Master EPP, International Macroeconomics
Lecture 5
Pricing to market and exchange rate pass through: empirics and theory

1 The exchange rate in a model of pricing-to-market (Betts & Devereux, 1996)

Consider a two country economy in which households supply labour and consume a basket of differentiated varieties of total measure unity. Preferences are given by the following utility function:

$$U = \left(logC + \frac{\gamma}{1-\epsilon} \left(\frac{M}{P} \right)^{1-\epsilon} + \eta log(1-h) \right)$$

where $C = \left[\int_0^1 c(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}}$ is the consumption basket, h represents total hours worked by the domestic household. Finally, households also value real money balances M/P. In each period, households receive income from wages (Wh), profits on their ownership of domestic firms (π) and transfers from government (TR). Moreover, they inherit their previously accumulated money holding M_0.

On the unitary mass of differentiated varieties available in each country, a share n is produced in the domestic country while $1-n$ is produced in the foreign country. To simplify the analysis, n and $1-n$ also represent the population of the home and foreign country, respectively. Finally, a proportion s of firms in each country can "price-discriminate", ie set prices directly in the final consumer's currency. The other $1-s$ firms cannot discriminate and set the same price in both markets (ie adopt a PCP strategy).[1] All firms in a given country share the same technological function. Thus, for domestic firms:

$$y(i) = Ah(i)$$

where A is the domestic aggregate productivity.

1. Write the aggregate price index as a function of individual prices and the exchange rate.

2. Write and solve the household's program.

3. Derive pricing strategies of LCP and PCP firms.

4. Show that PPP holds in this model when prices are fully flexible. Log-linearized price indices around a symmetric flexible price equilibrium to show that PPP does not hold in the short-run when prices are sticky.

5. Use the log-linearized money demand equations and the definition of price indices to get the fundamental exchange rate equation around the flexible-price equilibrium. What impact has pricing-to-market on the dynamics of the exchange rate?

2 Pricing-to-Market, Trade Costs, and International Relative Prices (Atkeson & Burstein, 2008)

Motivation: Data on international relative price fluctuations for developed countries suggest that i) the terms of trade for manufactured goods are substantially less volatile than the corresponding PPI-based

[1] Note that it is sufficient to assume that PCP firms choose to set their price in their own currency. Under this strategy, it can be shown that firms have no incentive to set a different price in their domestic and export market.

RER for manufactured goods and ii) fluctuations in the CPI-based RER for goods are roughly the same size as those in the PPI-based real exchange rate for manufactured goods. Both of these observations arise because, at the aggregate level, data on export and import prices show substantial and systematic deviations from relative PPP in comparison with source country producer prices. Atkeson & Burstein build a model of international trade and international relative prices that accounts for these aggregate price observations. In their model, deviations from relative PPP arise as a result of the decision of individual firms to price-to-market in response to aggregate shocks. Pricing-to-market behaviors arise endogenously thanks to two key ingredients: imperfect competition with variable markups, and international trade costs.

Consider a model in which two symmetric countries (indexed by i = 1, 2) produce and trade a continuum of goods subject to frictions in international goods markets. Aggregate shocks to productivity are the driving force behind fluctuations in international relative prices.
Preferences in country i are given by:

$$E_0 \sum_{t=0}^{\infty} \beta^t u(c_{it}, 1 - l_{it})$$

where β is the discount factor, and $u(c, 1-l) = log[c^{\mu}(1-l)^{1-\mu}]$. Here c_{it} denotes final consumption and l_{it} denotes working hours of the representative household of country i at time t. Households in each country trade a complete set of international assets. This implies that, at every date and in every state of nature, nominal consumptions are equalized across countries in equilibrium.
The structure of consumption and production is as follows. At the lowest level of aggregation in our model, individual firms produce differentiated goods. Goods are then aggregated into sectors. There are only a relatively small number of firms in each individual sector, each one producing a distinct good. Sectors are then further aggregated into a consumption composite, called final consumption. Final consumption, c_{it}, is produced by a competitive firm using the output of a continuum of sectors $y_{ijt} \quad for\ j \in [0,1]$ as inputs subject to a CES production function:

$$c_{it} = \left[\int_0^1 y_{ijt}^{\frac{\eta-1}{\eta}} dj \right]^{\frac{\eta}{\eta-1}}$$

In each country i and sector j, there are K domestic firms selling distinct goods and an additional K foreign firms that may, in equilibrium, sell goods in that sector. Firms $k = 1, 2, ..., K$ are domestic and $k = K+1, K+2, ..., 2K$ are foreign. The number of producers is taken as exogenous. Output in each sector is given by:

$$y_{ijt} = \left[\sum_{k=1}^{2K} q_{ijkt}^{\frac{\rho-1}{\rho}} \right]^{\frac{\rho}{\rho-1}}$$

where q_{ijkt} denotes sales in country i of firm k in sector j.
Each firm has a constant returns to scale production function that has labor as the only input. The production functions for firms from country i are given by $A_i z l$, where z differs across firms and A_i denotes aggregate productivity that affects all firms based in country i. Each firm in sector j based in country i draws its idiosyncratic productivity z from a log-normal distribution, $N(0, \theta)$. This idiosyncratic component of productivity is fixed over time. The marginal cost of production, exclusive of trade costs, for a firm with productivity z based in country i is $W_i/(A_i z)$. In addition to the production costs, there are costs of international trade. International trade is prohibitively costly for final consumption. The output of firms can be traded, under two type of costs: a fixed labor cost F for any firm that wishes to export any of its output to the other country, and an iceberg type

marginal cost of exporting denoted by τ. With this iceberg trade cost, the marginal cost for a firm with productivity z based in country 1 to sell its output in country 2 is $\tau W_1/(A_1 z)$. With the fixed cost, the decision to export becomes endogenous.

1. Write and solve the household program.

2. Write the optimal demand of sectoral composite goods (y_{ijt}) and of individual goods (q_{ijkt}).

The market structure is as follows. Individual goods producing firms are engaged in imperfect competition. Goods are imperfect substitutes: $\rho < \infty$. Moreover, goods within a sector are assumed to be more substitutable than goods across sectors: $1 < \eta < \rho$. Firms play a static game of quantity (Cournot) competition. Specifically, each firm k chooses its quantity q_{ijkt} sold in country i taking as given the quantities chosen by the other firms in the economy, as well as the domestic wage rate (W_{1t} for firms with $k < K$ and W_{2t} for those with $k > K$), and the final consumption price P_{it} and quantity c_{it}. Each firm does recognize that sectoral prices P_{ijt} and quantities y_{ijt} vary when that firm changes its quantity q_{ijkt}.

3. Suppose that only the K domestic firms produce and sell in each country in sector j. What are the equilibrium quantities and prices? Discuss the following limiting cases: i) large number of firms ($K \to \infty$), ii) a single firm by sector, iii) $\rho = \eta$.

To determine how many foreign firms pay the fixed trade cost to supply the domestic market, an iterative procedure is used. Still taking the wage rate, W_{it}, and the final consumption price P_{it} and quantity c_{it} as given , it is assumed that foreign firms consider entry sequentially in reverse order of unit costs: the lowest cost producer $k+1$ enters, if it still makes profits, the second lowest cost producer $k+2$ enters, etc.

4. What is the optimal behaviour of the lowest cost foreign producer?

5. Discuss the model's predictions in terms of pricing-to-market by individual firms.

In the paper, the model is calibrated to match different US empirical evidence. An aggregate productivity shock in country 1 is then simulated and the predicted impact on relative prices is computed. Three alternative versions are compared: i) the constant markup version of the model where $\rho = \eta$, ii) the frictionless trade version where $\tau = 1$ and $F = 0$, iii) the complete version with variable markups and trade frictions. Numerical simulations of these models can be compared to illustrate the role of each assumption in shaping the complete model's implications for international relative prices. Tables 1 summarizes results of these calibration exercises.

6. Comment simulations of Table 1. Is the model able to reproduce the stylized facts discussed in the exercise's introduction ?

Table 1: Impact of a 1% shock on relative production costs

	Complete Model	Constant Markups	Frictionless Trade
PPI-based RER (decomposition %)			
Terms-of-trade, country 1	53.4%	100%	100%
PPI/Export price, country 1	23.1%	0%	0%
Export price/PPI, country 2	23.6%	0%	0%
PPI, country 1	0.86%	1%	0.76%
Export price, country 1	0.69%	1%	0.76%
Import price, country 1	0.31%	0%	0.23%
PPI, country 2	0.14%	0%	0.23%
CPI-RER/PPI-RER	82.3%	66.9%	0%

Source: Atkeson & Burstein (2008). Benchmark calibration.