solely held by home households, the home government rebates seignior age revenue to domestic households as lump-sum transfers. The home government budget constraint can be obtained as:

$$\int_0^1 \left(M_t(j) - M_{t-1}(j)\right) dj + \int_0^1 \mathrm{T}_t(j) dj = 0. \tag{14}$$

The foreign government faces the same constraint.

The international bond markets should be clear in each period:

$$\int_0^1 B_t(j) dj + \int_0^1 B_t\left(j^*\right) dj^* = \int_0^1 B_t^*(j) dj + \int_0^1 B_t^*\left(j^*\right) dj^* = 0. \tag{15}$$

The initial money balance is assumed to be zero in each country based on $R_{t_0}(j) - M_{t_0-1}(j) = 0$ and $R^*_{t_0}\left(j^*\right) - M^*_{t_0-1}\left(j^*\right) = 0$. Then, in equilibrium, the current account is balanced at any subsequent point in time. Shocks adjustments are made only through changes in terms of trade without variations in national foreign wealth. This suggests that:

$$(1-\gamma) P_t C_t = \gamma \varepsilon_t P_t^* C_t^*, \tag{16}$$

That is, the international ratio of marginal utilities from nominal spending is constant.

*Production and Constraints*

Production technology is linear in labor input. Productivity is sector-specific as well as country-specific. Each brand is produced by a single firm and is sold under monopolistic competition. In the home country, the output of brand *h* (*Y*(*h*)) and that of brand *n* (*Y*(*n*)) are produced with the following production functions:

$$Y_t(h) = A_{T,t} L_t(h), Y_t(n) = A_{N,t} L_t(n), \tag{17}$$

where $A_{T,t}$ and $A_{N,t}$ are productivity in the home tradable and non-tradable goods sectors, respectively. The foreign firms' production functions are defined analogously.

Productivity shocks are governed by the following stochastic processes:

$$\ln A_{k,t} = \ln A_{k,t-1} + u_{k,t}, \tag{18}$$

$$\ln A^*_{k,t} = \ln A^*_{k,t-1} + u^*_{k,t}, \tag{19}$$

where $u_{k,t}$ and $u^*_{k,t}\left(k = T, N\right)$ are zero-mean, independently and identically distributed, normally distributed random variables with variance $\sigma^2_{u_k}$ and $\sigma^2_{u^*_k}$, respectively. Brand *h* is tradable and can be consumed by home and foreign households. The total consumption of brand *h* should not be larger than the output. The resource constraint can be described as:

$$Y_t(h) \geq \int_0^1 C_t(h, j)\,dj + \int_0^1 C_t^*\left(h, j^*\right)dj^*. \tag{20}$$

The home non-tradable brands, on the other hand, are solely consumed by home households. The resource constraint for brand *n* is:

$$Y_t(n) \geq \int_0^1 C_t(n, j)\,dj. \tag{21}$$

The labor is assumed to be freely mobile within a country. The home country's labor market must satisfy:

$$\int_0^1 L_t(j)\,dj \geq \int_0^1 L_t(h)\,dh + \int_0^1 L_t(n)\,dn. \tag{22}$$

The markets for brand *f*, brand *n**, and foreign labor are subject to similar constraints.

Firms take the nominal wage as given. In the home country, the marginal cost of producing a tradable brand is $W_t/A_{T,t}$ and that of producing a non-tradable brand is $W_t/A_{N,t}$, where $W_t$ is the nominal wage. Note that the marginal cost is identical across firms within the same sector. Then the profit of the firm producing brand h can be obtained as:

$$\Pi_t(h) = \left(P_t(h) - \frac{W_t}{A_{T,t}}\right)\int_0^1 C_t(h, j)\,dj + \left(\varepsilon_t P_t^*(h) - \frac{W_t}{A_{T,t}}\right)\int_0^1 C_t^*\left(h, j^*\right)dj^*, \tag{23}$$

where $\varepsilon_t$ is the nominal exchange rate, defined as the home currency price of one unit of the foreign currency at time *t*. In addition, the profit of the firm producing brand *n* of the home non-tradable good is obtained as:

$$\Pi_t(n) = \left(P_t(n) - \frac{W_t}{A_{N,t}}\right)\int_0^1 C_t(n, j)\,dj. \tag{24}$$

Firms are assumed to be monopolistic competitors. They set prices at the beginning of each period that is before the realization of shocks. Once prices are set, they are sticky for one period. When firms choose prices, they ignore the impact of their pricing decisions on the aggregate price indices.

*Monetary Policy*

The monetary authority in each country controls the money supply process. Following Devereux and Engel (2003), the home and foreign log money supply are assumed as Equations 25 and 26, respectively.

$$m_t = m_{t-1} + \mu_t \tag{25}$$

$$m_t^* = m_{t-1}^* + \mu_t^*, \tag{26}$$

Monetary policy is defined as rules for $\mu_t$ and $\mu_t^*$. The monetary rules are designed to respond to unanticipated shocks, so that $E_{t-1}\mu_t = 0$ and $E_{t-1}\mu_t^* = 0$ holds.

*Optimal Pricing*

This section discusses optimal pricing decisions by firms and assigns an equilibrium for the case of VCP with the home currency. The other cases (PCP, LCP, and VCP with the home currency) are analogous. Under VCP with the home currency, tradable goods firms, in both the home and foreign countries, price their products in the home country's currency when they export. For domestic sales, prices are set in home currency.

The optimal price is set as follows. Taking prices and wages as given, household j in the home country maximizes Equation 1 subject to Equations 2–6 together with their analogs, 7–12 and 13, by choosing the optimal levels of consumption, labor, and asset holdings.

Household *j*'s optimal intertemporal decision on bonds suggests the following Euler equation:

$$\frac{1}{P_t C_t(j)} = (1 + i_{t+1}) \beta E_t \left[ \frac{1}{P_{t+1} C_{t+1}(j)} \right]. \tag{27}$$

Assume that $Q_{t,t+1}(j)$ is household *j*'s stochastic discount factor. Due to the log utility on consumption, the stochastic discount factor is described as Equation 28:

$$Q_{t,t+1}(j) = \beta \frac{P_t C_t(j)}{P_{t+1} C_{t+1}(j)}. \tag{28}$$

Since consumption is equalized across households, the stochastic discount factor is also identical, that is $Q_{t,t+1}(j) = Q_{t,t+1}$, which leads to the following Euler equation:

$$1 = (1 + i_{t+1}) E_t Q_{t,t+1}. \tag{29}$$

Home tradable firm *h* sets its optimal price so as to maximize the current discount value of profits:

$$E_{t-1}\left[ Q_{t-1,t} \Pi_t(h) \right]. \tag{30}$$

Since home currency is used for international transactions, foreign tradable goods firms have to price their exports in home currency, while they set their prices for domestic sales in foreign currency. Maximizing Equation 30 for $P_t(h)$ and $P^*_t(h)$, and rearranging the first order condition with Equation 16 leads to Equations 31 and 32:

$$P_t(h)=\frac{\theta}{\theta-1}E_{t-1}\left[\frac{W_t}{A_{T,t}}\right] \tag{31}$$

$$P_t^*(h)=\frac{\theta}{\theta-1}E_{t-1}\left[\frac{W_t}{\varepsilon_t A_{T,t}}\right]. \tag{32}$$

For home tradable brand firm h, the domestic sales price is the expected marginal cost multiplied by the markup $\theta/(\theta-1)$, and the export price is the expected marginal cost denominated in foreign currency multiplied by the same markup. Both $P_t(h)$ (denominated in home currency) and $P^*_t(h)$ (denominated in foreign currency) are determined based on information at the time $t-1$ due to the structure of price rigidity. The pricing decision is symmetric so that all home tradable firms set the price $P_t(h)=P_{H,t}(h)$ for all *h*.

Similarly, home non-tradable firm *n* maximizes the current discount value of profits as Equation 33:

$$E_{t-1}\left[Q_{t-1,t}\,\Pi_t(n)\right], \tag{33}$$

And as a result, the optimal price of brand *n* is assigned by Equation 34:

$$P_t(n)=\frac{\theta}{\theta-1}E_{t-1}\left[\frac{W_t}{A_{N,t}}\right]. \tag{34}$$

The prices of home non-tradable firms at time *t* are identical and equal to the expected marginal cost (conditional on information available at the time $t-1$) augmented by the markup.

Since home currency is used as a vehicle currency, foreign tradable goods firms use pricing to the market. Home tradable goods firms face a different situation. Since home firms price both their exports and domestic sales in home currency, the law of one price is held for each home tradable firm: The home export prices that foreign consumers face are equal to home currency prices for the home market multiplied by the nominal exchange rate; that is,

$$P_t(f)=\varepsilon_t P_t^*(f). \tag{35}$$

Consequently, the law of one price is held for tradable goods price indices in home and foreign countries $P_{F,t} = \varepsilon_t P^*_{F,t}$. Given the law of one price for each brand, foreign firms maximize their profits according to $P^*_t(f)$ for the domestic market, and $P_t(f)$ for the export market. The profits are calculated through Equations 36 and 37:

$$P^*_t(f) = \frac{\theta}{\theta - 1} E_{t-1}\left[\frac{W^*_t}{A^*_{T,t}}\right] \tag{36}$$

$$P_t(f) = \frac{\theta}{\theta - 1} \varepsilon_t E_{t-1}\left[\frac{W^*_t}{A^*_{T,t}}\right]. \tag{37}$$

The decision of foreign non-tradable firm $n^*$ is obtained through the same procedure. It is calculated through Equation 38:

$$P^*_t\left(n^*\right) = \frac{\theta}{\theta - 1} E_{t-1}\left[\frac{W^*_t}{A^*_{N,t}}\right]. \tag{38}$$

The prices of foreign brands are characterized in the same manner as those of home brands: Prices are identical across brands in the same market and depend on the expected marginal cost augmented by the markup. One prominent observation is that the prices of foreign brands in the home market are subject to the realization of the nominal exchange rate at time *t*. Note that this is not the case for the prices of home brands in the foreign market $P^*_t(h)$. This is the consequence of the VCP framework. Since foreign currency is used for all international transactions, the prices of foreign brands are set in foreign currency. Then, in the home markets, the foreign brands' prices must be denominated in home currency by way of the current nominal exchange rate.

## Optimal Policy

This section solves the model and analyzes the optimal policy. We consider the rigid price equilibrium and optimal policy rules under VCP with home currency.

Here the model is solved under the assumption that prices are set before the realization of shocks. In addition, they are rigid for one period, and the optimal policy rules are derived. In this part, we study VCP with home currency. The procedure for the other cases is analogous and is not repeated.

If the home currency is used in all international transactions, any price for goods that home households purchase would preset one period in advance. On the other hand, the home tradable goods' prices in foreign market equal the prices in the home market, which are present in home currency, converted into foreign currency prices by the nominal exchange rate in the current period.

In sum, under the assumption of rigid prices and VCP with home currency, $P_{F,t}, P^*_{F,t}, P^*_{H,t}, P_{N,t}$, and $P^*_{N,t}$ are set at the beginning of period *t*, and are rigid during that period, while $P_{H,t}$ is affected by the realization of the current nominal exchange rate $\varepsilon_t$ as shown already. So, the home price index $P_t$ and the foreign price index $P_t^*$ are included in the information set for time t and time $t-1$, respectively.

Then, deriving the optimal policy rules is straightforward. Taking the invoicing currencies (i.e. parameters $\eta$ and $\eta^*$), maximizing the welfare functions (Corsetti and Pesenti, 2005), given the policy coefficients, leads to the optimal policy rules, summarized in Table 1.[1]

**Table 1.** Optimal Policy Rules under VCP with Home Currency

| Foreign country | Home country |
|---|---|
| $\xi_1 = \frac{\gamma\phi}{1-\eta(2-\eta)(1-\gamma)\phi}$ | $\psi_1 = \frac{(1-\eta^*)(1-\gamma)\phi}{1-\eta^*(2-\eta^*)(1-\gamma)\phi}$ |
| $\xi_2 = \frac{1-\phi}{1-\eta(2-\eta)(1-\gamma)\phi}$ | $\psi_2 = 0$ |
| $\xi_3 = \frac{(1-\eta)(1-\gamma)\phi}{1-\eta(2-\eta)(1-\gamma)\phi}$ | $\psi_3 = \frac{\gamma\phi}{1-\eta^*(2-\eta^*)(1-\gamma)\phi}$ |
| $\xi_4 = 0$ | $\psi_4 = \frac{1-\phi}{1-\eta^*(2-\eta^*)(1-\gamma)\phi}$ |

**Source**: Research finding.

## The Choice of Vehicle Currency

This paper studies the welfare model by using the optimal policy rules under different pricing schemes. In the model, each country's welfare can be described in closed form, and it is, therefore, possible to analytically compare welfare under different pricing schemes. The following assumption summarizes the result.

Suppose that the home country is the vehicle currency. This condition is obtained by comparing the foreign country's welfare under VCP with home currency and PCP. Then, the foreign country prefers VCP with home currency over PCP if and only if:

$$\sigma_{u_N}^2 > \Lambda_1 \sigma_{u_T}^2 + \Lambda_3 \sigma_{u_T^*}^2 \tag{39}$$

where:

$$\Lambda_1 = \frac{\gamma\phi\left[2\left(1-\phi\right)+\gamma\left(1-\gamma\right)\phi^2\right]}{\left(1-\phi\right)^2\left[2-\left(1-\gamma\right)\phi\right]} \tag{39-a}$$

$$\Lambda_3 = \frac{\left(1-\gamma\right)\phi\left(1-\left(1-\gamma\right)\phi\right)^2}{\left(1-\phi\right)^2\left[2-\left(1-\gamma\right)\phi\right]} \tag{39-b}$$

1. The model solution by MATLAB is available in Appendix A.

The home country prefers VCP with the foreign currency over PCP if and only if:

$$\sigma^2_{u_N^*} > \Lambda_3 \sigma^2_{u_T} + \Lambda_1 \sigma^2_{u_T^*} \tag{40}$$

where:

$$\Lambda_1 = \frac{\gamma\phi\left[2(1-\phi)+\gamma(1-\gamma)\phi^2\right]}{(1-\phi)^2\left[2-(1-\gamma)\phi\right]} \tag{40-a}$$

$$\Lambda_3 = \frac{(1-\gamma)\phi\left(1-(1-\gamma)\phi\right)^2}{(1-\phi)^2\left[2-(1-\gamma)\phi\right]} \tag{40-b}$$

It is of interest to determine whether VCP can improve the welfare of both the vehicle and non-vehicle currency countries. For simplicity, assume the symmetric volatilities of productivity shocks as
$\sigma^2_{u_N} = \sigma^2_{u_N^*}, \sigma^2_{u_T} = \sigma^2_{u_T^*}$.

Then, the condition for the vehicle currency country is:

$$\frac{\sigma^2_{u_N}}{\sigma^2_{u_T}} > \frac{(1-\phi)\gamma + \left(1-(1-\gamma)\phi\right)\left(2\gamma^2\phi - 2\gamma\phi + \phi + 2\gamma - 1\right)}{(1-\gamma)(1-\phi)^2} \tag{41}$$

On the other hand, the condition for the non-vehicle currency country is as Equation 42:

$$\frac{\sigma^2_{u_N}}{\sigma^2_{u_T}} > \frac{\gamma\phi\left(2(1-\phi)+\gamma(1-\gamma)\phi^2\right)+(1-\gamma)\phi\left(1-(1-\gamma)\phi\right)^2}{(1-\phi)^2\left(2-(1-\gamma)\phi\right)} \tag{42}$$

As a result, conditions 41 and 42 are characterized by two parameters on consumption indices $\gamma$ and $\phi$ and also by the volatility ratio between the tradable and non-tradable goods sectors. It is of interest to provide the choice theory of vehicle currency in international trade and determine which currency in international trade of Iran is the same as a vehicle currency. We calibrate the model in the next section and address this aim both empirically and theoretically.

## An Application for Iran

According to Conditions 41 and 42, there are four parameters to be calibrated. Some of these parameters can be set directly from other empirical studies especially here from Asia Productivity Organization (APO), and some others can be set directly from the present study. These parameters include:variance of labor , the $\sigma^2_{u_T}$ productivity in tradable sector;-nonthe variance of labor productivity in the , $\sigma^2_{u_N}$ tradable sector;-on homeweight the , $\gamma$and ;weight on tradable goodsthe , $\phi$ produced tradable goods, as shown in Table 2.

**Table 2.** Parameters Used for Calibration

| | |
|---|---|
| $\sigma_{u_T}^2$ | Variance of labor productivity in the tradable sector |
| $\sigma_{u_N}^2$ | Variance of labor productivity in the non-tradable sector |
| $\phi$ | Weight on tradable goods |
| $\gamma$ | Weight on home-produced tradable goods |

To provide the choice theory of vehicle currency in international trade, and to determine which currency in international trade of Iran and its most important trading partners is the vehicle currency, we assume that:

1. Iran is its home country and China is a foreign country as its major trading partner. Additionally, the home country is the vehicle currency country.
2. According to APO (2007), each country produces finance goods as a proxy of tradable goods and construction goods as a proxy of non-tradable goods[1].

$\sigma_{u_T}^2, \sigma_{u_N}^2$ : Depending on the definitions of output and labor input measures, labor productivity can be measured in several ways. This paper presents the labor productivity measure in terms of GDP per worker[2]. Figure 1 indicates the cross-country comparisons of per-worker productivity levels. On this measure, Iran followed a productivity level of 48.3%, while China reached the productivity level of 17.4%. Thus, the volatility ratio between the tradable and non-tradable goods sectors equals 0.36.

The conditions characterizing a solution to the model consist of two measurements:

$$2.77 > \frac{(1-\phi)\gamma + (1-(1-\gamma)\phi)(2\gamma^2\phi - 2\gamma\phi + \phi + 2\gamma - 1)}{(1-\gamma)(1-\phi)^2}$$

which is held for vehicle currency country, and

$$2.77 > \frac{\gamma\phi(2(1-\phi) + \gamma(1-\gamma)\phi^2) + (1-\gamma)\phi(1-(1-\gamma)\phi)^2}{(1-\phi)^2(2-(1-\gamma)\phi)}$$

which is held for non-vehicle currency countries.

Since the conditions are highly nonlinear in these parameters, we used MATLAB to illustrate the conditions under which VCP is preferred to PCP as shown in Figure 1.[3]

1. See APO Data book, 2017, Table 18 in Section 6.3, p.114.
2. See APO Data book, 2017, Figure 106 in Appendix 4.
3. Calculations available upon request.

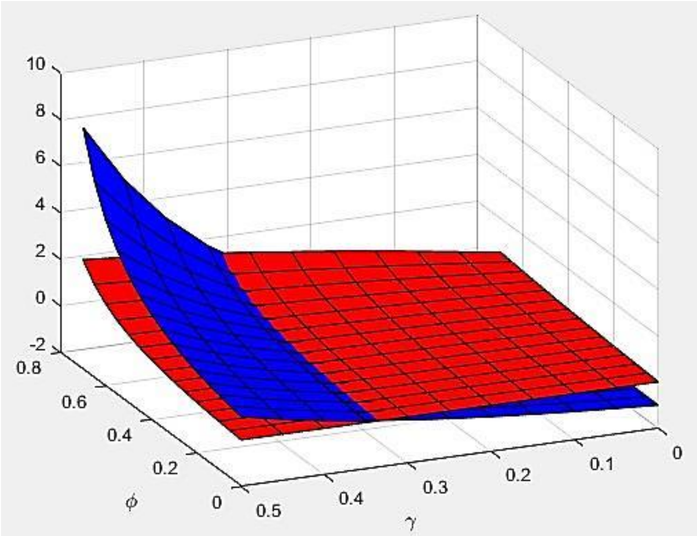


**Figure 1**. Parameter Regions for the Case of VCP Being Preferred
**Source**: Research finding.

In this respect, if $(\phi, \gamma)$ equals ($\phi$, 0.33), Rial (home country currency) is preferred by both countries. In other words, if the weight on tradable goods equals $\phi$, and the weight on home-produced tradable goods equals 0.33, Rial (the home country currency) is preferred by both countries.

## Conclusion

This paper investigated welfare consequences under various assumptions on the export invoicing currency. Using a standard two-country general equilibrium model with price rigidity and introducing non-tradable goods, we derived optimal rules and the welfare model in a closed-form. Then, with the assumption that one country's exports were priced in a particular currency (its currency or the other country's currency), the other country's welfare was analytically examined, depending on the invoicing currency for its exports.

We found that VCP could enhance welfare for both vehicle currency countries and non-vehicle currency countries in terms of PCP. In addition, this paper provided the Choice Theory of vehicle currency in international trade, specifically for Iran as the case study. So that if $(\phi, \gamma)$ equals ($\phi$, 0.33), Rial (home country currency) is preferred by both country, and is used as a vehicle currency.

## References

[1] Bacchetta, P., & Van Wincoop, E. (2005). A Theory of the Currency Denomination of International Trade. *Journal of International Economics*, *67*(2), 295–319.

[2] Canzoneri, M. B., Cumby, R. E., & Diba, B. T. (2005). The Need for International Policy Coordination: What's Old, What's New, What's yet to come? *Journal of International Economics*, *66*, 363–384.

[3] Chung, W. (2016). Imported Inputs and Invoicing Currency Choice: Theory and Evidence from UK Transaction Data. *Journal of International Economics*, *99*, 237–250.

[4] Corsetti, G., & Pesenti, P. (2005). International Dimensions of Optimal Monetary Policy. *Journal of Monetary Economics*, *52*, 281–305.

[5] Devereux, M. B., & Charles, M. E. (2003). Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility. *Review of Economic Studies*, *70*(4), 765–783.

[6] Devereux, M., Engel, C., & Storgaard, P. (2004). Endogenous Exchange Rate Pass-Through When Nominal Prices Are Set in Advance. *Journal of International Economics, 63*, 263–291.

[7] Donnenfeld, S., & Zilcha, I. (1991). Pricing of Exports and Exchange Rate Uncertainty. *Review of International Economics, 32*, 1009–1022.

[8] Donnenfeld, S., & Haug, A. (2003). Currency Invoicing in International Trade: An Empirical Investigation. *Review of International Economics, 11*, 332–345.

[9] Duarte, M., & Obstfeld, M. (2008). Monetary Policy in the Open Economy Revisited: The Case for Exchange-Rate Flexibility Restored. *Journal of International Money and Finance, 27*(6), 949–957.

[10] Engel, C. (2006). Equivalence Results for Optimal Pass-Through, Optimal Indexing to Exchange Rates, and Optimal Choice of Currency for Exporting Price. *Journal of the European Economic Association, 4*, 1249–1260.

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

[12] 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.

[13] ---------- (2008). Vehicle Currency Use in International Trade. *Journal of International Economics, 76*, 177–192.

[14] Gopinath, G., & Itskhoki, O. (2010). Frequency of Price Adjustment and Pass-through. *Quarterly Journal of Economics*, *125*(2), 675–727.

[15] Kamps, A. (2006). The Euro as Invoicing Currency in International Trade. *ECB Working Paper, 665*, Retrieved from https://www.researchgate.net/publication/4807070_The_Euro_as_Invoicing_Currency_in_International_Trade

[16] Krugman, P. (1980). Vehicle Currencies and the Structure of International Exchange. *Journal of Money, Credit, and Banking, 12*, 513–526.

[17] Ligthart, J., & da Silva, J. A. (2007). Currency Invoicing in International Trade: A Panel Data Approach. *Center Discussion Paper Series,* Retrieved from: https://research.tilburguniversity.edu/en/publications/currency-invoicing-in-international-trade-a-panel-data-approach

[18] Obstfeld, M., & Kenneth, R. (1995). Exchange Rate Dynamics Redux. *Journal of Political Economy*, *103*(3), 624–660.

[19] Rey, H. (2001). International Trade and Currency Exchange. *Review of Economic Studies*, *68*, 443–464.

[20] Sokolova, M. V. (2015). Strategic Currency Choice in International Trade. *CESifo Working Paper, 5574,* Retrieved from https://www.researchgate.net/publication/282810146_Strategic_Currency_Choice_in_International_Trade

[21] Viaene, J., & Vries, C. (1992). On the Design of Invoicing Practices in International Trade. *Open Economies Review, 3,* 133–142.


## Appendix

*Appendix A: Proof of the Home Country's Optimal Policy Rules*

Maximizing the welfare functions by using the policy coefficients of $\xi_i\,,\psi_i$ encoded in Matlab:

$$\begin{aligned} W &= -\frac{\sigma_c^2}{2} - \frac{\eta^2(1-\gamma)\phi(1-(1-\gamma)\phi)}{2}\sigma_e^2 + \gamma\phi\sigma_{cu_T} \\ &+(1-\gamma)\phi\sigma_{cu_T^*} + (1-\phi)\sigma_{cu_N} + \eta\gamma(1-\gamma)\phi^2\sigma_{eu_T} \qquad \text{(c-1)} \\ &-\eta(1-\gamma)\phi(1-(1-\gamma)\phi)\sigma_{eu_T^*} + \eta(1-\gamma)\phi(1-\phi)\sigma_{eu_N}\,. \end{aligned}$$

$$\sigma_c^2 = [(1-\eta(1-\gamma)\phi)\xi_1 + \eta(1-\gamma)\phi\psi_1]^2\sigma_{u_T}^2$$
$$+[(1-\eta(1-\gamma)\phi)\xi_2 + \eta(1-\gamma)\phi\psi_2]^2\sigma_{u_N}^2$$
$$+[(1-\eta(1-\gamma)\phi)\xi_3 + \eta(1-\gamma)\phi\psi_3]^2\sigma_{u_T^*}^2$$
$$+[(1-\eta(1-\gamma)\phi)\xi_4 + \eta(1-\gamma)\phi\psi_4]^2\sigma_{u_N^*}^2. \quad \text{(c-2)}$$

$$\sigma_e^2 = (\xi_1-\psi_1)^2\sigma_{u_T}^2 + (\xi_2-\psi_2)^2\sigma_{u_N}^2$$
$$+(\xi_3-\psi_3)^2\sigma_{u_T^*}^2 + (\xi_4-\psi_4)\sigma_{u_N^*}^2. \quad \text{(c-3)}$$

$$\sigma_{cu_T} = [(1-\eta(1-\gamma)\phi)\xi_1 + \eta(1-\gamma)\phi\psi_1]\sigma_{u_T}^2. \quad \text{(c-4)}$$

$$\sigma_{cu_N} = [(1-\eta(1-\gamma)\phi)\xi_2 + \eta(1-\gamma)\phi\psi_2]\sigma_{u_N}^2. \quad \text{(c-5)}$$

$$\sigma_{cu_T^*} = [(1-\eta(1-\gamma)\phi)\xi_3 + \eta(1-\gamma)\phi\psi_3]\sigma_{u_T^*}^2. \quad \text{(c-6)}$$

$$\sigma_{eu_T} = (\xi_1-\psi_1)\sigma_{u_T}^2. \quad \text{(c-7)}$$

$$\sigma_{eu_N} = (\xi_2-\psi_2)\sigma_{u_N}^2. \quad \text{(c-8)}$$

$$\sigma_{eu_T^*} = (\xi_3-\psi_3)\sigma_{u_T^*}^2. \quad \text{(c-9)}$$

```
syms W sigmasquarec sigmasquaree sigmasquareUT sigmasquareUN sigmasquareUstarT sigmasquareUstarN gamma xi1 xi2 xi3 xi4 phi psi1 psi2 psi3 psi4 sigmacUT sigmacUN sigmacUstarT sigmaeUT sigmaeUN sigmaeUstarT a b c d e f g h ;

sigmasquarec = ((1-(1-gamma)*phi)*xi1+(1-gamma)*phi*psi1)^2*sigmasquareUT + ((1-(1-gamma)*phi)*xi2+(1-gamma)*phi*psi2)^2*sigmasquareUN + ((1-(1-gamma)*phi)*xi3+(1-gamma)*phi*psi3)^2*sigmasquareUstarT+ ((1-(1-gamma)*phi)*xi4+(1-gamma)*phi*psi4)^2*sigmasquareUstarN ;

sigmasquaree = (xi1-psi1)^2*sigmasquareUT + (xi2-psi2)^2*sigmasquareUN + (xi3-psi3)^2*sigmasquareUstarT + (xi4-psi4)^2*sigmasquareUstarN ;

sigmacUT = ((1-(1-gamma)*phi)*xi1+(1-gamma)*phi*psi1)*sigmasquareUT ;

sigmacUN = ((1-(1-gamma)*phi)*xi2+(1-gamma)*phi*psi2)*sigmasquareUN ;

sigmacUstarT = ((1-(1-gamma)*phi)*xi3+(1-gamma)*phi*psi3)*sigmasquareUstarT ;

sigmaeUT = (xi1-psi1)*sigmasquareUT ;

sigmaeUN = (xi2-psi2)*sigmasquareUN ;

sigmaeUstarT = (xi3-psi3)*sigmasquareUstarT ;
```

```
W = - a/2 - (((1-gamma)*phi*(1-(1-gamma)*phi))/2)*b + gamma*phi*c + (1-gamma)*phi*d + (1-phi)*e + gamma*(1-gamma)*phi^2*f - (1-gamma)*phi*(1-(1-gamma)*phi)*g + (1-gamma)*phi*(1-phi)*h ;

subs ( W , [a,b,c,d,e,f,g,h] , [sigmasquarec , sigmasquaree , sigmacUT , sigmacUstarT , sigmacUN , sigmaeUT , sigmaeUstarT , sigmaeUN] ) ;

j = jacobian ( utility , [xi1 , xi2 , xi3 , xi4 , psi1 , psi2 , psi3 , psi4] ) ;

s = solve( j , [xi1 , xi2 , xi3 , xi4 , psi1 , psi2 , psi3 , psi4] ) ;
```