Local-currency price stability of imports

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Outline

- some evidence on ERPT
- real determinants
- nominal rigidities
- a theory-informed look at regression models

1 Introduction and evidence

In previous lectures we have focused on international price adjustment as a core element of international transmission mechanism, showing its interrelation with the structure of international financial markets.

In the model, the RER is more volatile than TOT, according to evidence.

PPP does not hold because (a) home bias in tradable consumption (b) nontradables consumption goods and (c) nontradable distribution services cause consumption baskets different across countries.

Yet the law of one price holds **at the border**. This is at odds with the evidence of stability of import prices in local currency.

What do we know about exchange rate pass-through (ERPT)?

Define exchange rate pass through as the elasticity of import prices to the exchange rate, for given marginal costs

$$p(f) = MKP \cdot \mathcal{E} \cdot MC^*$$

In response to a shocks that move the exchange rate, for any given marginal cost (in foreign currency), incomplete pass through means that firms absorb part of the shocks by charging a different markup in the export markets. That is to say, markup adjustment is destination-specific. Under the maintained assumption of no or limited arbitrage in the goods market across borders, the literature has explored two main hypotheses:

1. nominal rigidities in local currency (LCP: local currency pricing)

- markup adjustment are suboptimal, in the sense that firms could increase current profits by changing prices

2. optimal pricing in the presence of differences in the price elasticity of demand across countries,

    - A sufficient condition for imperfect pass-through: the elasticity of demand is increasing in import (border) prices (e.g., see Marston [1990]) — since higher elasticity $=>$ lower optimal markup!

Some examples from the literature

- No deviations from the law of one price, perfect ERPT

- In models assuming CES utility, firms have no incentive to price discriminate in a flex price equilibrium

$$p = \mathcal{E}p^* = mkp * E(mc)$$

- Deviation from the law of one price, but perfect pass-through
  - Assume CES demand functions, but posit different elasticity of substitution for tradables produced in country H, say θ_H and θ_H^*. If no arbitrage is possible clearly steady state markups will be different across countries, $mkp \neq mkp^*$. Home firms will charge different prices in the Home and the Foreign markets. However, absent price rigidities, optimal markups will be constant: any shock affecting marginal costs will be 'passed-through' one-to-one on prices.

- Strategic interactions in non-competitive markets
  - Dornbusch AER 1987.
  - Corsetti and Dedola (2005) on vertical interactions between upstream and downstream producers.
  - Akteson and Burstein AER 2008, revisiting Dornbusch 87.
  - Ravn et al. NBER wp 12961 2007 using deep habits.
  - Drosz 2008, costumers as capital.
- Vast monetary literature assuming nominal rigidities in local currency after Betts and Devereux JIE 2000.

Some empirical evidence

- Various empirical studies suggest that ERPT is
  - far from complete for international (import) prices,
  - drops substantially for consumer prices
  - different across industries
  - changes over different time horizons
  - incomplete ERPT is not only a short-run phenomenon; ERPT remains incomplete over long horizon.

Example: Campa and Goldberg estimate structural pass-through elasticities for import prices (NOTE: these are not consumer prices elasticities):

- for the euro area: .52 (one month), .72 (four months)

- for OECD countries: .46 (one month) and .64 (four months)

Caveat: What econometricians observe is the exchange rate, unit values (i.e. total value of merchandise divided by stated quantities) at the border, and CPI. We do not have studies connecting border prices to consumer prices of the same imported goods

Micro-studies: Industry partial equilibrium studies (Goldberg and Verboven 2001 Golberg and Hellerstein 2007 Nakamura 2007) typically find that local costs and (optimal) markup adjustment play a large role in explaining local currency price stability.

Goldberg and Verboven (2001): based on comprehensive and detailed data of automobile retail prices in five European countries, these authors show that a 1% change in the nominal exchange rate induces a 0.46% adjustment in the export prices in exporter currency, equivalent to a 0.54 pass-through. They attribute a pass-through between 0.37 and 0.39% to local cost (i.e., nominal wages in local currency) in the destination country, markup adjustment accounts for the rest.

Engel critique: the large weight attributed to local costs by these studies may be misattributed, as they ignore nominal rigidities. Goldberg and Hellerstein and Nakamura explicitly account for sticky prices. Their findings: nominal rigidities weigh very little (10 percent) in the adjustment, but they may be important in shaping the adjustment dynamics.

This squares well with the point by Obstfeld and Rogoff JIE 2000: in the data (and consistent with the received wisdom), nominal depreciation is associated with deteriorating terms of trade.

To wit: suppose import prices are preset in local currency, that is, the price of Foreign import from Home P_H^* is constant. The Home terms of trade TOT$=\frac{P_F}{\uparrow \mathcal{E} P_H^*}$ actually improve with a depreciation! Why? A nominal depreciation raises the revenues of Home firms one-to-one with each sale abroad (while lowering the revenue of foreign firms). The OR evidence clearly sets an empirical **hurdle** for LCP models assuming a high degree of price stickiness in local currency — although it does not necessarily exclude LCP with some mild price adjustment within the period, according to Calvo or Rotemberg model.

2 Optimal price discrimination: a model with vertical interactions

As in the previous lecture, posit

$$C_t(j) \equiv \frac{C_{\mathsf{T},t}(j)^{\xi} C_{\mathsf{N},t}(j)^{1-\xi}}{\xi^{\xi}(1-\xi)^{1-\xi}}$$

$$C_{\mathsf{T},t}(j) \equiv 2C_{\mathsf{H},t}(j)^{1/2} C_{\mathsf{F},t}(j)^{1/2}; \quad C_{\mathsf{N},t}(j) \equiv \left[\int_0^1 C_t(n,j)^{\frac{\theta-1}{\theta}} dn\right]^{\frac{\theta}{\theta-1}}.$$

Bringing one unit of *traded goods* to consumers requires η units of a basket of differentiated nontraded goods

$$\eta = \left[\int_0^1 \eta(n)^{\frac{\theta-1}{\theta}} dn\right]^{\frac{\theta}{\theta-1}}.$$

Assume that each upstream tradable producer is a monopolistic competitor but firms providing distribution sectors are perfectly competitive. This market structure rules out double marginalization and makes the allocation independent of ownership structure (the price is the same whether or not producers and distributors are vertically integrated).

The **optimal prices of nontraded goods** is a constant markup over marginal cost

$$p_t(n) = P_{\mathsf{N},t} = \frac{\theta}{\theta - 1}\frac{W_t}{Z_{\mathsf{N},t}} = mkp_{\mathsf{N}} \cdot MC.$$

Optimal pricing is instead different for **traded goods.** Let $\bar{p}_t(h)$ denote the price of brand h expressed in the Home currency, at *producer* level. With a competitive distribution sector, the consumer price of good h is simply

$$p_t(h) = \bar{p}_t(h) + \eta P_{\mathsf{N},t}.$$

2.1 Optimal price discrimination

In the tradable sector, each Home firm maximizes

$$\left[\bar{p}_t(h)C_t(h) + \mathcal{E}_t\bar{p}_t^*(h)C_t^*(h)\right] - \frac{W_t}{Z_{\mathsf{H},t}}\left[C_t(h) + C_t^*(h)\right]$$

$$\begin{aligned} C_t(h) &= \left(\frac{\bar{p}_t(h) + \eta P_{\mathsf{N},t}}{P_{\mathsf{H},t}}\right)^{-\theta} C_{\mathsf{H},t}, \\ C_t^*(h) &= \left(\frac{\bar{p}_t^*(h) + \eta P_{\mathsf{N},t}^*}{P_{\mathsf{H},t}^*}\right)^{-\theta} C_{\mathsf{H},t}^*. \end{aligned}$$

Monopolistic firms take account of the implications of distributive trade on the demand elasticity for their product, and find it optimal to charge different prices to firms distributing in the Home and in the Foreign market.

Optimal pricing and market-specific markups

Making use of P_N the optimal wholesale prices $\bar{p}(h)$ and $\bar{p}^*(h)$ are:

$$\bar{p}_t(h) = \overbrace{\frac{\theta}{\theta-1}\left(1+\frac{\eta}{\theta-1}\frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}}\right)}^{mkp_{\mathsf{H},t}}\frac{W_t}{Z_{\mathsf{H},t}},$$

$$\bar{p}_t^*(h) = \overbrace{\frac{\theta}{\theta-1}\left(1+\frac{\eta}{\theta-1}\frac{\mathcal{E}_t W_t^*}{W_t}\frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}^*}\right)}^{mkp_{\mathsf{H}^*,t}}\frac{W_t}{Z_{\mathsf{H},t}}\frac{1}{\mathcal{E}_t}.$$

Despite CES preferences, markups $mk_{\mathsf{H},t}$ and $mk_{\mathsf{H}^*,t}$ are not constant, but include a state-contingent component. Since in general $mkp_{\mathsf{H},t} \neq mkp_{\mathsf{H}^*,t}$ the optimal wholesale price will not obey the law of one price $\bar{p}_t(h) \neq \mathcal{E}_t\bar{p}_t^*(h)$.

Incomplete pass-through

Note that shocks raising marginal costs (W and Z_H and $\mathcal{E}$) will result in a lower markup. Hence there will be '**strategic complementarity**' in the sense of Woodford (intuitively, the opposite movements in costs and markups reduce the equilibrium adjustment in prices).

- As a corollary, given wages a shock to $\mathcal{E}_t$ (say, monetary expansion causes domestic depreciation) will be passed-through the price of Foreign import from Home only partially.

Key to this result is the low degree of substitutability between traded input and distribution services. To wit: derive the model under a Cobb-Douglas aggregator $\bar{p}_t(h)^{\varkappa}\left(\eta P_{\mathsf{N},t}\right)^{1-\varkappa}$.

Different Demand Elasticities

The price elasticity of the demand for the good h will depend on:

- relative productivity across domestic sectors *in the Home market*

$$\xi_{C_t(h),\bar{p}_t(h)} \equiv -\frac{\partial C_t(h)}{\partial \bar{p}(h)} \frac{\bar{p}_t(h)}{C_t(h)} = \theta \frac{1 + \frac{\eta}{\theta - 1} \frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}}}{1 + \eta \frac{\theta}{\theta - 1} \frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}}}.$$

- on productivity in the nontraded goods at Home and abroad, relative wages and the exchange rate *in the export market:*

$$\xi_{C_t^*(h),\bar{p}_t^*(h)} \equiv -\frac{\partial C_t^*(h)}{\partial \bar{p}^*(h)} \frac{\bar{p}^*(h)}{C_t^*(h)} = \theta \frac{1 + \frac{\eta}{\theta - 1} \frac{\mathcal{E}_t W_t^*}{W_t} \frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}^*}}{1 + \eta \frac{\theta}{\theta - 1} \frac{\mathcal{E}_t W_t^*}{W_t} \frac{Z_{\mathsf{H},t}}{Z_{\mathsf{N},t}^*}}.$$

Important properties of elasticities

- the elasticity of foreign demand for h goods $\xi_{C_t^*(h),\bar{p}_t^*(h)}$ with respect to its foreign wholesale price is non linear in the exchange rate: a relatively appreciated Home currency (a low $\mathcal{E}_t$) corresponds to a relatively large price elasticity.

- it is easy to verify that $\xi_{C_t^*(h),\bar{p}_t^*(h)}$ is increasing in the wholesale price — as shown by the literature on international trade (e.g., see Marston [1990]), this is a sufficient condition for incomplete exchange rate pass-through.

Elasticities fall with distribution margins

Moreover, consider the 'distribution margin,' i.e., the share of distributive trade in the consumer price of the good h in the Home (Foreign) market. Then:

$$\xi_{C_t(h),\bar{p}_t(h)} = \theta\left(1 - \frac{\eta P_{\mathsf{N},t}}{p_t(h)}\right),$$
$$\xi_{C_t^*(h),\bar{p}_t^*(h)} = \theta\left(1 - \frac{\eta P_{\mathsf{N},t}^*}{p_t^*(h)}\right).$$

The demand elasticities to the wholesale prices are monotonic functions of the distribution margins: distributive trade lowers price elasticities below the constant preference parameter θ.

2.2 Optimal pricing with cross-border arbitrage

Most open macro models with monopolistic competition assume that firms have the power to segment markets across national borders — ruling out arbitrage across wholesale markets.

Yet, there is no reason to exclude the possibility that domestic retailers buy goods from foreign retailers, rather than from monopolistic producers in the wholesale market.

Study of the constrained optimal pricing problem for the firms.

No arbitrage constraint (1)

If the representative Home firm sets the wholesale price in the Foreign country above the consumer price of its own good in the Home country, firms distributing good h in the Foreign country would find it profitable to buy it from Home retailers rather than in the wholesale market.

- This implies that optimal price discrimination is possible only as long as the following no-arbitrage conditions are verified:

$$\begin{aligned} \mathcal{E}_t p_t^*(h) &= \mathcal{E}_t \left(\bar{p}_t^*(h) + \eta P_{\mathsf{N},t}^* \right) \geq \bar{p}_t(h) \\ p_t(h) &= \bar{p}_t(h) + \eta P_{\mathsf{N},t} \geq \mathcal{E}_t \bar{p}_t^*(h). \end{aligned}$$

No arbitrage constraint (2)

Using optimal prices, these conditions can be synthetically written as:

$$\frac{1}{\theta} \leq \frac{\mathcal{E}_t W_t^*}{W_t} \frac{Z_{\mathsf{N},t}}{Z_{\mathsf{N},t}^*} \leq \theta.$$

A large depreciation of the nominal exchange rate could reduce the Home consumer price of h in Foreign currency below the optimal export price $\bar{p}_t^*(h)$ — violating the second inequality above. In that case, arbitrage in the goods market would force firms to set the foreign wholesale price and the domestic price equal to each other: $\mathcal{E}_t \bar{p}_t^*(h) = p_t(h)$.

By the same token, a large nominal appreciation could reduce the foreign retail price of h in the Home currency below the wholesale price at Home. In this case, ruling out arbitrage requires firms to set $\bar{p}_t(h) = \mathcal{E}_t p_t^*(h)$.

Intuitive account of arbitrage-constrained pricing

Suppose that to rule out arbitrage Home firms must set: $p_t(h) = \mathcal{E}_t \bar{p}_t^*(h)$. The firms problem must now allow for this constraint.

- When the constraint is binding, Home firms will now raise $\bar{p}_t(h)$ somewhat while lowering $\bar{p}_t^*(h)$ somewhat, relative to their optimal level in the absence of arbitrage. As the two prices cannot be set independently, the drop in the markup in the foreign market is partly offset by a higher markup at home.

Note however that, even when the no-arbitrage condition is binding, *wholesale* prices will still be different in the Home and Foreign markets because of distribution margins: with $\eta > 0$, the law of one price cannot hold.

2.3 How much local currency price stability can the model explain?

Log linearizing import prices in equilibrium, the coefficient of the exchange rate can be interpreted as a **'structural pass-through' coefficient**:

$$\widehat{\bar{P}}_{\mathsf{f},t} = \frac{1}{1+\mu\left(mkp_{\mathsf{f}}-1\right)}\left(\widehat{\mathcal{E}}_t + \widehat{MC^*}_{\mathsf{f},t}\right) + \frac{\mu\left(mkp_{\mathsf{f}}-1\right)}{1+\mu\left(mkp_{\mathsf{f}}-1\right)}\widehat{MC}_{\mathsf{n},t} \quad (1)$$

- The structural ERPT coefficient clearly depends on distribution margin μ and markups mkp. Setting $\mu = 50\%$ and $mkp = 1.20$, ERPT is about 90%. If $mkp = 1.40$, ERPT falls to 80%.

- At retail price level, with $\mu = 50\%$, ERPT is 1/2 of the above: 40 to 45 percent.

Structural pass through versus 'conditional pass through'

- The structural pass-through coefficient captures a relation between two endogenous variables $\widehat{\bar{P}}_{\mathsf{f},t}$ and $\widehat{\mathcal{E}}_t + \widehat{MC^*}_{\mathsf{f},t}$, which holds in equilibrium as the economy responds to all real and monetary shocks.

- However, prices, exchange rates and marginal costs may respond differently to different shocks. For instance, when one asks the questions: how would (import prices and) inflation react to (a) a surprise increase in oil price decided by OPEC, (b) a surprise monetary policy decisions? In either case the answer is likely not to coincide with the structural pass-through coefficient.

A numerical exercise

To understand pass-through conditional on shocks, versus structural PT, consider a numerical exercise in general equilibrium. The exercise is described in Corsetti and Dedola JIE 2005: it assumes incomplete market (bond economy), monetary and real (productivity) shocks, up to 1% deviation from steady state values, either permanent of temporary. Calibration: $Z_T/Z_N = 2$, distribution margin 55%, steady state markup 15% in NT but 40% in T. T and NT have same weight in consumption. Wages are preset for one period.

Table 2
Impact responses of selected variables to nominal and real shocks[a] (percentage deviations from steady-state values and elasticities)

	Monetary shock	Shock to tradables		Shock to nontradables		Economy-wide shock	
		Temporary	Permanent	Temporary	Permanent	Temporary	Permanent
Nominal exchange rate	1.5%	0.2%	5.9%	0.2%	5.7%	0.4%	11.8%
Real exchange rate	1.2%	0.2%	4.7%	1.0%	5.3%	1.6%	10.2%
Terms of trade	0.9%	1.0%	4.3%	−0.1%	3.2%	0.9%	7.6%
Producer import price	1.2%	0.2%	4.7%	−0.01%	4.3%	0.2%	9.3%
Consumer import price	0.6%	0.1%	2.4%	−0.5%	1.7%	−0.4%	4.1%
CPI	0.2%	−0.1%	0.5%	−0.8%	−0.2%	−0.8%	0.3%
ERPT ξ							
Producer import price $\xi_{\bar{P}_{F,t},\mathcal{E}_t}$	0.80	0.81	0.82	−0.06	0.76	0.36	0.78
Consumer import price $\xi_{P_{F,t},\mathcal{E}_t}$	0.40	0.41	0.35	−2.20	0.30	−0.99	0.35
CPI $\xi_{P_t,\mathcal{E}_t}$	0.12	−0.32	0.08	−3.34	−0.03	−1.87	0.02

[a] See the main text for an explanation of the experiments.

- EPRT varies depending on shocks. However, it happens to be at most 82%, as predicted by our structural ERPT coefficient.

- Nominal and real exchange rate comove positively. Same for TOT, with one exception.

- Despite flexible prices the elasticity of the CPI to the exchange rate is quite low in general.

  – For instance, in response to an economy-wide permanent shock to productivity, the nominal exchange rate depreciates by more than 11.8% but retail inflation in imports and overall CPI is only 4.1 and 0.3%, respectively.

- However, the general equilibrium effects on the CPI of exchange rate fluctuations are by no means trivial, since domestic prices can move by more, or in the opposite direction relative to the exchange rate.
  - For instance, nominal shocks and shocks to Z_H imply essentially the same exchange rate pass-through into import prices, at both producer level (around 80%) and consumer level (around 40%). Yet the elasticity of CPI ranges between 12% and 32%.

- Both the rate of currency depreciation and pass-through increase sharply when shocks to productivity are permanent, as opposed to temporary. This result implies that pass-through should be increasing in the size of exchange rate changes.25.

Two different implications of distribution services

Keep the two elements that drive the results on local currency price stability separate

- Local inputs dampen the response of consumer prices to changes in the prices of imported components even for fixed markups; this effect is there with perfect competition (Burstein, Neves and Rebelo JME 2003). Also local cost components may reflect more than distribution: for instance, assembling of imported input and local input.

- Low elasticity of substitution between imported and local component affects trade elasticity. Hence, assuming imperfect competition, we obtain markup adjustment (Corsetti and Dedola JIE 2005, Burstein Eichenbaum Rebelo JPE 2006. IMF's GEM.).

3 Nominal rigidities

The results above suggests that models featuring interaction between upstream and downstream firms using local inputs, and destination-specific markup fluctuations can deliver remarkable results in terms of CPI elasticity relative to the exchange rate. However, they usually fall short of matching the very low ERPT in the short run which result from standard empirical analyses. Many authors believe that nominal rigidities can fill this gap.

As an example, following Rotemberg [1982] one can add rigidities to the above model by positing that all firms (but distributors) face a quadratic cost when adjusting their prices (a cost which is however set equal to zero in steady state). To change its product prices, a firm needs to use resources, in the form of a CES basket of all the goods in the same sector of the economy. The price-adjustment costs faced by firms in the traded goods sector are:

$$
\begin{aligned}
AC^{p}_{\mathsf{H},t}(h) &= \frac{\kappa^{p}_{\mathsf{H}}}{2}\left(\frac{\bar{p}_t(h)}{\bar{p}_{t-1}(h)}-\pi\right)^2 D_{\mathsf{H},t},\\
AC^{p*}_{\mathsf{H},t}(h) &= \frac{\kappa^{p}_{\mathsf{H}}}{2}\left(\frac{\bar{p}^*_t(h)}{\bar{p}^*_{t-1}(h)}-\pi^*\right)^2 D^*_{\mathsf{H},t},
\end{aligned}
$$

where π and π^* are the domestic and foreign steady-state inflation rates and κ^{p}_{H}, κ^{p}_{H}, are adjustment cost parameters and, without loss of generality, costs are denominated in the Home currency. As firms producing traded goods charge different prices in different markets, the cost of changing prices is incurred in each market independently of the other. Costs in the nontraded goods sector are similarly defined (with κ^{p}_{N}).

Key property: the parameters κ_{H}^{p}, κ_{H}^{p} have their counterparts in the probability of a price change in the Calvo model. They can be calibrated in terms of 'average duration of prices.'

Structural pass-through coefficient with price stickiness

$$\begin{aligned}\widehat{\bar{\bar{P}}}_{\mathsf{f},t} &= \frac{1}{1+\mu\left(mkp_{\mathsf{f}}-1\right)+\kappa_{\mathsf{F}}^{p}\pi^{2}\left(mkp_{\mathsf{f}}-1\right)\left(1+\beta\right)}\left(\widehat{\mathcal{E}}_{t}+\widehat{MC^{*}}_{\mathsf{f},t}\right) \\ &+\frac{\mu\left(mkp_{\mathsf{f}}-1\right)\left(\widehat{P}_{\mathsf{n},t}\right)+\kappa_{\mathsf{F}}^{p}\pi^{2}\left(mkp_{\mathsf{f}}-1\right)\left(\beta E_{t}\widehat{\bar{\bar{P}}}_{\mathsf{f},t+1}+\widehat{\bar{\bar{P}}}_{\mathsf{f},t-1}\right)}{1+\mu\left(mkp_{\mathsf{f}}-1\right)+\kappa_{\mathsf{F}}^{p}\pi^{2}\left(mkp_{\mathsf{f}}-1\right)\left(1+\beta\right)}\end{aligned}$$

The ERPT coefficient also depends on nominal rigidities.

- Calibrating an average price rigidity for 4-month, the short-run ERPT at the border falls from 90 to 27 percent; with an average 3-quarter rigidity, ERPT is 4 percent.

- In the long-run, nominal rigidities are irrelevant, and ERPT remains incomplete per effect of μ and mkp.

- When you increase average price rigidity, at some point the correlation between the exchange rate and TOT changes sign, at odds with the evidence stressed by Obstfeld and Rogoff 2000.

Letting $\mu \to 0$ (no distribution) affects very little the short run pass-through coefficient, which remains low mostly per effect of nominal rigidities. However (a) it makes ERPT perfect in the long run) and (b) it does affect substantially the elasticity of import prices at consumer level:

$$p_t(h) = \bar{p}_t(h) + \eta P_{\mathsf{N},t}.$$

Lesson: while assuming sticky prices in conjunction with vertical interaction and markup adjustment improves the performance of the model in some dimensions, sticky prices in isolation run into problems. This is because, ignoring real factors affecting local currency price stability, explaining stable import prices vis-a-vis high volatility of the exchange rate would necessarily require the assumption of a very high degree of nominal rigidity in import pricing, much higher than in the domestic good pricing, or wage setting (see Lubik and Schorfeide NBER 2006).

4 A theory-informed look at ERPT regressions

When bringing the model to the data, the analysis above suggests that an empirical specification of the regression model consistent with theory should include (a) marginal costs in the tradable sector, (b) marginal costs or prices in the distribution sector (which in the derivation above are the same as nontradable goods) — to account for the effect of distributive trade on the price elasticity and markup — as well as (c) the expected value of $E_t\widehat{\bar{P}}_{\mathsf{f},t+1}$ — to account for the dynamic dimension of optimal pricing with forward-looking price setters. Omitting any of these variables would likely result into biased estimates. Since data availability is a binding constraint, to what extent can we rely on ERPT results from empirical regression models? (The analysis below follows Corsetti Dedola and Leduc JME 2008.)

According to the taxonomy in Goldberg and Knetter (1997), the typical ERPT regression framework can be written as

$$\mathcal{P}_t = \alpha + \gamma \mathcal{E}_t + \beta \mathcal{C}_t + \delta \mathcal{D}_t + u_t, \tag{2}$$

where all variables are in logs: $\mathcal{P}_t$ is the import price denominated in local currency, $\mathcal{C}_t$ is a measure of exporter's marginal costs, $\mathcal{D}_t$ may include controls for shifts in import demand (like prices of competing goods or income in the importing country), as well as lagged values of the dependent variable to capture dynamics, and $\mathcal{E}_t$ is the nominal exchange rate (importer's currency per unit of exporter's currency). The coefficient γ is referred to as the pass-through coefficient. ERPT — conditional on controls $\mathcal{D}_t$ and $\mathcal{C}_t$ — is full or complete if $\gamma = 1$ and is incomplete if $\gamma < 1$. Provided one can find an accurate measure of $\mathcal{C}_t$ and $\mathcal{D}_t$, the coefficient γ measures pass-through as the change in markup isolated in the structural equation derived above.

Typically, marginal costs are proxied by cost indices plagued by measurement error, which may be correlated with exchange rates. The research on pricing-to-market (PTM) addresses this issue by including prices and costs in both the origin and the destination markets. Costs, and thus errors in costs, influence the export price relative to the domestic price only when there is a difference in the demand elasticity in the two markets (e.g., see Marston [1990]).

Exchange rate volatility and disconnect

An key issue in this literature is the extent to which the exchange rate may be correlated with marginal costs and demand. To understand this fully, consider a specification of the model in section 1 of this lecture, with flexible prices. Regress import prices on the contemporaneous exchange rate only. Using expression (1), the regression bias in estimating γ is

$$bias = \frac{Cov\left(\mathcal{E}_t, \frac{1}{1+\mu(mk_{\mathsf{f}}-1)} MC^*_{\mathsf{f},t} + \frac{\mu(mk_{\mathsf{f}}-1)}{1+\mu(mk_{\mathsf{f}}-1)} MC_{\mathsf{n},t}\right)}{Var\left(\mathcal{E}_t\right)} \quad (3)$$

- If the exchange rate is ‘disconnected’ from fundamentals, the Covariance term above is zero: there is no bias.

- *Other things equal*, the size of the bias falls with the volatility of the exchange rate.

- In general however, the bias depends on the covariance between $\mathcal{E}_t$ and the productivity shocks $Z_{\mathsf{f},t}$ and $Z_{\mathsf{n},t}$ affecting marginal costs in the two economies.

  – In general equilibrium, exchange rate volatility is no guarantee of accuracy in pass-through estimates.

4.1 A quantitative analysis of the bias

Idea: using a model similar to the one specified in this lecture as a lab, generate time series from the model, and run empirical ERPT regressions, comparing results with the structural equations of the model. The specification is a standard two-country model with tradables and nontradables, with new Keynesian features (money in utility function, Rotemberg adjustment costs).

We already pointed out that, if exchange rate volatility is driven by exogenous shocks (say, noise traders deviating from Euler equation), the regression bias is zero. What is interesting here is an assessment of the conflicting role of exchange rate volatility and covariance with fundamentals.

Main ingredients: specify a model generating high exchange rate volatility as a function of fundamentals.

Two specification/Calibration strategies to generate high volatility

1. set a relatively low price elasticity of imports, drawing on BKK and CDL. The coefficient of relative risk aversion equal to 2; tradables elasticity of substitution to 0.5.

2. set a high degree of risk aversion, drawing on Chari, Kehoe and McGrattan [2002] (henceforth CKM). Coefficient of relative risk aversion equal to 5; tradables elasticity 1.5. Investment adjustment cost, b, is calibrated to match the standard deviation of U.S. investment relative to that of U.S. output).

CKM idea. In complete market economies,

$$\left(\frac{C}{C^*}\right)^{\sigma} = RER.$$

if risk aversion is sufficiently large, a high variability of the ratio of Home to Foreign consumption can correspond to large equilibrium movements in the real exchange rate. Corsetti et al. JME 2008 further shows that the mechanism works

- also with incomplete markets
- not only for nominal but also for technological shocks, provided that the national economies are sufficiently insulated from one another by the presence of nontraded goods.

The role of monetary policy

To pin down exchange rates and prices, monetary policy is assumed to follow an empirical Taylor-type rule with an interest-smoothing component. Monetary authorities set the short-term nominal interest rate, i_t, as a function of the deviations of expected CPI inflation (π) and GDP (y) from steady state values (π^{ss} and y^{ss}).

$$i_t = \rho i_{t-1} + \Psi(1-\rho)E(\pi_{t+1} - \pi^{ss}) + \gamma(1-\rho)(y_t - y^{ss}). \qquad (4)$$

The exchange rate follows from combining the standard Euler equations for bond holdings by the Home and the Foreign households (holding the law of one price)

$$E_t\left[\frac{\beta_t \partial U\left[C_{t+1}, \frac{M_{t+2}}{P_{t+1}}, L_{t+1}\right] / \partial C_{t+1}}{\partial U\left[C_t, \frac{M_{t+1}}{P_t}, L_t\right] / \partial C_t} \frac{P_t}{P_{t+1}}\right] = E_t\left[\frac{\beta_t^* \partial U\left[C_{t+1}^*, \frac{M_{t+2}^*}{P_{t+1}^*}, L_{t+1}^*\right] / \partial C_{t+1}^*}{\partial U\left[C_t^*, \frac{M_{t+1}^*}{P_t^*}, L_t^*\right] / \partial C_t^*} \frac{P_t^*}{P_{t+1}^*} \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}\right]$$

Nominal and real exchange rates

- With flexible prices, given the money demand function implicit in utility, monetary policy pins down the evolution of the price level and the other nominal variables in each country; thus, given the equilibrium real exchange rate, the nominal exchange rate will be determined by the relative monetary stance in the countries.

- With sticky prices, instead, monetary policy will have also some short-run effects on real variables; however, in line with the Taylor rule, monetary policy will be mainly concerned with stabilizing inflation, so that price level movements are quite smooth. It follows that nominal exchange rates will closely mimic real exchange rates.

Table 1. Parameter values

Benchmark Models	
Preferences and Technology	
Risk aversion	$\sigma = 2, 5$
Disutility of labor	$\alpha = 1.13$
Velocity parameter	$\chi = 0.1$
Elasticity of substitution between:	
Home and Foreign traded goods	$\frac{1}{1-\rho} = 0.5, 1.5$
traded and non-traded goods	$\frac{1}{1-\phi} = 0.74$
Home non-traded goods	$\theta_{\mathrm{N}} = 7.7$
Home traded goods	$\theta_{\mathrm{H}} = 15.3$
Elasticity of the discount factor	
with respect to C and L	$\psi = 0.006$
Distribution margin	$\mu = 0.5 \quad (\eta = 1.22)$
Labor share in tradables	$\xi = 0.61$
Labor share in nontradables	$\zeta = 0.56$
Depreciation rate	$\vartheta = 0.025$
Monetary Policy	
Lagged interest-rate coefficient	$\rho = 0.84$
Weight on inflation	$\Psi = 2.19$
Weight on output gap	$\gamma = 0.3$
Sectoral productivity shocks	
Sectoral autocorrelation matrix	$\lambda = \begin{bmatrix} 0.95 & 0.0 \\ 0.0 & 0.95 \end{bmatrix}$
Sectoral variance-covariance matrix (in percent)	$\Omega = \begin{bmatrix} 0.7 & 0.00123 \\ 0.00123 & 0.7 \end{bmatrix}$

Main features of the model

- In response to real (productivity) shocks, exchange rates and relative prices are highly volatile, their movements persistent and correlated.
  - No need to emphasize nominal shocks, as typically done in the literature on purchasing power parity.

- For a degree of price stickiness consistent with the evidence in Bils and Klenow (2004) (average duration of prices: 4.3 months), the real exchange rate is positively correlated with the terms of trade and the price of imports, weakly correlated with the CPI
  - In accord to the hurdle proposed by Obstfeld and Rogoff

- A reasonably small degree of price stickiness generates a low short-run pass-through:
  - With the Bils and Klenow specification, LCP generates low pass-through (.27) without inducing a negative correlation between exchange rate and terms of trade. This result qualifies the argument in Obstfeld and Rogoff (2000) against LCP.
  - For a standard calibration of the average duration () the pass-through coefficient is .04.
- Pass-through rises over time. Because of price discrimination, however, pass-through remains incomplete also in the long run.
  - This result is impossible in LCP model ignoring price discrimination

Table 2A. Exchange rates and prices in the theoretical economies[a]
Economy with $\sigma = 2, \omega = 0.5$

Statistics	U.S. Data	Flexible prices	Taylor rule Sticky prices low *LCP*	Sticky prices high *LCP*	Inflation Targeting Sticky prices low *LCP*
Standard deviation (relative to GDP)					
Real exchange rate (CPI based)	3.04	3.36	4.10	7.50	3.71
Nominal exchange rate	3.36	4.40	5.15	8.31	3.71
Terms of trade	1.71	2.93	3.28	6.58	2.88
Imports	3.28	2.28	2.29	2.38	2.30
Auto-correlation					
Real exchange rate	0.81	0.73	0.70	0.72	0.74
GDP	0.87	0.72	0.74	0.87	0.71
Correlation with real exchange rate					
Nominal exchange rate	0.96	0.92	0.95	0.98	1.00
Terms of trade	0.35	0.52	0.30	-0.41	0.46
Cross-country consumption ratio	-0.45	-0.67	-0.77	-0.88	-0.76
Correlation with nominal exchange rate					
Import prices	0.45	0.91	0.88	0.70	0.86
CPI level	-0.17	0.42	0.40	0.30	-0.28
Difference between cross-correlation of					
GDP and consumption	0.22	0.33	0.40	0.55	0.40
Correlation with GDP					
Net exports	-0.51	-0.42	-0.36	-0.28	-0.40

[a]See main text for a description of the different model economies.

Table 2B. Exchange rates and prices in the theoretical economies[a]

Economy with $\sigma = 5, \omega = 1.5$

Statistics	U.S. Data	Flexible prices	Taylor Rule Sticky prices low LCP	Sticky prices high LCP	Inflation Targeting Sticky prices low LCP
Standard deviation (relative to GDP)					
Real exchange rate (CPI based)	3.04	3.41	3.54	3.69	3.66
Nominal exchange rate	3.26	3.68	3.81	3.19	3.66
Terms of trade	1.71	2.69	2.33	2.32	2.46
Imports	3.28	2.36	1.92	1.39	1.82
Auto-correlation					
Real exchange rate	0.81	0.71	0.72	0.81	0.66
GDP	0.87	0.71	0.76	0.82	0.72
Correlation with real exchange rate					
Nominal exchange rate	0.96	0.62	0.63	0.65	1.00
Terms of trade	0.35	0.54	0.33	-0.21	-0.03
Cross-country consumption ratio	-0.45	1.00	1.00	1.00	1.00
Correlation with nominal exchange rate					
Import prices	0.45	0.58	0.53	0.45	0.71
CPI level	-0.17	0.14	0.15	0.19	0.68
Difference between cross-correlation of					
GDP and Consumption	0.32	-0.35	-0.26	-0.13	-0.20
Correlation with GDP					
Net exports	-0.51	0.66	0.63	0.57	0.60

[a]See main text for a description of the different model economies.

Two empirical models: 'ERPT regression' and 'PTM regression'

- The ERPT regression includes Foreign nominal wages, W_t^*, to control for marginal costs in the exporting country, and Home real GDP, Y_t, to control for demand conditions in the importing country.

$$\bar{P}_{\mathsf{f},t} = \alpha + \gamma \mathcal{E}_t + \beta W_t^* + \delta_1 Y_t + \delta_2 \bar{P}_{\mathsf{f},t-1}. \tag{5}$$

- The PTM regression, instead, include the domestic price of Foreign exports, $\bar{P}^*_{\mathsf{f},t}$ and the Home PPI of tradables, $\bar{P}_{\mathsf{h},t}$, for the same reasons. The PTM literature imposes the homogeneity constraint $\beta = \gamma$ (e.g., see Marston [1990]), reflecting the theoretical *a-priori* that the exchange-rate pass-through should be equal to that of marginal costs.

$$\bar{P}_{\mathsf{f},t} = \alpha + \gamma \mathcal{E}_t + \beta \bar{P}^*_{\mathsf{f},t} + \delta_1 \bar{P}_{\mathsf{h},t} + \delta_2 \bar{P}_{\mathsf{f},t-1}, \tag{6}$$

- In either model γ represents the estimate of the short-run ERPT coefficient, while $\frac{\gamma}{1-\delta_2}$ will be the estimate of the long-run ERPT coefficient.

The two regressions above are clearly mis-specified in light of the theoretical model above, as they do not control for the effects of distribution on demand elasticities. Moreover, they suffer from measurement error problems, as they rely on proxies of the marginal costs (which is generally not observable). The ERPT model only includes nominal wages, but omits the cost of capital and measures of technology shocks. By the same token, the inclusion of the Foreign price of Home imports among the regressors in the PTM model is a potential source of bias, as this price includes a Foreign market time-varying markup.

The Table below presents the results from running regressions on artificial time series. For each theoretical economy, the table shows the *true value of* short-run and long-run coefficients γ and $\dfrac{\gamma}{1-\delta_2}$ in the two rows under the heading *Structural (* reflecting the value of the structural parameters in the log-linearized first order conditions of the monopolistic Foreign exporter). As a useful benchmark, the tables also include a control regression in which the import price is regressed only on its lag and the exchange rate — the "naïve" specification.

Table 3. Estimates of ERPT coefficients for Import Prices in artificial data[a]

Specifications	Economy with $\sigma = 2, \omega = 0.5$			*Economy with* $\sigma = 5, \omega = 1.5$		
	Flexible prices	Sticky prices low LCP	Sticky prices high LCP	Flexible prices	Sticky prices low LCP	Sticky prices high LCP
Structural						
Short run	0.93	0.27	0.04	0.93	0.27	0.04
Long run	0.93	0.93	0.93	0.93	0.93	0.93
Naive: $\overline{P}_{F,t} = \alpha + \gamma E_t + \delta_2 \overline{P}_{F,t-1}$						
Short run	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Long run	1.60	1.46	1.11	0.25	0.28	1.15
PTM: $\overline{P}_{F,t} = \alpha + \gamma E_t + \beta \overline{P}^*_{F,t} + \delta_1 \overline{P}_{H,t} + \delta_2 \overline{P}_{F,t-1}$						
Short run	0.92	0.50	0.21	0.93	0.60	0.24
Long run	0.93	0.94	0.96	0.94	0.88	0.74
ERPT (1): $\overline{P}_{F,t} = \alpha + \gamma E_t + \beta W^*_t + \delta_1 Y_t + \delta_2 \overline{P}_{F,t-1}$						
Short run	0.18	0.13	0.10	0.08	0.06	0.06
Long run	1.00	1.00	1.00	1.00	1.00	1.00
ERPT (2): $\overline{P}_{F,t} = \alpha + \gamma E_t + \beta W^*_t + \delta_1 \overline{P}_{H,t} + \delta_2 \overline{P}_{F,t-1}$ or $\overline{P}_{F,t} = \alpha + \gamma E_t + \beta \overline{P}^*_{F,t} + \delta_1 Y_t + \delta_2 \overline{P}_{F,t-1}$						
Short run	0.29	0.27	0.17	0.90	0.51	0.18
Long run	0.88	0.90	0.92	0.99	1.00	1.00

[a]See main text for a description of the different model economies and the specification of the regression models.

Main results

- Importance of controls: The naïve model is nowhere close to recovering the structural parameters

- Estimates are clearly biased. However, in most cases the two regression models (PTM and ERPT) distinguish between short run and long run ERPT coefficient when these are truly different.

- Performance crucially depends on the quality of proxies for marginal costs and demand. In the baseline
  - Controls for MC and import demand in the PTM model improve the regression's performance

- Relatively bad proxies for MC and import demand explain why the ERPT model performs less well

- However, the quality of alternative proxies for marginal costs and demand conditions are sensitive to the nature of shocks hitting the economy.
  - The relative performance is reversed with monetary shocks

The relative performance is reversed with monetary shocks

Models (monetary shocks only)	Sticky Prices Low LCP	Sticky Prices High LCP
Structural		
Short run	0.27	0.04
Long run	0.93	0.93
PTM		
Short run	0.08	0.01
Long run	0.11	0.02
ERPT		
Short run	0.47	0.10
Long run	1.00	1.00

Conclusions

Bias is decreasing in the volatility of the exchange rate, but also depends on the covariance between the exchange rate and determinants of import prices.

- This covariance is zero only in models where exchange rate volatility is posited to be exogenous. If the exchange rate is truly 'disconnected from fundamentals', bias in ERPT regression models is not an issue.

- High endogenous volatility of the exchange rate tends to alleviate, but not eliminate, regression biases.

Moreover, results suggest that the quality of different regressors as proxies for marginal costs and demand conditions may vary, depending on the set of shocks on which the estimates are conditioned. Assessing the sensitivity of pass-through estimates to the inclusion of alternative proxies for marginal costs and import demand seems to be a crucial step towards gauging the reliability of ERPT estimates.

Note on the literature

A few papers have studied a firm's optimal choice of the currency in which to price exports subject to nominal rigidities (Bacchetta and Van Wincoop JIE 2006, Corsetti and Pesenti 2002, Devereux, Engel and Storgaard JIE 2004 Engel JEEA 2007). The objective is to determine which choice of currency maximizes firm's value (present discounted value of profits).

Real factors (market share, distribution, etc) clearly affect this choice. In Engel's synthesis, firms optimally chose LCP if real factors would make the local price of imports stable independently of nominal rigidities.