Financial Hedging and Optimal Currency of Invoicing

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Trade Invoicing and Exchange Rates

Trade invoicing is at the core of international economics:

- **Prices** are often sticky in a currency.
- Invoicing determines the **real** effects of exchange rate fluctuations.
- Majority of international trade and debt **financing** is in the dollar, especially in emerging markets.

Question: how does FX financial hedging affect the currency of invoicing choice in international trade?

- Classic theory: irrelevant (e.g. New Keynesian models)
- This paper: relevant

This Paper

Result: financial hedging affects invoicing when *quantities* are in part set in advance and hedging markets are imperfect.

- Classic: sticky prices, flexible quantities (Calvo, 1983)

This Paper

Result: financial hedging affects invoicing when *quantities* are in part set in advance and hedging markets are imperfect.

- Classic: sticky prices, flexible quantities (Calvo, 1983)

Prediction: the producer invoices in its own currency when the buyer has a higher FX risk bearing capacity:

> *"[P]art of the intensive involvement in the buying process is to reduce risk for our vendors. We pay for that mustard in euros, their local currency now. We assume the risk of that currency fluctuation so that folks can just focus on making mustard... [and] our costs go down..."*

—"Value and Supply Chain at Trader Joe's (2021)"

Literature

1. **Open economy with sticky prices**
   - International Macro: Bacchetta and van Wincoop (2005); Engel (2006); Gopinath, Itskhoki and Rigobon (2010); Goldberg and Tille (2016); Gopinath et al. (2020); Amiti, Itskhoki and Konings (2022); Mukhin (2022)
   - Financial Frictions: Smith and Stulz (1985); Froot, Scharfstein and Stein (1993); Rampini and Viswanathan (2010); Gopinath and Stein (2021); Drenik, Kirpalani and Perez (2022); Coppola, Krishnamurthy and Xu (2023)
2. **Normative implications for capital controls in general equilibrium: a dollarization dilemma**
   - Monetary and Financial Policy: Farhi and Werning (2016); Korinek (2018); Bianchi and Lorenzoni (2022); Basu et al. (2023); Egorov and Mukhin (2023)
3. **Rationalize the rise of the renminbi and the dominance of the dollar with financial hedging**
   - Empirical Evidence: Ito et al. (2018); Barbiero (2020); Alfaro, Calani and Varela (2021); Lyonnet, Martin and Mejean (2022); Benguria and Novy (2025); Boz et al. (2025); Bahaj and Reis (2026)

Environment

- **Timing**: Static model with risk
- **States**: Exogenous vector $x \in \mathbb{R}^k$
  - e.g. costs, aggregate demand, exchange rates, etc.
- US market consists of a measure of buyers indexed by $m \in [0, 1]$
  - **Preferences**: US buyers have constant elasticity of demand preferences $Q^{-1/\sigma}$ for some elasticity $\sigma > 1$.
  - Total quantities sold to the US market are $Q = \int_0^1 Q^m dm$.
- French producer earns profits $(P - C)\, Q$ from selling (mustard) to US market at unit price P and quantity Q.
  - **Technology**: constant marginal cost C varies across states x.
  - French producer is a monopolist.

Exchange Rates and Prices

Euro and dollar:

- Normalize the first period exchange rate to 1
- Dollar appreciation $s = S - 1$
- Euro is the numeraire for all prices and payoffs

Pricing Schedule: Euro prices are fixed in advanced, but invoiced in a share of the dollar $\beta \in [0, P_0]$

$$P(s) = P_0 + \beta \cdot s \qquad \forall x \in X$$

- Formalizes **sticky** prices
  - $\beta = 0$: French producer sets prices in euros (PCP)
  - $\beta = P_0$: French producer sets prices in dollars (LCP)

Quantities (Key Contribution)

Quantity Schedule: The buyers in the US market are heterogeneous. The buyers indexed $m \in [0, \delta]$ fix quantities ex-ante Q_{ea}, while the remaining buyers determine quantities ex-post $Q_{ep}(x)$, so that

$$Q(x) = \delta\, Q_{ea} + (1 - \delta)\, Q_{ep}(x) \qquad \forall x \in X$$

- BLS firm surveys: $\delta > 0.5$ (Gopinath and Rigobon, 2008)
  - Classic New Keynesian models: $\delta = 0$ (Calvo, 1983)
- My terminology: Quantities are **flexible** when they are ex-post determined $\delta = 0$, otherwise they are **sticky**.

Example: TJ's Master Vendor Agreement

Financial Frictions

- Exogenous marginal utility of wealth (euros): M^i for French seller and M^j for US buyers.
- Financial Frictions: Assume $M^i \neq M^j$
- Sufficient Statistic: effective forward rate,

$$F_i = \mathbb{E}\left[\frac{M^i}{\mathbb{E}\left[M^i\right]}S\right] \qquad F_j = \mathbb{E}\left[\frac{M^j}{\mathbb{E}\left[M^j\right]}S\right],$$

  summarizes FX risk bearing capacity. If $F_i < F_j$, then US buyers are more willing to bear FX risk than the French seller.
- Buyer's participation and incentive constraints

$$Q_{ea} \leq \mathbb{E}\left[\frac{M^j}{\mathbb{E}\left[M^j\right]}P\right]^{-\sigma} \qquad Q_{ep}\left(x\right) \leq P\left(s\right)^{-\sigma}.$$

Seller's Problem

The French producer chooses a price level P_0 and currency of invoicing β to maximize expected discounted profits

$$\max_{\{P_0,\beta\}} \mathbb{E}\left[M^i\left(P-C\right)Q\right]$$

$$\text{s.t.} \quad Q\left(x\right) = \delta\,\mathbb{E}\left[\frac{M^j}{\mathbb{E}\left[M^j\right]}P\right]^{-\sigma} + \left(1-\delta\right)\,P\left(s\right)^{-\sigma} \qquad \text{(Q Schedule)}$$

$$P\left(s\right) = P_0 + \beta \cdot s \qquad \text{(P Schedule)}$$

Flexible Price $P^*(x)$

Linearize the FOC around the expected state $x \to \mathbb{E}[x]$

In the classic theory, the **flexible** price $P^*(x)$ only depends on real risks, e.g. cost shocks $x = \langle C, ... \rangle$:

$$P^*(x) \approx \frac{\sigma}{\sigma - 1} \cdot C \qquad \text{(Classic Theory } \delta = 0\text{)}$$

Real risk: producer sets a markup $\frac{\sigma}{\sigma-1} \geq 1$ over marginal cost C.

Flexible Price $P^*(x)$

Linearize the FOC around the expected state $x \to \mathbb{E}[x]$

$$P^*(x) \approx \frac{\sigma}{\sigma - 1} \cdot C + \frac{\delta}{1-\delta}\frac{1}{\sigma - 1}\mathbb{E}[P^*]\left(\frac{M^i}{\mathbb{E}[M^i]} - \frac{M^j}{\mathbb{E}[M^j]}\right).$$

Real risk: producer sets a markup $\frac{\sigma}{\sigma-1} \geq 1$ over marginal cost C.

Financial risk: producer charges markup to share risk in bad states $M^i > M^j$.

Flexible Price $P^*(x)$

Linearize the FOC around the expected state $x \to \mathbb{E}[x]$

Key takeaway: risk-sharing is irrelevant w/ flex quantities $\delta = 0$.

$$P^*(x) \approx \frac{\sigma}{\sigma - 1} \cdot C + \frac{\delta}{1-\delta} \frac{1}{\sigma - 1} \mathbb{E}[P^*] \left(\frac{M^i}{\mathbb{E}[M^i]} - \frac{M^j}{\mathbb{E}[M^j]} \right).$$

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Minimum-Variance Hedging Formula

Lemma

To a second-order approximation, the optimal currency of invoicing β^* for the sticky price $P(s) = P_0 + \beta^* s$ is the "minimum-variance hedging formula" (Johnson, 1960; Stein, 1961) for the exchange rate s and the linearized flexible price $P^*(x)$

$$\beta^* \approx \frac{\text{Cov}\,(s, P^*)}{\text{Var}\,(s)}, \qquad \textit{as } x \to \mathbb{E}[x].$$

- If the dollar comoves with the desired flex price, the optimal currency of invoicing is the dollar.
  - $\longrightarrow$ dominance of the dollar in trade comes from its ability to hedge real and financial risks.

Optimal Sticky Price Invoicing

Project linearized flexible price onto the dollar

In the classic theory, invoicing hedges the real risks of trade, such as the currency composition of costs:

$$\beta^*/P_0 \approx \frac{\text{Cov}\left(C/\mathbb{E}\left[C\right], s\right)}{\text{Var}\left(s\right)} \qquad \text{(Classic Theory } \delta = 0\text{)}$$

Real hedging: producer hedges dollar inputs (Engel 2006)

Optimal Sticky Price Invoicing

Project linearized flexible price onto the dollar

$$\beta^*/P_0 \approx \frac{\mathrm{Cov}\left(C/\mathbb{E}\left[C\right], s\right)}{\mathrm{Var}\left(s\right)} + \frac{\delta}{1-\delta}\frac{1}{\sigma-1}\frac{F_i - F_j}{\mathrm{Var}\left(s\right)}.$$

Real hedging: producer hedges dollar inputs (Engel 2006)

Financial hedging: euro invoicing if the buyer has a higher risk bearing capacity $F_i < F_j$

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This paper: sticky quantities determine the relevance of financial hedging

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$F_i - F_j$ is a **sufficient statistic** for theories of costly FX hedging and reflects the producer's *relative* hedging incentives:

1. Distress price of FX (Froot, Scharfstein, and Stein, 1993)
2. Collateral value (Gopinath and Stein, 2021)
3. Measurements of CIP, liquidity, etc.

Conditions for Irrelevance

Theorem

Suppose the technology and the preferences for tradable goods are analytic and there is a unique solution. To a second-order approximation, financial hedging is irrelevant only if:

1. *Quantities are flexible $\delta = 0$; or*
2. *The relative cost of FX hedging is zero $F_i = F_j$.*

Even if FX risk sharing generates value, it does not affect trade invoicing without sticky quantities.

- Result does not depend on preferences or technology

Optimal Trade Invoicing Formula | Sketch of the Proof

Case Study: RMB adoption

- In 2014, the China and Korea summit established an offshore RMB market known as "CNK."
  - Offshore market reduces RMB hedging costs for Korean exporters by providing onshore liquidity.
  - **Standard model**: no effect on invoicing.
- Event study between China and Korea:
  1. Parameterize the model with won, dollar, and renminbi
  2. Simulate the effect of a 50 bps reduction in RMB hedging costs
  3. Empirically estimate its effect on renminbi adoption
- See the paper for calibration details.

RMB/KRW Hedging Subsidy (50 bps)

A simulated increase in renminbi invoicing shares

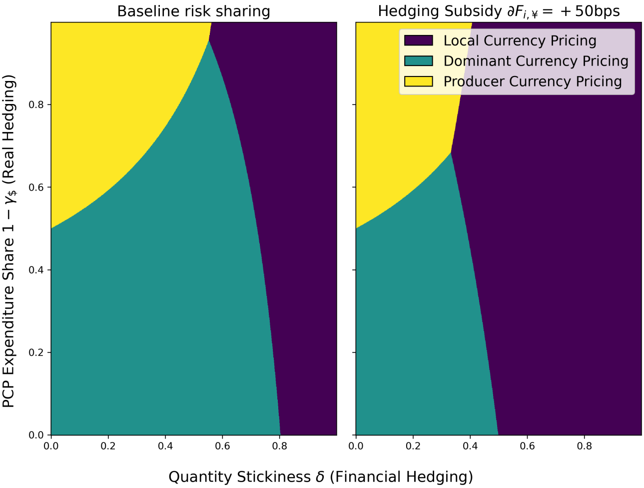


Figure: Regions represent the optimal currency of invoicing across seller-buyer pairs. The "CNK" market leads to a substitution from the **dollar** to the **renminbi**. The standard flex quantity model assumes $\delta = 0$.

Causal Effect of Financial Hedging

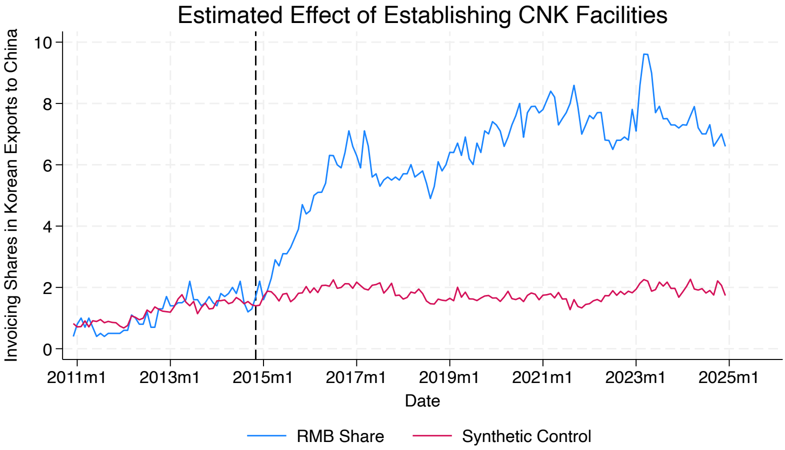
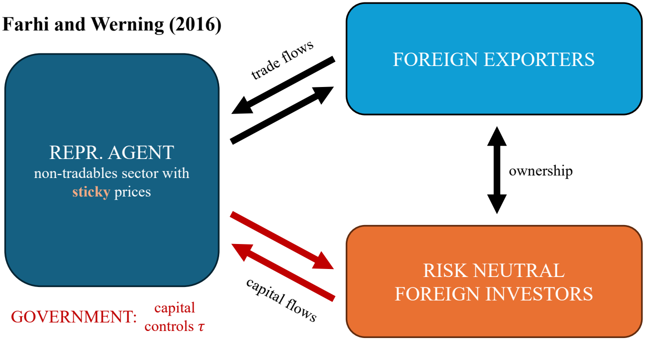


Figure: RMB invoicing shares in Korean exports to China and a synthetic control group. The effect is significant at the 5% level from April 2015 to February 2020, based on permutation-based tests. Source: Bank of Korea.

Methodology | Synthetic Weights | Pseudo-Test P-Values | Total Sales

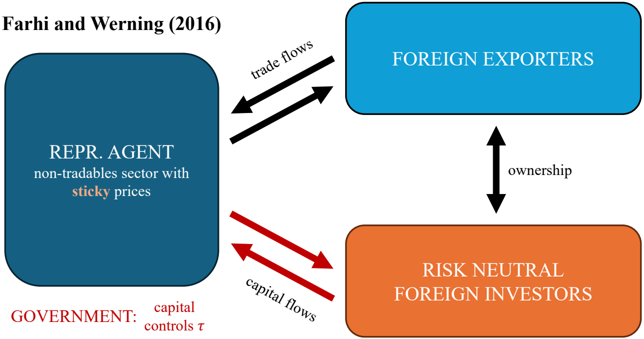
Invoicing and Macro-Pru: A New Keynesian Model

- In the theory of real hedging, taxes on financial hedging have no direct effect on invoicing decisions.
- **Classic result**: capital controls on dollar debt are *optimal* to reduce systemic dollar FX exposure in the presence of pecuniary or demand externalities.



Invoicing and Macro-Pru: A New Keynesian Model

- In my model, dollar invoicing patterns depend on financial incentives to acquire dollars.
- **Macro model w/ sticky quantities**: capital controls on dollar debt *amplify* dollar invoicing, offsetting the positive effects of capital controls and increasing systemic trade risk.



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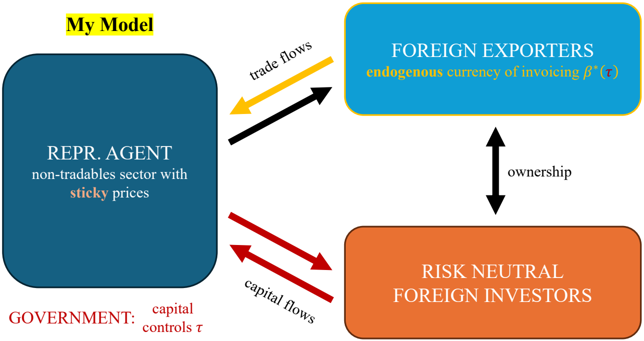

The "Dollarization Dilemma"

Dollar capital controls cause a substitution towards DCP, as a form of regulatory arbitrage.

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- Planner's problem: Implementability Cons. Full Description

$$\max \left\{ \mathcal{W}\left(\tau^{B^F}, \tau^{B^H}, ...\right)\right\}. \qquad \text{(Indirect Welfare Function)}$$

- **Capital controls**: planner deters borrowing with taxes on dollar debt τ^{B^F} and home currency debt τ^{B^H}:

$$1 = \mathbb{E}\left[M^j \left(1 + \tau^{B^F}\right) R^* S\right] \qquad 1 + \tau^{B^H} = \mathbb{E}\left[M^i R\right].$$

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- **Dilemma**: Substitution towards dollar invoicing

$$\beta^*/P_0 \approx 1 + \frac{\delta}{1-\delta} \frac{\frac{\sigma}{\sigma-1} - 1}{\text{Var}\,(s)} \underbrace{\frac{R}{R^*}\left(\frac{1}{1+\tau^{B^H}} - \frac{1}{1+\tau^{B^F}}\right)}_{F_i - F_j}.$$

Optimal Capital Controls

Dollarization has an ambiguous effect on welfare:

1. Holding quantities fixed, dollar trade $\iff$ dollar IOU
   - **Income Effect** (Nurkse, 1944; Krugman and Taylor, 1978)
2. Quantities adjust, i.e. "expenditure switching"
   - **Substitution Effect** (Friedman, 1953; Mundell, 1961)

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Proposition

The optimal capital control on dollar debt τ^{B^F} is decreasing in the welfare cost of trade dollarization $\partial_\beta \mathcal{W}$. The effect vanishes when quantities are flexible, domestic households are risk-neutral, or the economy is in trade autarky.

Invoicing Wedge τ^S Optimal Capital Controls Formula

Conclusion

- The classic theory of trade invoicing says that financial hedging is irrelevant.
- I show this irrelevance result assumes the New Keynesian setup, sticky prices and flexible quantities.
- My theory changes the normative implications of capital controls, due to the substitution between dollar trade and finance.
- Financial hedging helps rationalize the dominance of the dollar in trade and finance; and the rise of the renminbi.

Appendix

Example: Master Vendor Agreement (1)

MASTER VENDOR AGREEMENT

This Master Vendor Agreement ("Agreement") is entered into this 31 day of July, 2018, by and between TRADER JOE'S COMPANY and its subsidiaries (including Trader Joe's East Inc.). (hereinafter collectively referred to as "TJ's") and Stonegate Foods, a CALIFORNIA ("VENDOR").

SCOPE OF AGREEMENT

A. TJ's and VENDOR desire to enter into (or continue) a business relationship with each other whereby TJ's may from time to time issue purchase orders to VENDOR for certain products.

B. TJ's and VENDOR desire to set forth herein the terms and conditions that will govern their business relationship.

C. TJ's and VENDOR acknowledge that this Agreement contains the entire agreement and understanding between the Parties concerning the business relationship between TJ's and VENDOR, and any and all prior oral or written agreements or understandings between the Parties related hereto are superseded. No representations, oral or otherwise, express or implied, other than those specifically referred to in this Agreement, have been made by any party hereto, except that any prior Vendor Representation Agreement regarding VENDOR's indemnity obligations to TJ's for the use of third-party brokers or intermediaries is incorporated into this Agreement by reference, but in the event of a conflict between the two agreements, the provisions of this Agreement control.

D. TJ's and VENDOR understand that this Agreement preempts the existence of and/or overrides any previous agreements, whether express or implied, or whether oral or in writing, between TJ's and VENDOR concerning TJ's obligation and/or commitment to purchase goods from VENDOR.

Example: Master Vendor Agreement (2)

TERMS AND CONDITIONS

1. Purchase Orders: It is understood and agreed that, by entering into a business relationship with VENDOR, TJ's may from time to time issue, but has not committed to issue, purchase orders to VENDOR. The parties to this Agreement understand that this Agreement and business relationship may never result in TJ's issuing any purchase orders to VENDOR and that by entering into this Agreement neither party has undertaken any obligations to the other except as expressly provided herein. VENDOR is not entering into this Agreement in reliance on the issuance of any future purchase orders by TJ's to VENDOR.

   (a) This Agreement shall be incorporated by reference and made a part of any purchase order hereinafter issued by TJ's to VENDOR.

   (b) Each of the terms and conditions set forth in this Agreement will apply to each purchase order unless otherwise specified by TJ's in writing.

   (c) The purchase order shall set forth the description and quantity of goods, price, arrival date or schedule, payment terms, pack/size, net weight per unit, type of packaging, point of delivery, and other terms.

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Example: 3M Company 10K

UNITED STATES
SECURITIES AND EXCHANGE COMMISSION
Washington, D.C. 20549

FORM 10-K

☒ **ANNUAL REPORT PURSUANT TO SECTION 13 OR 15(d) OF THE SECURITIES EXCHANGE ACT OF 1934**
For the fiscal year ended December 31, 2019

Commission file number 1-3285

3M COMPANY

State of Incorporation: **Delaware** I.R.S. Employer Identification No. **41-0417775**
Principal executive offices: **3M Center, St. Paul, Minnesota 55144**
Telephone number: **(651) 733-1110**

⋮

Managing currency risks:

The stronger U.S. dollar had a negative impact on sales in full year 2019 compared to the same period last year. Net of the Company's hedging strategy, foreign currency was neutral to earnings for full year 2019 compared to the same period last year. 3M utilizes a number of tools to hedge currency risk related to earnings. 3M uses natural hedges such as pricing, productivity, hard currency and hard currency-indexed billings, and localizing source of supply. 3M also uses financial hedges to mitigate currency risk. In the case of more liquid currencies, 3M hedges a portion of its aggregate exposure, using a 12, 24 or 36 month horizon, depending on the currency in question. For less liquid currencies, financial hedging is frequently more expensive with more limitations on tenor. Thus, this risk is

largely managed via local operational actions using natural hedging tools as discussed above. In either case, 3M's hedging approach is designed to mitigate a portion of foreign currency risk and reduce volatility, ultimately allowing time for 3M's businesses to respond to changes in the marketplace.

Figure: 3M Company's 10K report in 2020 and its discussion of currency invoicing and financially hedging illiquid currencies. It hedges to allow time for strategy adjustments. Source: SEC EDGAR Back

A Model of **Perfect** FX Hedging

$$1 = \mathbb{E}\left[MR^*S\right] \qquad \text{(Dollar Euler Eq'n)}$$

$$1 = \mathbb{E}\left[MR\right] \qquad \text{(Euro Euler Eq'n)}$$

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A Model of **Perfect** FX Hedging

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A Model of **Perfect** FX Hedging

$$\frac{R}{R^*} = \mathbb{E}\left[\frac{M}{\mathbb{E}\left[M\right]} S\right] \qquad \text{(Certainty Eqv of Dollar Risk)}$$

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A Model of **Perfect** FX Hedging

$$F = \frac{R}{R^*} = \mathbb{E}\left[\frac{M}{\mathbb{E}[M]} S\right] \qquad \text{(Covered Interest Parity)}$$

no arbitrage $\longrightarrow$ forward rate $F = R/R^*$

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A Model of **Perfect** FX Hedging

$$F = \mathbb{E}\left[\frac{M}{\mathbb{E}\left[M\right]}S\right] \qquad \text{(Forward Rate)}$$

Frictionless benchmark: dollar forward rate is the certainty equivalent of dollar risk

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Defining Financial Risk

Definition

The ***financial risk*** *generated by prices* π_P *and states* π_x *is given by the total derivative on profits*

$$\pi_P := \partial_P \pi + \partial_Q \pi \cdot \partial_P Q \qquad \pi_x := \partial_x \pi + \partial_Q \pi \cdot \partial_x Q$$

- $\partial_P \pi$ is the "valuation effect" holding quantities fixed.
- $\partial_Q \pi \cdot \partial_P Q$ is the "real effect" associated with a decrease in quantities when prices increase.
  - If quantities are fixed $\delta \to 1$, there are no real risks to trade. Trader Joe's demand does not depend on the realized price.

Main Result

Theorem

Consider the seller's problem. To a second-order approximation, the optimal currency of invoicing is given by

$$\beta^* \approx -\left(\underbrace{\frac{\bar{\pi}_{Px}}{\bar{\pi}_{PP}} b_{xs}}_{Real\ Hedging} + \underbrace{\frac{\delta \partial_P \bar{\pi}}{\bar{\pi}_{PP}} \frac{F_i - F_j}{\mathrm{Var}\ (s)}}_{Financial\ Hedging} \right)$$

where b_{xs} is the regression coefficient of exchange rates on x.

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Why Quantity Commitments Matter

A sketch of the irrelevance result

Without quantity commitments, demand only depends on the realized price and state

$$Q(P, x) \qquad \text{(No Commitment)}$$

$$\pi(P, Q, x) \qquad \text{(Technology)}$$

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flex price soln:
$\max_{P(x)} \left[M^i \pi\left(P, Q(P, x), x\right)\right]$

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State-contingent first-order condition:

$$\underbrace{M^i \mathbb{P}(x)}_{\text{discounted probability}} \cdot \left(\underbrace{\partial_P \pi + \partial_Q \pi \cdot \partial_P Q}_{\text{first-order effect on profits}} \right) = 0$$

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$\max_{P(x)}\left[M^i\pi\left(P,Q\left(P,x\right),x\right)\right]$

At the optimal price, discount factor M^i drops out because quantities hedge profits state-by-state:

$$\underbrace{\partial_P\pi^*}_{\text{valuation effect}} + \underbrace{\partial_Q\pi^*\cdot\partial_P Q}_{\text{real effect}} = 0. \qquad \text{(First-Order Effect on Profits)}$$

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First-order price perturbations do not create financial risk:

$$\frac{d}{dP\left(x\right)}\pi^* = 0, \qquad \text{(Envelope Theorem)}$$

$\longrightarrow$ renegotiation limits risk sharing (Hart and Moore, 1988).

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Why Quantity Commitments Matter

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With quantity commitments, demand depends on the price schedule (e.g., expected price)

$$Q[P, x] \qquad \text{(Commitment)}$$
$$\pi(P, Q, x) \qquad \text{(Technology)}$$

↓ flex price soln: $\max_{P(x)} \left[M^i \pi(P, Q[P, x], x)\right]$

Price fluctuations create financial risk:

$$\frac{d}{dP(x)}\pi^* = -\underbrace{\frac{1}{M^i \mathbb{P}(x)} \mathbb{E}\left[M^i \partial_Q \pi^* \frac{dQ}{dP}\right]}_{\text{functional derivative across states}} > 0.$$

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With quantity commitments, demand depends on the price schedule (e.g., expected price)

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↓ flex price soln:
$\max_{P(x)}\left[M^i \pi\left(P, Q\left[P, x\right], x\right)\right]$

In the Armington fixed-quantity setup:

$$\frac{d}{dP\left(x\right)}\pi^* \propto \frac{\delta}{1-\delta}\left(\mathcal{M}-1\right) \qquad \text{(Passthrough of Financial Risk)}$$

$\longrightarrow$ the seller shares financial risk through prices.

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Why Does This Affect RMB Invoicing?

Notes from the 2014 HSBC Seoul Press Conference

South Korea's strong trade ties with China and policy support from government and central bank position nation as offshore yuan center, Justin Chan, HSBC's co-head of markets for Asia Pacific, says at Seoul press briefing.

** South Korean importers can get cheaper pricing from Chinese businesses when using yuan as it reduces exchange-rate risks; South Korea exporters can benefit by gaining access to a wider pool of importers when using yuan.*

** Demand for won-yuan direct trading will increase given trade relations between the two countries and as RQFII will lead to more investment into China.*

—Bloomberg First Word, Sept. 17 2014

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WSJ Exerpt

Jung Eunbo, Korea's deputy finance minister, said increasing the use of yuan for trade settlement will reduce transaction costs for local exporters. Currently 85% of Korea's trade is settled in U.S. dollars. That means exporters need to sell yuan for dollars before turning them into Korean won.

Mr. Jung, in an interview, acknowledged that greater use of the yuan in Korea also would reduce appreciation pressures on the won. That's because Korea over time hopes to develop a deep off shore market for yuan-denominated bonds and other financial instruments. Then Korean exporters won't need to convert their overseas earnings into won at all.

—WSJ, Nov. 2014

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CNYKRW Transaction Costs

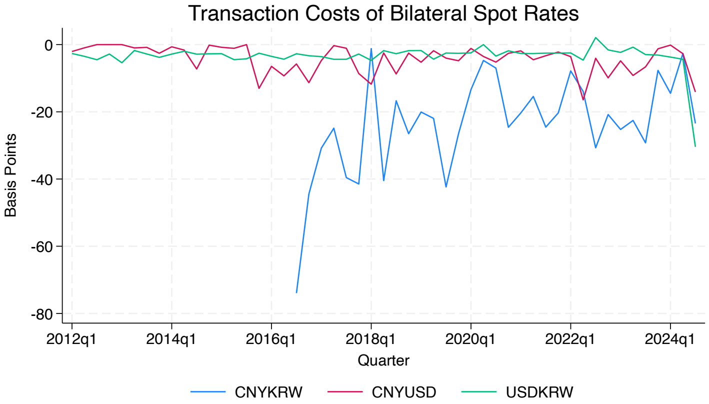

Figure: Data pulled from Bloomberg. CNY bid-ask spreads are based on quotes from the Chinese Foreign Exchange Trading System.

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Synthetic Control Method

- The treatment effect of the CNK FX market is the change in the renminbi invoicing share of Korean exports to China,

$$T_t = \beta^{RMB}_{KOR\to CHN,t} - \mathbb{E}\left[\beta^{RMB}_{KOR\to CHN,t} \mid \text{No CNK Facility}\right].$$

- To compute the counterfactual shares, I construct a "synthetic control" group using control units (Abadie et al., 2010):

$$\mathbb{E}\left[\beta^{RMB}_{KOR\to CHN,t} \mid \text{No CNK Facility}\right] = \sum_{reg\in\mathcal{J}}\sum_{cur\in\mathcal{C}} wts_{reg,cur}\,\beta^{cur}_{KOR\to reg,t}.$$

- There are 21 control units. Export regions $reg \in \mathcal{J}$ exclude China; Currencies $cur \in \mathcal{C}$ include only the producer, local, and dominant (USD) currencies. Time t is indexed at the monthly horizon.

- Weights $wts_{reg,cur}$ are computed to match the RMB's quarterly invoicing shares from 2010 to 2014.

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Synthetic Control Method Weights

Control Unit			**Control Unit**		
Region	**Currency**	**Weight**	**Region**	**Currency**	**Weight**
Europe	EUR	0	Middle East	KRW	0
—	GBP	0	—	USD	0
—	KRW	0	SEA	HKD	0.114
—	RUB	0.56	—	KRW	0
—	USD	0	—	SGD	0
Japan	JPY	0	—	USD	0
—	KRW	0.295	USA	KRW	0
—	USD	0	—	USD	0
LatAm	BRL	0.031	Other	KRW	0
—	KRW	0	—	USD	0
—	USD	0	**TOTAL**		1

Table: This table represents the region-currency (ISO3) weights $wts_{reg,cur}$ assigned by the synthetic control method, used for computing counterfactual invoicing shares. Weights are assigned to match the quarterly preintervention path of invoicing shares, from December 2010 until September 2014. Source: Bank of Korea.

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Synthetic Control Method P-Values

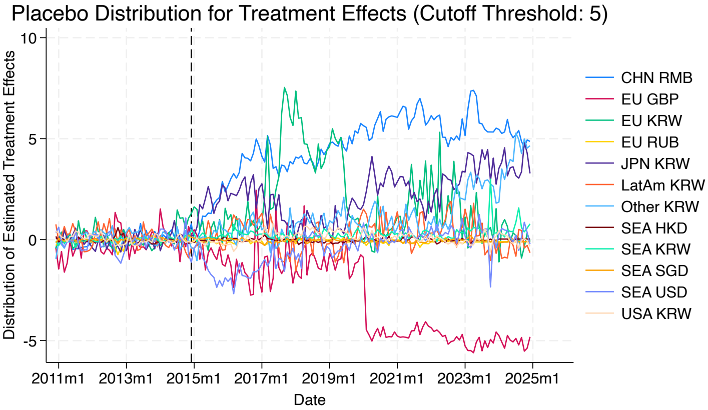

Figure: Distribution of treatment effects after applying the RMSPE filter. Control units are retained if their pre-treatment RMSPE is less than five times that of the treated (CHN-RMB) unit.

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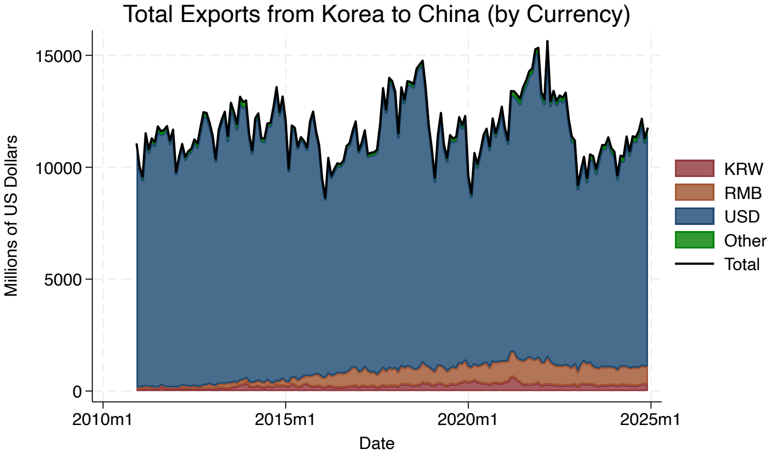
Total Sales from Exporting



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Household Problem

$$\max_{C_{NT,t}, C_{T,t}, N_t, B_t^F, B_t^H} \mathbb{E}\left[\sum_{t=0}^{1} \rho^t U\left(C_{NT,t}, C_{T,t}, N_t\right)\right]$$

subject to the budget constraint

$$\begin{aligned} & P_{NT,t}C_{NT,t} + P_{T,t}C_{T,t} + S_t B_t^F + B_t^H \\ & \quad \leq W_t N_t + P_{X,t}X_t + \Pi_t + T_t + \frac{1}{R_t^*\left(1+\tau_t^{B^F}\right)} S_t B_{t+1}^F + \frac{1}{R_t} B_{t+1}^H. \end{aligned}$$

- Non-tradable $P_{NT,t}C_{NT,t}$ and tradable $P_{T,t}C_{T,t}$ expenditure
- Labor income $W_t N_t$
- Local currency B_t^H and dollar bonds B_t^F
- X_t commodities exports, Π_t non-tradable firm profits, and government transfers T_t.

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Producer's Problem

- Tradable and non-tradable goods are produced by a market of domestically-owned competitive firms
- Firms combine varieties using CES aggregator with elasticity σ
- Prices are set one period in advance and a fraction δ of domestic aggregator firms fix quantities in advance.
- Tradable goods have optimal dollar passthrough β.

Non tradables use linear labor technology:

$$\Pi_t = \left[P_{NT,t} - (1+\tau_L)\frac{W_t}{A_t}\right] C_{NT,t},$$

tradables have constant dollar marginal cost C

$$\Pi_t = \left[P_{T,t} - CS_t\right] C_{T,t},$$

and prices are sticky

$$P_{NT,1} = P_{NT,0} \qquad P_{T,1} = P_{T,0} + \beta S_1.$$

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Resource Constraints

Government's budget constraint satisfies

$$T_t = \tau_L W_t N_t + \frac{\tau^{B^F}}{1+\tau^{B^F}} \frac{S_t}{R_t^*} B_t^F + \frac{\tau^{B^H}}{1+\tau^{B^H}} \frac{1}{R_t} B_t^H.$$

And the domestic labor market clears

$$C_{NT,t} = A_t N_t.$$

Finally, the aggregate tradable resource constraint is given by

$$P_{T,0} C_{T,0} \leq \frac{1}{R_0^*} B_1^F + \frac{\mathbb{E}\left[1/S_1\right]}{R_0^*} B_1^H + P_{X,0} X_0$$
$$P_{T,1} C_{T,1} + B_1^F + B_1^H \leq P_{X,1} X_1.$$

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Implementability Constraints

$$1 = \mathbb{E}\left[\rho \frac{\partial_{C_T} U_1}{\partial_{C_T} U_0} \frac{P_{T,0}}{P_{T,1}} R_0^* \left(1 + \tau^{B^F}\right) S_1\right] \qquad \text{(Foreign Bond Euler Eqn)}$$

$$1 = \mathbb{E}\left[\rho \frac{\partial_{C_T} U_1}{\partial_{C_T} U_0} \frac{P_{T,0}}{P_{T,1}} R_0\right] \qquad \text{(Home Bond Euler Eqn)}$$

$$\frac{\partial_{C_T} U_t}{\partial_{C_{NT}} U_t} = \frac{P_{T,t}}{P_{NT,t}} \qquad \text{(Intratemporal Maximization)}$$

$$\frac{W_t}{P_{NT,t}} = -\frac{\partial_N U_t}{\partial_{C_{NT}} U_t} \qquad \text{(Labor Supply)}$$

$$R_0 \mathbb{E}\left[\frac{1}{S_1}\right] = \left(1 + \tau^{B^H}\right) R_0^* \qquad \text{(UIP)}$$

$$P_{NT,1} = (1 + \tau_L) \mathcal{M} \cdot \mathbb{E}\left[W_1 / A_1\right] \qquad \text{(Non-Tradable Price)}$$

$$P_{T,1} = \mathcal{M} \cdot C\mathbb{E}\left[S_1\right] + \beta\left(S_1 - \mathbb{E}\left[S_1\right]\right) \qquad \text{(Tradable Price Level)}$$

$$\beta / \mathbb{E}\left[P_{T,1}\right] = 1 + \frac{\delta}{1-\delta} \frac{\mathcal{M} - 1}{\text{Var}\ (S_1)} \frac{R_0}{R_0^*} \left(\frac{1}{1 + \tau^{B^H}} - \frac{1}{1 + \tau^{B^F}}\right) \qquad \text{(Optimal Invoicing)}$$

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Planner's Problem

Primal Approach

- Using the homotheticity of consumption, write

$$C_{NT,t} = \alpha\left(p_t\right) C_{T,t}$$

where $p_t = P_{T,t}/P_{NT,t}$.

- The primal approach to the planner's problem is

$$\max_{\left\{C_{T,t}, P_{NT,1}, S_1, B_1^H, B_1^F\right\}} \mathbb{E}\left[\sum_{t=0}^{1} \rho^t U\left(\alpha_t C_{T,t}, C_{T,t}, \frac{\alpha_t}{A_t} C_{T,t}\right)\right]$$

subject to the tradable goods resource constraint and the following implementability conditions

$$P_{T,1} = \mathcal{M} \cdot C\mathbb{E}\left[S_1\right] + \beta\left(S_1 - \mathbb{E}\left[S_1\right]\right)$$

$$\beta/\mathbb{E}\left[P_{T,1}\right] = 1 + \frac{\delta}{1-\delta} \frac{\mathcal{M}-1}{\text{Var}\ \left(S_1\right)} \frac{R_0}{R_0^*}\left(\frac{1}{1+\tau^{B^H}} - \frac{1}{1+\tau^{B^F}}\right).$$

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Invoicing Wedge τ^S

Definition

The labor market wedge is

$$\tau_t^L = 1 + \frac{1}{A_t}\frac{\partial_N U_t}{\partial_{C_{NT}} U_t}.$$

Definition

The invoicing wedge is a scalar that represents the marginal effect of an increase in dollar passthrough on welfare

$$\tau^S = \text{Cov}\left(S_1, \partial_{C_T} U_1 \left[\underbrace{\partial_p \alpha_1 C_{T,1} \tau_1^L}_{\textit{Substitution Effect}} - \underbrace{\left(1 + \frac{\alpha_1}{p_1}\tau_1^L\right) C_{T,1}}_{\textit{Income Effect}}\right]\right).$$

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Optimal Capital Controls Formula

Proposition

The optimal tax on dollar borrowing τ^{B^F} *and subsidy on home-currency foreign lending* τ^{B^H} *are characterized by expectations and covariance terms that depend on the labor market wedge* τ_t^L *and the trade invoicing wedge* τ^S*,*

$$1+\tau^{B^F} = \mathbb{E}\left[\frac{1+\frac{\alpha_1}{p_1}\tau_1^L + \frac{d\beta/dC_{T,1}}{\mu_1 \partial_{C_T} U_1}\tau^S}{1+\frac{\alpha_0}{p_0}\tau_0^L}\right] + \frac{\text{Cov}\left(M_1 S_1, \frac{1+\frac{\alpha_1}{p_1}\tau_1^L + \frac{d\beta/dC_{T,1}}{\mu_1 \partial_{C_T} U_1}\tau^S}{1+\frac{\alpha_0}{p_0}\tau_0^L}\right)}{\mathbb{E}\left[M_1 S_1\right]}$$

$$1+\tau^{B^H} = \mathbb{E}\left[\frac{1+\frac{\alpha_1}{p_1}\tau_1^L + \frac{d\beta/dC_{T,1}}{\mu_1 \partial_{C_T} U_1}\tau^S}{1+\frac{\alpha_0}{p_0}\tau_0^L}\right] + \frac{\text{Cov}\left(M_1, \frac{1+\frac{\alpha_1}{p_1}\tau_1^L + \frac{d\beta/dC_{T,1}}{\mu_1 \partial_{C_T} U_1}\tau^S}{1+\frac{\alpha_0}{p_0}\tau_0^L}\right)}{\mathbb{E}\left[M_1 S_1\right]}.$$

In these equations, M_1 *is the local agent's nominal SDF,* μ_1 *is the probability of the state occurring, and* β *is the desired dollar passthrough in tradable goods prices. The term* $\frac{d\beta/dC_{T,1}}{\mu_1 \partial_{C_T} U_1}$ *is zero when quantities are fully flexible* $\delta = 0$*, markups are zero* $\mathcal{M} = 1$*, or local agents are risk neutral* $M_1 = 1/R_0$*.*

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