Topic 4: What Determines Exchange Rates?

Part 1: Definitions and empirical regularities

- The models we studied earlier include only real variables and relative prices. We now extend these models to have a nominal side and nominal exchange rates.

- Some Basic Definitions:

  - nominal exchange rate (e): home currency price of a unit of foreign currency. Note that a rise in e is a depreciation in the value of the home currency.

  - real exchange rate (q): relative aggregate price levels of two economies. Usually defined as ratio of CPIs: $q=eP^*/P$.

- Purchasing power parity (PPP), hypothesis that the aggregate price level should be the same across countries when adjusted to a common currency.

$$eP^* = P$$

Note that PPP implies that real exchange rate is constant at value q=1.

- Relative PPP: in percent changes:

$$\%\Delta e = \%\Delta P - \%\Delta P^*$$

Currency depreciation equals inflation differential.

Logic of PPP

- Based on the law of one price (LOP) for individual goods. says the price of any individual good should be the same across countries when converted to same currency:

$$P^i = e\, P^{i*}, \quad \text{for individual good } i$$

- Failure of condition implies an arbitrage opportunity to purchase good where cheap and resell where expensive:

- This should affect the prices, lowering them where they had been high, and raising them where had been low

- PPP claims this equality applies also if goods prices are aggregated to compute CPI.

There are several reasons why PPP might fail to hold:

1) Different consumption baskets across countries: aggregating goods prices with different weights produces different aggregate values.

2) Nontraded goods: Nontraded goods may have different prices in different countries, because it is impossible to arbitrage these if they can't be traded

3) trade barriers: also can prevent arbitrage

4) Imperfect competition: market segmentation lets firms set different prices for differing market conditions.

5) sticky prices, if the exchange rate changes while prices can't adjust right away, this would cause prices of goods to be different for a while, in common units.

Stylized facts

Transparency of statistics for the real exchange rate

- very volatile: 4x that of output.
- very persistent: serial correlation of 0.8 on average.
- The Real and nominal exchange rates move closely together. The correlation is is almost unity.

  Similar characteristics to the terms of trade in Backus et al (1992).

Mussa (1986 Carnegie Rochester): also noted that the volatility of both real and nominal exchange rates are lower during fixed nominal exchange rate regimes.

Table 1
Data

	serial correlations:			standard dev.:	correlation:
	q	q (not filtered)	output	s.d.(q)/s.d.(output)	cor(s,q)
Canada	0.88	0.95	0.89	2.05	0.94
France	0.78	0.91	0.84	7.57	0.99
Germany	0.74	0.93	0.74	4.35	0.99
Italy	0.79	0.93	0.83	4.26	0.98
Japan	0.81	0.93	0.67	5.87	0.98
United Kingdom	0.79	0.95	0.85	4.79	0.98
Average	0.80	0.93	0.80	4.81	0.98

All series are quarterly and are Hodrick-Prescott filtered, unless otherwise stated. The real exchange rate (q) is computed as the CPI-adjusted bilateral exchange rate with the U.S. dollar, using quarterly data from International Financial Statistics. The nominal exchange rate is represented in the table by s.

Debate over real v. nominal shocks:

Nominal shocks: (Mussa position)

- Using the definition of the real exchange rate above:

$$q = e\frac{P*}{P}$$

- Then one way to explain the volatility of the real exchange rate and its comovement with e, is to assume prices are sticky:

- If money supply or demand shocks affect e, while P and $P*$ are fixed, then this is passed on to q.

- We will study sticky price models in detail soon.

Real shocks: (Stockman position)

- Inverting the definition of the real exchange rate:

$$e = q\frac{P}{P*}$$

- Can argue that it is movements in the real exchange rate, due to real shocks (such as productivity shocks in RBC models) that get passed on to nominal exchange rate.

- This theory also can explain the comovement of real and nominal exchange rates.

- It can easily explain persistence of real exchange rate, since productivity shocks are usually highly persistent.

Questions for discussion:

1) How does the "real exchange rate puzzle" remind you of the "relative price puzzle" we discussed previously in the context of RBC models?

2) What problems do you see with the Stockman position (real shocks) in explaining some items on the list of stylized facts for the real exchange rate given above?

3) What shortcomings do you see in the Mussa explanation (nominal shocks) for persistent real exchange rates, given it is based on sticky prices?

4) How might you test between the nominal shock and real shock explanations for the real exchange rate?

Part 2: Time-series studies of PPP

Early tests of relationship of nominal e and relative prices (PPP) took the form of a simple OLS regression (1970s):

$$e_t = \alpha + \beta\left(p_t - p^*{}_t\right) + \varepsilon_t$$ where all variables are in logs

- The test is if β =1.

- Most tests rejected this.

- But know now that if the nominal exchange rate or relative prices are nonstationary, we can't use traditional confidence intervals for β.

Unit Root tests

- Next set of tests impose the assumption that β=1 and compute real exchange rate, then test if it is stationary.

- The idea is that even if PPP does not hold at each point in time, we want to test if it holds as a long-run equilibrium condition.

- The real exchange rate may be pushed away from its equilibrium PPP value by shocks, but will it tend to return to it’s equilibrium value over time?

- So we compute: q = e x (P* / P), and apply one of a variety of unit root tests.

- Early tests were not favorable to PPP: could not reject unit root in the real exchange rate.

- But literature realized this could be due to the notoriously weak power of existing tests to reject unit root.

- Frankel (1986 book chapter) showed the post Bretton Woods data used in the preceding studies simply is not enough data to be able to reject a unit root.

Suppose the real exchange rate (q) follows an autoregression:

$$\left(q_t - \overline{q}\right) = \rho\left(q_{t-1} - \overline{q}\right) + \varepsilon_t$$

And suppose the half-life is 36 months, so that the autoregressive coefficient for monthly data would be 0.981.

- The authors then demonstrate it would require 72 years of data to be able to correctly reject unit root at 5% level.

- Literature in recent years has progressively found stronger evidence to support PPP in the long run, and the time to get there may be shorter than originally thought.

Approaches taken in the literature:

1) Longer Time Series: (Lothian and Taylor, 1996 JPE):
   - 200 years of data on dollar/pd and pd/FF, strongly rejects unit root, both for full sample and pre 1945 period (since 1945-73 had fixed exchange rates).

   - Graphs of the autocorrelation functions show that it may take a very long time for the real exchange rate to return to its equilibrium level, but it does eventually get there.

   - Autoregressions estimate an autoregressive coefficient for the dollar pound rate of 0.887, or a decay rate of 0.113. This indicates the half life of fluctuations in the real exchange rate is log(1/2) / log(0.887) = 5.7 years.

   - Similar autoregressions indicated a half-life of about 3 years for the pound/French franc real exchange rate.

$$q_t = \kappa + \lambda\left(t - \frac{T}{2}\right) + \delta q_{t-1} + u_t, \tag{3}$$

where $T + 1$ is the sample size and u_t is an error that may be serially correlated and heterogeneously distributed.[14] Then use the semi-nonparametric test statistics developed by Phillips (1987*a*, 1987*b*) and Phillips and Perron (1988) to test the following hypotheses:

$$H_A: \delta = 1; \quad H_B: (\kappa, \lambda, \delta) = (0, 0, 1); \quad H_C: (\lambda, \delta) = (0, 1). \tag{4}$$

TABLE 1

Unit Root Tests for Real Exchange Rates

	τ_μ	τ_τ	$Z(\tau_\mu)$	$Z(\Phi_1)$	$Z(\tau_\tau)$	$Z(\Phi_2)$	$Z(\Phi_3)$
				Dollar-Sterling			
1791–1990:							
Log level	−3.47*	−4.36*	−3.52*	6.20*	−4.61*	7.17*	10.76*
First difference	−13.24	−13.21	−13.31	88.36	−13.27	58.56	87.81
Second difference	−21.92	−21.86	−31.47	491.55	−13.15	322.66	483.99
1791–1945:							
Log level	−3.85*	−4.58*	−4.01*	8.08*	−4.79*	7.68*	11.49*
First difference	−12.29	−12.25	−12.45	77.37	−12.40	51.17	76.73
Second difference	−20.22	−20.15	29.76	441.07	−29.44	287.86	431.76
1946–90:							
Log level	−1.47	−2.85	−1.52	1.31	−2.71	3.12	4.48
First difference	−5.52	−5.50	−5.53	14.93	−5.47	9.84	14.62
Second difference	−8.71	−8.56	−12.10	69.71	−11.44	43.61	65.41
1974–90:							
Log level	−1.21	−1.42	−1.18	1.05	−1.37	.91	1.01
First difference	−2.62	−2.57	−2.43	2.59	−2.28	1.64	2.45
Second difference	−4.47	−4.30	−5.36	13.37	−4.71	7.31	10.51
				Franc-Sterling			
1803–1990:							
Log level	−4.85*	−4.83*	−5.17*	13.41*	−5.16*	8.94*	13.40*
First difference	−14.77	−14.73	−14.97	111.85	−14.91	74.08	111.12
Second difference	−24.35	−24.28	−37.62	705.41	−37.31	462.86	694.23
1803–1945:							
Log level	−3.27*	−3.21	−3.93*	8.06*	−3.97*	5.46*	8.03*
First difference	−9.44	−9.44	−9.30	42.66	−9.23	78.65	47.96
Second difference	−16.60	−16.57	−22.07	240.18	−22.05	161.38	241.93
1946–90:							
Log level	−2.05	−3.15	−2.00	2.05	−3.34	3.82	5.69
First difference	−8.64	−8.49	−8.65	37.55	−8.48	24.95	37.27
Second difference	−10.61	−10.40	−16.10	130.07	−15.35	81.04	119.44
1974–90:							
Log level	−1.78	−.87	−1.86	3.22	−.62	2.03	1.62
First difference	−2.47	−2.87	−2.43	2.95	−2.57	2.61	3.73
Second difference	−3.69	−4.17	−3.98	6.42	−3.72	4.83	7.16

Note.—The null hypothesis and test statistics are discussed in the text and defined in Perron (1988). Allowance was made for up to fifth-order serial correlation using the lag window recommended by Newey and West (1987). The asymptotic critical values are taken from Fuller (1976) and Dickey and Fuller (1981) and are as follows:

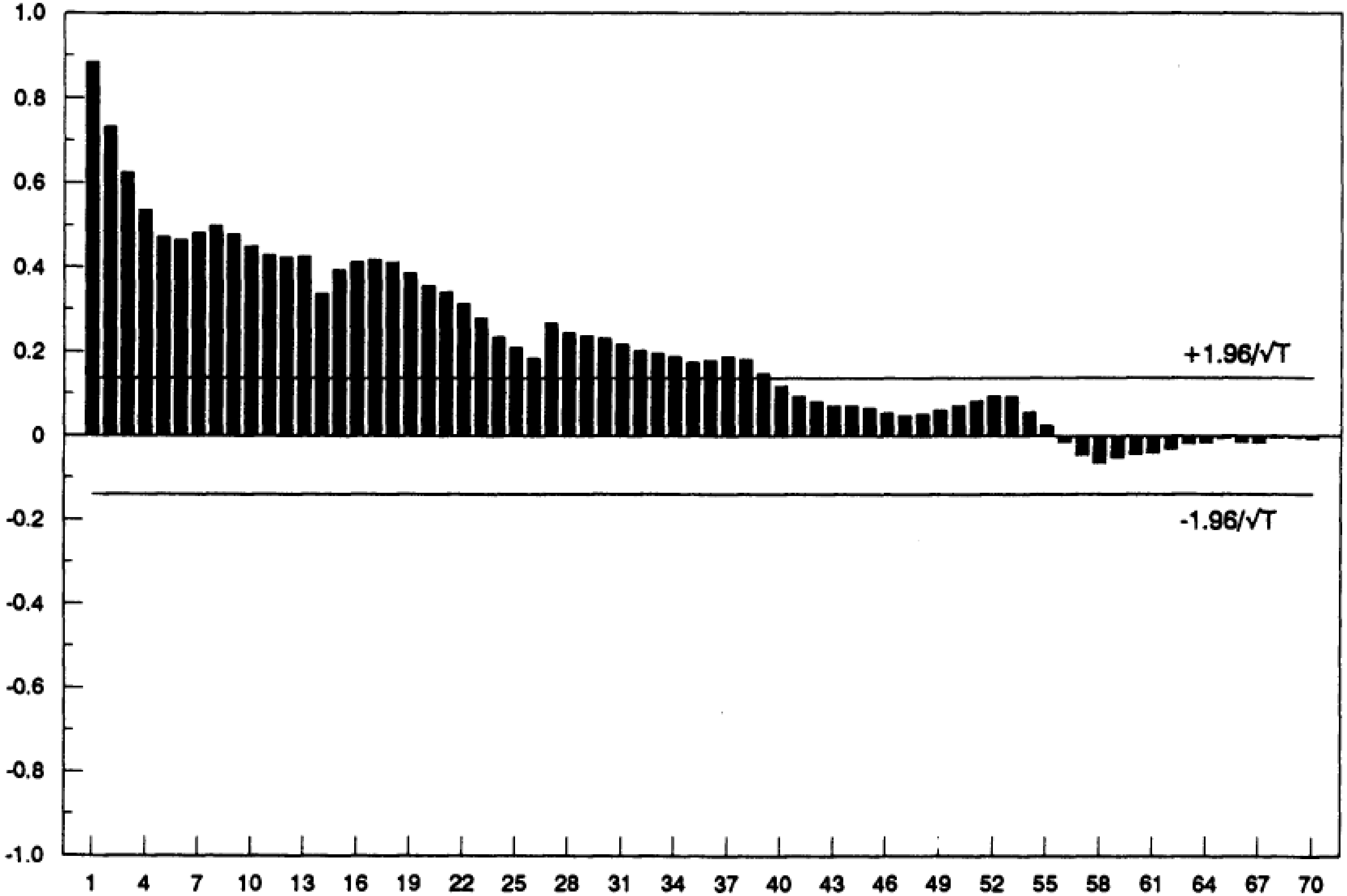


FIG. 4.—Sample autocorrelation function for dollar-sterling real exchange rate

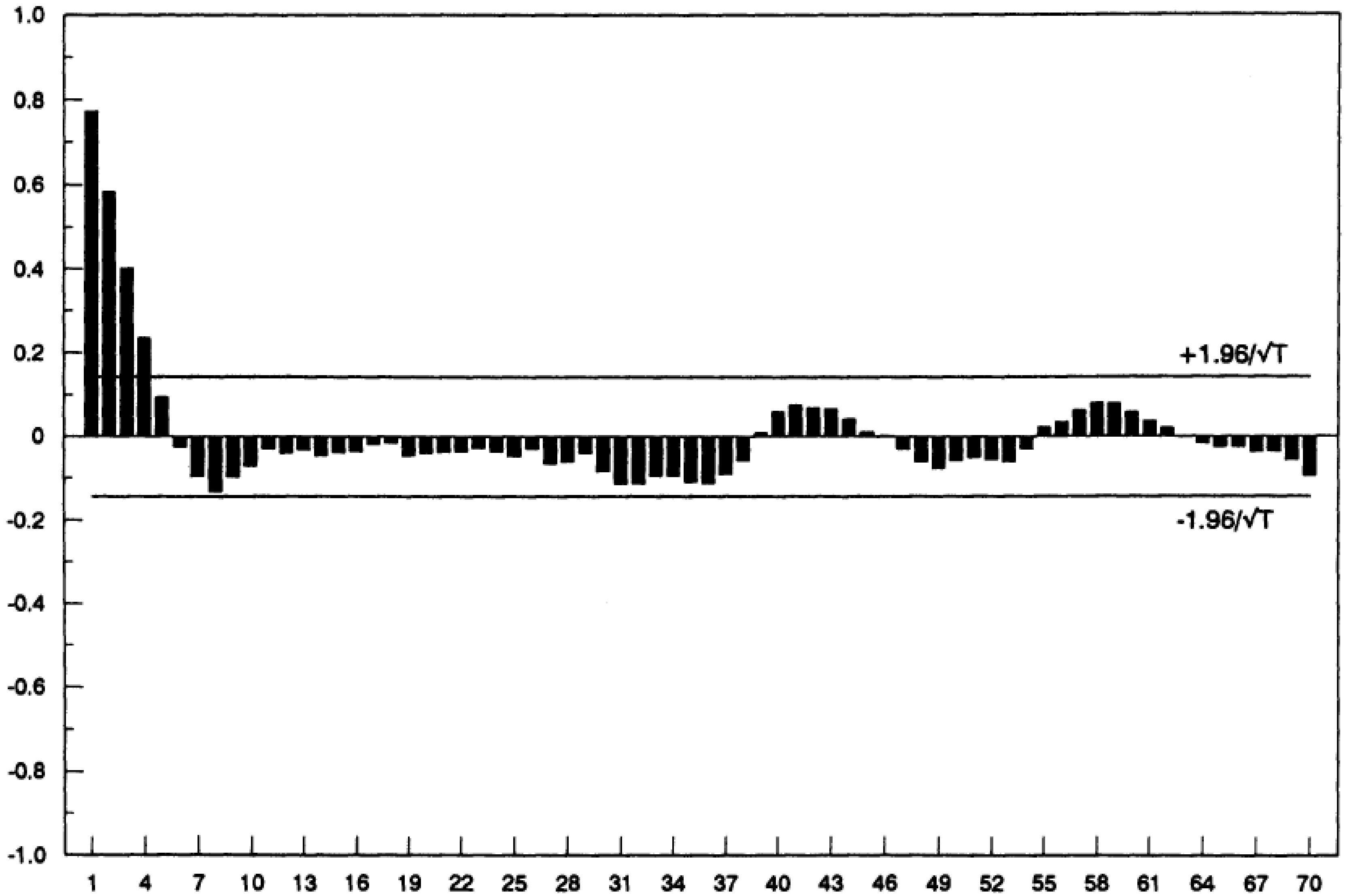
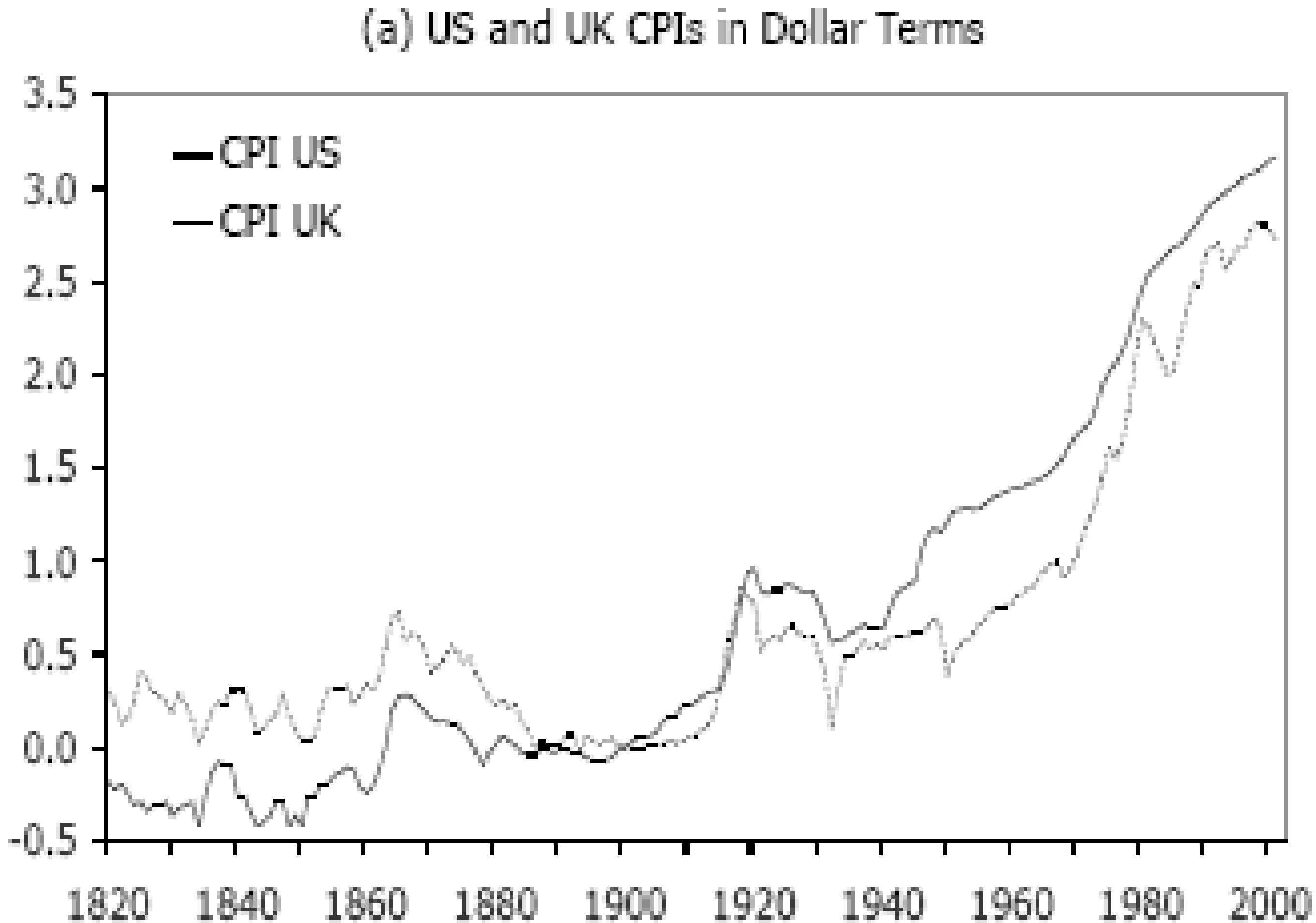
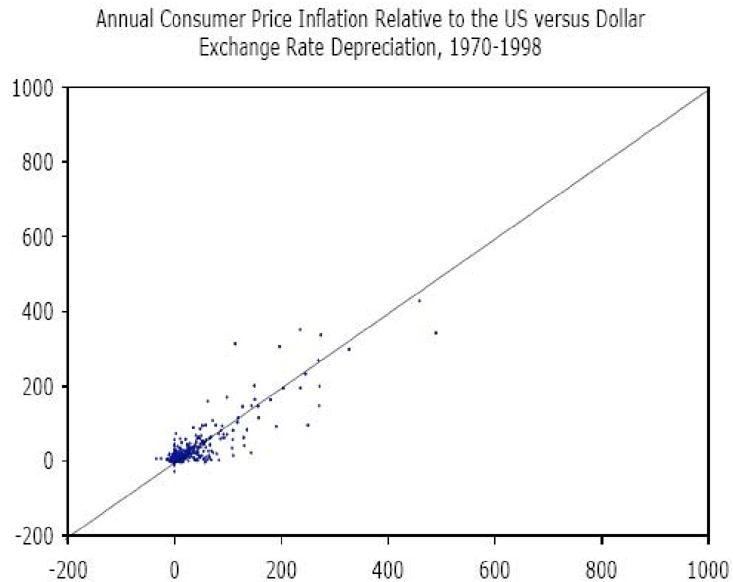


FIG. 6.—Sample autocorrelation function for franc-sterling real exchange rate

Taylor-Taylor




Annual Consumer Price Inflation Relative to the US versus Dollar Exchange Rate Depreciation, 1970-1998
1000
800
600
400
200
0
-200
-200
0
200
400
600
800
1000


Consumer Price Inflation Relative to the US versus Dollar Exchange Rate Depreciation, 29-Year Average, 1970-1998
10
8
6
4
2
0
-2
-2
0
2
4
6
8
10

2) Panel regressions:

- If we need more data to get a good test, then take multiple time series for multiple bilateral exchange rates, and use them together in a panel regression.

- Use annual data for 150 countries. They mostly reject the unit root using critical values for panel regression. They estimate a half-life of about 4 years.

- Introduced by Frankel and Rose (JIE 1996).

- Large literature using more recent panel econometric techniques; control for contemporaneous correlation in errors (CCE).

<u>**Aggregation Bias:** Imbs et al (QJE 2005) (skip?)</u>

- <u>Idea</u>: This paper questions the stylized fact that real exchange rates are persistent.
- It claims that large estimates of half-lives simply due to an econometric bias, arising from heterogeneity in the persistences of individual goods in the CPI basket.
- If econometric methods are used to control for this heterogeneity, then the estimate of the half life of PPP deviations drops to <u>less than one year</u>.
- <u>Implication</u>: There is hope for the sticky price explanation for real exchange rates, if the persistence of real exchange rates and prices both are about 1 year.

Imbs et. Al. Setup:

For simplicity, consider a panel of just one country pair. There are N sectors indexed by i.

Suppose the international relative price in each sector, q_{it}, follows the process:

$$q_{it} = \lambda_i + \rho_i q_{it-1} + \varepsilon_{it}$$

Where ρ_i represents the persistence, characterized by: $\rho_i = \rho + \eta_i$, where η_i is mean zero.

ε_{it} is the sectoral disturbance term with variance σ_i^2 and covariance across sectors σ_{ij} (reflecting common shocks).

Put the sectors in order of increasing persistence: $\rho_{i+1} > \rho_i$

Define the real exchange rate as an aggregation over sectors:

$$q_t = \sum_{j=1}^{N} \omega_j q_{jt}, \quad \sum_{j=1}^{N} \omega_j = 1$$

This implies for an AR(1) specification of the real exchange rate:

$$q_t = \rho q_{t-1} + \varepsilon_t$$

$$\varepsilon_t = \sum_{j=1}^{N} \omega_j \varepsilon_{jt} + \sum_{j=1}^{N} \eta_j \omega_j q_{jt-1}$$

The lagged dependent variable in error term biases the least squares estimate of the persistence parameter, call it ρ^Q.

$$p\lim_{N\to\infty,T\to\infty}\left(p^{Q}\right)=\rho+\Delta$$

$$\Delta=\sum_{i=1}^{N}\left(\rho_i-\rho\right)\delta_i$$

$$where\ \delta_i=\frac{\left(\dfrac{\omega_i^2}{1-\rho_i^2}\right)\sigma_i^2+\sum_{i\neq j}^{N}\left(\dfrac{\omega_i\,\omega_j}{1-\rho_i\,\rho_j}\right)\sigma_{ij}}{\sum_{i=1}^{N}\left(\left(\dfrac{\omega_i^2}{1-\rho_i^2}\right)\sigma_i^2+\sum_{i\neq j}^{N}\left(\dfrac{\omega_i\,\omega_j}{1-\rho_i\,\rho_j}\right)\sigma_{ij}\right)}$$

is a weighting over the sectors.

The paper proves that:

1) The bias is positive if the covariance between the vector of persistence parameters ρ_i and the vector of coefficients δ_i is positive, as this implies that the high persistence sectors have disproportionate weights in the average.

2) The positive bias tends to increase with the cross-sectoral dispersion in persistence.

Note: the covariances between sectoral price residuals affect both the magnitude and sign of the bias, so we will need to control for these correlations in empirical work.

The main point: in the face of heterogeneity, the persistence of the real exchange rate will not be a consistent estimate of the mean persistence of relative prices.

Econometric method:

- Use estimation models that allow for heterogeneity - Mean Group (MG) estimator of Pesaran and Smith (1995), a generalized fixed effects estimator that allows for heterogeneity.

- Will combine this with common correlated effects (CCE) estimator, that controls for correlation in the residuals.

Data: Eurostat, price indices for 19 two-digit consumption goods for 13 countries, monthly 1981:1-1995:12 to avoid periods with missing data. Prices relative to US dollar.

TABLE III

PERSISTENCE ESTIMATES USING DISAGGREGATED DATA

$$q_{ict} = \gamma_c + \sum_{k=1}^{K} \rho_{ik} q_{ict-k} + e_{ict}$$

Model	P	$\sum_{k=1}^{K} \rho_{ik}$	Half-life	LAR	CIR
Fixed effects	12	0.98	36 (21, 47)	0.97 (0.961, 0.981)	46.71
Fixed effects (SURE)	12	0.98	34 (27, 43)	0.97 (0.958, 0.978)	44.30
Fixed effects (CCE)	12	0.99	58 (10, 91)	0.99 (0.980, 0.995)	104.20
Mean group	19	0.97	26 (14, 28)	0.95 (0.903, 0.973)	33.15
Mean group (SURE)	20	0.96	22 (17, 27)	0.96 (0.945, 0.968)	29.48
Mean group (CCE)	12	0.95	11 (7, 12)	0.95 (0.924, 0.963)	20.51

[a]$H0$: $\rho_i = \rho$	98.15 (0.0000)	[d]$H0$: $E(\gamma_c, X) = 0$	14765 (0.000)
[b]$H0$: $\rho_i = \rho$	4353.4 (0.0007)	[e]$H0$: $\gamma_c = 0$	2.1168 (0.000)
[c]$H0$: $E(\eta_i, X) = 0$	485.02 (0.0022)	[f]LM	2194698 (0.000)

Findings

- Sectoral data appears at first to be highly persistent, as in past studies of aggregate data. Half-lives around 3 years.

- Controlling for heterogeneity and common correlated effects (MG-CCE, main case) reduces the persistence to half-life of less than one year.

- This lower degree of persistence could plausibly be explained by price stickiness.

Bergin, Glick, Wu (2014 ***Journal of Monetary Economics*****)**

Idea: apply panel methods to estimate half-life of real exchange rate for fixed exchange rate period of Bretton Woods (WWII – 1973).

Finding: The long half-life of aggregate real exchange rates during floating exchange rate period does not apply to the fixed exchange rate period.

Data:

- Bilateral nominal exchange rates with the U.S. dollar and consumer prices indices, for 20 industrialized countries.

- Source: International Financial Statistics.

- Annual in frequency 1949 to 2010. Monthly frequency starting in 1957.

Methodology:

- Compute real exchange rate, and estimate autoregression:

$$q_{j,t} = c_j + \sum_{m=1}^{M} \rho_{j,m}(q_{j,t-m}) + \varepsilon_{j,t}$$

- Estimate for two periods: Use panel estimator that controls for common correlated error terms, by including cross-sectional means in the regression.

- Also to control for potential bias, conduct bootstrap bias correction procedure of Kilian (1998).

Results:

- Half-life of Bretton Woods period is 2.27 years; for post Bretton Woods period is 4.31 years. Confirmed in graph.

- Mussa question: why would nominal exchange rate regime affect persistence of the real exchange rate?

Figure 1. Adjustment of the real exchange rate to a one std. dev shock.

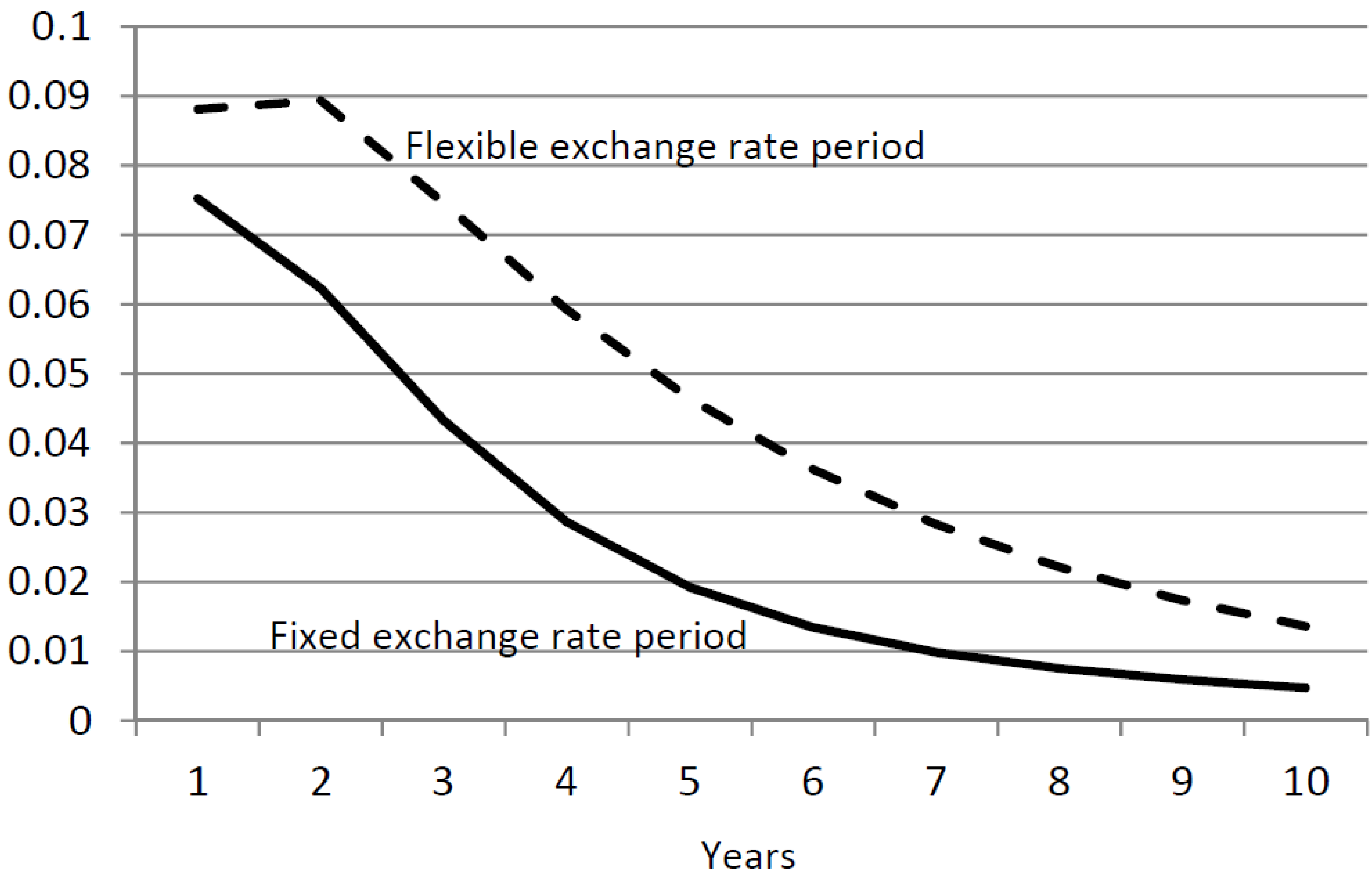


Table 2. Half-lives in Autoregressions of Real Exchange Rates

Sample	#pairs	Half-life
<u>Annual Data (one lag):</u>		
Bretton Woods	20	2.27
(5%, 95%)		(1.43, 3.39)
(10%, 90%)		(1.57, 3.02)
Post-Bretton Woods	20	4.31
(5%, 95%)		(3.44, 5.24)
(10%, 90%)		(3.63, 4.97)

Results cont: Source of Mussa volatility finding

- Can decompose the variance of the real exchange rate.

$$\operatorname{var}\left(q_{j,t}\right)=\left(\frac{1}{1-\rho_{j}^{2}}\right)\cdot\operatorname{var}\left(\varepsilon_{j,t}\right)$$

- Var(q) rose by 102%, first term on right rose by 66%.
- So nearly 2/3 of rise in variance under flexible exchange rates is due to rise in persistence rather than rise in volatility of exogenous shock.

Table 3: Decomposition of Change in Real Exchange Rate Volatility

Sample	(1) var(q)	(2) ρ	(3) $\frac{1}{1-\rho^2}$	(4) (1)/(3)
Bretton Woods	0.012	0.737	2.188	
Post-Bretton Woods	0.025	0.852	3.639	
%Change	102.4%		66.4%	0.648

Column (1) reports the average variance of the real exchange rate in the data set. Column (2) reports estimates of the autoregressive parameters from equation (2). Columns (3) and (4) are author computations based on the preceding columns.

- Results cont: Why regimes matter
  - Estimate a VECM with 2 equations

$$\Delta e_{j,t} = \alpha_{e,j} + \rho_{e,j}(q_{j,t-1}) + \mu^{e}_{e,j}(\Delta e_{j,t-1}) + \mu^{p}_{e,j}(\Delta p_{j,t-1}) + \zeta^{e}_{j,t}$$
$$\Delta p_{j,t} = \alpha_{p,j} + \rho_{p,j}(q_{j,t-1}) + \mu^{e}_{p,j}(\Delta e_{j,t-1}) + \mu^{p}_{p,j}(\Delta p_{j,t-1}) + \zeta^{p}_{j,t}$$

  - Majority of rise in real exchange rate variance is due to greater persistence in short run response of inflation to e shocks and p shocks: $\underline{\mu^{e}_{p,j}}$ and $\underline{\mu^{p}_{p,j}}$.
  - Can be interpreted as a rise in price stickiness or inertia.
  - Supports use of sticky price models to explain real exchange rate behavior.

Table 5
Vector Error Correction Estimates and Real Exchange Rate Half-lives

	(1)	(2)	(3)	(4)
	Bretton Woods		Post-Bretton Woods	
	e equation	*p equation*	*e equation*	*p equation*
Coefficient Estimates:				
Speed of adjustment (ρ)	-0.223***	-0.102**	-0.168***	-0.049***
	(0.100)	(0.050)	(0.029)	(0.011)
Dynamic response to *e* (μ^e)	0.212**	-0.143*	0.183***	-0.026
	(0.115)	(0.066)	(0.050)	(0.016)
Dynamic response to *p* (μ^p)	-0.322**	0.303***	-0.329**	0.555***
	0.151	0.087	0.123	0.073
	e shock	*p* shock	*e* shock	*p* shock
Half-life of *q*:	2.03	1.56	3.05	3.84
(5%, 95%)	(0.85, 4.33)	(0.80, 2.80)	(2.49, 3.70)	(2.10, 5.92)
(10%, 90%)	(1.02, 3.40)	(0.88, 2.40)	(2.61, 3.54)	(2.45, 5.38)

Table 6
Vector Error Correction Estimates and Half-lives in Nested Model

	(1) *e* equation	(2) *p* equation
Coefficient Estimates:		
Speed of adjustment (ρ)	-0.330***	-0.079***
	(0.063)	(0.025)
Change in speed of adjust. (ρ_d)	0.169***	0.030
	(0.068)	(0.028)
Dynamic response to *e* (μ^e)	0.261***	-0.086***
	(0.068)	(0.028)
Change in dynamics to *e* (μ_d^e)	-0.091	0.052*
	(0.082)	(0.035)
Dynamic response to *p* (μ^p)	-0.269*	0.285***
	(0.153)	(0.086)
Change in dynamic to *p* (μ_d^p)	-0.066	0.267***
	(0.183)	(0.103)

Table 7
Simulation Results

Parameter change:	(1) Change in var(q) (in %)	(2) Change in half-life of real exchange rate (in years): e shock	(3) p shock
Exchange rate equation:			
Speed of adjustment in e (ρ_e)	9.47	0.55	0.36
Dynamic response by e to e (μ_e^e)	-2.85	-0.09	0.09
Dynamic response by e to p (μ_e^p)	-0.20	0.02	0.02
Price equation:			
Speed of adjustment in p (ρ_p)	9.52	0.48	0.33
Dynamic response by p to e (μ_p^e)	11.79	0.35	-0.07
Dynamic response by p to p (μ_p^p)	12.75	-0.21	1.35

Part 3: Empirical tests of exchange rate models

PPP provides a basis for a convenient starting point for a simple theory of the nominal exchange rate.

- Rearranging PPP implies that the nominal exchange should be the ratio of national price levels:

$$e = P / P^*$$

- This theory becomes usable if we combine PPP with a theory of what determines the overall national price level, such as a money market equilibrium theory:

- Suppose that real money demand is a positive function of income (y) and a negative function of interest rate (i) (we derive such conditions later in a micro-founded model:

$$m^d = m^d\left(y, i\right)$$

- And nominal money supply is exogenous: $M^S = M$

- Suppose money market equilibrium condition equating real money demand with real money supply:

$$m^d\left(y, i\right) = \frac{M}{P}$$

- Produces a theory of the price level:

$$P = M \Big/ m^d\left(y, i\right)$$

- This provides one simple theory of the exchange rate.

$$e = \frac{P}{P^*} = \frac{M \big/ m^d\left(y, i\right)}{M^* \big/ m^d\left(y^*, i^*\right)} = \left(\frac{M}{M^*}\right) \Bigg/ \left(\frac{m^d\left(y, i\right)}{m^d\left(y^*, i^*\right)}\right)$$

$$e = \frac{P}{P^*} = \frac{M \big/ m^d(y,i)}{M^* \big/ m^d(y^*,i^*)} = \left(\frac{M}{M^*}\right) \Bigg/ \left(\frac{m^d(y,i)}{m^d(y^*,i^*)}\right)$$

- A version of the "<u>monetary approach to exchange rates</u>"

- Predicts that the home currency depreciates if the home money supply rises, output falls, or interest rate rises (may reflect rise in expected inflation).

Meese - Rogoff (JIE 1983):

- Study out of sample fit of exchange rate models developed in the 1970s, such as monetary model above.

- Some early tests indicated these models fit the data fairly well, when tested "in sample."

- Write flexible price monetary model, based on PPP, as:

$$s_t = m_t - m_t^* - \gamma(y_t - y_t^*) + \lambda(i_t - i_t^*)$$

m and m^* represent money supplies in logs, y represents income in logs and i the nominal interest rate.

The latter two terms enter because they determine the level of real money demand in the monetary model.

- The γ and λ terms are parameters estimated from data.

- The authors also test a sticky price version of the monetary model, which adds an extra term involving expected future exchange rate movements.

- Begin by estimating the parameter values based on data running from March 1973 to December 1976.

- Then generate forecast for the exchange rate for January 1977 using parameters estimated on data for preceding months, and value for the regressors for the month of the forecast. $\hat{s}_{1/77}$ This is “out of sample forecast.”

- Then add one month of data and re-estimate the model, and then construct the February 1977 fitted value by using actual data on right side variables for Feb. 1977.

- To be concrete, for example with the flex-price model, we would have

$$\hat{s}_{2/77} = m_{2/77} - m^*_{2/77} - \tilde{\gamma}(y_{2/77} - y^*_{2/77}) + \tilde{\lambda}(i_{2/77} - i^*_{2/77})$$

They then calculate out-of-sample mean-squared-error

$$\frac{1}{k}\sum_{j=1}^{k}(s_j - \hat{s}_j)^2$$

- Is it a big number? Compare it to the mean-squared change in the log of the exchange rate. That is, the m.s.e. from a "naïve" forecast of the exchange rate:

$$\frac{1}{k}\sum_{j=1}^{k}(s_j - s_{j-1})^2$$

They generally found that at 1-, 3-, 6- and 12-month horizons, the model could not "beat a random walk".

Table 1

Root mean square forecast errors.[a]

Exchange rate	Model: / Horizon	Random walk	Forward rate	Univariate autoregression	Vector autoregression	Frenkel-Bilson[b]	Dornbusch-Frankel[b]	Hooper-Morton[b]
	1 month	3.72	3.20	3.51	5.40	3.17	3.65	3.50
$/mark	6 months	8.71	9.03	12.40	11.83	9.64	12.03	9.95
	12 months	12.98	12.60	22.53	15.06	16.12	18.87	15.69
	1 month	3.68	3.72	4.46	7.76	4.11	4.40	4.20
$/yen	6 months	11.58	11.93	22.04	18.90	13.38	13.94	11.94
	12 months	18.31	18.95	52.18	22.98	18.55	20.41	19.20
	1 month	2.56	2.67	2.79	5.56	2.82	2.90	3.03
$/pound	6 months	6.45	7.23	7.27	12.97	8.90	8.88	9.08
	12 months	9.96	11.62	13.35	21.28	14.62	13.66	14.57
Trade-	1 month	1.99	N.A.	2.72	4.10	2.40	2.50	2.74
weighted	6 months	6.09	N.A.	6.82	8.91	7.07	6.49	7.11
dollar	12 months	8.65	14.24	11.14	10.96	11.40	9.80	10.35

[a]Approximately in percentage terms.

[b]The three structural models are estimated using Fair's instrumental variable technique to correct for first-order serial correlation.

A common interpretation of the Implications:

- The result indicates that macroeconomic fundamentals are not useful for explaining exchange rate movements.

- A long subsequent literature has supported this finding, testing various improvements on the macroeconomic model, and finding they cannot beat a random walk.

- In response, some papers use models of other types to explain exchange rate movements. One example is to borrow from the finance literature and use models of information heterogeneity among traders.

Flood & Rose (EJ 1999) "Understanding Exchange Rate Volatility Without the Contrivance of Macroeconomics".

- Note that standard macro fundamentals are not sufficiently volatile to explain the high volatility of the exchange rate.

- Build on Mussa observation: exch. rate volatility under flexible exch rate regimes higher than under fixed regimes.

- But macro fundamentals under flexible exchange rate regimes is not noticeably higher.

- Instead argue that foreign exchange market is subject to shocks: taste shocks between home and foreign bond.

- A flexible exchange rate regime allowing international asset trade lets these shocks affect equilibrium exch. rate.

Engel & West Papers (2005, 2006, 2008)

- These papers offer a reinterpretation of the earlier evidence, indicating that it need not conflict with a fundamental based model of the exchange rate.

- They borrow from asset pricing models in finance, which posit asset price is a discounted sum of future fundamentals (ie stock price is discounted sum of future dividends)

$$s_t = (1-b)\sum_{j=0}^{\infty} b^j E_t x_{t+j} + (1-b)\sum_{j=0}^{\infty} b^j E_t z_{t+j}$$

where b is the discount factor
x are observable fundamentals
z are unobservable fundamentals

Engel and West show:

- If the fundamentals are nonstationary, then as the discount factor approaches 1, the exchange rate implied by this model approaches a random walk.

- Intuition: Think of fundamentals as having a random walk component, and a stationary component that fluctuates around the random walk component.

- As b goes to one, the distant future matters a lot. All the weight goes to the permanent component of fundamentals because stationary component expected to die out.

TABLE 1

POPULATION AUTOCORRELATIONS AND CROSS CORRELATIONS OF Δs_t

				Correlation of Δs_t with:					
	b (1)	φ_1 (2)	φ (3)	Δs_{t-1} (4)	Δs_{t-2} (5)	Δs_{t-3} (6)	Δx_{t-1} (7)	Δx_{t-2} (8)	Δx_{t-3} (9)
1.	.50	1.0	.3	.15	.05	.01	.16	.05	.01
2.			.5	.27	.14	.07	.28	.14	.07
3.			.8	.52	.42	.34	.56	.44	.36
4.	.90	1.0	.3	.03	.01	.00	.03	.01	.00
5.			.5	.05	.03	.01	.06	.03	.01
6.			.8	.09	.07	.06	.13	.11	.09
7.	.95	1.0	.3	.02	.01	.00	.02	.01	.00
8.			.5	.03	.01	.01	.03	.01	.01
9.			.8	.04	.04	.03	.07	.05	.04
10.	.90	.90	.5	.04	−.01	−.03	.02	−.03	−.05
11.	.90	.95	.5	.05	.01	−.01	.04	−.00	−.02
12.	.95	.95	.5	.02	−.00	−.01	.01	−.02	−.03
13.	.95	.99	.5	.02	.01	.00	.03	.01	−.00

NOTE.—The model is $s_t = (1-b)\sum_{j=0}^{\infty} b^j E_t x_{t+j}$ or $s_t = b\sum_{j=0}^{\infty} b^j E_t x_{t+j}$. The scalar variable x_t follows an AR(2) process with autoregressive roots φ_1 and φ. When $\varphi_1 = 1.0$, $\Delta x_t \sim$ AR(1) with parameter φ. The correlations in cols. 4–9 were computed analytically. If $\varphi_1 = 1.0$, as in rows 1–9, then in the limit, as $b \rightarrow 1$, each of these correlations approaches zero.

b is discount factor, φ and φ_1 are persistence of fundamentals

First, is this relevant?

- It depends on how big b is in practice. What matters is the size of b and the persistence of the transitory component.

- Engel-West do some calibration and simulation exercises. Simulate data for b=0.9, and put in standard tests, cannot reject nonstationarity of exchange rate.

- The implication is that we cannot discard models based on fundamentals if they cannot forecast out of sample. This is what you should expect if fundamentals are highly persistent and discount factors are high.

One test of the theory: Granger Causality tests

- If expectations for future fundamentals determine the exchange rate, than instead of testing whether lagged fundamentals explain exchange rates, we should be testing if lagged exchange rate predicts fundamentals.

- The authors test this by Granger causality tests.

- Obtain data on fundamentals from monetary model: relative money supplies across countries, interest rate differential, inflation differential, output growth differential

- Regress fundamentals on lags of the exchange rate, and vice versa.

- Test for significant of coefficients in regression.

Estimate VAR:

$$s_t - s_{t-1} = \alpha_1 + \beta_1(x_{ot-1} - s_{ot-1}) + \sum_{i=1}^{I} \gamma_{1i}(s_{t-i} - s_{t-1-i}) + \sum_{j=1}^{J} \delta_{1j}(x_{ot-j} - x_{ot-1-j})$$

$$x_{ot} - x_{ot-1} = \alpha_2 + \beta_2(x_{ot-1} - s_{ot-1}) + \sum_{i=1}^{I} \gamma_{2i}(s_{t-i} - s_{t-1-i}) + \sum_{j=1}^{J} \delta_{2j}(x_{ot-j} - x_{ot-1-j})$$

The null that the exchange rate does not Granger cause the fundamentals is represented by the restriction $\beta_2 = \gamma_{21} = \gamma_{22} = \ldots = \gamma_{2J} = 0$. If we reject this null, it means we "accept" the hypothesis that the exchange rate is helpful in forecasting future values of x_{ot}. Conversely, in order to accept the hypothesis that the observed fundamentals Granger cause the exchange rate, we must reject the null $\beta_1 = \delta_{11} = \delta_{12} = \ldots = \delta_{1J} = 0$. We set the lag length J to 4.

TABLE 3
BIVARIATE GRANGER CAUSALITY TESTS, DIFFERENT MEASURES OF Δf_t, FULL SAMPLE: 1974:1–2001:3

	Canada	France	Germany	Italy	Japan	United Kingdom
	A. Rejections at 1% (***), 5% (**), and 10% (*) Levels of H_0: Δs_t Fails to Cause Δf_t					
1. $\Delta(m - m^*)$		*		**	**	
2. $\Delta(p - p^*)$			***	***	***	
3. $i - i^*$		**			**	
4. $\Delta(i - i^*)$		**			***	
5. $\Delta(m - m^*) - \Delta(y - y^*)$		*		*		
6. $\Delta(y - y^*)$						
	B. Rejections at 1% (***), 5% (**), and 10% (*) Levels of H_0: Δf_t Fails to Cause Δs_t					
1. $\Delta(m - m^*)$						
2. $\Delta(p - p^*)$	*					
3. $i - i^*$					**	
4. $\Delta(i - i^*)$						
5. $\Delta(m - m^*) - \Delta(y - y^*)$						
6. $\Delta(y - y^*)$						

NOTE.—See the notes to earlier tables for variable definitions. Statistics are computed from fourth-order bivariate VARs in $(\Delta s_t, \Delta f_t)'$. Because four observations were lost to initial conditions, the sample generally is 1975:2–2001:3, with exceptions as indicated in the note to table 2.

Findings:

- It appears that the exchange rate Granger causes fundamentals.

- But fundamentals do not Granger cause the exchange rate.

- This is consistent with their theory.

A further test of the theory: quasi present value tests

- The theory proposed above resembles the present value model for the current account we studied earlier (CA was a discounted sum of expected changes in net output, NO.)

- Recall that to test that model, we used VARs on NO and CA to generate a forecast of future changes in NO. These put into a present value formula to compute CA prediction.

- The authors are reluctant to fully use the present value model here, as some of the fundamentals are assumed unobservable.

- Engel-West (2005) does part of the test, by running a VAR on lagged fundamentals (and the exchange rate) to get a forecast of future changes in fundamentals, call it F.

- Then just see of this F is correlated with changes in the exchange rate. Results will report correlations between measures of future fundamentals (F) and exchange rate.

- F1 is fundamentals forecast using just lagged fundamentals in the VAR, F2 uses exchange rate also in the VAR.

This table reports the median values across countries

Information Set	$b = 0.5$	$b = 0.9$
F_{1t}	−.04	−.05
F_{2t}	.10	.24

Findings:

- The correlations are far less than 1, reflecting the absence of key fundamentals, assumed to be unobservable.
- The result works best when the exchange rate is included in the VAR (F1), and the discount factor is high (b=0.9).
- The fact there is some correlation indicates some support for the theory.

Engel - West (2006 JMCB) goes farther in implementing the present value test, but for slightly different exch. rate model.

Instead of using PPP with money demand, they start instead with monetary policy rules: interest rate reaction functions to inflation (π) and output gap (*y*):

$$i_t = \gamma_q q_t + \gamma_\pi E_t \pi_{t+1} + \gamma_y y_t$$ for home country

$$i^*{}_t = \gamma_q q_t{}^* + \gamma_\pi E_t \pi^*{}_{t+1} + \gamma_y y_t{}^*$$ for foreign

A Taylor rule: central bank raises interest rate in response to expected future inflation to try to prevent that inflation. Also raises interest rate in response to expected output above normal level, as may also be inflationary.

Combine these with uncovered interest rate parity condition (to be discussed later) in place of the PPP condition used in monetary model above:

$$i_t - i_t^* = E_t s_{t+1} - s_t$$

Sub in policy rules for interest rates and solve forward, to compute a forward looking equation for real exch. rate, q:

$$q_t = -\sum_{j=0}^{\infty} \left(\frac{1}{1+\gamma_q} \right)^j E_t \left[(\gamma_\pi - 1)\left(\pi_{t+1} - \pi^*{}_{t+1}\right) + \gamma_y \left(y_t - y_t^* \right) \right]$$

Take estimates of policy parameters from Taylor rule literature γ_π and γ_y; γ_q from related open-economy literature.

Estimate expected future inflation and output by estimating a VAR on these variables, and generating forecast.

Substitute forecasts and parameters into the present value condition above (as we did previously in class for present value tests of current account models).

Engel-West (2006) used data on US dollar-Deutsch Mark exchange rate, 1979:10-1998:12.

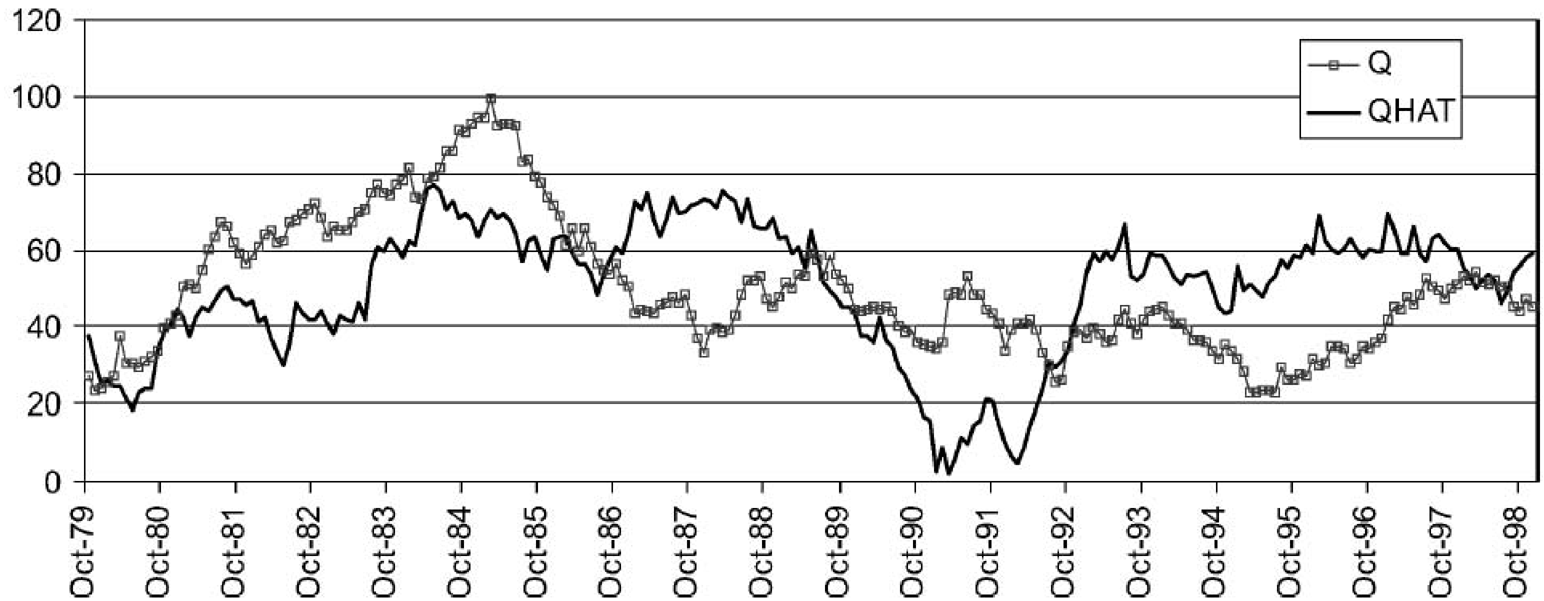


FIG. 2. Actual (q) and Model-Based ($\hat{q}_t$) Real Exchange Rates (Notes: $\hat{q}$ is the fitted value of the real exchange rate from the baseline specification presented in Table 1, scaled to have the same mean and standard deviation as the actual real exchange rate q.)

Results limited because expectations of market participants depend on many things other than just the lagged values.

- Figure not terrible. Correlation between model prediction and data on real exchange rate is 0.32.

- But prediction is much less volatile; sdev is 1/5 of data.

Questions for Discussion:

1) We see the important role of expectations. What do you think about the merits of the alternative ways of dealing with expectations here: VARs, surveys? Any better ideas?

2) Are there more general monetary models you think might work better (Several have been tried in the literature)

Part 4: A theory of real exch. rate: Balassa-Samuelson

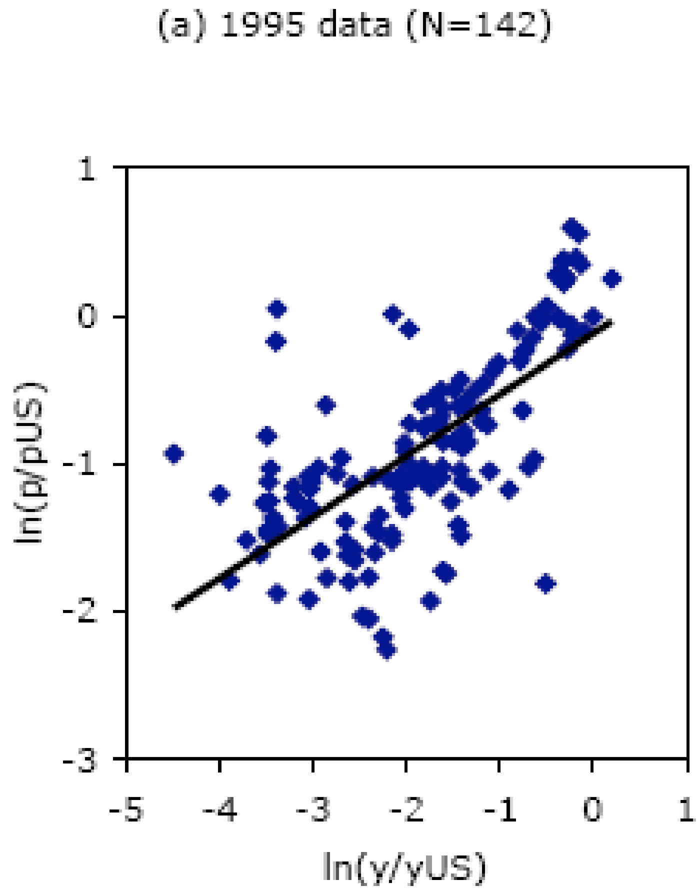
1) Background:

Observation: Richer countries have higher costs of living (appreciated real exchange rates)

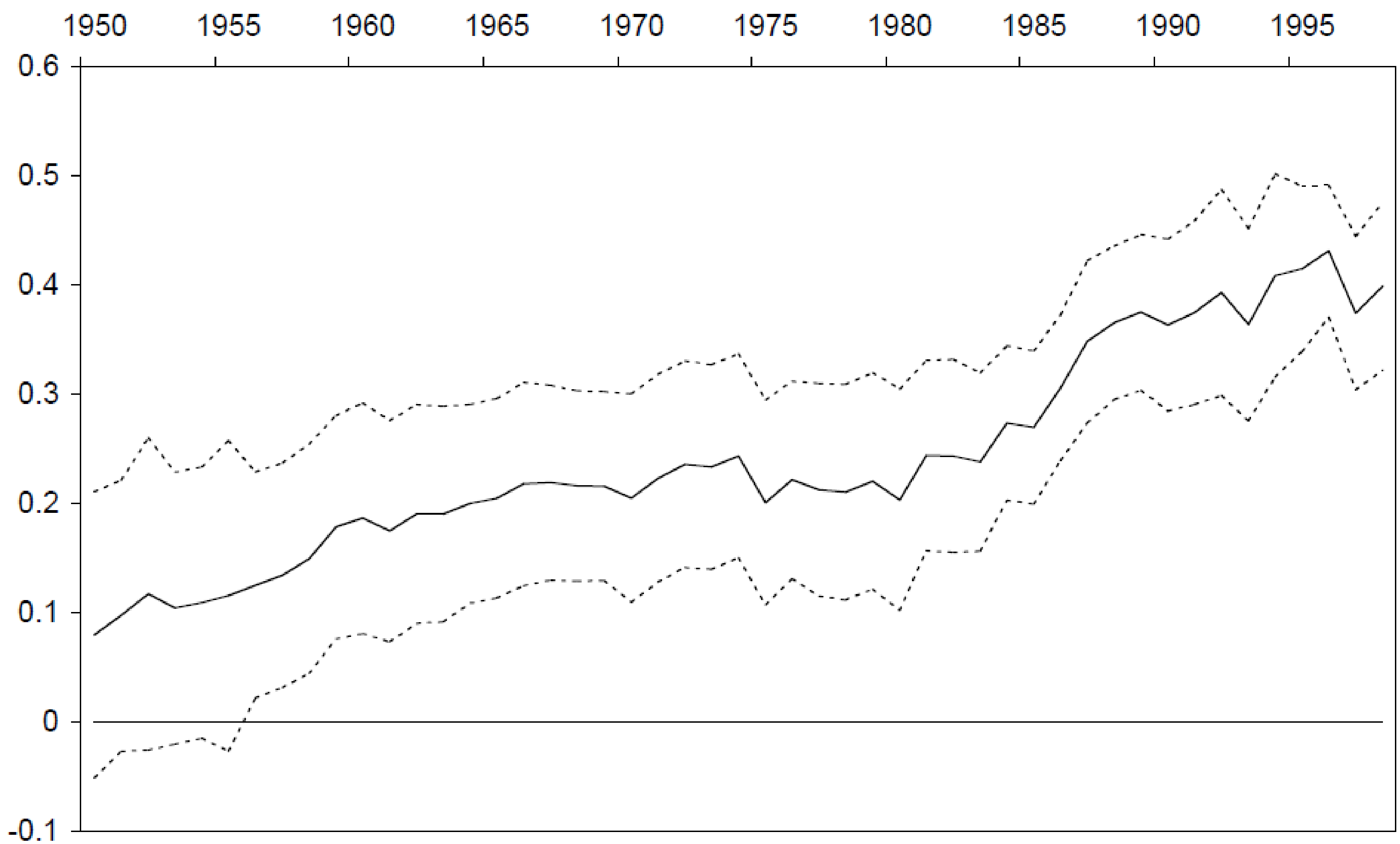
$$\ln(P_i / P_{US}) = \alpha + \beta \ln(y_i / y_{US}) + \varepsilon_i$$

In data find significant positive value of β for last half of 20th century.

Taylor-Taylor (2004):



The Balassa-Samuelson Effect in Cross Sections
PWT data 1950Ğ1998, full sample (53²N²165)



There is a classic model due to Balassa (1964) and Samuelson (1964) that offers an explanation

Two countries
Two goods: traded and nontraded
One factor: labor usable for producing either good

Production:

$$Y_T = A_T L_T$$
$$Y_N = A_N L_N$$
$$Y^*_T = A^*_T L^*_T$$
$$Y^*_N = A_N^* L_N^*$$

Competitive price setting:

$P_T = W / A_T$ where W is wage

$$P_N = W / A_N$$

$$P^*_T = W^* / A^*_T$$
$$P^*_N = W^* / A^*_N$$

Law of one price for traded goods:

$$P_T = P_T^*$$

$$W / A_T = W^* / A_T^{\ *}$$

$$W / W^* = A_T / A_T^*$$

Cobb Douglas preferences and price index:

$$C = aC_N^{\theta} C_T^{1-\theta}$$

$$P = P_N^{\theta} P_T^{1-\theta}$$

Real exchange rate, given no nominal exchange rate here:

$$q = \frac{P^*}{P}$$

Substitute in:

$$q = \frac{P^*}{P} = \frac{P_N^{*\theta} P_T^{*1-\theta}}{P_N^{\theta} P_T^{1-\theta}} = \frac{P_N^{*\theta} P_T^{1-\theta}}{P_N^{\theta} P_T^{1-\theta}} = \left(\frac{P_N^*}{P_N} \right)^{\theta} = \left(\frac{W^* / A_N^*}{W / A_N} \right)^{\theta} = \left(\frac{A_T^* / A_N^*}{A_T / A_N} \right)^{\theta}$$

- So if we want to explain why q falls when productivity rises in the home country, this would be the case if the productivity gain is biased toward traded goods:

$$\uparrow \frac{A_T}{A_T^*} \rightarrow \uparrow \frac{W}{W^*} \uparrow \frac{P}{P^*}$$

- Usually a rise in productivity lowers the price of a good, but in this two-sector framework a productivity shock to the traded sector instead raises the average price level.

2) Engel (1999 JPE):

- Question for debate: To what degree are the puzzling movements of real exchange rates due to nontraded goods?

- Uses a particular decomposition of PPP deviations into two parts:

Decomposition: If traded goods are share gamma of home price index (in logs):

$p = \gamma p^T + (1-\gamma) p^N$ and likewise for foreign price p*

Then we can decompose the real exchange rate (q) into:

$$q = s + p^* - p$$
$$= \left(s + p^{*T} - p^T\right) + (1-\gamma)(p^T - p^N) - (1-\gamma^*)(p^{*T} - p^{*N})$$

- The first term represents deviations in the price of traded which measures failures in the law of one price (due to reasons other than nontradedness).

- The second two terms represent deviations in the price of traded to nontraded goods.

Data:

Five means to measure nontraded versus traded prices:

1) T = commodities; N = services plus housing
2) Use pre-made OECD price indexes.
3) T= goods; N= services
4) Producer price index (PPI) = T prices, CPI-PPI = N
5) Use marketing services as a nontraded component

- Consider various time horizons: one month to 30 years.
- G-7 countries (less UK). Compute relative prices relative to the U.S.
- Length of data series depends on what data is used. Most are monthly, ranging from 1962 to 1995.

Decomposition: of real exchange rate deviations into contributions of traded goods prices (x) and nontraded (y):

- Measure deviations as mean squared error of differences:

$$\mathrm{MSE}(x_t - x_{t-n}) = \mathrm{var}(x_t - x_{t-n}) + [\mathrm{mean}(x_t - x_{t-n})]^2$$

where n indicates lagged periods

- Compute decomposition due to traded prices:

$$\frac{\mathrm{MSE}(x_t - x_{t-n})}{\mathrm{MSE}(x_t - x_{t-n}) + \mathrm{MSE}(y_t - y_{t-n})},$$

Results:

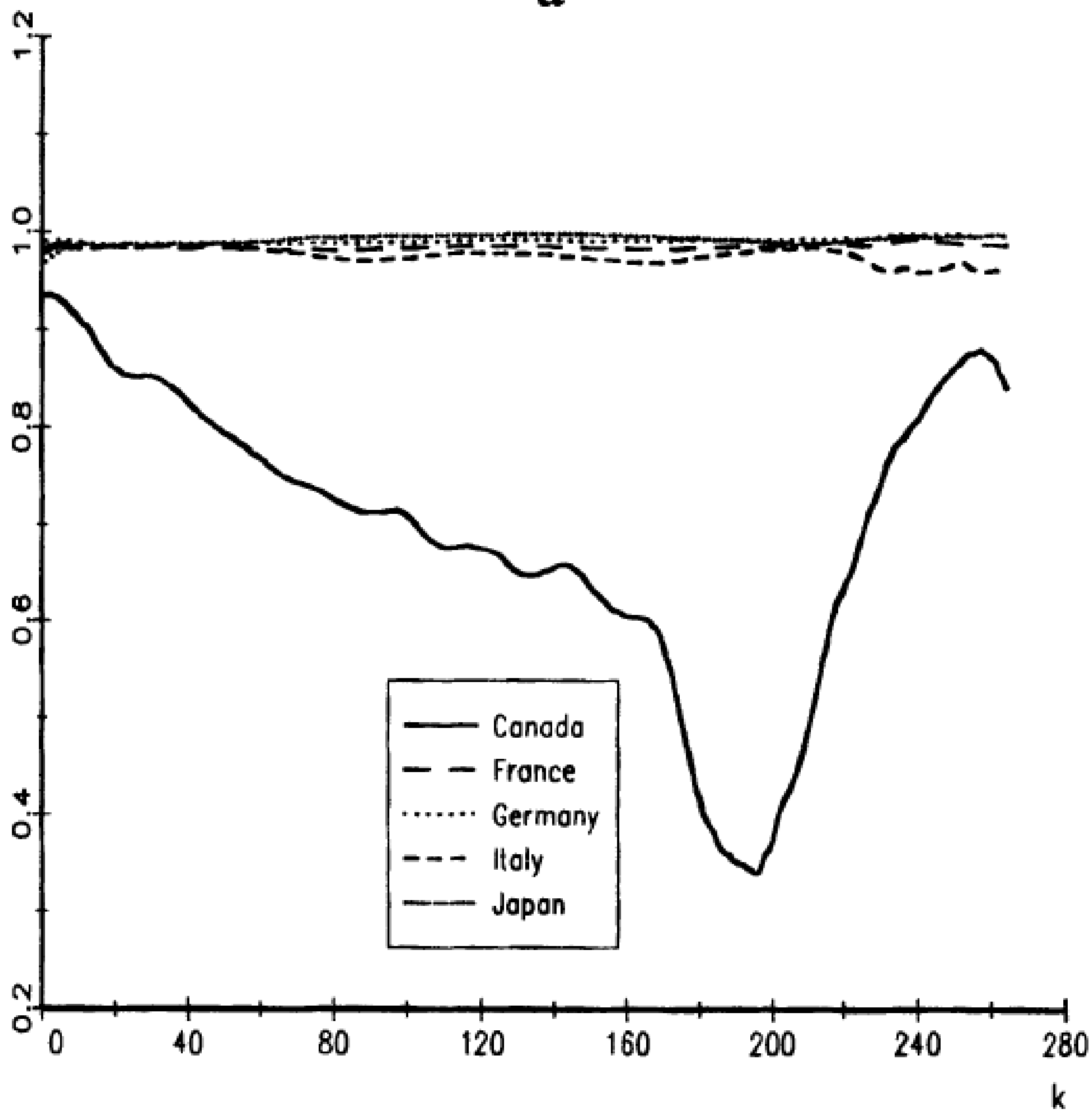
- Figure 2 shows what fraction of variation in the real exchange rate is due to the traded goods component over different time horizons (k). Top panel is for 1973 to 1995 sub-sample, and bottom is for 1962-1969 sample.

- The traded goods component accounts for nearly 100% of the real exchange rate variation with the U.S. for all time horizons, for all the countries except Canada.

- Same results for the other measures of nontraded goods.

- Engel's overall conclusion is that changes in the relative price of nontraded goods does not matter for the real exchange rate; the important contribution comes from deviations from the law of one price.

a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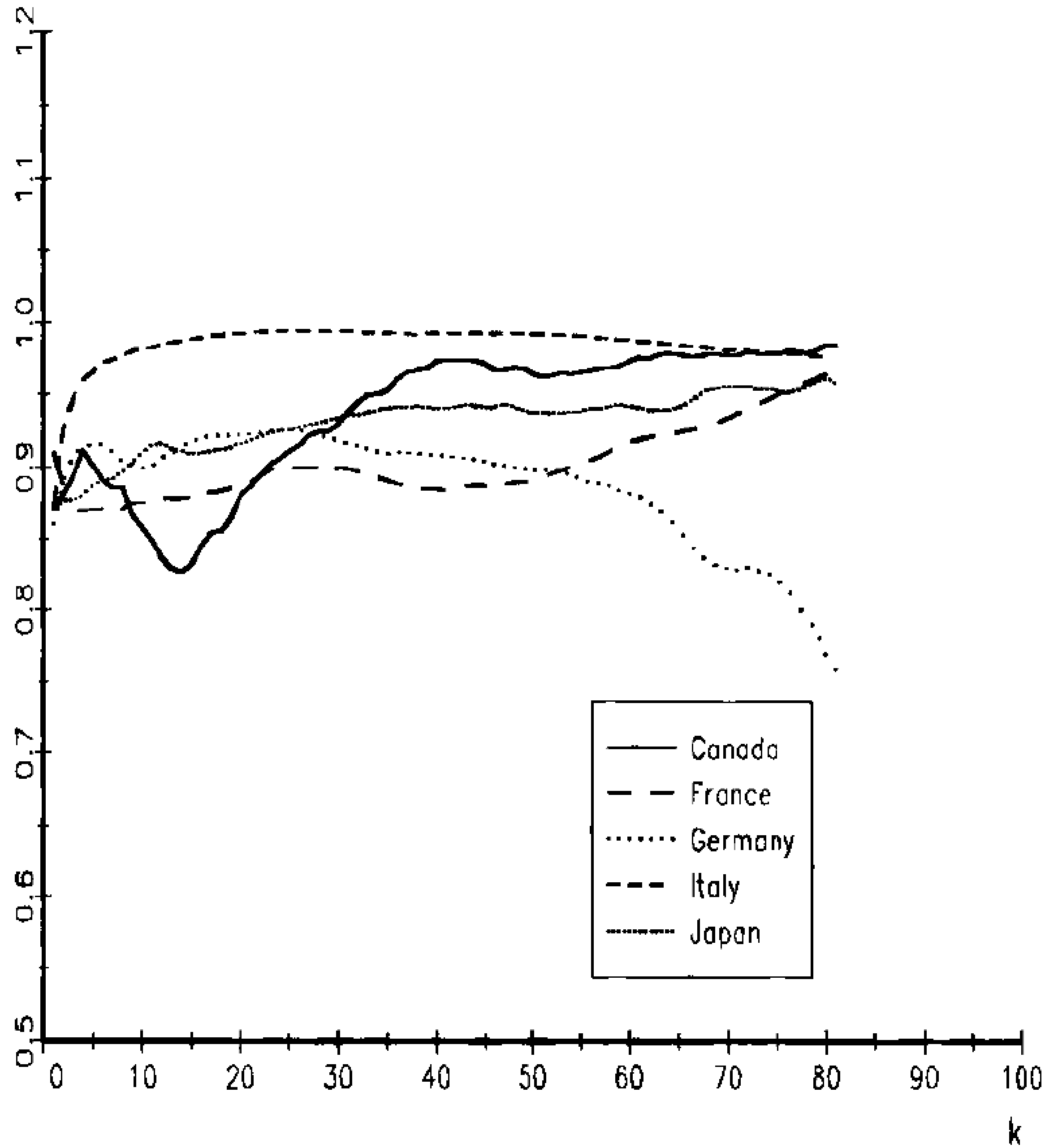

1.2
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Canada
France
Germany
Italy
Japan

3) **Betts and Kehoe (2006 JME): (skip?)**

Has a different answer to the question from Engel, using different data and a different methodology.

Data:

Bilateral exchange rate with the US for 5 trading partners: Canada, Germany, Japan, Korea, Mexico. 1980-2000.

Construct real exchange rate with three alternative measures of aggregate prices:

- gross output deflators(GO)
- consumer price index (CPI)
- personal consumption deflators (PCD)

Four alternative ways of measuring traded goods prices

- GO deflator for relatively traded goods
- Producer Price Index (PPI)
- CPI for all goods (but not services)
- PCD for all commodities (goods): personal consumption expenditure deflator.

Decomposition of the real exchange rate:

$$q = s + p^* - p$$

$$= \left(s + p^{*T} - p^{T}\right) + (p^{T} - p) - (p^{*T} - p^{*}) = rerT + rerN$$

- First term is the relative price of traded goods across countries.

- Second term is the "real exchange rate for nontraded goods:" relative price of traded goods to the domestic overall price (includes nontraded prices)

- Note that this decomposition does not rely upon a Cobb-Douglas aggregator.

Results:

Report 3 moments:

- correlation of rer and rerN,
- relative standard deviation of each
- variance decomposition: var(rerN) / (var(rerN) + var(rerT))

Main case: annual data, GO deflator (robustness later).

See table 3 for summary measures of trade weighted average over all countries. (first column main case)

Finding: See a clear role for nontraded prices: rerN accounts for 21-33% of rer movement, depending on price measures. This is higher than in Engel.

Table 3
Comparison of series trade weighted average. Annual data

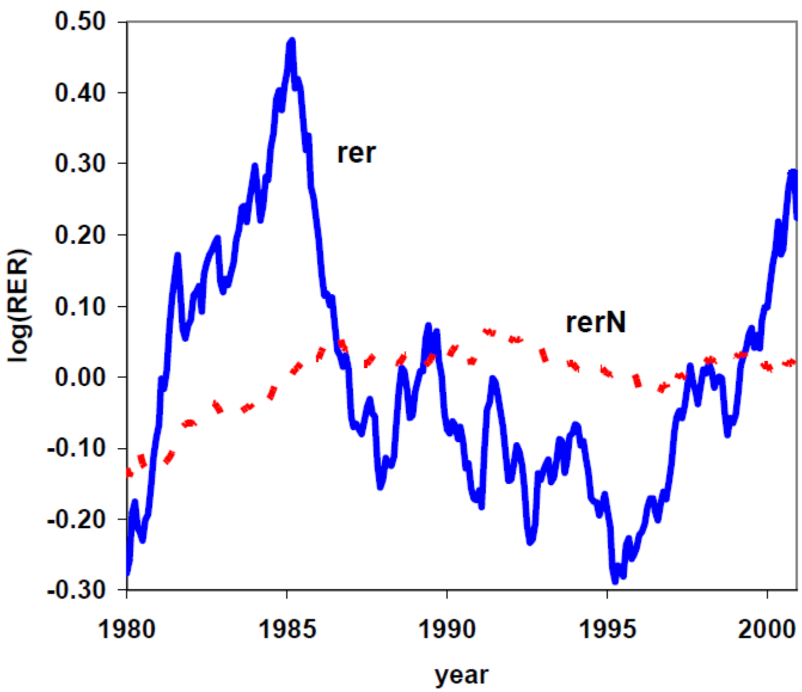
	GO Deflators	*PPI– CPI*	Components of *CPI*	Components of *PCD*
Levels				
corr(rer,rer^N)	0.44	0.73	0.23	0.27
std(rer^N)/std(rer)	0.36	0.48	0.45	0.36
vardec(rer,rer^N)	0.21	0.33	0.22	0.15
Detrended levels				
corr(rer,rer^N)	0.68	0.77	0.00	0.23
std(rer^N)/std(rer)	0.32	0.32	0.22	0.15
vardec(rer,rer^N)	0.18	0.20	0.08	0.03
1 year changes				
corr(rer,rer^N)	0.47	0.63	0.02	0.14
std(rer^N)/std(rer)	0.27	0.33	0.19	0.13
msedec(rer,rer^N)	0.11	0.19	0.06	0.04
4 year changes				
corr(rer,rer^N)	0.70	0.78	0.10	0.37
std(rer^N)/std(rer)	0.34	0.34	0.23	0.16
msedec(rer,rer^N)	0.21	0.25	0.14	0.08

Comparison of different countries:

- Fig 1 shows difference of case with Canada and Germany in correlation of movements in rerN with overall rer.

- Table 5 shows that this is associated with greater importance of bilateral trade with Canada than Germany.

Germany-U.S. Real Exchange Rate
Monthly CPI/PPI



Canada-U.S. Real Exchange Rate
Monthly CPI/PPI

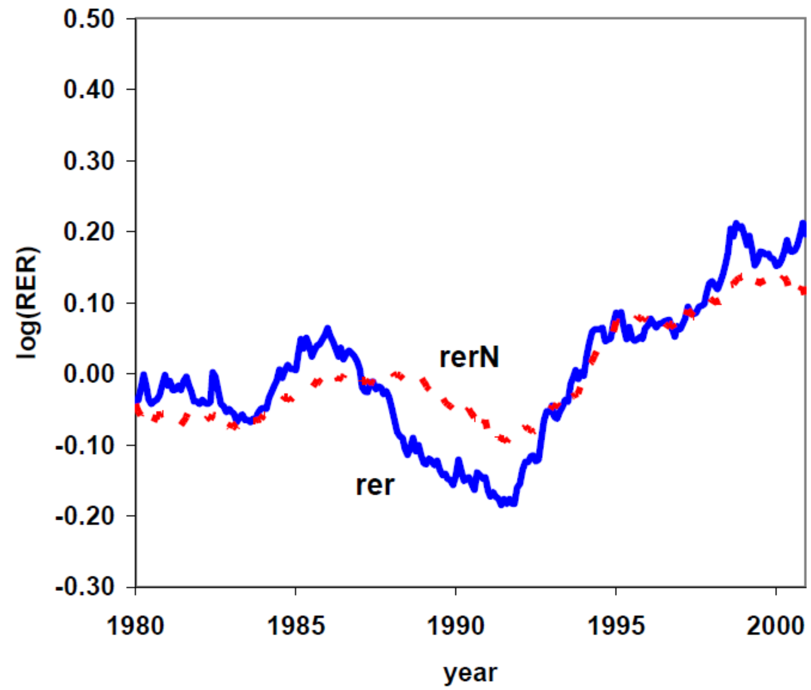


Table 5
Comparison of countries gross output deflators. Annual data

	Canada	Germany	Japan	Korea	Mexico
Importance of trade to country *i*					
2000 bilateral trade/*GDP*	0.58	0.05	0.04	0.14	0.44
2000 bilateral trade/trade	0.82	0.08	0.26	0.20	0.83
Rank of U.S. as partner	1	3	1	1	1
Importance of trade to U.S.					
2000 bilateral trade/U.S. *GDP*	0.04	0.01	0.02	0.01	0.03
2000 bilateral trade/U.S. trade	0.21	0.04	0.11	0.03	0.13
Rank of country *i* as partner	1	6	3	7	2
Levels					
corr(rer,rer^N)	0.81	−0.55	−0.33	0.65	0.75
std(rer^N)/std(rer)	0.51	0.25	0.14	0.21	0.36
vardec(rer,rer^N)	0.38	0.04	0.02	0.05	0.18
Detrended levels					
corr(rer,rer^N)	0.78	0.18	0.47	0.82	0.84
std(rer^N)/std(rer)	0.45	0.20	0.12	0.18	0.36
vardec(rer,rer^N)	0.29	0.04	0.02	0.04	0.20
1 year changes					
corr(rer,rer^N)	0.54	0.16	0.30	0.81	0.52
std(rer^N)/std(rer)	0.40	0.13	0.12	0.23	0.25
msedec(rer,rer^N)	0.20	0.03	0.02	0.08	0.07
4 year changes					
corr(rer,rer^N)	0.74	0.24	0.52	0.80	0.91
std(rer^N)/std(rer)	0.47	0.21	0.12	0.18	0.38
msedec(rer,rer^N)	0.33	0.07	0.02	0.05	0.25

Robustness:

- Frequency does not matter (table 1)
- Detrending matters (table 1)
- Price series matter (table 3, rows 1-3): larger role for nontraded prices if use measure price of traded goods based on production site values (GO deflator or PPI) rather than consumption values (CPI PCD), which include prices of nontraded distribution services.

Table 1
Comparison of frequencies Canada–U.S. Real exchange rate. *PPI-CPI* data 1980–2000

	Annual	Annual	Quarterly	Quarterly	Quarterly	Monthly	Monthly	Monthly	Monthly
Levels									
corr(rer,rer^N)	0.88		0.88			0.88			
std(rer^N)/std(rer)	0.70		0.69			0.69			
vardec(rer,rer^N)	0.66		0.65			0.65			
Detrended levels									
corr(rer,rer^N)	0.88		0.88			0.87			
std(rer^N)/std(rer)	0.51		0.51			0.51			
vardec(rer,rer^N)	0.41		0.41			0.41			
Changes	1 lag (1 year)	4 lags (4 years)	1 lag (1 quarter)	4 lags (1 year)	16 lags (4 years)	1 lag (1 month)	3 lags (1 quarter)	12 lags (1 year)	48 lags (4 years)
corr(rer,rer^N)	0.70	0.82	0.56	0.70	0.82	0.48	0.48	0.67	0.82
std(rer^N)/std(rer)	0.55	0.55	0.51	0.55	0.55	0.55	0.51	0.55	0.55
msedec(rer,rer^N)	0.40	0.51	0.28	0.39	0.51	0.29	0.26	0.37	0.50

Conclusions:

- The relative price of nontraded goods does play some role. Less than 50%, but more than Engel claims.

- Gives support to traditional Balassa-Samuelson explanation for real exchange rate determination, relative to Engel story of monetary shocks under sticky prices.

- Results vary by countries. Nontraded prices are more important for countries that trade a lot with each other.

- The results also depend on the price measure used and method of detrending.

4) **Berka, Devereux and Engel (2015, R&R *American Economic Review*)**

- Uncovers statistical evidence of BS mechanism in Eurozone, linking differential TFP gains in traded v. nontraded sectors to RER appreciation.
- Employs a more general (but standard) macro model with retail services, that shows RER also affected by terms of trade, and hence by labor wedge affecting wages.
- Empirical implication: should include proxy for terms of trade, unit labor cost (ULC), in usual BS regression.
- Once included in regression, find predicted signs on TFP traded, nontraded, and ULC; significant, robust.
- Calibrated stochastic model generates artificial data, and repeats regressions with same results.

What's New

- Central idea similar Engel (1999): need relative price of traded goods in RER equation, not just relative price (or relative productivity) of traded to nontraded.
- New part: show in their model this can be proxied by unit labor cost. And implement empirically.
- Really new part: It works well.
- Question: Does the fact have to do so much to detect BS at work, questions how important BS's role is.

(slides from Xioatong Su)

The model: a representative household

- Utility evaluated from date 0

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma}}{1-\sigma} - \Upsilon_t \frac{N_t^{1+\psi}}{1+\psi} \right), \quad \beta < 1.$$

- Υ_t disutility in labor supply, time-varying and country specific
- C_t composite Home consumption bundle

$$C_t = \left(\gamma^{\frac{1}{\theta}} C_{Tt}^{1-\frac{1}{\theta}} + (1-\gamma)^{\frac{1}{\theta}} C_{Nt}^{1-\frac{1}{\theta}} \right)^{\frac{\theta}{\theta-1}}$$

- C_{Tt} the composite consumption of traded goods
- C_{Nt} the composite consumption of non-traded goods

The model: a representative household

- Traded consumption is decomposed into consumption of Home retail goods, and Foreign retail goods.

$$C_{Tt} = \left(\omega^{\frac{1}{\lambda}} C_{Ht}^{1-\frac{1}{\lambda}} + (1-\omega)^{\frac{1}{\lambda}} C_{Ft}^{1-\frac{1}{\lambda}}\right)^{\frac{\lambda}{\lambda-1}}$$

- if ω = 1/2, no home bias.
- Retail consumption of traded goods requires the use of non-traded goods in order to facilitate consumption. (new)

$$C_{Ht} = \left(\kappa^{\frac{1}{\phi}} I_{Ht}^{1-\frac{1}{\phi}} + (1-\kappa)^{\frac{1}{\phi}} V_{Ht}^{1-\frac{1}{\phi}}\right)^{\frac{\phi}{\phi-1}}$$

$$C_{Ft} = \left(\kappa^{\frac{1}{\phi}} I_{Ft}^{(1-\frac{1}{\phi})} + (1-\kappa)^{\frac{1}{\phi}} V_{Ft}^{1-\frac{1}{\phi}}\right)^{\frac{\phi}{\phi-1}}$$

- ϕ to be fairly low.

The model: a representative household

- The consumption aggregates imply the following price index definitions:

$$P_t = \left(\gamma P_{Tt}^{1-\theta} + (1-\gamma) P_{Nt}^{1-\theta}\right)^{\frac{1}{1-\theta}},$$

$$P_{Tt} = \left(\omega \tilde{P}_{Ht}^{1-\lambda} + (1-\omega) \tilde{P}_{Ft}^{1-\lambda}\right)^{\frac{1}{1-\lambda}},$$

$$\tilde{P}_{Ht} = \left(\kappa P_{Ht}^{1-\phi} + (1-\kappa) P_{Nt}^{1-\phi}\right)^{\frac{1}{1-\phi}}$$

$$\tilde{P}_{F} = \left(\kappa P_{Ft}^{1-\phi} + (1-\kappa) P_{Nt}^{1-\phi}\right)^{\frac{1}{1-\phi}}$$

- Law of one price: $P_{Ht} = P_{Ht}^{*}, \qquad P_{Ft} = P_{Ft}^{*}$
- real exchange rate: $Q_t = \dfrac{P_t^{*}}{P_t}.$

The model: a representative household

- complete international financial markets $\frac{C_t^{-\sigma}}{P_t} = \frac{C_t^{*-\sigma}}{P_t^*}$
- implicit labor supply $W_t = \Upsilon_t P_t C^\sigma N_t^\psi$
- The demand functions

$$C_{Tt} = \gamma \left(\frac{P_{Tt}}{P_t}\right)^{-\theta} C_t, \qquad C_{Nt} = (1-\gamma)\left(\frac{P_{Nt}}{P_t}\right)^{-\theta} C_t$$

$$C_{Ht} = \omega \left(\frac{\tilde{P}_{Ht}}{P_{Tt}}\right)^{-\lambda} C_{Tt}, \qquad C_{Ft} = (1-\omega)\left(\frac{\tilde{P}_{Ft}}{P_{Tt}}\right)^{-\lambda} C_{Tt}$$

$$I_{Ht} = \kappa\omega \left(\frac{P_{Ht}}{\tilde{P}_{Ht}}\right)^{-\phi} \left(\frac{\tilde{P}_{Ht}}{P_{Tt}}\right)^{-\lambda} C_{Tt}, \qquad I_{Ft} = \kappa(1-\omega)\left(\frac{P_{Ft}}{\tilde{P}_{Ft}}\right)^{-\phi} \left(\frac{\tilde{P}_{Ft}}{P_{Tt}}\right)^{-\lambda} C_{Tt},$$

(I: demand net of distribution services)

The model: Firm

- Firm production function

$$Y_{Nt}(i) = A_{Nt}N_{Nt}(i)^{\alpha} \qquad Y_{Ht}(i) = A_{Ht}N_{Ht}(i)^{\alpha}$$

- Firm is a monopolistic competitor, set its price equal to marginal cost, adjusted by a constant markup.
- If in a flexible price environment:

$$P_{Nt}^{flex} = \Omega \frac{W_t}{\alpha A_{Nt} L_{Nt}^{\alpha-1}}, \qquad P_{Ht}^{flex} = \Omega \frac{W_t}{\alpha A_{Ht} L_{Ht}^{\alpha-1}}$$

- If sticky price, will follow a Calvo price adjustment specification. The probability of the firm being allowed to adjust its price is $1-\zeta_i$,

The model: market clearing conditions

- goods market clearing conditions

$$
\begin{aligned}
Y_{Ht} &= I_{Ht} + I^*_{Ht} \\
Y^*_{Ft} &= I_{Ft} + I^*_{Ft}, \\
Y_{Nt} &= C_{Nt} + V_{Ht} + V_{Ft}, \\
Y^*_{Nt} &= C^*_{Nt} + V^*_{Ht} + V^*_{Ft}.
\end{aligned}
$$

- labor market clearing conditions

$$N_t = N_{Nt} + N_{Ht}$$

$$N^*_t = N^*_{Nt} + N^*_{Ht}$$

The model: Real Exchange Rate Decomposition

- Engel (1999): a log linear approximation of the real exchange

$$q = (1-\gamma)q_n + q_T \qquad (7)$$

$$q_n \equiv (p_N^* - p_T^* - (p_N - p_T)), \text{ and } q_T \equiv p_T^* - p_T.$$

- q_n difference across countries in the relative local currency price of non-traded to traded goods
- q_T traded goods real exchange rate at the retail level

$$q_T = \frac{1-\kappa}{\kappa} q_n + (2\omega - 1)\tau + p_H^* - p_H \qquad (8)$$

- $\tau = p_F^* - p_H^* = p_F - p_H$ Home terms of trade
- $p_H^* - p_H$ deviation from the LOP in Home traded goods

The model: Relative Productivity and Real Exchange Rates

- Consider a special case: a) $\omega = \frac{1}{2}$, b) $\alpha = 1$, c) $\zeta_i = 0$, which means: no home bias, output is linear in labor input and all prices are perfectly flexible

$$q = (1-\gamma)q_n + q_T \quad (7)$$

$$q_T = \frac{1-\kappa}{\kappa}q_n + (2\omega - 1)\tau + p_H^* - p_H \quad (8)$$

- Now we have $q = (1-\gamma\kappa)(p_N^* - p_N)$ (9)
- non-traded goods prices influence the real exchange rate
  - directly through the price of consumer non-traded goods $(p_N^* - p_N)$ and indirectly through the distribution cost of traded goods $(1-\gamma\kappa)$

The model: Relative Productivity and Real Exchange Rates

$$q = (1 - \gamma\kappa)(p_N^* - p_N) \qquad (9)$$

- Since prices are fully flexible and output is linear in labor $p_N = w - a_N,$
- the real exchange rate then becomes

$$q = (1 - \gamma\kappa)(w^* - a_N^* - (w - a_N)) \qquad (10)$$

- By wage equalization among sectors

$$q = (1 - \gamma\kappa)(p_F^* - p_H + (a_F^* - a_H) - (a_N^* - a_N)) \qquad (11)$$

  - terms of trade component
  - relative traded goods productivity
  - relative non-traded goods productivity

$$q = (1 - \gamma\kappa)(p_F^* - p_H + (a_F^* - a_H) - (a_N^* - a_N)) \tag{11}$$

- unit labor cost: nominal wage divided by output per worker

$$\text{ulc} = w - \gamma\kappa(y_H - n_H) - (1 - \gamma\kappa)(y_N - n_N) = w - \gamma\kappa a_H - (1 - \gamma\kappa)a_N$$

- relative unit labor cost for Foreign to Home

$$\text{rulc} = p_F^* - p_H + (1 - \gamma\kappa)(a_F^* - a_H) - (1 - \gamma\kappa)(a_N^* - a_N) \tag{12}$$

- Finally, substitute (12) into (11)

$$q = (1 - \gamma\kappa)\ \text{rulc} + (1 - \gamma\kappa)\gamma\kappa(a_F^* - a_H) - (1 - \gamma\kappa)\gamma\kappa(a_N^* - a_N) \tag{13}$$

  - amended Balassa-Samuelson model

The model: Relative Productivity and Real Exchange Rates

- amended Balassa-Samuelson model

$$q = (1 - \gamma\kappa)\ \mathrm{rulc} + (1 - \gamma\kappa)\gamma\kappa(a_F^* - a_H) - (1 - \gamma\kappa)\gamma\kappa(a_N^* - a_N) \qquad (13)$$

- Conditional on relative unit labor costs, real exchange rate is
  - positively related to relative traded goods productivity
  - negatively to relative non-traded goods productivity
  - A rise in Home traded productivity should lead to real exchange rate appreciation, while a rise in Home non-traded productivity should lead to real exchange rate depreciation.

The model: Relative Productivity and Real Exchange Rates

- However, relative unit labor costs are endogenous.
- One more assumption: d) $\theta = \phi = 1$.
- Terms of trade and the real exchange rate are given by

$$p_F^* - p_H = -\frac{1}{D}\left[\sigma(1+\psi) - \psi(\sigma-1)(1-\gamma\kappa)^2\right](a_F^* - a_H)$$
$$+\frac{1}{D}\left[\psi(\sigma-1)(1-\gamma\kappa)^2\right](a_N^* - a_N) + \frac{1}{D}\sigma(\chi^* - \chi) \qquad (14)$$

$$q = \frac{1}{D}\left[\sigma\psi\gamma\kappa^2(\lambda-1)(1-\gamma\kappa)\right](a_F^* - a_H)$$
$$-\frac{1}{D}\left[\sigma(1+\psi+\psi\gamma\kappa^2(\lambda-1))\right](a_N^* - a_N) + \frac{1}{D}(1-\gamma\kappa)(\chi^* - \chi) \qquad (15)$$
$$D = \psi(1-\gamma\kappa)^2 + \sigma(1+\psi\gamma\kappa(1-\gamma\kappa+\lambda\kappa+(1-\kappa)))$$

- Through the terms of trade channel, labor supply shocks cause an appreciation of the real exchange rate, independently of sectoral productivity.

The model: Unit labor cost

- labor wedge
  - Is the gap between the marginal product of labor and the measured MRS between consumption and leisure of the representative household
  - Sources: movements in labor taxes, variation in monopoly power in wage setting, sticky nominal wages…
- In this model
  - $\chi * - \chi$ as an unobserved relative preference shock, which is equivalent to the labor wedge definition.
  - using reported ULC as a variable influenced by both the labor wedge and movements in relative sectoral productivities without further assumptions

Data: Real Exchange Rates

- Disaggregated price data
  - constructed by Eurostat, part of the Eurostat-OECD PPP Program
  - Price Level Indices: the price of a good at a given time for a given country, relative to a reference country price
  - annual, over 1995-2009; 12 countries in Eurozone
  - 146 “basic headings” of consumer goods and services: include food, clothing, housing costs, durable goods, transportation costs, as well as medical and educational services
  - cover 100% of the consumption basket

Table 1. PLI basic headings, Household expenditures

T	Rice	T	Major tools and equipment
T	Other cereals, flour and other cereal products	T	Small tools and miscellaneous accessories
T	Bread	T	Non-durable household goods
T	Other bakery products	NT	Domestic services
T	Pasta products	NT	Household services
T	Beef and Veal	T	Pharmaceutical products
T	Pork	T	Other medical products
T	Lamb, mutton and goat	T	Therapeutical appliances and equipment
T	Poultry	NT	Medical Services
T	Other meats and edible offal	NT	Services of dentists
T	Delicatessen and other meat preparations	NT	Paramedical services
T	Fresh, chilled or frozen fish and seafood	NT	Hospital services
T	Preserved or processed fish and seafood	T	Motor cars with diesel engine
T	Fresh milk	T	Motor cars with petrol engine of cubic capacity of less than 1200cc
T	Preserved milk and other milk products	T	Motor cars with petrol engine of cubic capacity of 1200cc to 1699cc
T	Cheese	T	Motor cars with petrol engine of cubic capacity of 1700cc to 2999cc
T	Eggs and egg-based products	T	Motor cars with petrol engine of cubic capacity of 3000cc and over
T	Butter	T	Motor cycles
T	Margarine	T	Bicycles
T	Other edible oils and fats	T	Animal drawn vehicles
T	Fresh or chilled fruit	T	Spare parts and accessories for personal transport equipment
T	Frozen, preserved or processed fruit	T	Fuels and lubricants for personal transport equipment
T	Fresh or chilled vegetables other than potatoes	NT	Maintenance and repair of personal transport equipment
T	Fresh or chilled potatoes	NT	Other services in respect of personal transport equipment
T	Frozen, preserved or processed vegetables	NT	Passenger transport by railway
T	Sugar	NT	Passenger transport by road
T	Jams, marmalades and honey	T	Passenger transport by air
T	Confectionery, chocolate and other cocoa preps	NT	Passenger transport by sea and inland waterway
T	Edible ice, ice cream and sorbet	NT	Combined passenger transport
T	Coffee, tea and cocoa	NT	Other purchased transport services
T	Mineral waters	NT	Postal services
T	Soft drinks and concentrates	T	Telephone and telefax equipment
T	Fruit and vegetable juices	NT	Telephone and telefax services
T	Spirits	T	Equipment for reception, recording and reproduction of sound and pictures
T	Wine	T	Photographic and cinematographic equipment and optical instruments
T	Beer	T	Information processing equipment

Data: Real Exchange Rates

- Disaggregated price data
  - both cross section and time series real exchange rate variation can be examined
  - construct aggregate and sectoral real exchange rates using expenditure weights (which is also time-varying)
- Advantages
  - Comprehensive, cover entire consumer basket
- Real Exchange Rates: separate goods into traded and non-traded categories

$$q = (1 - \gamma) q_n + q_T \tag{7}$$

$$q_n \equiv (p_N^* - p_T^* - (p_N - p_T)), \text{ and } q_T \equiv p_T^* - p_T.$$

Data: Productivity and Unit Labor Cost

- Productivity
  - Annual sectoral panel TFP level data
  - Combine two sources:
    - Groningen Growth and Development Center's (GGDC thereafter) 1997 TFP level database
    - KLEMS time-series database
- Unit Labor Cost
  - OECD Stat database
  - average ULC in the EU17 relative to ULC in country i

Empirical:

direct investigation of the Balassa-Samuelson

$$q = (1-\gamma)q_n + q_T$$

$$q_T = \frac{1-\kappa}{\kappa} q_n + (2\omega - 1)\tau + p_H^* - p_H$$

$$q_n \equiv (p_N^* - p_T^* - (p_N - p_T)), \text{ and } q_T \equiv p_T^* - p_T.$$

Table 4. Price regressions

Table 4a: Regression of q on the q_n

	1	2	3	4
	Pool	FE	RE	XS
$\mathbf{q_n}$	**0.70*****	**0.60*****	**0.61*****	**0.71****
	(0.058)	(0.076)	(0.07)	(0.247)
$\overline{R}^2$	0.44	0.93	0.36	0.40
N	180	180	180	12
HT	–	–	not reject	–

Table 4b new: Regression of q_T on q_n

	5	6	7	8
	Pool	FE	RE	XS
$\mathbf{q_n}$	**0.26*****	0.11	**0.12***	**0.89*****
	(0.057)	(0.076)	(0.07)	(0.12)
$\overline{R}^2$	0.10	0.89	0.02	0.70
N	180	180	180	12
HT	–	–	not reject	–

Table 4c: Regression of the q on q_T

	9	10	11	12
	Pool	FE	RE	XS
$\mathbf{q_T}$	**1.19*****	**1.08*****	**1.09*****	**1.20*****
	(0.038)	(0.053)	(0.048)	(0.11)
$\overline{R}^2$	0.84	0.98	0.77	0.83
N	180	180	180	12
HT	–	–	not reject	–

Empirical: central findings

$$q = (1 - \gamma\kappa)\ \text{rulc} + (1 - \gamma\kappa)\gamma\kappa(a_F^* - a_H) - (1 - \gamma\kappa)\gamma\kappa(a_N^* - a_N) \qquad (13)$$

Table 5. RER - TFP regression

	Pool			Fixed effects			Random effects			Cross-section		
	1a	1b	1c	2a	2b	2c	3a	3b	3c	4a	4b	4c
TFP	**0.43***	–	–	-0.10	–	–	-0.04	–	–	**0.51**	–	–
	(0.067)			(0.11)			(0.094)			(0.21)		
TFP_T	–	**0.50***	**0.76***	–	0.003	**0.18**	–	0.05	**0.26***	–	**0.67***	**0.93***
		(0.059)	(0.062)		(0.11)	(0.090)		(0.09)	(0.079)		(0.145)	(0.19)
TFP_N	–	-0.09	**-0.29***	–	**-0.36***	**-0.36**	–	**-0.29***	**-0.36***	–	-0.05	-0.27
		(0.08)	(0.078)		(0.22)	(0.18)		(0.164)	(0.13)		(0.184)	(0.22)
ULC	–	–	**0.43***	–	–	**0.46***	–	–	**0.46***	–	–	**0.43**
			(0.079)			(0.072)			(0.077)			(0.20)
$\overline{R}^2$	0.25	0.41	0.57	0.84	0.85	0.90	-0.007	0.02	0.32	0.28	0.62	0.76
N	117	117	117	117	117	117	117	117	117	9	9	9
HT	–	–	–	–	–	–	reject	reject	reject			

- Conclusion: There is support for the Balassa-Samuelson link between traded TFP and real exchange rates, both in the cross section and time series, but only when we control for non-traded productivity and unit labor costs.

Quantitative analysis: simulation

Table 6. Calibration

Households			
Share of C on traded goods	γ	0.5	49.9% in data
Share of wholesale traded goods in C_T	κ	0.6	59% in data
E.O.S. between H and F retail Traded goods	λ	8	Corsetti et al. (2010)
E.O.S. between traded good and retail service	ϕ	0.25	Low by common argument
E.O.S. between traded and nontraded goods	θ	0.7	standard estimate from pre. lit.
Weight on H goods in C_T	ω	0.5	No home bias
Coefficient of relative risk aversion	σ	2	standard in DSGE
Frisch elasticity of labor supply	ψ	1	
Discount factor	β	0.99	
Firms			
Elasticity of labor in Y	α	1	
Speed of Calvo price adjustment		0.10, 0.20/quarter	Bils and Klenow (2004)
Monetary policy			
Weight on inflation targeting	σ_p	2	Steinsson (2008)

$r_t = \rho + \sigma_p \pi_t^*$ central bank targets the inflation rate in the Foreign country

Quantitative analysis: simulation

- Three different price adjustment:
  - Sticky Price Model A, adjust at a rate of 10% per quarter (half life of a price is approximately 7 quarters)
  - Sticky Price model B, adjust 20% , half life 3.5 quarters
  - Fully flexible prices
- Three different kinds of shocks:
  - productivity shocks of two sectors, a_{Ht} , a_{Tt}
  - shocks to the labor wedge χ_t.
  - set Foreign shocks equal to zero, calibrate each of the Home country shocks using data relative to the EU set of countries

Table 8. Properties of model Real Exchange Rates

	Sticky price A	**Sticky price B**	**Flexible price**	**Data**
	1	2	3	4
STD (Time Series)	0.034 (0.029,0.041)	0.037 (0.032,0.044)	0.042 (0.036,0.049)	0.033
STD (Cross Section)	0.086 (0.060,0.126)	0.087 (0.058,0.125)	0.088 (0.061,0.126)	0.113
Serial Correlation	0.717 (0.641,0.805)	0.691 (0.604,0.777)	0.607 (0.511,0.706)	0.669

Results in the "Data" column repeat those from Table 3. Results in the other columns are based on regressions with simulated data (500 simulations of the DGP, as described in Appendix B, with $\kappa = 0.6$ and $\gamma = 0.5$). As in our data, panels of synthetic data are generated for 15-year (60-quarter) periods. 10% standard errors are reported in the parentheses. The calibration in column "Sticky price A" assumes a 10% price adjustment per quarter. "Sticky price B" assumes a 20% price adjustment per quarter.

TABLE 9. Model price regressions

Table 9a: Time Series Regressions

	Sticky price A	**Sticky price B**	**Flexible price**	**Data**
	1	2	3	4
Regression of q on q_n	1.167 (1.148,1.192)	1.168 (1.151,1.188)	1.169 (1.153,1.192)	0.60
Regression of q_T on q_n	0.665 (0.647,0.681)	0.665 (0.648,0.681)	0.666 (0.649,0.682)	0.11
Regression of q on q_T	1.757 (1.720,1.791)	1.752 (1.722,1.793)	1.756 (1.722,1.789)	1.08

Table 9b: Cross Section Regressions

	Sticky price A	**Sticky price B**	**Flexible price**	**Data**
	5	6	7	8
Regression of q on q_n	1.162 (1.127,1.200)	1.160 (1.125,1.203)	1.163 (1.127,1.201)	0.71
Regression of q_T on q_n	0.662 (0.632,0.689)	0.659 (0.629,0.692)	0.662 (0.633,0.689)	0.89
Regression of q on q_T	1.757 (1.730,1.784)	1.757 (1.729,1.788)	1.757 (1.732,1.785)	1.20

$$q = (1-\gamma\kappa)\ \text{rulc} + (1-\gamma\kappa)\gamma\kappa(a_F^* - a_H) - (1-\gamma\kappa)\gamma\kappa(a_N^* - a_N) \tag{13}$$

Table 10a. Time Series Regression Results

	Sticky price A	**Sticky price B**	**Flexible price**	**Data**
	1	2	3	4
Traded TFP	0.195	0.202	0.219	0.18
	(0.104,0.287)	(0.128,0.267)	(0.197,0.242)	
Nontraded TFP	-0.312	-0.299	-0.225	-0.36
	(-0.439,-0.153)	(-0.395,-0.202)	(-0.249,-0.207)	
ULC	0.338	0.442	0.698	0.46
	(0.298,0.390)	(0.404,0.485)	(0.681,0.712)	

Table 10b. Cross Section Regression Results

	Sticky price A	**Sticky price B**	**Flexible price**	**Data**
	5	6	7	8
Traded TFP	0.349	0.350	0.354	0.93
	(0.262,0.461)	(0.254,0.446)	(0.245,0.470)	
Nontraded TFP	-0.266	-0.265	-0.251	-0.27
	(-0.385,-0.141)	(-0.369,-0.150)	(-0.380,-0.124)	
ULC	0.448	0.444	0.470	0.43
	(0.350,0.563)	(0.369,0.544)	(0.358,0.585)	

Conclusions

- Real exchange rates in the Eurozone are driven by:
  - differences in the relative prices of non-traded to traded goods
  - differences in the relative productivity levels in the traded versus non-traded sectors
  - variations in unit labor costs, partly by non-productivity related factors
- Model fits the actual pattern of real exchange rates under price stickiness