Workshop on Monetary Policy in Developing Economies
Istanbul School of Central Banking

Monetary Policy, Capital Flows, and Exchange Rates

Part 1: Exchange Rates and Monetary Policy

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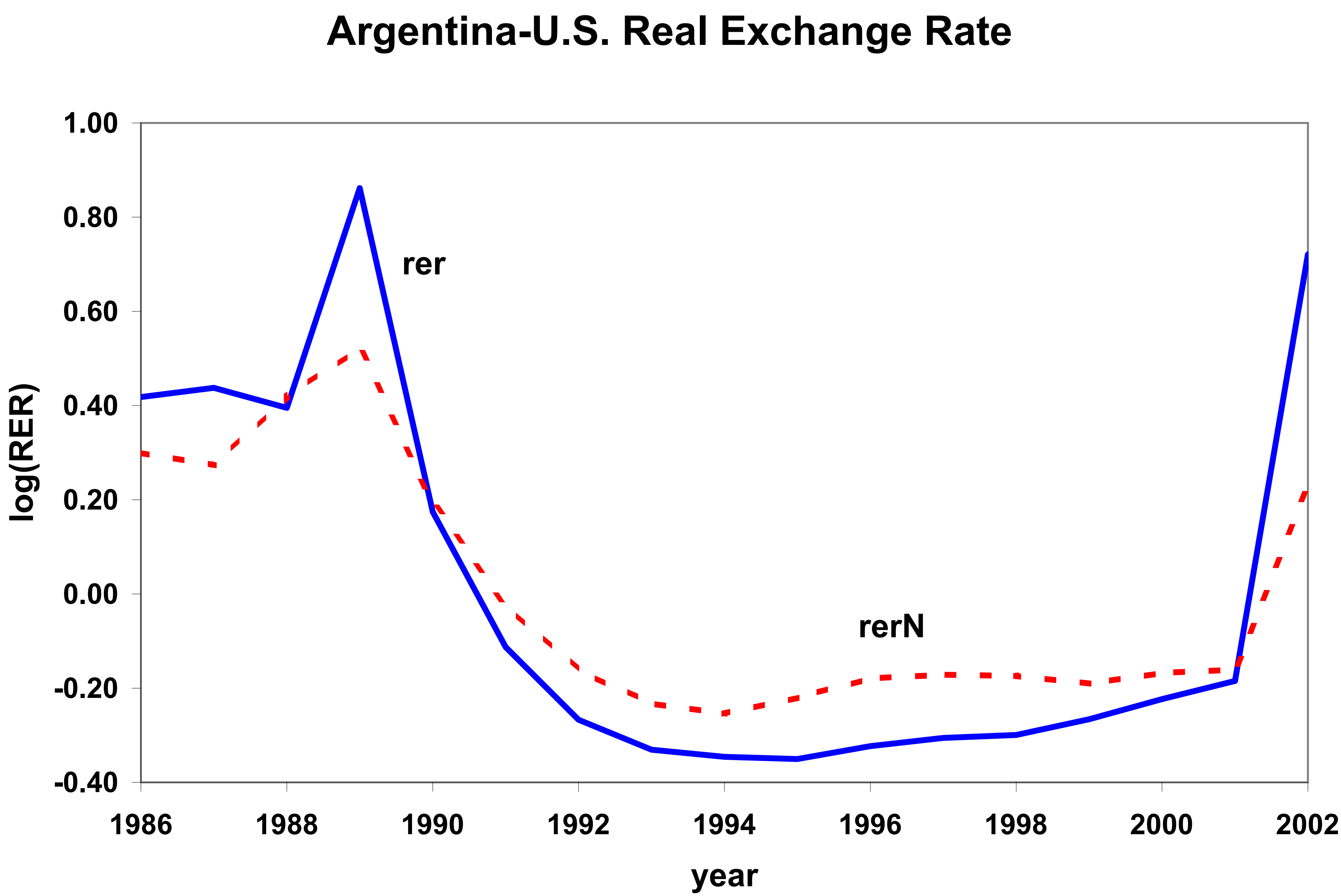
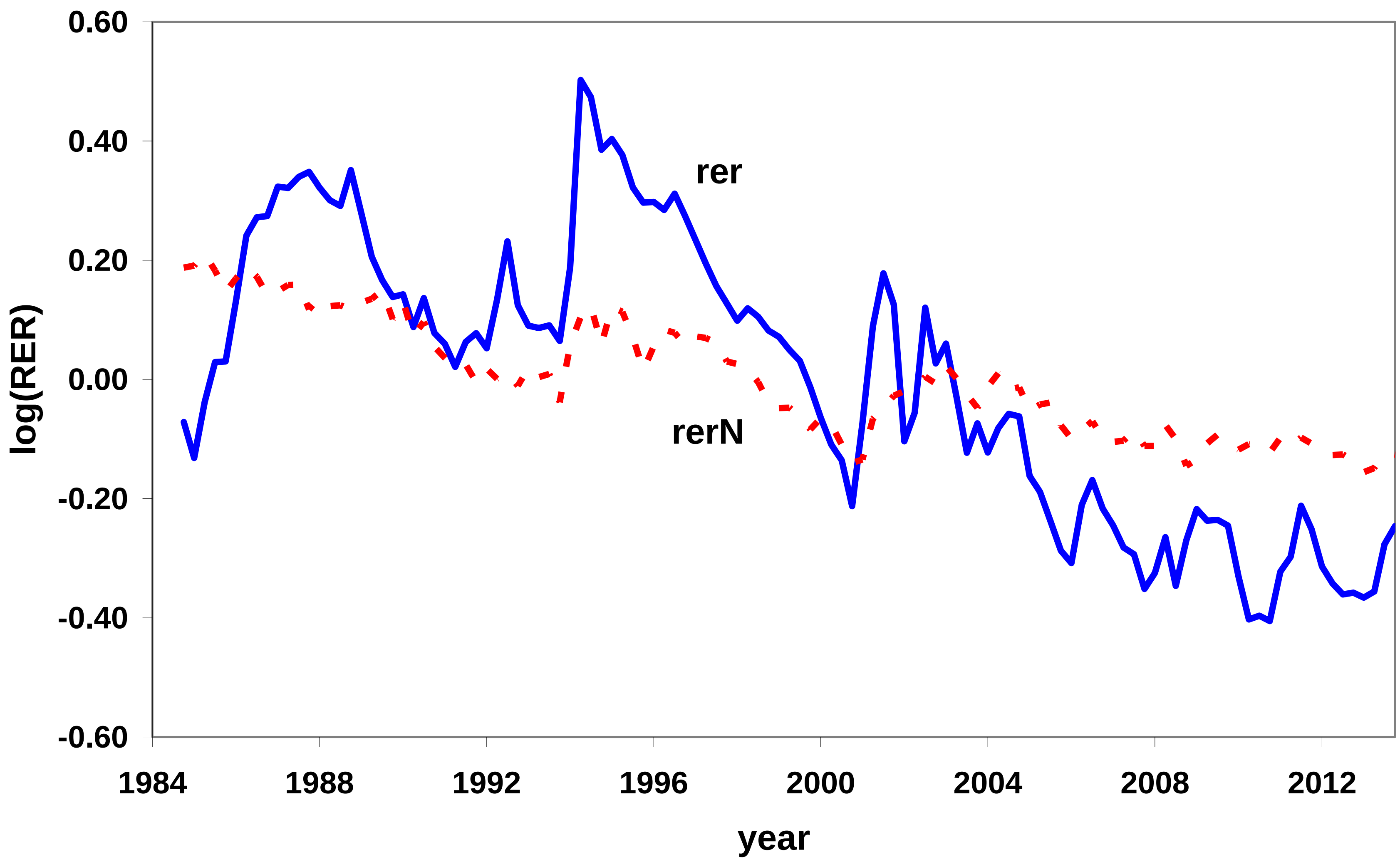


Argentina-U.S. Real Exchange Rate
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
log(RER)
rer
rerN
1986
1988
1990
1992
1994
1996
1998
2000
2002
year

Turkey-Germany Real Exchange Rate



TRADABILITY OF GOODS AND REAL EXCHANGE RATE MOVEMENTS

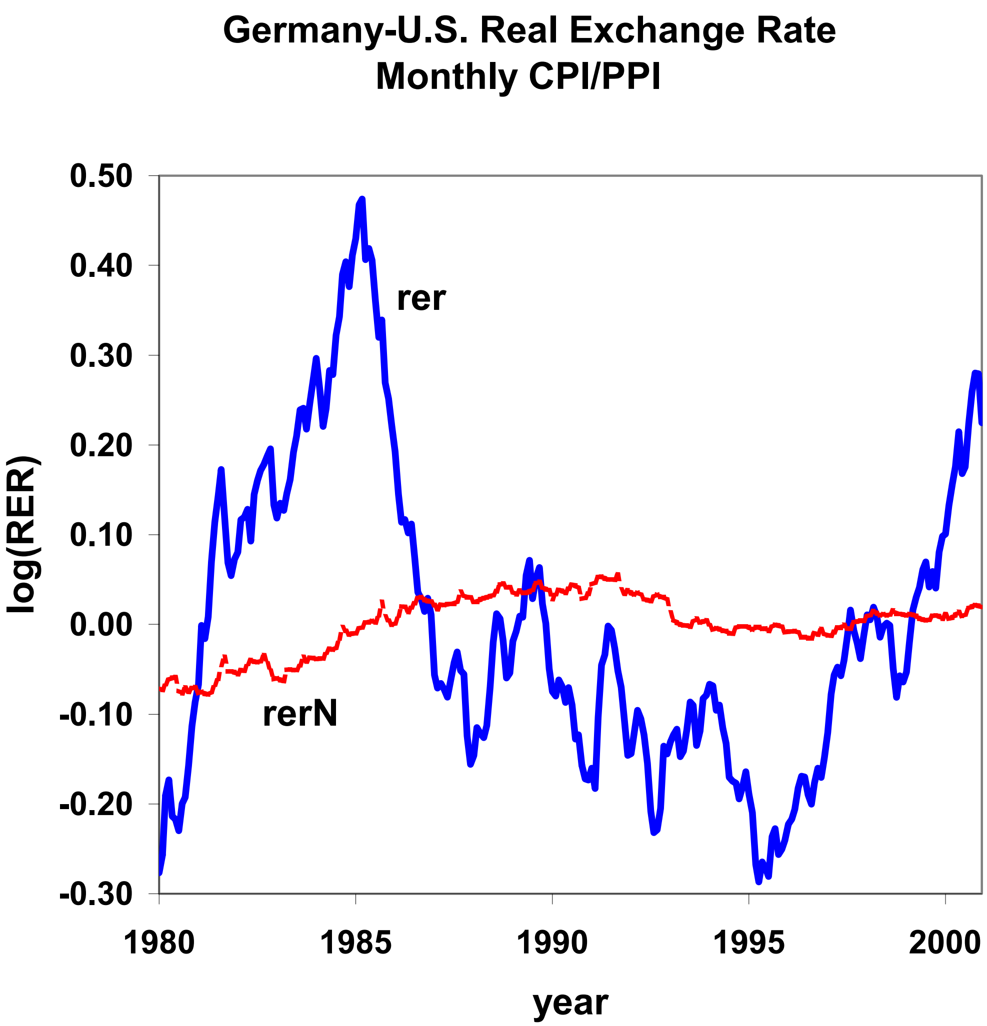
Timothy J. Kehoe and Caroline M. Betts

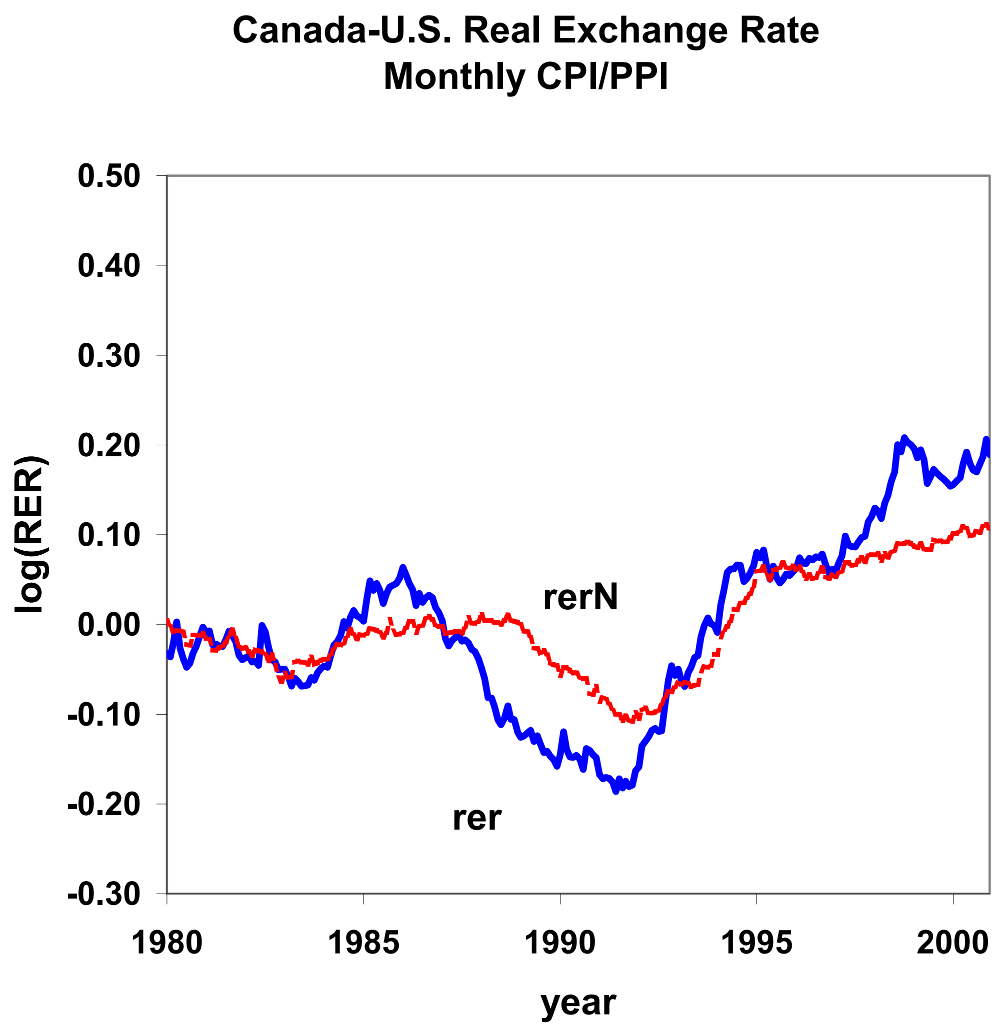
1. "U.S. Real Exchange Rate Fluctuations and Relative Price Fluctuations"

2. "Real Exchange Rate Movements and the Relative Price of Nontraded Goods"

3. "Tradability of Goods and Real Exchange Rate Fluctuations"

U.S. BILATERAL REAL EXCHANGE RATES
AND RELATIVE PRICES OF NONTRADED GOODS





We investigate the empirical relation between

the U.S. bilateral real exchange rate with 5 of her largest trade partners

and

the bilateral relative price of nontraded to traded goods.

We measure the relation by

simple correlation (comovements)

relative standard deviation (volatility)

variance decompositions (percent of fluctuations)

We find the relation depends crucially on

1. the price series used to measure the relative price of nontraded goods
2. the choice of trade partner.

Specifically, the relation is stronger when

1. traded goods prices are measured using production site prices — not final consumption price data
2. the trade intensity between the U.S. and a trade partner is larger — links international relative price behavior and size of trade flows

Traditional theory real exchange rate theory (Cassel, Pigou, and many others)

dichotomy of goods into

- costlessly traded (arbitraged prices)

- entirely nontraded (domestic prices)

INAPPROPRIATE

PLAN OF DISCUSSION

- Methodology
- Data
- Results
- What We Learn
- Extended Results (paper 2)
- Theoretical Model (paper 3)
- Conclusions

METHODOLOGY

Traditional real exchange rate theory attributes all (or most) real exchange rate movements to changes in the relative price of nontraded goods.

Recent empirical analyses using variance decompositions argue there is almost no role for relative price of nontraded goods in real exchange rate movements. All movements are driven by deviations from law of one price.

REAL EXCHANGE RATE MEASUREMENT

Bilateral real exchange rate between the United States and country i:

$$RER_{i,us} = NER_{i,us} \frac{P_{us}}{P_i}$$

$NER_{i,us}$: nominal exchange rate — country i currency units per U.S. dollar

P_j: price deflator or index for the basket of goods consumed or produced in country j, $j = us,\ i$.

Traditional theory dichotomizes goods into

- costlessly traded (arbitraged prices)
- entirely nontraded (domestic prices)

$$P_j(P_j^T, P_j^N)$$

Decompose

$$RER_{i,us} = \left(NER_{i,us} \frac{P_{us}^T}{P_i^T} \right) \left(\frac{P_i^T}{P_i} \Big/ \frac{P_{us}^T}{P_{us}} \right)$$

$$RER_{i,us} = RER_{i,us}^{T} \times RER_{i,us}^{N}$$

where

$$RER_{i,us}^{T} = NER_{i,us} \frac{P_{us}^{T}}{P_{i}^{T}}$$

is the real exchange rate of traded goods — the component that measures deviations from the law of one price and

$$RER_{i,us}^{N} = \left(\frac{P_i^T}{P_i(P_i^T, P_i^N)} \right) \Big/ \left(\frac{P_{us}^T}{P_{us}(P_{us}^T, P_{us}^N)} \right)$$

is what we refer to as the (bilateral) relative price of nontraded (to traded) goods.

In logarithms,

$$rer_{i,us} = rer_{i,us}^{T} + rer_{i,us}^{N}.$$

In the case where

$$P_j\left(P_j^T, P_j^N\right) = \left(P_j^T\right)^{\gamma_j}\left(P_j^N\right)^{1-\gamma_j},$$

$$\begin{aligned}
RER_{i,us}^N &= \left(\frac{P_i^T}{P_i(P_i^T, P_i^N)}\right) \Bigg/ \left(\frac{P_{us}^T}{P_{us}(P_{us}^T, P_{us}^N)}\right) \\
&= \left(\frac{P_i^T}{\left(P_i^T\right)^{\gamma_i}\left(P_i^N\right)^{1-\gamma_i}}\right) \Bigg/ \left(\frac{P_{us}^T}{\left(P_{us}^T\right)^{\gamma_{us}}\left(P_{us}^N\right)^{1-\gamma_{us}}}\right) \\
&= \left(\frac{P_i^T}{P_i^N}\right)^{1-\gamma_i} \Bigg/ \left(\frac{P_{us}^T}{P_{us}^N}\right)^{1-\gamma_{us}}
\end{aligned}$$

SUMMARY STATISTICS

Analyze the relation between $rer_{i,us}$ and $rer_{i,us}^N$:

1. $corr(rer_{i,us}, rer_{i,us}^N) = \dfrac{cov(rer_{i,us}, rer_{i,us}^N)}{\left(var(rer_{i,us})var(rer_{i,us}^N)\right)^{1/2}}.$

2. $\dfrac{std(rer_{i,us}^N)}{std(rer_{i,us})} = \left(\dfrac{var(rer_{i,us}^N)}{var(rer_{i,us})}\right)^{1/2}$

3. $vardec(rer_{i,us}, rer_{i,us}^N) = \dfrac{var(rer_{i,us}^N)}{var(rer_{i,us}^N) + var(rer_{i,us}^T)}$

(Another possibility:

$$vardec^2(rer_{i,us}, rer_{i,us}^N) = \frac{var(rer_{i,us}^N) + cov(rer_{i,us}^N, rer_{i,us}^T)}{var(rer_{i,us})}.)$$

DATA

Data on 5 of largest trade partners of the United States:

- Canada (1)
- Mexico (2)
- Japan (3)
- Germany (6)
- Korea (7).

These countries account for 53 percent of U.S. trade in 2000.

Construct measures of $rer_{i,us}$:

Need aggregate price indices (and nominal exchange rates)

1. Deflator for Gross Output at production site for all goods and services produced by a country (GO)

2. Consumer Price Index for entire basket of consumption goods and services (CPI)

3. Personal Consumption Deflators for all personal consumption expenditures (PCD).

(Another possibility: Deflator for Gross Domestic Product for all goods and services produced by a country (GDP).)

Construct measures of $rer_{i,us}^{N}$:

Need traded goods price measures

1. Deflator for GO of agriculture, mining, and manufacturing
2. Producer price index for entire basket of producer goods (PPI).
3. CPI for "traded" components of consumption basket - all goods less food.
4. PCD for "traded" components of personal consumption expenditures - commodities.

(Another possibility: Deflator for GDP of agriculture, mining, and manufacturing.)

WHAT WE LEARN

- The frequency of the data does not matter.

- Detrending matters (theory should guide for the choice and the explanation for why it matters).

- The size of bilateral trade relationship is crucial.

  The larger is the trade relationship, the more closely related are $rer_{i,us}$ and $rer_{i,us}^{N}$.

- The data series used to measure the relative price of nontraded goods $rer_{i,us}^{N}$ matters a lot.

good conceptually	**not good conceptually**
sectoral GO deflators	CPI components
PPIs	PCD components
	(sectoral GDP deflators)

highly correlated

CPI components-PCD components

sectoral GOP deflators-PPIs (-sectoral GDP deflators)

widely available	**less widely available**	**difficult to obtain**
PPIs	CPI components	sectoral GO deflators
	PCD components	
	(sectoral GDP deflators)	

SUGGESTION

MODIFY THE TRADITIONAL THEORY SO THAT GOODS DIFFER BY DEGREE OF TRADABILITY

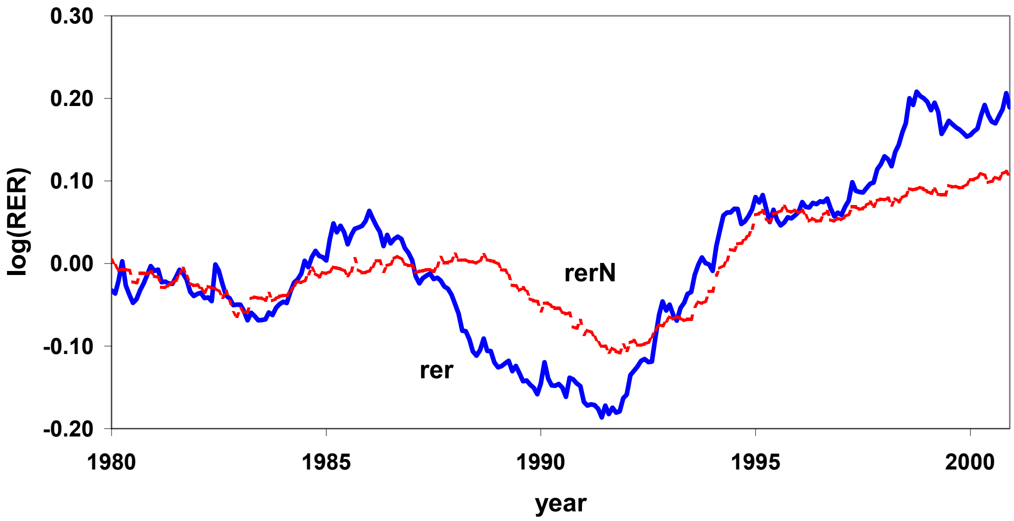
TABLE 1

COMPARISON OF FREQUENCIES: CANADA-U.S. REAL EXCHANGE RATE PPI-CPI data 1980-2000

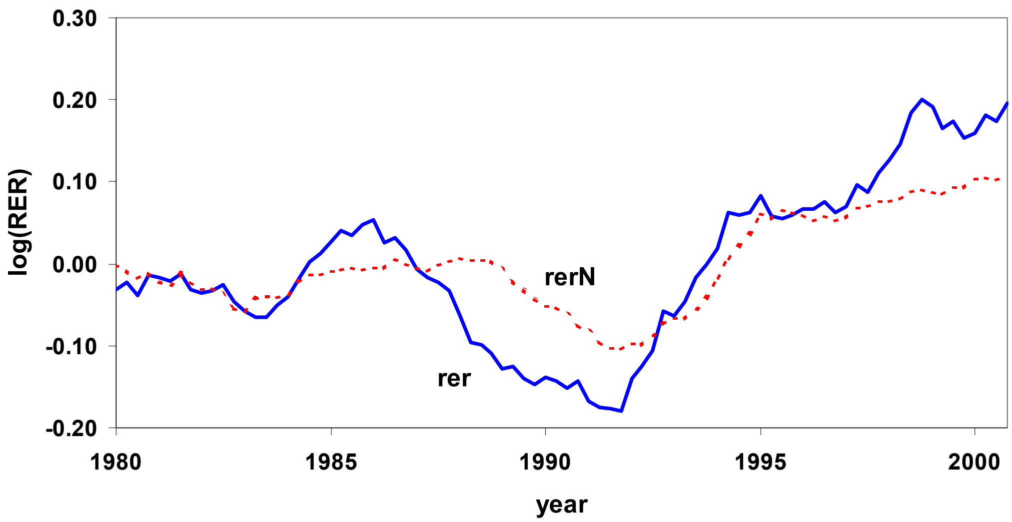
	annual	annual	quarterly	quarterly	quarterly	monthly	monthly	monthly	monthly
Levels									
corr(rer,rer^N)	0.88		0.88			0.88			
std(rer^N)/std(rer)	0.70		0.69			0.69			
vardec(rer,rer^N)	0.66		0.65			0.65			
Detrended levels									
corr(rer,rer^N)	0.88		0.88			0.87			
std(rer^N)/std(rer)	0.51		0.51			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
vardec(rer,rer^N)	0.40	0.51	0.28	0.39	0.51	0.29	0.26	0.37	0.50

CANADA-U.S. REAL EXCHANGE RATE

Monthly CPI/PPI



Quarterly CPI/PPI



Annual CPI/PPI

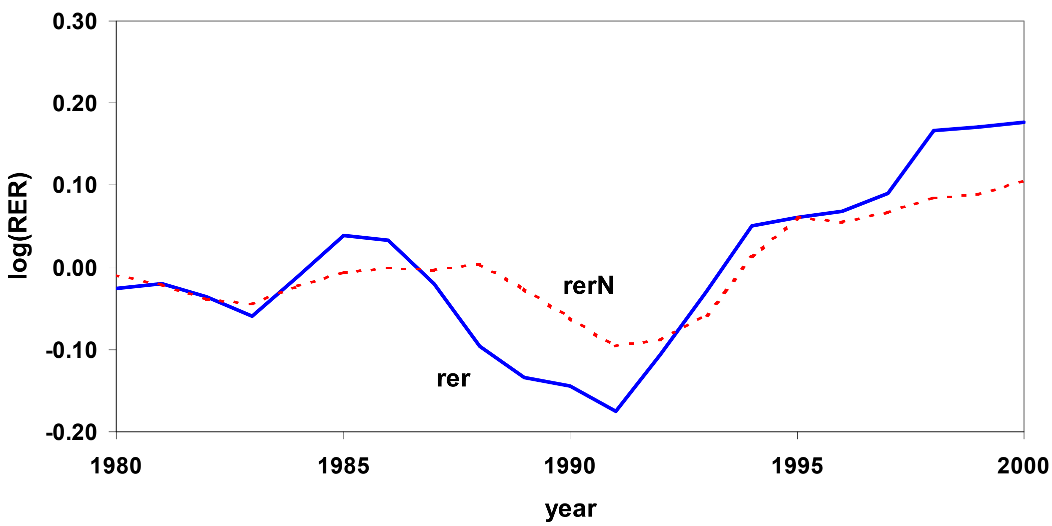


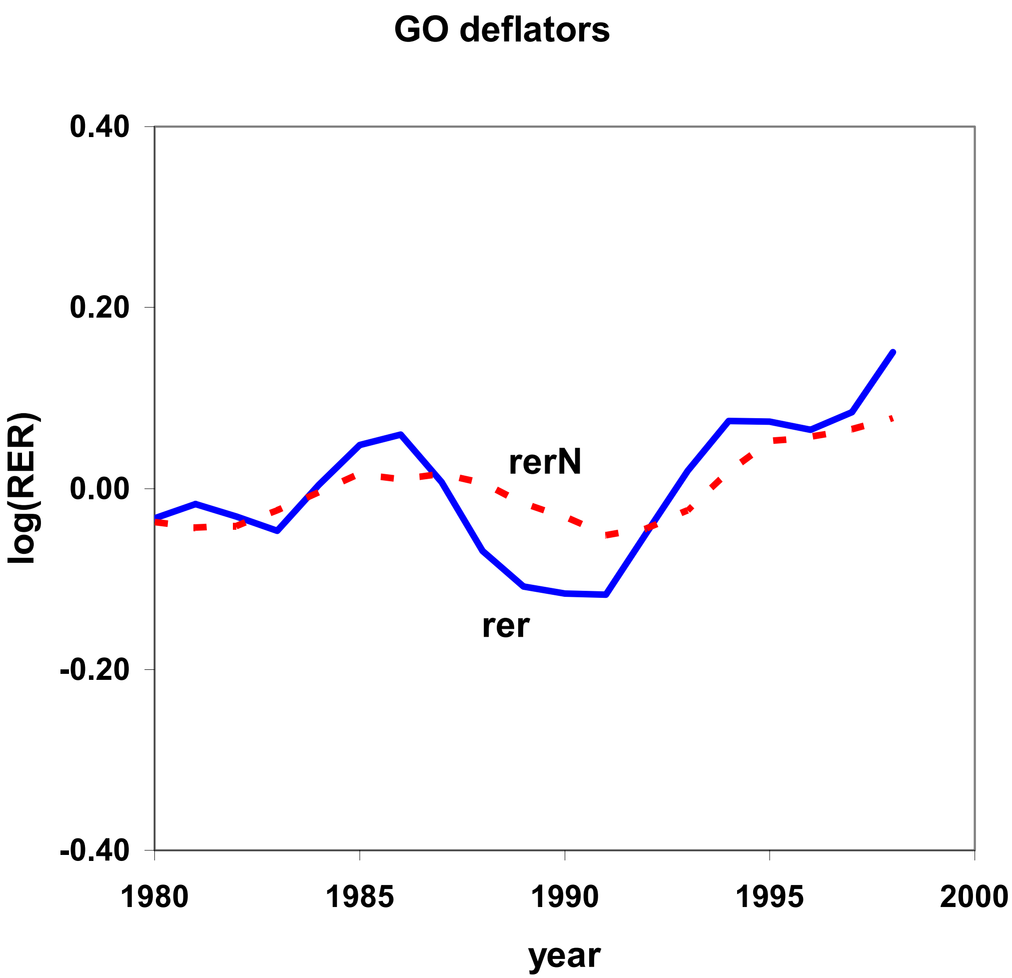
TABLE 2A

CANADA-U.S. REAL EXCHANGE RATE
Annual Data

	GO Deflators 1980-1998	PPI-CPI 1980-2000	Components of CPI 1980-2000	Components of PCD 1980-2000
Levels				
corr(rer,rer^N)	0.81	0.88	0.46	0.42
std(rer^N)/std(rer)	0.51	0.70	0.63	0.57
vardec(rer,rer^N)	0.38	0.66	0.33	0.27
Detrended levels				
corr(rer,rer^N)	0.78	0.88	-0.43	-0.32
std(rer^N)/std(rer)	0.45	0.51	0.17	0.14
vardec(rer,rer^N)	0.29	0.41	0.02	0.02
1 year changes				
corr(rer,rer^N)	0.54	0.70	-0.07	-0.11
std(rer^N)/std(rer)	0.40	0.55	0.20	0.13
vardec(rer,rer^N)	0.20	0.40	0.09	0.06
4 year changes				
corr(rer,rer^N)	0.74	0.82	-0.19	-0.08
std(rer^N)/std(rer)	0.47	0.55	0.16	0.13
vardec(rer,rer^N)	0.33	0.51	0.12	0.09

FIGURE 3A

CANADA-U.S. REAL EXCHANGE RATE



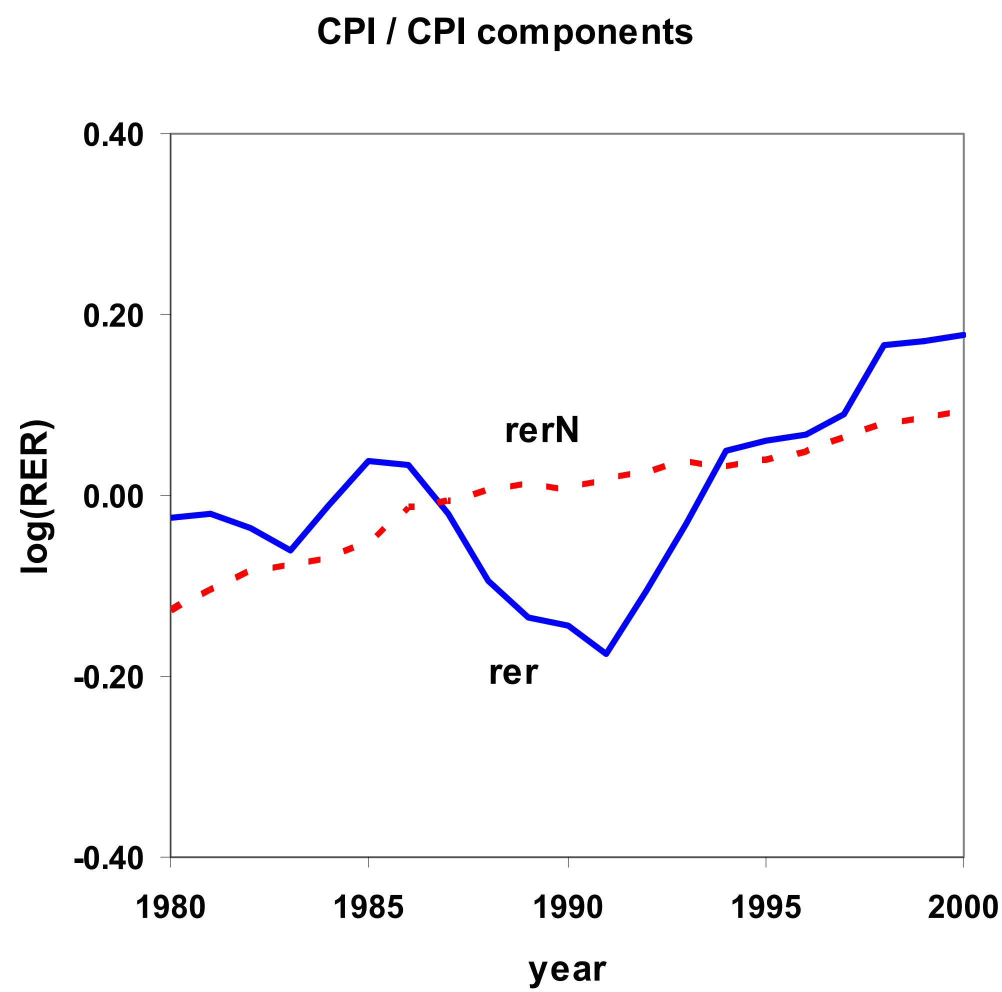


TABLE 2B

GERMANY-U.S. REAL EXCHANGE RATE
Annual Data

	GO Deflators 1980-2000	PPI-CPI 1980-2000	Components of CPI 1980-2000	Components of PCD 1980-2000
Levels				
corr(rer,rer^N)	-0.55	-0.33	-0.05	-0.24
std(rer^N)/std(rer)	0.25	0.73	0.15	0.25
vardec(rer,rer^N)	0.04	0.21	0.02	0.05
Detrended levels				
corr(rer,rer^N)	0.18	-0.15	0.24	0.37
std(rer^N)/std(rer)	0.20	0.13	0.12	0.10
vardec(rer,rer^N)	0.04	0.02	0.01	0.01
1 year changes				
corr(rer,rer^N)	0.16	-0.24	0.18	-0.02
std(rer^N)/std(rer)	0.13	0.14	0.10	0.07
vardec(rer,rer^N)	0.03	0.04	0.01	0.01
4 year changes				
corr(rer,rer^N)	0.24	0.02	0.31	0.49
std(rer^N)/std(rer)	0.21	0.12	0.10	0.09
vardec(rer,rer^N)	0.07	0.10	0.01	0.02

FIGURE 3B

GERMANY-U.S. REAL EXCHANGE RATE

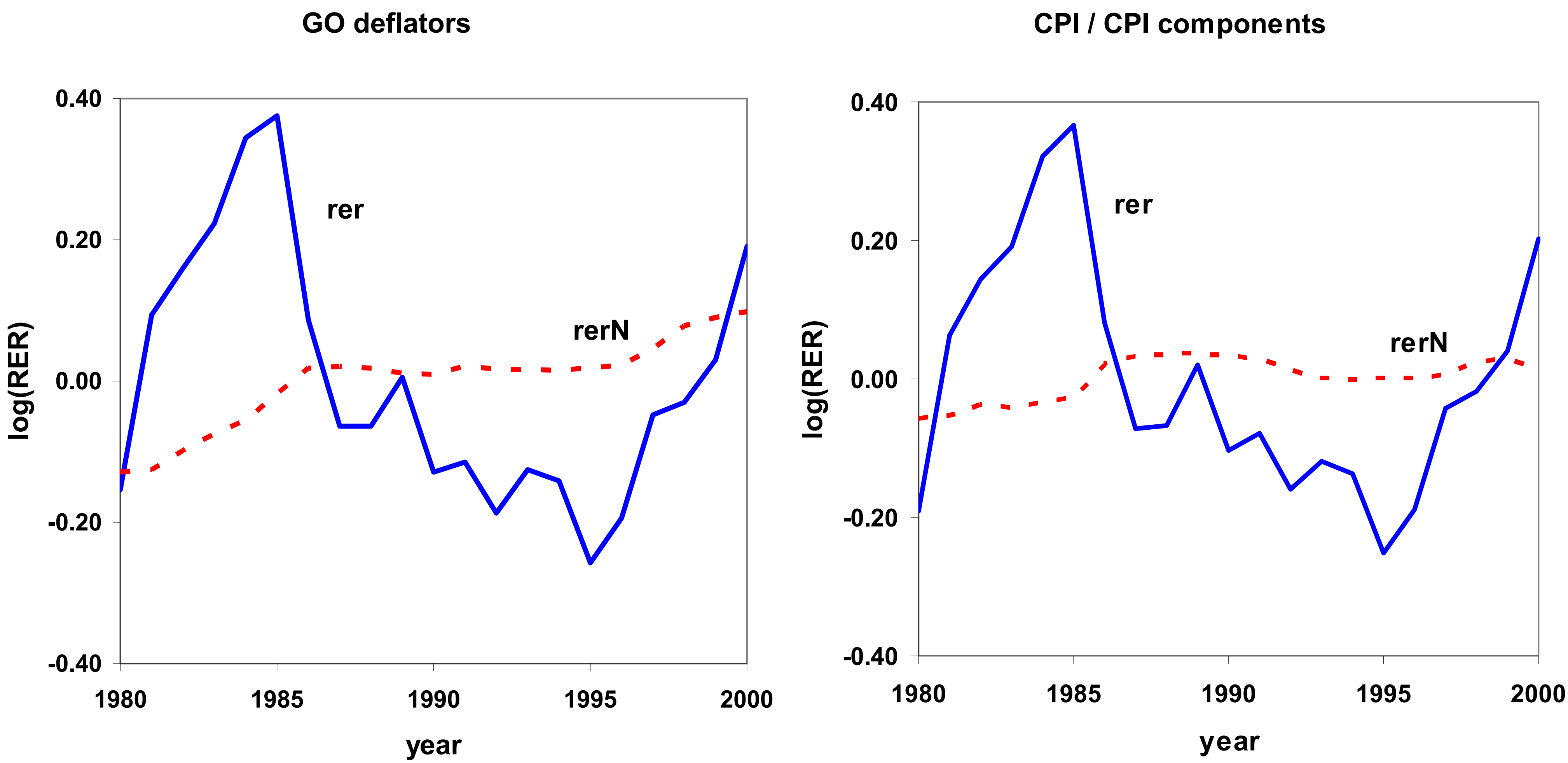


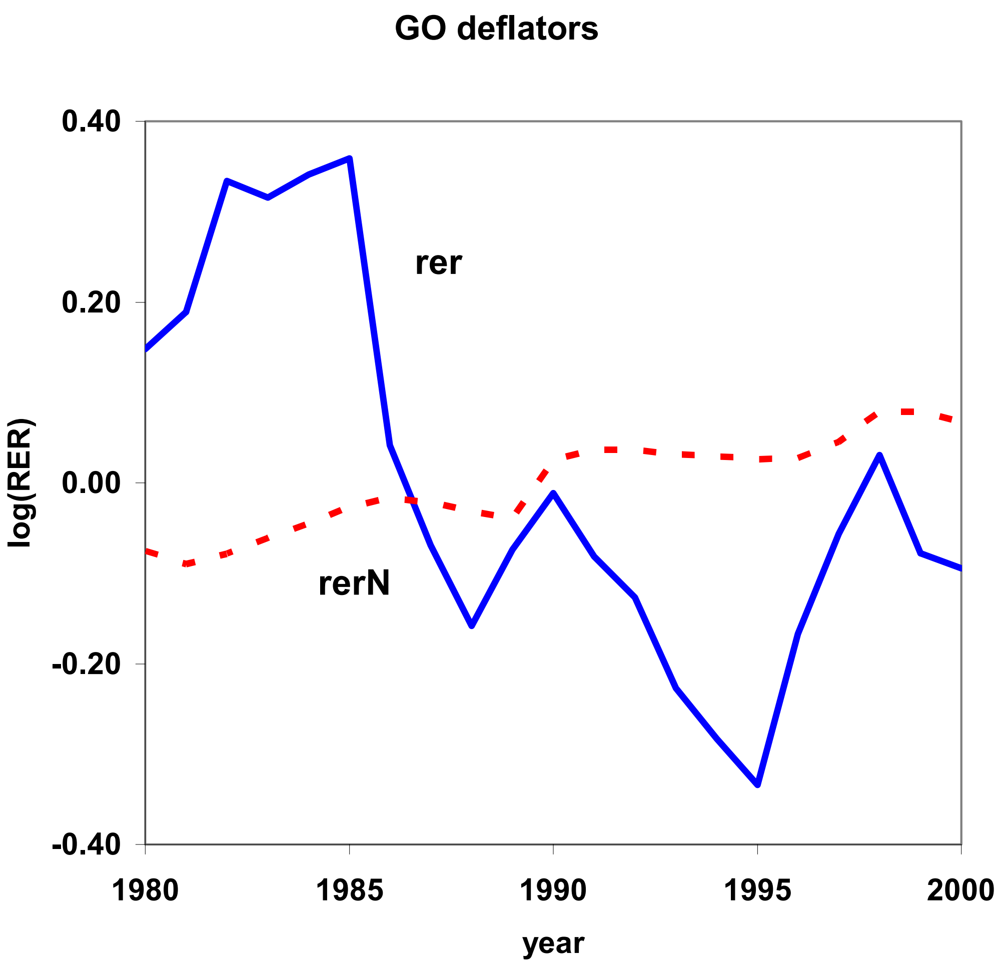
TABLE 2C

JAPAN-U.S. REAL EXCHANGE RATE
Annual Data

	GO Deflators 1980-2000	PPI-CPI 1980-2000	Components of CPI 1980-2000	Components of PCD 1990-2000
Levels				
corr(rer,rer^N)	-0.33	0.92	-0.74	-0.60
std(rer^N)/std(rer)	0.14	0.27	0.17	0.13
vardec(rer,rer^N)	0.02	0.11	0.02	0.01
Detrended levels				
corr(rer,rer^N)	0.47	0.95	-0.27	0.35
std(rer^N)/std(rer)	0.12	0.16	0.07	0.07
vardec(rer,rer^N)	0.02	0.03	0.00	0.00
1 year changes				
corr(rer,rer^N)	0.30	0.87	-0.32	0.13
std(rer^N)/std(rer)	0.12	0.17	0.09	0.07
vardec(rer,rer^N)	0.02	0.05	0.01	0.01
4 year changes				
corr(rer,rer^N)	0.52	0.95	-0.36	0.43
std(rer^N)/std(rer)	0.12	0.16	0.06	0.07
vardec(rer,rer^N)	0.02	0.05	0.01	0.01

FIGURE 3C

JAPAN-U.S. REAL EXCHANGE RATE



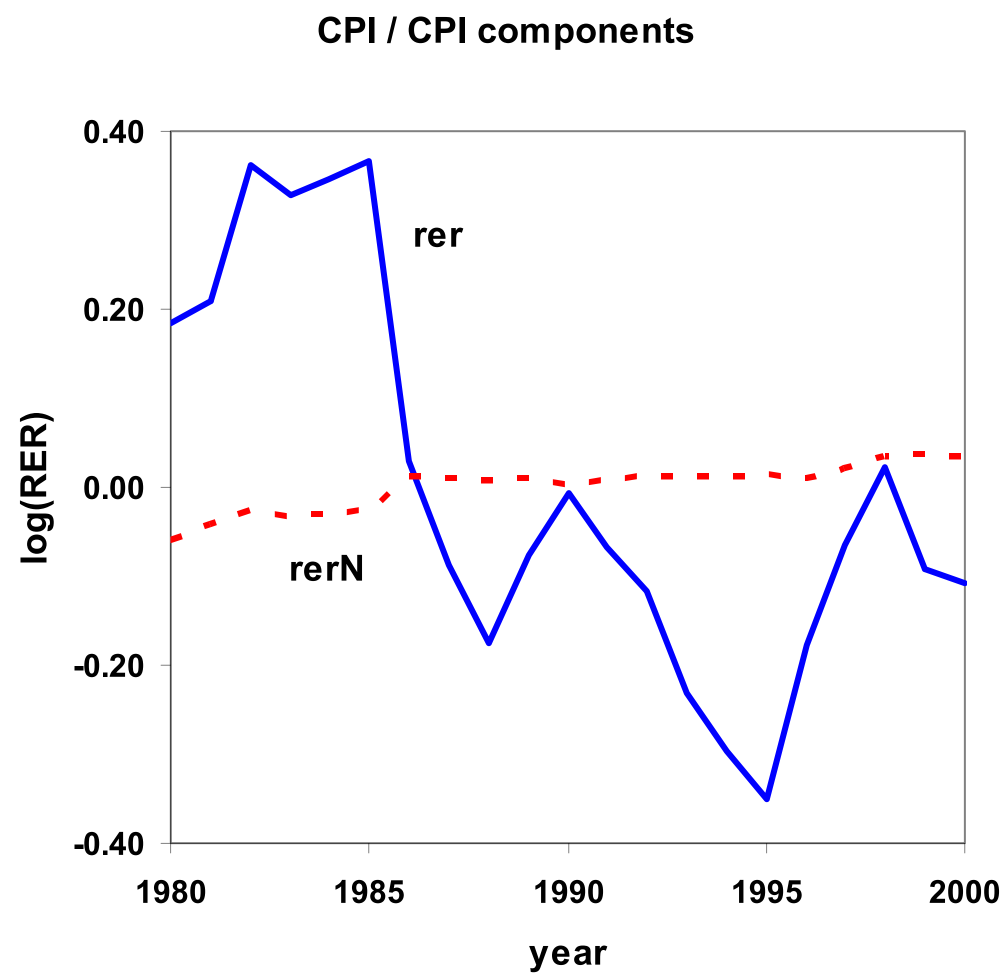


TABLE 2D

KOREA-U.S. REAL EXCHANGE RATE

Annual Data

	GO Deflators 1980-2000	PPI-CPI 1980-2000	Components of CPI 1980-2000	Components of PCD 1980-2000
Levels				
corr(rer,rer^N)	0.65	0.43	0.64	0.72
std(rer^N)/std(rer)	0.21	0.48	0.23	0.36
vardec(rer,rer^N)	0.05	0.22	0.06	0.18
Detrended levels				
corr(rer,rer^N)	0.82	0.94	0.63	0.72
std(rer^N)/std(rer)	0.18	0.30	0.21	0.24
vardec(rer,rer^N)	0.04	0.14	0.05	0.08
1 year changes				
corr(rer,rer^N)	0.81	0.88	0.57	0.49
std(rer^N)/std(rer)	0.23	0.26	0.22	0.16
vardec(rer,rer^N)	0.08	0.10	0.06	0.03
4 year changes				
corr(rer,rer^N)	0.80	0.94	0.62	0.72
std(rer^N)/std(rer)	0.18	0.30	0.21	0.24
vardec(rer,rer^N)	0.05	0.13	0.06	0.08

FIGURE 3D

KOREA-U.S. REAL EXCHANGE RATE

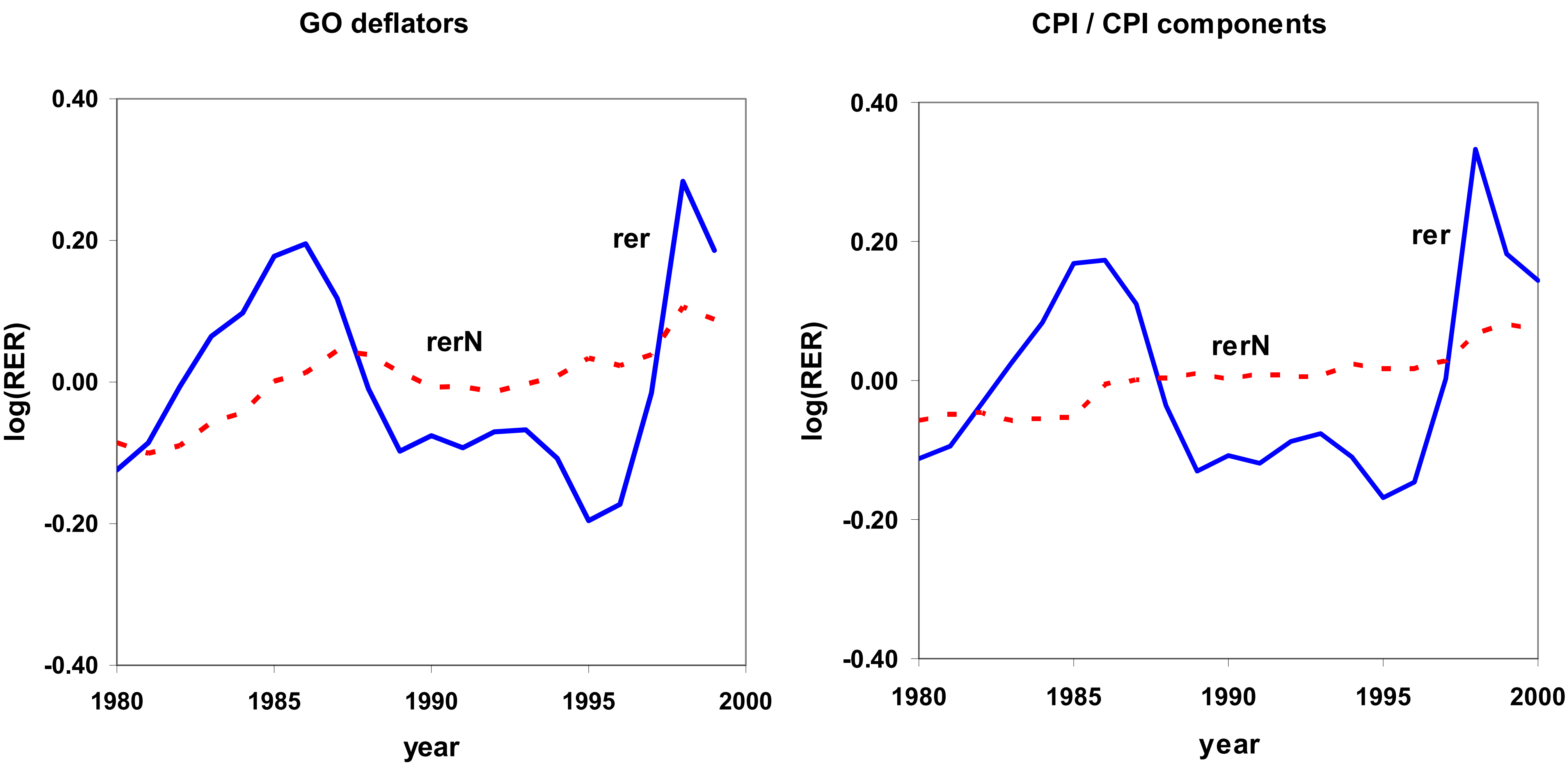


TABLE 2E

MEXICO-U.S. REAL EXCHANGE RATE
Annual Data

	GO Deflators 1980-2000	PPI-CPI 1981-2000	Components of CPI 1980-2000	Components of PCD 1980-2000
Levels				
corr(rer,rer^N)	0.75	0.74	0.64	0.81
std(rer^N)/std(rer)	0.36	0.21	0.55	0.23
vardec(rer,rer^N)	0.18	0.06	0.33	0.08
Detrended levels				
corr(rer,rer^N)	0.84	0.73	0.67	0.84
std(rer^N)/std(rer)	0.36	0.22	0.46	0.24
vardec(rer,rer^N)	0.20	0.06	0.26	0.08
1 year changes				
corr(rer,rer^N)	0.52	0.54	0.26	0.51
std(rer^N)/std(rer)	0.25	0.19	0.28	0.16
vardec(rer,rer^N)	0.07	0.04	0.08	0.03
4 year changes				
corr(rer,rer^N)	0.91	0.78	0.73	0.92
std(rer^N)/std(rer)	0.38	0.24	0.51	0.27
vardec(rer,rer^N)	0.25	0.08	0.34	0.12

FIGURE 3E

MEX ICO-U.S. REAL EXCHANGE RATE

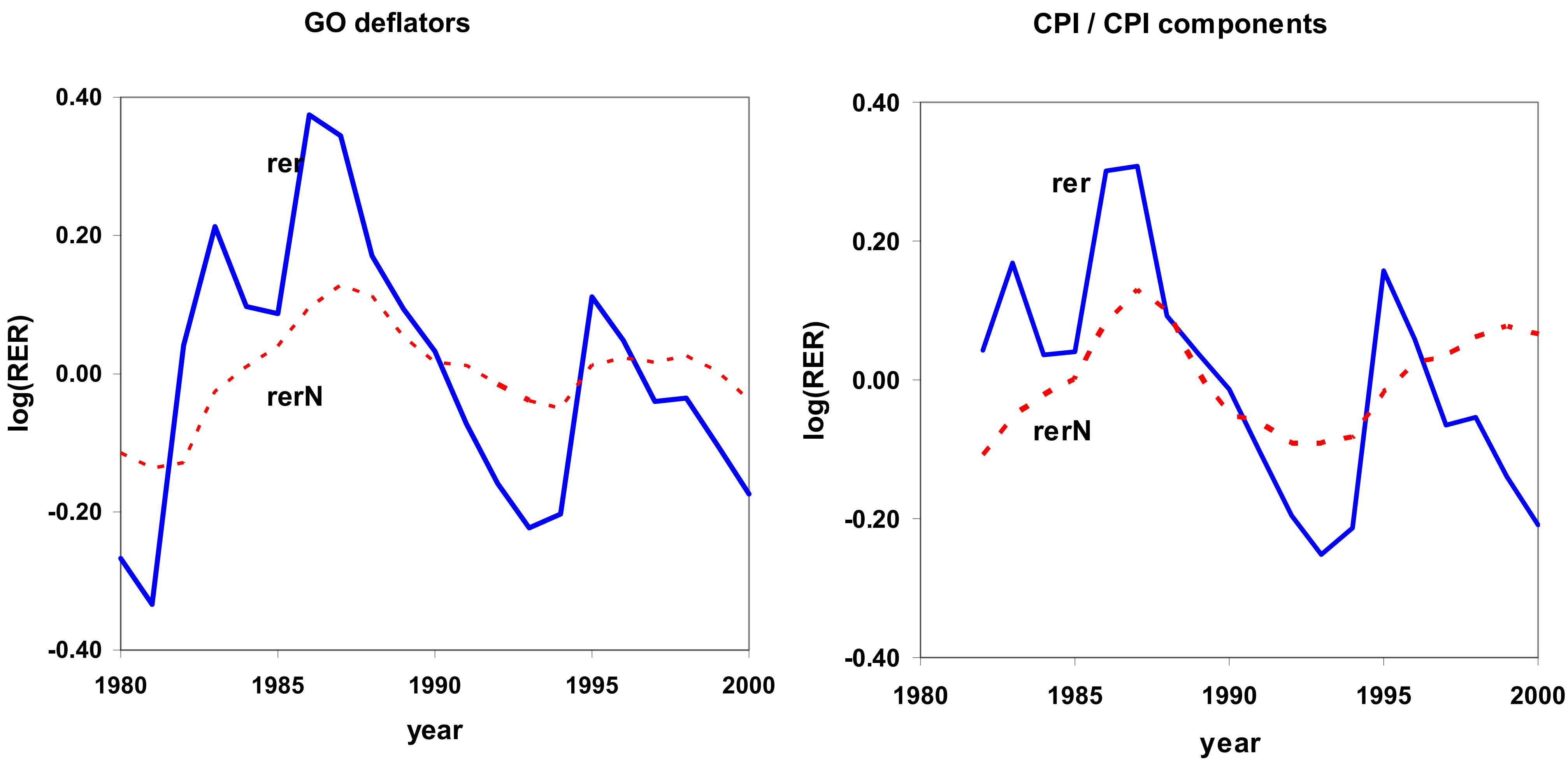


TABLE 3

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
vardec(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
vardec(rer,rer^N)	0.21	0.25	0.14	0.08

TABLE 4

COMPARISON OF SERIES:
CORRELATIONS OF DIFFERENT MEASURES OF rer^N
Annual Data

	Canada	Germany	Japan	Korea	Mexico	weighted average
Levels						
PPI-CPI-GO deflator	0.97	0.92	-0.61	0.09	0.70	0.52
CPI components-GO deflator	0.52	0.91	0.85	0.76	0.54	0.64
PCD components-GO deflator	0.54	0.99	0.91	0.02	0.95	0.72
PCD components-CPI components	0.996	0.88	0.94	0.19	0.68	0.84
Detrended levels						
CPI-PPI/GO deflator	0.96	0.54	0.37	0.89	0.71	0.74
CPI components/GO deflator	-0.18	0.83	0.61	0.71	0.82	0.37
PCD components/GO deflator	-0.12	0.88	0.81	0.77	0.96	0.47
PCD components/CPI components	0.92	0.90	0.40	0.88	0.86	0.80
1 year changes						
CPI-PPI/GO deflator	0.88	0.48	0.28	0.88	0.56	0.64
CPI components/GO deflator	-0.19	0.73	0.44	0.52	0.73	0.29
PCD components/GO deflator	-0.14	0.65	0.79	0.59	0.86	0.41
PCD components/CPI components	0.79	0.60	0.48	0.53	0.75	0.69
4 year changes						
CPI-PPI/GO deflator	0.98	0.56	0.47	0.91	0.81	0.80
CPI components/GO deflator	0.04	0.89	0.54	0.69	0.86	0.46
PCD components/GO deflator	0.03	0.97	0.79	0.75	0.97	0.54
PCD components/CPI components	0.87	0.92	0.19	0.91	0.89	0.75

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
vardec(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
vardec(rer,rer^N)	0.33	0.07	0.02	0.05	0.25

TABLE A

GROSS DOMESTIC PRODUCT DEFLATORS
Annual Data

	Canada 1980-1998	Germany 1980-2000	Japan 1980-2000	Korea 1980-2000	Mexico 1980-2000	weighted average
Levels						
corr(rer,rer^N)	0.80	-0.32	-0.69	0.00	0.74	0.34
std(rer^N)/std(rer)	0.90	0.53	0.22	0.26	0.50	0.59
vardec(rer,rer^N)	0.69	0.15	0.03	0.06	0.33	0.38
Detrended levels						
corr(rer,rer^N)	0.63	0.19	-0.24	0.56	0.84	0.47
std(rer^N)/std(rer)	0.75	0.27	0.18	0.18	0.47	0.49
vardec(rer,rer^N)	0.48	0.07	0.03	0.04	0.33	0.29
1 year changes						
corr(rer,rer^N)	0.05	-0.14	-0.29	0.61	0.47	0.11
std(rer^N)/std(rer)	0.81	0.18	0.16	0.26	0.36	0.48
vardec(rer,rer^N)	0.33	0.05	0.03	0.09	0.15	0.18
4 year changes						
corr(rer,rer^N)	0.65	0.18	-0.16	0.56	0.91	0.51
std(rer^N)/std(rer)	0.68	0.27	0.16	0.19	0.47	0.46
vardec(rer,rer^N)	0.54	0.12	0.03	0.06	0.40	0.34

TABLE B

COMPARISON OF GROSS DOMESTIC PRODUCT DEFLATORS AND GROSS OUTPUT DEFLATORS

Annual Data

	Canada 1980-1998	Germany 1980-2000	Japan 1980-2000	Korea 1980-2000	Mexico 1980-2000	weighted average
Levels						
corr(rer(GDP),rer(GO))	0.99	0.99	0.997	0.94	0.98	0.99
corr(rer^N(GDP),rer^N(GO))	0.96	0.97	0.89	0.86	0.97	0.94
std(rer(GDP))/std(rer(GO))	1.27	1.11	1.10	1.34	1.09	1.18
std(rer^N(GDP))/std(rer^N(GO))	2.23	1.68	1.74	1.66	1.52	1.87
Detrended levels						
corr(rer(GDP),rer(GO))	0.98	0.88	0.995	0.99	0.99	0.98
corr(rer^N(GDP),rer^N(GO))	0.88	0.80	0.69	0.86	0.98	0.86
std(rer(GDP))/std(rer(GO))	1.07	0.94	1.06	1.22	1.11	1.08
std(rer^N(GDP))/std(rer^N(GO))	1.77	1.51	1.57	1.22	1.45	1.59
1 year changes						
corr(rer(GDP),rer(GO))	0.99	0.99	0.99	0.99	0.99	0.99
corr(rer^N(GDP),rer^N(GO))	0.87	0.48	0.57	0.76	0.92	0.78
std(rer(GDP))/std(rer(GO))	1.04	1.05	1.05	1.19	1.09	1.06
std(rer^N(GDP))/std(rer^N(GO))	2.13	1.50	1.49	1.35	1.58	1.76
4 year changes						
corr(rer(GDP),rer(GO))	0.99	0.998	0.997	0.99	0.99	0.99
corr(rer^N(GDP),rer^N(GO))	0.96	0.85	0.71	0.90	0.99	0.91
std(rer(GDP))/std(rer(GO))	1.01	1.07	1.06	1.20	1.14	1.07
std(rer^N(GDP))/std(rer^N(GO))	1.47	1.75	1.49	1.28	1.42	1.47

EXTENDED RESULTS

Examine sample of 50 countries and all possible 1225 bilateral real exchange rates.

Use same methodology and summary statistics and CPI-PPI measures of prices.

Examine robustness of results to

1. Presence of U.S. in bilateral trade partner pairs in the sample.
2. Presence of rich-country/poor-country bilateral trade pairs in the sample.
3. Presence of high-inflation/low inflation bilateral trade pairs in the sample.

Find that there is a substantive relation between $rer_{i,us}$ and $rer_{i,us}^{N}$ on average.

The relation does not depend on these three factors (at least in the manner one might expect).

Strength of the relation depends crucially on size of the trade relationship between two trade partners.

COUNTRIES IN THE SAMPLE

Average percent world trade 1980–2005

Argentina	0.36	Hong Kong (P.R.C.)	2.52	Peru	0.12
Australia	1.12	India	0.66	Philippines	0.43
Austria	1.14	Indonesia	0.75	Saudi Arabia	1.31
Belgium	2.75	Ireland	0.73	South Africa	1.73
Brazil	0.94	Israel	0.41	Singapore	0.47
Canada	3.67	Italy	4.19	Spain	1.88
Chile	0.25	Japan	6.87	Sri Lanka	0.08
Colombia	0.20	Jordan	0.08	Sweden	1.37
Costa Rica	0.07	Korea	1.95	Switzerland	1.68
Cyprus	0.06	Luxembourg	0.17	Thailand	0.80
Denmark	0.83	Malaysia	1.04	Trinidad and Tobago	0.07
Egypt	0.26	Mexico	1.49	Turkey	0.54
El Salvador	0.04	Netherlands	3.84	United Kingdom	5.19
Finland	0.67	New Zealand	0.25	United States	13.60
France	5.64	Norway	0.79	Uruguay	0.05
Germany	9.24	Pakistan	0.20	Venezuela	0.42
Greece	0.39	Panama	0.15	Total	83.47

US BILATERAL REAL EXCHANGE RATES

Means weighted by trade

	all	income level		inflation		trade intensity		std(rer)	
		high	low	high	low	high	low	high	low
levels									
corr(rer, rer^N)	0.60	0.58	0.69	0.63	0.59	0.72	0.34	0.58	0.63
std(rer^N)/std(rer)	0.46	0.48	0.41	0.41	0.47	0.52	0.33	0.32	0.64
vdec(rer, rer^N)	0.30	0.31	0.24	0.22	0.31	0.37	0.12	0.15	0.48
4-quarter differences									
corr(rer, rer^N)	0.60	0.61	0.56	0.57	0.60	0.68	0.42	0.56	0.64
std(rer^N)/std(rer)	0.41	0.41	0.39	0.37	0.42	0.47	0.27	0.27	0.58
msedec(rer, rer^N)	0.20	0.21	0.17	0.17	0.21	0.26	0.08	0.10	0.34
16-quarter differences									
corr(rer, rer^N)	0.73	0.75	0.66	0.71	0.74	0.82	0.55	0.70	0.78
std(rer^N)/std(rer)	0.39	0.39	0.39	0.37	0.39	0.45	0.26	0.26	0.55
msedec(rer, rer^N)	0.24	0.24	0.22	0.22	0.24	0.31	0.09	0.11	0.40
countries	49	27	22	17	32	20	29	34	15
percent US trade	87.2	68.3	18.9	16.0	71.2	59.9	27.3	48.5	38.7

INCOME LEVELS

ALL BILATERAL REAL EXCHANGE RATES

Means weighted by trade

	all	high/ high	high/ low	low/ low
levels				
corr(rer, rer^{N})	0.52	0.46	0.72	0.63
std(rer^{N})/std(rer)	0.64	0.67	0.49	0.55
vdec(rer, rer^{N})	0.33	0.33	0.32	0.33
4-quarter differences				
corr(rer, rer^{N})	0.51	0.50	0.57	0.61
std(rer^{N})/std(rer)	0.50	0.53	0.39	0.43
msedec(rer, rer^{N})	0.22	0.22	0.18	0.22
16-quarter differences				
corr(rer, rer^{N})	0.64	0.63	0.66	0.71
std(rer^{N})/std(rer)	0.51	0.54	0.41	0.45
msedec(rer, rer^{N})	0.28	0.28	0.26	0.30
bilateral pairs	1225	378	616	231
percent of world trade	71.0	56.0	14.0	1.0

INFLATION LEVELS

ALL BILATERAL REAL EXCHANGE RATES

Means weighted by trade

	all	high/ high	high/ low	low/ low
levels				
corr(rer, rer^{N})	0.52	0.66	0.66	0.49
std(rer^{N})/std(rer)	0.64	0.54	0.48	0.67
vdec(rer, rer^{N})	0.33	0.32	0.28	0.34
4-quarter differences				
corr(rer, rer^{N})	0.51	0.66	0.58	0.50
std(rer^{N})/std(rer)	0.50	0.41	0.36	0.53
msedec(rer, rer^{N})	0.22	0.23	0.17	0.22
16-quarter differences				
corr(rer, rer^{N})	0.64	0.78	0.69	0.63
std(rer^{N})/std(rer)	0.51	0.42	0.38	0.53
msedec(rer, rer^{N})	0.28	0.28	0.24	0.28
bilateral pairs	1225	136	561	528
percent of world trade	71.0	0.6	10.5	59.8

TRADE INTENSITY AND REAL EXCHANGE RATE VARIABILITY

ALL BILATERAL REAL EXCHANGE RATES

Means weighted by trade

	all	trade intensity		std(rer)	
		high	low	high	low
levels					
corr(rer, rer^N)	0.52	0.57	0.47	0.63	0.44
std(rer^N)/std(rer)	0.64	0.71	0.57	0.42	0.79
vdec(rer, rer^N)	0.33	0.37	0.29	0.24	0.39
4-quarter differences					
corr(rer, rer^N)	0.51	0.57	0.47	0.58	0.47
std(rer^N)/std(rer)	0.50	0.64	0.38	0.32	0.63
msedec(rer, rer^N)	0.22	0.28	0.16	0.13	0.27
16-quarter differences					
corr(rer, rer^N)	0.64	0.69	0.60	0.69	0.60
std(rer^N)/std(rer)	0.51	0.61	0.43	0.33	0.64
msedec(rer, rer^N)	0.28	0.33	0.23	0.18	0.34
bilateral pairs	1225	49	1176	918	307
percent world trade	71.0	32.0	38.9	29.6	41.4

CHINA BILATERAL REAL EXCHANGE RATES

Means weighted by trade
Annual data

		income level		inflation		trade intensity		std(rer)	
	all	**high**	**low**	**high**	**low**	**high**	**low**	**high**	**low**
levels									
corr(rer, rer^N)	0.79	0.80	0.71	0.79	0.79	0.84	0.74	0.78	0.81
std(rer^N)/std(rer)	0.65	0.67	0.48	0.54	0.66	0.81	0.48	0.45	0.88
vdec(rer, rer^N)	0.46	0.47	0.34	0.41	0.46	0.59	0.32	0.30	0.64
1-year lags									
corr(rer, rer^N)	0.38	0.37	0.46	0.57	0.37	0.44	0.30	0.42	0.32
std(rer^N)/std(rer)	0.38	0.38	0.35	0.36	0.38	0.44	0.31	0.27	0.49
msedec(rer, rer^N)	0.16	0.16	0.15	0.17	0.16	0.21	0.11	0.09	0.24
4-year lags									
corr(rer, rer^N)	0.86	0.87	0.76	0.86	0.86	0.92	0.79	0.84	0.88
std(rer^N)/std(rer)	0.56	0.57	0.44	0.48	0.56	0.63	0.48	0.41	0.73
msedec(rer, rer^N)	0.48	0.49	0.33	0.39	0.48	0.60	0.35	0.29	0.69
countries	50	28	22	17	33	2	48	40	10
percent China trade	89.4	82.3	7.1	3.9	85.5	47.0	42.4	47.2	42.2

TRADE BLOCS

US BILATERAL REAL EXCHANGE RATES

Means weighted by trade

	all	**EU**	**non-EU**	**NAFTA**	**non-NAFTA**	**other**
levels						
corr(rer, rer^N)	0.60	0.27	0.71	0.81	0.52	0.63
std(rer^N)/std(rer)	0.46	0.32	0.51	0.55	0.42	0.48
vdec(rer, rer^N)	0.30	0.10	0.36	0.49	0.20	0.26
4-quarter differences						
corr(rer, rer^N)	0.60	0.41	0.66	0.69	0.55	0.63
std(rer^N)/std(rer)	0.41	0.22	0.47	0.50	0.37	0.45
msedec(rer, rer^N)	0.20	0.05	0.25	0.33	0.14	0.19
16-quarter differences						
corr(rer, rer^N)	0.73	0.57	0.79	0.80	0.70	0.78
std(rer^N)/std(rer)	0.39	0.22	0.44	0.49	0.34	0.41
msedec(rer, rer^N)	0.24	0.07	0.29	0.39	0.17	0.22
countries	49	14	35	2	47	33
percent US trade	87.2	21.0	66.2	28.6	58.6	37.6

TRADE BLOCS
ALL BILATERAL REAL EXCHANGE RATES
Means weighted by trade

	all	EU/ EU	EU/ NAFTA	EU/ other	NAFTA/ NAFTA	NAFTA/ other	other/ other
levels							
corr(rer, rer^N)	0.52	0.35	0.30	0.54	0.81	0.63	0.67
std(rer^N)/std(rer)	0.64	0.88	0.33	0.59	0.54	0.49	0.57
vdec(rer, rer^N)	0.33	0.35	0.11	0.32	0.48	0.27	0.38
4-quarter differences							
corr(rer, rer^N)	0.51	0.43	0.41	0.44	0.69	0.63	0.60
std(rer^N)/std(rer)	0.50	0.71	0.22	0.37	0.50	0.44	0.42
msedec(rer, rer^N)	0.22	0.27	0.06	0.15	0.33	0.19	0.21
16-quarter differences							
corr(rer, rer^N)	0.64	0.57	0.55	0.56	0.80	0.78	0.69
std(rer^N)/std(rer)	0.51	0.72	0.24	0.43	0.49	0.41	0.44
msedec(rer, rer^N)	0.28	0.33	0.08	0.23	0.38	0.23	0.31
bilateral pairs	1225	91	42	462	3	99	528
percent world trade	71.0	23.1	6.6	12.3	7.9	11.3	9.8

ALL BILATERAL REAL EXCHANGE RATES

Unweighted means

		trade intensity		std(rer)		trading blocs					
	all	**high**	**low**	**high**	**low**	**EU/ EU**	**EU/ NAFTA**	**EU/ other**	**NAFTA/ NAFTA**	**NAFTA/ other**	**other/ other**
levels											
corr(rer, rer^N)	0.59	0.56	0.60	0.66	0.39	0.52	0.50	0.56	0.74	0.60	0.65
std(rer^N)/std(rer)	0.59	0.87	0.58	0.53	0.77	0.85	0.34	0.54	0.42	0.53	0.63
vdec(rer, rer^N)	0.35	0.40	0.35	0.34	0.36	0.41	0.14	0.30	0.30	0.30	0.40
4-quarter differences											
corr(rer, rer^N)	0.51	0.52	0.51	0.55	0.39	0.47	0.51	0.49	0.59	0.54	0.53
std(rer^N)/std(rer)	0.43	0.72	0.42	0.38	0.58	0.70	0.24	0.37	0.40	0.46	0.45
msedec(rer, rer^N)	0.20	0.27	0.20	0.18	0.24	0.28	0.07	0.16	0.22	0.20	0.23
16-quarter differences											
corr(rer, rer^N)	0.59	0.62	0.59	0.62	0.48	0.60	0.57	0.56	0.65	0.63	0.60
std(rer^N)/std(rer)	0.46	0.70	0.45	0.42	0.60	0.70	0.26	0.40	0.39	0.47	0.49
msedec(rer, rer^N)	0.28	0.35	0.28	0.27	0.31	0.36	0.09	0.23	0.24	0.27	0.33
bilateral pairs	1225	49	1176	918	307	91	42	462	3	99	528
percent world trade	71.0	32.0	38.9	29.6	41.4	23.1	6.6	12.3	7.9	11.3	9.8

TRADE WEIGHTED REGRESSIONS

Standard errors in parentheses

	sum income	**diff income**	**sum inflation**	**diff inflation**	**trade intensity**	**std(rer)**	**EU/ EU**	**EU/ NAFTA**	**EU/ other**	**NAFTA/ NAFTA**	**NAFTA/ other**	**constant**	R^2
levels													
corr(rer, rer^N)	–0.004 (0.018)	–0.011 (0.021)	–0.200 (0.131)	0.044 (0.151)	0.314* (0.117)	1.617* (0.165)	–0.099* (0.037)	–0.268* (0.044)	–0.024 (0.037)	0.091 (0.080)	–0.013 (0.037)	0.382 (0.380)	0.292
std(rer^N)/std(rer)	–0.019 (0.020)	0.064* (0.023)	0.066 (0.142)	0.392* (0.163)	0.821* (0.127)	–2.813* (0.179)	–0.001 (0.040)	–0.236* (0.047)	–0.0414 (0.040)	–0.714* (0.087)	–0.197* (0.040)	1.336* (0.412)	0.363
vdec(rer, rer^N)	–0.015 (0.011)	0.011 (0.013)	–0.048 (0.080)	0.202* (0.092)	0.230* (0.071)	–0.878* (0.101)	–0.121* (0.022)	–0.264* (0.027)	–0.074* (0.022	–0.088 (0.049)	–0.144* (0.022)	0.821* (0.232)	0.242
4-quarter lags													
corr(rer, rer^N)	0.001 (0.009	–0.070* (0.011)	–0.116 (0.067)	0.035 (0.077)	0.003 (0.060)	1.520* (0.085)	–0.029 (0.019)	–0.173* (0.022)	–0.098* (0.019	0.181* (0.041)	0.058* (0.019)	0.352 (0.195)	0.419
std(rer^N)/std(rer)	–0.011 (0.021	0.099* (0.024)	0.072 (0.148)	0.100 (0.170)	1.016* (0.132)	–2.631* (0.186)	0.012 (0.041)	–0.169* (0.049)	–0.084* (0.041	–0.712* (0.090)	–0.096* (0.041)	0.951* (0.428)	0.313
msedec(rer, rer^N)	–0.008 (0.008	0.021* (0.009)	0.035 (0.054)	0.058 (0.062)	0.235* (0.048)	–0.965* (0.068)	–0.048* (0.015)	–0.155* (0.018)	–0.081* (0.015	–0.088* (0.033)	–0.050* (0.015)	0.519* (0.157)	0.354
16-quarter lags													
corr(rer, rer^N)	–0.007 (0.011	–0.092* (0.013)	–0.173* (0.076)	0.246* (0.088)	0.218* (0.068)	1.358* (0.096)	–0.018 (0.021)	–0.129* (0.026)	–0.071* (0.021	0.041 (0.047)	0.080* (0.021)	0.616* (0.221)	0.333
std(rer^N)/std(rer)	–0.011 (0.019	0.098* (0.023)	0.104 (0.139)	0.060 (0.159)	0.406* (0.123)	–2.524* (0.175)	0.033 (0.039)	–0.198* (0.046)	–0.080* (0.039	–0.351* (0.085)	–0.097* (0.039)	1.014* (0.402)	0.301
msedec(rer, rer^N)	–0.016 (0.009	0.026* (0.011)	–0.034 (0.067)	0.229* (0.077)	0.297* (0.060)	–1.111* (0.085)	–0.076* (0.019)	–0.208* (0.022)	–0.090* (0.019	–0.159* (0.041)	–0.110* (0.019)	0.778* (0.195)	0.314

THEORETICAL MODEL

Take new approach to investigating origins of real exchange rate fluctuations — allow goods to differ by degree of tradability.

Two factors determine tradability of a good:

1. degree of substitutability in consumption with same good produced in other countries
2. size of real cost of trade between any two countries for a particular good.

IN THE MODEL, THE DEGREE OF TRADABILITY OF A GOOD IS EXACTLY EQUAL TO ITS DEGREE OF ACTUAL TRADEDNESS.

OUTLINE

1. MOTIVATION

Characterize sources of real exchange rate movements; changes in international relative prices of nontraded/traded goods.

2. THEORY

Develop J sector, I country intertemporal model of real exchange rate determination.

Allow three possible sources of deviations from law of one price at sectoral level.

3. CALIBRATED MODEL

Quantitatively evaluate a 3 sector, 2 country model, calibrated to data on Mexico and United States.

4. MODEL WITH MONEY

Superimpose a quantity theory model of money to be able to compare nominal and real exchange rate movements.

FUNDAMENTAL HYPOTHESIS IS THAT TRADABILITY EQUALS TRADEDNESS.

MOTIVATION

$$RER = NER \times \frac{P_{us}}{P_{mex}}$$

$$= \frac{pesos}{dollar} \times \frac{dollars/basket_{us}}{pesos/basket_{mex}} = \frac{baskets_{mex}}{basket_{us}}$$

Traditional way to think about RER movements:

no movements in international relative price of traded goods when law of one price holds.

movements in internal relative price of nontraded to traded goods across countries determines RER.

Suppose law of one price holds for all traded goods;

$$P_{mex}^{T} = NER \times P_{us}^{T}.$$

RER when law of one price holds is

$$RER^{N} = \frac{P_{mex}^{T}}{P_{us}^{T}} \times \frac{P_{us}}{P_{mex}},$$

$$RER^{N} = \frac{P_{us}}{P_{us}^{T}} / \frac{P_{mex}}{P_{mex}^{T}}.$$

RER^{N} is exactly equal to the RER when there are no law of one price deviations.

Compare RER and RER^N in data for Mexico and US 1980-1998; they are not the same at all.

$$\sigma(RER) = 2.81 \times \sigma(RER^N),$$

$$corr(RER, RER^N) = 0.82.$$

Traded goods: agriculture, mining, and manufacturing;

Nontraded goods: services and construction.

TABLE 1
Tradedness and Deviations From Law of One Price: 1980-1998

Sector	Tradedness	Deviation
Primaries *	20.37	17.63
Manufactures *	36.37	15.10
Services	4.30	24.26

Tradedness

$$100 \times (imports_{i,1993} + exports_{i,1993})/gross\ output_{i,1993}$$

Deviation

$$100 \times [\sum_{t=1980}^{1998} (\log RER_{it} - \overline{\log RER_i})^2/18]^{1/2},$$

where RER_{it} is real exchange rate for sector i

(RER_{it} is constant if law of one price holds).

THE MODEL

There are I countries, J sectors/types of goods in every country.

Same types of good produced in different countries are imperfect substitutes in consumption.

In addition, goods are technologically differentiated: there are transactions costs of trade.

Size of costs of trade plus degree of substitutability in consumption determine tradability of each of $I \times J$ goods.

CONSUMER-WORKERS

Representative consumer in country i has the period utility function:

$$u^i(c^i_1(c^i_{11},\ldots,c^i_{1I}),\ldots,c^i_J(c^i_{J1},\ldots,c^i_{JI}),\ell^i;z^i)$$

Here, c^i_{jh} is consumption in country i of good j produced in country h, ℓ^i is leisure in country i, and z^i is a real demand shock.

SECTORS

Each good is produced by one sector with a production function of the form (for country h, good j)

$$y_{jh} = f_{jh}(\ell_{jh}).$$

Economy must satisfy the feasibility conditions

$$\sum_{i=1}^{I}(1+\delta^i_{jh})c^i_{jh} = y_{jh}, \;\; j = 1,\ldots,J; \; h = 1,\ldots,I;$$

$$\sum_{j=1}^{J}\ell_{ji} + \ell^i = \bar{\ell}^i, \;\; i = 1,\ldots,I.$$

UNCERTAINTY

At every date t, there are K possible events $\eta_t = 1, \ldots, \text{K}$;
$(z^1(\eta_t), \ldots, z^I(\eta_t))$ are idiosyncratic demand shocks at t.

η is governed by a stationary first order Markov process,
with transition matrix $\Pi(\eta, \eta')$ where $\pi_{ij} = prob(\eta_t = j | \eta_{t-1} = i)$.

A *state* is a history of events $s = (\eta_0, \eta_1, \ldots, \eta_{t(s)})$;
then $\pi(s) = \pi_{\eta_0 \eta_1} \pi_{\eta_1 \eta_2} \cdots \pi_{\eta_{t(s)-1} \eta_{t(s)}}$.

Set of states S is countable.

THE CONSUMER'S SEQUENTIAL MARKETS PROBLEM

Consumers can trade in spot markets and a complete set of Arrow securities in every state.

$$max \quad \sum_{s \in S} \beta^{t(s)} \pi(s) u^i(c^i_{1s}, \ldots, c^i_{Js}, \ell^i_s; z^i(\eta_s))$$

$$s.t. \quad \sum_{j=1}^{J} \sum_{h=1}^{I} (1 + \delta^i_{jh}) p_{jhs} c^i_{jhs} + \sum_{\eta'=1}^{K} q_{(s,\eta')} b^i_{(s,\eta')}$$

$$\leq w^i_s(\bar{\ell}^i - \ell^i_s) + r^i_s + b^i_s \;\; for \; all \; s$$

$$c^i_{js} = c^i_j(c^i_{j1s}, \ldots, c^i_{jIs}) \;\; for \; all \; i, j, s$$

$$r^i_s = \sum_{j=1}^{J} (p_{jis} y_{jis} - w^i_s \ell_{jis}) \;\; for \; all \; i, s$$

$$b^i_s \geq -\overline{B} \;\; for \; all \; s$$

$$b^i_{\eta_0} = 0.$$

PROFIT MAXIMIZATION BY SECTORS

$$max \quad p_{jhs} y_{jhs} - w_s^h \ell_{jhs}$$

$$s.t. \quad y_{jhs} = f_{jh}(\ell_{jhs}).$$

$$r_s^i = \sum_{j=1}^{J} (p_{jis} y_{jis} - w_s^i \ell_{jis})$$

SEQUENTIAL MARKETS EQUILIBRIUM

A *sequential markets equilibrium* is a sequence of quantities $(\hat{c}^i_{js}, \hat{c}^i_{jhs}, \hat{\ell}^i_s, \hat{b}^i_s, \hat{y}_{jhs}, \hat{\ell}_{jhs})$, prices $\left(\hat{p}^i_{jhs}, \hat{w}^i_s, \hat{q}_{(s,\eta)}\right)$, and profits $\hat{r}^i_s$, such that

i) given prices and profits the quantities $\left(\hat{c}^i_{js}, \hat{c}^i_{jhs}, \hat{\ell}^i_s, \hat{b}^i_s\right)$ solve the utility maximization problem of consumer i;

ii) given prices, the quantities $\left(\hat{y}_{jhs}, \hat{\ell}_{jhs}\right)$ solve the profit maximization problem of sector j in country h in state s;

iii) $\hat{r}^i_s$ are profits in country i in state s;

iv) the quantities $\left(\hat{c}^i_{jhs}, \hat{\ell}^i_s, \hat{y}_{jhs}, \hat{\ell}_{jhs}\right)$ satisfy the feasibility conditions;

v) the Arrow securities $\hat{b}^i_s$ satisfy the market clearing conditions

$$\sum_{i=1}^{I} \hat{b}^i_s = 0 \text{ in state } s.$$

COMPUTING EQUILIBRIUM

WORLD PLANNER'S DYNAMIC PROBLEM

For a given vector of welfare weights $a = (a^1, \ldots, a^I)$ solve the world planner's problem

$$max \quad \sum_{i=1}^{I} a^i \sum_{s \in S} \beta^{t(s)} \pi(s) u^i(c^i_{1s}, \ldots, c^i_{ns}, \ell^i_s; z^i(\eta_s))$$

$$s.t. \quad \sum_{i=1}^{I} (1 + \delta^i_{jh}) c^i_{jhs} \le f_{jh}(\ell_{jhs}) \;\; for\ all\ j, h, s$$

$$\sum_{j=1}^{J} \ell_{jis} + \ell^i_s \le \bar{\ell}^i \;\; for\ all\ i, s$$

$$c^i_{js} = c^i_j(c^i_{j1s}, \ldots, c^i_{jIs}) \;\; for\ all\ i,j,s.$$

WORLD PLANNER'S STATIC PROBLEM

It is easy to show that the solution to this infinite horizon problem can be derived by solving the K static problems

$$max \quad \sum_{i=1}^{I} a^i u^i(c_1^i, \ldots, c_J^i, \ell^i; z^i(\eta))$$

$$s.t. \quad \sum_{i=1}^{I} (1 + \delta_{jh}^i) c_{jh}^i \leq f_{jh}(\ell_{jh}) \ \ for \ all \ j,h$$

$$\sum_{j=1}^{J} \ell_{jh} + \ell^i \leq \bar{\ell}^i \ \ for \ all \ i$$

$$c_j^i = c_j^i(c_{j1}^i, \ldots, c_{jI}^i) \ \ for \ all \ i,j.$$

Denote the solution to this problem by

$$(c_j^i(a,\eta), c_{jh}^i(a,\eta), \ell^i(a,\eta), y_{jh}(a,\eta), \ell_{jh}(a,\eta)).$$

PRICES

Define the prices $(p_{jh}(a,\eta), w^i(a,\eta), q(a,\eta,\eta'))$ and profits $P^h(a,\eta)$ by the following rules

$$p_{jh}(a,\eta) = a^h \frac{\partial u^h(c_1^h,\ldots,c_n^h,\ell^h;z^h(\eta))}{\partial c_j^h} \times \frac{\partial c_j^h(c_{j1}^h,\ldots,c_{jm}^h)}{\partial c_{jh}^h}$$

$$w^i(a,\eta) = a^i \frac{\partial u^i(c_1^i,\ldots,c_n^i,\ell^i;z^i(\eta))}{\partial \ell^i}$$

$$q(a,\eta,\eta') = \beta\pi_{\eta,\eta'}.$$

$$r^h(a,\eta) = \sum_{j=1}^{J}(p_{jh}(a,\eta)y_{jh}(a,\eta) - w^h(a,\eta)\ell_{jh}(a,\eta)).$$

Numeraire is marginal social welfare in event η.

TRANSFER FUNCTIONS

The transfer to country i when event η occurs is given by

$$\tau^i(a,\eta) = \sum_{j=1}^{J}\sum_{h=1}^{I} p_{jh}(a,\eta)(1+\delta^i_{jh})c^i_{jh}(a,\eta) - \sum_{j=1}^{J} p_{ji}(a,\eta)y_{ji}(a,\eta).$$

$\tau^i(a,\eta)$ is the trade deficit of country i when event η occurs (measured in units of marginal social welfare in event η.

The present value of all current and future savings given utility weights a and current event η is given by

$$b^i(a,\eta) = -\tau^i(a,\eta) + \beta \sum_{\eta'=1}^{K} \pi_{\eta\eta'} b^i(a,\eta').$$

Notice that this is a Bellman equation.

Theorem 1

Suppose that sequence of quantities $\left(\widehat{c}^{\,i}_{js}, \widehat{c}^{\,i}_{jhs}, \widehat{\ell}^{\,i}_{s}, \widehat{b}^{\,i}_{s}, \widehat{y}_{jhs}, \widehat{\ell}_{jhs}\right)$, prices $\left(\widehat{p}^{\,i}_{jhs}, \widehat{w}^{\,i}_{s}, \widehat{q}_{(s,\eta)}\right)$, and profits $\widehat{r}^{\,i}_{s}$ is an equilibrium. Then $\left(\widehat{c}^{\,i}_{js}, \widehat{c}^{\,i}_{jhs}, \widehat{\ell}^{\,i}_{s}, \widehat{b}^{\,i}_{s}, \widehat{y}_{jhs}, \widehat{\ell}_{jhs}\right)$ solves the static social planner's problem in event η_s.

Conversely suppose that $(c^i_j(\widehat{a},\eta), c^i_{jh}(\widehat{a},\eta), \ell^i(\widehat{a},\eta), y_{jh}(\widehat{a},\eta), \ell_{jh}(\widehat{a},\eta))$ solves the static social planner's problem. If $b^i(\widehat{a},\eta_0) = 0$ for all i, then the sequence

$$\left(\widehat{c}^{\,i}_{js}, \widehat{c}^{\,i}_{jhs}, \widehat{\ell}^{\,i}_{s}, \widehat{b}^{\,i}_{s}, \widehat{y}_{jhs}, \widehat{\ell}_{jhs}\right) =$$

$$(c^i_j(\widehat{a},\eta_s), c^i_{jh}(\widehat{a},\eta_s), \ell^i(\widehat{a},\eta_s), y_{jh}(\widehat{a},\eta_s), \ell_{jh}(\widehat{a},\eta_s))$$

$\left(\widehat{p}^{\,i}_{jhs}, \widehat{w}^{\,i}_{s}, \widehat{q}_{(s,\eta)}\right) = (p_{jh}(\widehat{a},\eta_s), w^i(\widehat{a},\eta_s), q(\widehat{a},\eta_s,\eta))$, and $\widehat{r}^{\,i}_{s} = r^i(\widehat{a},\eta_s)$ is an equilibrium.

Theorem 2

There exists a vector of welfare weights, $\hat{a}=\left(\hat{a}^1,\ldots,\hat{a}^I\right)$ such that $b^i(\hat{a},\eta_0) = 0,\ i = 1,\ldots,I.$

In practice, rather than compute $\hat{a}$, we calibrate the model so that the values of output, consumption, and trade in a benchmark year, 1993 in the case of our Mexico-U.S. model, are an equilibrium. This allows us to calibrate the vector $\hat{a}$

CALIBRATED MODEL

Calibrate sectoral parameters ($\zeta^i_j,\ \theta_{jh},\ \delta^i_{jh}$) to match bilateral trade and output numbers by sector for benchmark year, 1993.

Take elasticity parameters from international real business cycle literature.

Compute statistics from 1980-1998 data that is logged and linearly detrended.

Compare statistics to those implied by model.

Markov process for η_t is calibrated, matches standard deviations/ autocorrelations of output.

Compare deviations from the law of one price with those in the model, sector by sector.

MEXICO-US CALIBRATED MODEL

$$u^i(c^i_{pri}, c^i_{man}, c^i_{ser}, \ell^i; z^i) =$$

$$\frac{\left(z^i \left(\left(\sum_{j=pri,man,ser} \zeta^i_j c^{i^\gamma}_j \right)^{1/\gamma} \right)^{\epsilon} + (1 - z^i)\ell^{i^\epsilon} \right)^{\psi/\epsilon} - 1}{\psi},$$

where

$$c^i_j = (\alpha_{mex} c^{i^\rho}_{j,mex} + \alpha_{us} c^{i^\rho}_{j,us})^{\frac{1}{\rho}},\ j = pri, man, ser$$

$$y_{ji} = \theta_{ji} \ell^{\lambda_{ji}}_{ji},\ j = pri, man, ser;\ i = mex, us$$

$$c^{mex}_{j,mex} + c^{us}_{j,mex}(1 + \delta^{us}_{j,mex}) = y_{j,mex},\ j = pri, man, ser$$

$$c^{mex}_{j,us}(1 + \delta^{mex}_{j,us}) + c^{us}_{j,us} = y_{j,us},\ j = pri, man, ser.$$

TABLE 2

1993 Benchmark Data Set
(Billion U.S. Dollars)

Variable	Mexico	U.S.
$\mathbf{y}^{j}_{pri}$	42.528	393.037
$\mathbf{y}^{j}_{man}$	200.469	3082.868
$\mathbf{y}^{j}_{ser}$	391.132	7820.442
$(\mathbf{1}+\boldsymbol{\delta}^{mex}_{pri,j})c^{mex}_{pri,j}$	35.870	2.006
$(\mathbf{1}+\boldsymbol{\delta}^{us}_{pri,j})c^{us}_{pri,j}$	6.658	391.031
$(\mathbf{1}+\boldsymbol{\delta}^{mex}_{man,j})c^{mex}_{man,j}$	167.197	39.629
$(\mathbf{1}+\boldsymbol{\delta}^{us}_{man,j})c^{us}_{man,j}$	33.272	3043.239
$(\mathbf{1}+\boldsymbol{\delta}^{mex}_{ser,j})c^{mex}_{ser,j}$	382.778	8.451
$(\mathbf{1}+\boldsymbol{\delta}^{us}_{ser,j})c^{us}_{ser,j}$	8.354	7811.991

PARAMETERIZE MARKOV PROCESS

Grid of 3 shocks on $(\bar{z}^i - 1/d^i, \bar{z}^i, \bar{z}^i + d^i)$.

$$\Pi^i = \begin{bmatrix} 1-2\pi^i & \pi^i & \pi^i \\ \pi^i & 1-2\pi^i & \pi^i \\ \pi^i & \pi^i & 1-2\pi^i \end{bmatrix}$$

3 parameters ($\bar{z}^i,\ d^i,\ \pi^i$) to match 3 observations for each country:

- 1993 output compared to mean output
- standard deviation of output
- serial correlation of output.

Shocks are independent across countries. $K = 3 \times 3$.

CALIBRATION OF TRANSPORTATION COSTS

$$\frac{\partial u^{mex}}{\partial c^{mex}_{man}}(\alpha_{mex} c^{mex^{\rho}}_{man,mex} + \alpha_{us} c^{mex^{\rho}}_{man,us})^{\frac{1}{\rho}-1} \alpha_{mex} c^{mex^{\rho-1}}_{man,mex} = p_{man,mex}$$

$$\frac{\partial u^{mex}}{\partial c^{mex}_{man}}(\alpha_{mex} c^{mex^{\rho}}_{man,mex} + \alpha_{us} c^{mex^{\rho}}_{man,us})^{\frac{1}{\rho}-1} \alpha_{us} c^{mex^{\rho-1}}_{man,us} = p_{man,us}(1 + \delta^{mex}_{man,us})$$

$$\frac{c^{mex}_{man,us}}{c^{mex}_{man,mex}} = \left(\frac{\alpha_{us} p_{man,mex}}{\alpha_{mex} p_{man,us}(1 + \delta^{mex}_{man,us})} \right)^{\frac{1}{1-\rho}}$$

In base year, 1993, $p_{man,mex} = p_{man,us} = 1$,

$$\frac{(1 + \delta^{mex}_{man,us}) c^{mex}_{man,us}}{c^{mex}_{man,mex}} = \left(\frac{\alpha_{us}}{\alpha_{mex}} \right)^{\frac{1}{1-\rho}} (1 + \delta^{mex}_{man,us})^{\frac{-\rho}{1-\rho}}.$$

Similarly,

$$\frac{c^{us}_{man,us}}{(1 + \delta^{us}_{man,mex}) c^{us}_{man,mex}} = \left(\frac{\alpha_{us}}{\alpha_{mex}} \right)^{\frac{1}{1-\rho}} (1 + \delta^{us}_{man,mex})^{\frac{\rho}{1-\rho}}.$$

In the absence of δ^i_{jh}'s,

$$\frac{c^{mex}_{man,us}}{c^{mex}_{man,mex}} = \frac{c^{us}_{man,us}}{c^{us}_{man,mex}} = \frac{y_{man,us}}{y_{man,mex}} = \frac{3082.868}{200.469} = 15.378$$

Suppose $\rho = 0.8,\ \alpha_{mex} = 0.4,\ \alpha_{us} = 0.6$:

$$\frac{(1+\delta^{mex}_{man,us})c^{mex}_{man,us}}{c^{mex}_{man,mex}} = \frac{33.272}{167.197} = 0.199,\quad \delta^{mex}_{man,us} = 1.485$$

$$\frac{c^{us}_{man,us}}{(1+\delta^{us}_{man,mex})c^{us}_{man,mex}} = \frac{3043.239}{39.629} = 76.793,\quad \delta^{us}_{man,mex} = 0.783.$$

Notice that $\rho = 0.8$ implies far more substitutability than does $\rho = 0.33$. With $\rho = 0.33$ (and $\alpha_{mex} = 0.25,\ \alpha_{us} = 0.75$),

$$\delta^{mex}_{man,us} = 739.232,\ \delta^{us}_{man,mex} = 239.964.$$

Home country bias is large for low values of ρ.

We have much lower values of δ^i_{jh} if we allow α^i_{jh} to differ across countries. (The models are equivalent.)

TABLE 3

Parameter Values

parameter	value	source
γ	-1.25	Stockman/Tesar (1994)
ϵ	0.00	Backus/Kehoe/Kydland (1992)
ρ	0.33	Backus/Kehoe/Kydland (1994)
ψ	-1.00	Backus/Kehoe/Kydland (1992)
λ_{ji}	0.33	Chari/Kehoe/McGrattan (1997)

MOMENTS

Consider some variable x in country i and a second variable y in country h; $i, h = mex, us$: $x^i(\eta^1, \eta^2)$ and $y^h(\eta^1, \eta^2)$.

Mean of x^i:

$$\mu(x^i) = \sum_{\eta^1=1}^{3} \sum_{\eta^2=1}^{3} \bar{\pi}^1_{\eta^1} \bar{\pi}^2_{\eta^2} x^i(\eta^1, \eta^2)$$

Variance of x^i:

$$\sigma^2(x^i) = \sum_{\eta^1=1}^{3} \sum_{\eta^2=1}^{3} \bar{\pi}^1_{\eta^1} \bar{\pi}^2_{\eta^2} (x^i(\eta^1, \eta^2) - \mu(x^i))^2$$

Correlation of x^i and y^h:

$$\rho(x^i, y^h) = \frac{1}{\sigma(x^i)\sigma(y^h)} \times \sum_{\eta^1=1}^{3}\sum_{\eta^2=1}^{3} \bar{\pi}^1_{\eta^1}\bar{\pi}^2_{\eta^2}(x^i(\eta^1,\eta^2) - \mu(x^i)) \times (y^h(\eta^1,\eta^2) - \mu(y^h))$$

Autocorrelation of x^i:

$$\rho\left(x^i, x^{i'}\right) = \frac{1}{\sigma^2(x^i)} \times \sum_{\eta^1=1}^{K^1}\sum_{\eta^2=1}^{K^2} \bar{\pi}^1_{\eta^1}\bar{\pi}^2_{\eta^2}(x^i(\eta^1,\eta^2) - \mu(x^i))$$

$$\times \sum_{\eta^{1'}=1}^{3}\sum_{\eta^{2'}=1}^{3} \pi_{\eta^1\eta^{1'}}\pi_{\eta^2\eta^{2'}}\left(x^i(\eta^{1'},\eta^{2'}) - \mu(x^i)\right)$$

Here, $\bar{\pi}^i_{\eta^i}$ is invariant distribution of η^i.

RESULTS

TABLE 4

Deviations from Law of One Price

	DATA	MODEL
Primaries	17.69	13.45
Manufactures	15.10	12.03
Services	24.18	18.94

Deviation

$$100 \times \{\sum_{\eta^1=1}^{3}\sum_{\eta^2=1}^{3} \bar{\pi}^1_{\eta^1}\bar{\pi}^2_{\eta^2}[\log(p_{j1}(\eta^1,\eta^2)/p_{j2}(\eta^1,\eta^2)) - \mu(\log(p_{j1}/p_{j2}))]^2\}^{1/2}$$

TABLE 5

Standard Deviations and Autocorrelations

	DATA		MODEL	
	σ	ρ	σ	ρ
Y^{us}	2.417	0.506	2.417	0.506
TB^{us}	0.060	0.616	0.107	0.563
Y^{mex}	4.950	0.578	4.950	0.578
TB^{mex}	1.448	0.599	2.467	0.563
RER	19.519	0.586	16.276	0.564
$\widehat{RER}$	6.949	0.807	4.008	0.565

TABLE 6

Correlations
data/(model)

	Y^{us}	TB^{us}	Y^{mex}	TB^{mex}	RER
TB^{us}	–0.284 (–0.421)				
Y^{mex}	–0.209 (0.071)	0.286 (0.866)			
TB^{mex}	0.473 (0.421)	–0.984 (–0.979)	–0.361 (–0.870)		
RER	0.343 (0.426)	–0.736 (–0.996)	–0.747 (–0.870)	0.781 (0.992)	
RER^{N}	0.322 (0.421)	–0.371 (–0.993)	–0.836 (–0.874)	0.436 (0.996)	0.817 (0.999)

TABLE 7

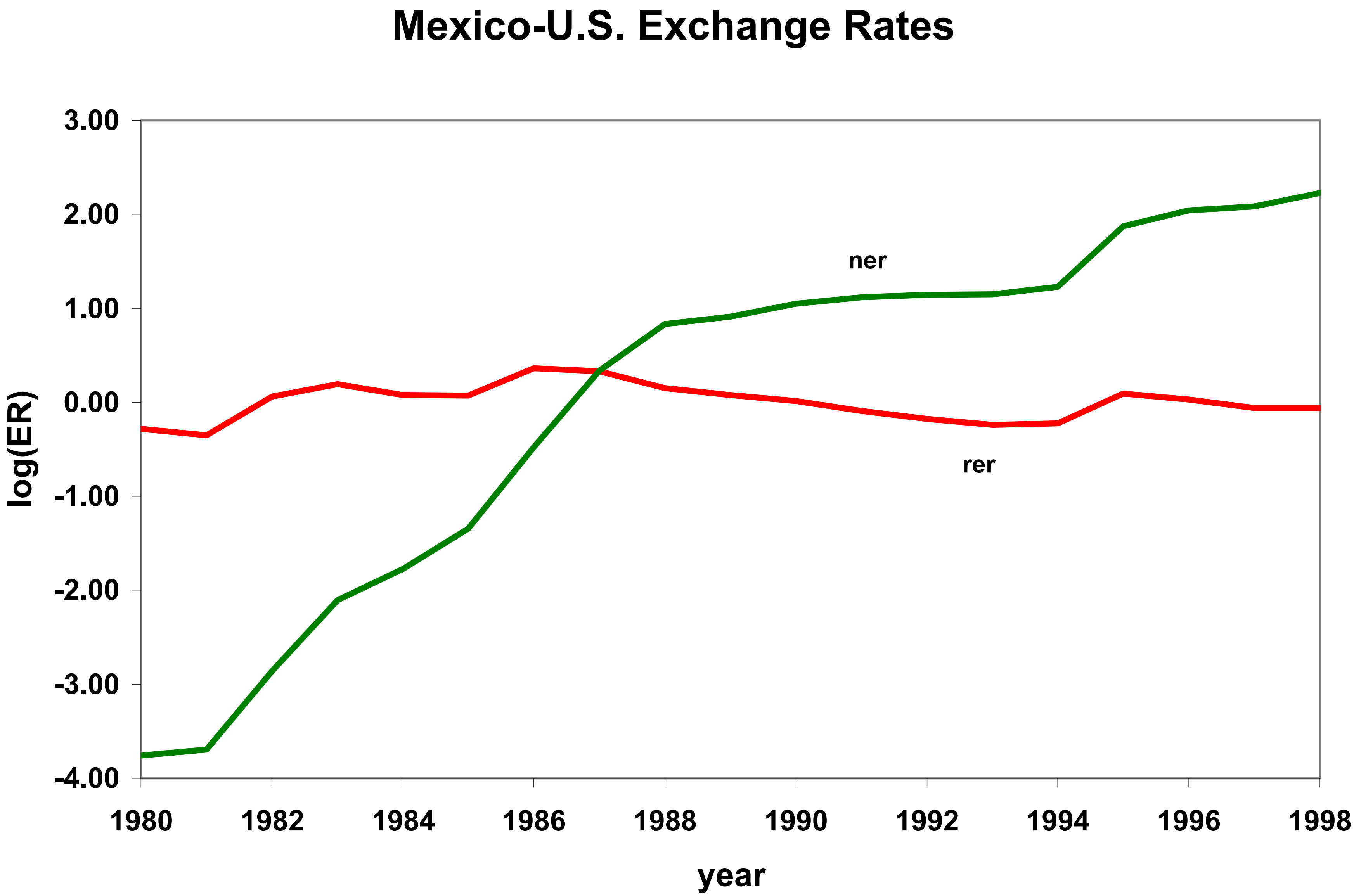
Deviations from Law of One Price
Alternative Specifications

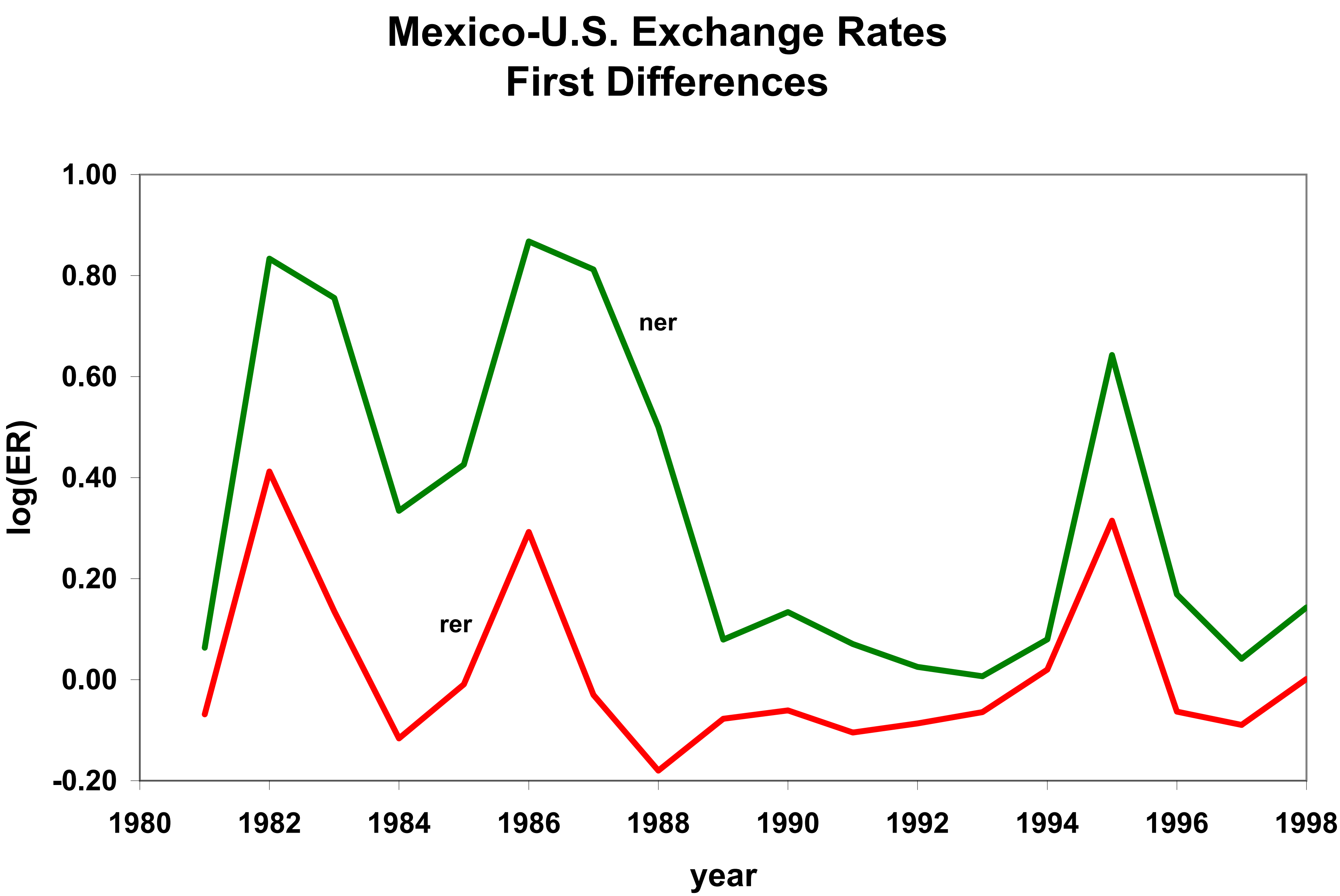
	DATA	MODEL	MODEL	MODEL	MODEL
		base case	$\rho = 0.80$	$\lambda_{ji} = 0.25$	$\gamma = -4.00$
pri	17.63	13.45	7.72	18.12	12.88
man	15.10	12.03	6.25	16.03	11.06
ser	24.26	18.94	16.10	26.91	19.77

TABLE 8

Standard Deviations - Alternative Specifications

	DATA	MODEL	MODEL	MODEL	MODEL
		base case	$\rho = 0.80$	$\lambda_{ji} = 0.25$	$\gamma = -4.00$
$\mathbf{Y}^{\mathbf{us}}$	2.417	2.417	2.417	2.417	2.417
$\mathbf{TB}^{\mathbf{us}}$	0.060	0.107	0.236	0.136	0.098
$\mathbf{Y}^{\mathbf{mex}}$	4.950	4.950	4.950	4.950	4.950
$\mathbf{TB}^{\mathbf{mex}}$	1.448	2.467	5.184	3.390	2.267
RER	19.519	16.276	12.240	22.629	16.385
$\mathbf{RER}^{N}$	6.949	4.008	5.726	6.250	5.011


Mexico-U.S. Exchange Rates
3.00
2.00
1.00
0.00
-1.00
-2.00
-3.00
-4.00
log(ER)
ner
rer
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
year


Mexico-U.S. Exchange Rates
First Differences
log(ER)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
ner
rer
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
year

MONETARY MODEL

Money is a veil.

Each country $i = 1, 2, \ldots, I$ has a monetary authority that prints distinct fiat currency i.

Goods must be paid for in the currency of the producer's country.

MONETARY SHOCKS

$$M^i_{(s,\eta')} = \mu^i(\eta')M^i_s.$$

As before, η is governed by a stationary first order Markov process with transition matrix $\Pi(\eta, \eta')$.

Consumers are paid interest on money balances. (No monetary friction!)

BUDGET CONSTRAINTS

$$\sum_{j=1}^{J} \sum_{h=1}^{I} (1+\delta_{jh}^{i}) E_{hs}^{i} P_{js}^{h} c_{jhs}^{i} + E_{1s}^{i} \sum_{\eta'=1}^{K} Q_{(s,\eta')} B_{(s,\eta')}^{i} + M_{s}^{i}$$

$$\leq W_{s}^{i}(\bar{l}^{i} - l_{s}^{i}) + R_{s}^{i} + E_{1s}^{i} B_{s}^{i} + \mu^{i}(\eta) M_{s-1}^{i}$$

P_{js}^{h} is the price of good j produced in country h in state s in units of currency h,

E_{hs}^{i} is the nominal exchange rate in units of currency i per unit of currency h in state s,

W_{s}^{i} is the wage in country i in units of currency i,

$B_{s}^{i}(s,\eta')$ is purchases in state s of a security that pays one unit of currency 1 if event η' occurs at $t(s)+1$,

$Q_{(s,\eta')}$ is the state s currency 1 price of a unit of currency 1 delivered at $t(s)+1$ if η' occurs,

R_{s}^{i} are profits in country i in units of currency i.

QUANTITY EQUATION

$$\sum_{j=1}^{J} \sum_{h=1}^{I} (1 + \delta_{ji}^{h}) P_{js}^{i} c_{jis}^{h} = M_{s}^{i} \text{ for all } s, i.$$

SEQUENTIAL MARKETS EQUILIBRIUM

A *sequential markets equilibrium* is a sequence of quantities $(\widehat{c}^{i}_{js}, \widehat{c}^{i}_{jhs}, \widehat{l}^{i}_{s}, \widehat{l}_{jhs}, \widehat{y}_{jhs}, \widehat{B}^{i}_{s}, \widehat{M}^{i}_{s})$, prices $(\widehat{P}^{i}_{js}, \widehat{W}^{i}_{s}, \widehat{Q}_{s}, \widehat{E}^{i}_{hs})$, and profits $\widehat{R}^{i}_{s}$ such that

i) given prices and profits, the quantities $(\widehat{c}^{i}_{js}, \widehat{c}^{i}_{jhs}, \widehat{l}^{i}_{s}, \widehat{B}^{i}_{s}, \widehat{M}^{i}_{s})$ solve the utility maximization problem of consumer i;

ii) given prices, the quantities $(\widehat{l}_{jhs}, \widehat{y}_{jhs})$ solve the profit maximization problem of sector j in country h in state s;

iii) the money stock $\widehat{M}^{i}_{s}$ satisfies $\widehat{M}^{i}_{s} = \mu^{i}(\eta)\widehat{M}^{i}_{s-1}$;

iv) $\widehat{R}^{i}_{s}$ are profits in country i in state s;

v) the quantities $(\widehat{c}^{i}_{js}, \widehat{c}^{i}_{jhs}, \widehat{l}^{i}_{s}, \widehat{l}_{jhs}, \widehat{y}_{jhs})$ satisfy the feasibility conditions*;*

vi) the securities $\widehat{B}^{i}_{s}$ satisfy the market clearing conditions $\sum_{i=1}^{I} \widehat{B}^{i}_{s} = 0$ in state s.

Theorem 3

Suppose that the sequence of quantities $(\widehat{c}^i_{js}, \widehat{c}^i_{jhs}, \widehat{l}^i_s, \widehat{l}_{jhs}, \widehat{y}_{jhs}, \widehat{B}^i_s, \widehat{M}^i_s)$, prices $(\widehat{P}^i_{js}, \widehat{W}^i_s, \widehat{Q}_s, \widehat{E}^i_{hs})$, and profits $\widehat{R}^i_s$ is an equilibrium of the the monetary economy. Then there exist bond holdings $\widehat{b}^i_s$, prices $(\widehat{p}_{jhs}, \widehat{w}^i_s, \widehat{q}_s)$, and profits $\widehat{r}^i_s$ that, together with the quantities $(\widehat{c}^i_{js}, \widehat{c}^i_{jhs}, \widehat{l}^i_s, \widehat{l}_{jhs}, \widehat{y}_{jhs})$ are an equilibrium of the economy without money.

Conversely, suppose that the sequence of quantities $(\widehat{c}^i_{js}, \widehat{c}^i_{jhs}, \widehat{l}^i_s, \widehat{l}_{jhs}, \widehat{y}_{jhs}, \widehat{b}^i_s)$, prices $(\widehat{p}^i_{jhs}, \widehat{w}^i_s, \widehat{q}_s)$, and profits $\widehat{r}^i_s$ is an equilibrium of the economy without money. Suppose too that $\mu^i(\eta)$ are monetary shocks and $\overline{M}^i_0$ are inital values of money. Then there exist bond holdings $\widehat{B}^i_s$, money stocks $\widehat{M}^i_s$, prices $(\widehat{P}^i_{js}, \widehat{W}^i_s, \widehat{Q}_s, \widehat{E}^i_{hs})$, and profits $\widehat{R}^i_s$ that, together with the quantities $(\widehat{c}^i_{js}, \widehat{c}^i_{jhs}, \widehat{l}^i_s, \widehat{l}_{jhs}, \widehat{y}_{jhs})$ are an equilibrium of the monetary economy.

TABLE 9

Standard Deviations of First Differences

	DATA	MODEL
ΔY^{us}	2.117	2.402
ΔTB^{us}	0.051	0.100
ΔY^{mex}	4.177	4.548
ΔTB^{mex}	1.264	2.306
ΔRER	16.560	15.190
ΔRER^{N}	3.988	3.739
ΔM^{us}	2.692	2.692
ΔP^{us}	2.031	3.340
ΔM^{mex}	15.706	15.706
ΔP^{mex}	23.675	17.756
ΔNER	31.964	29.082

TABLE 10

Correlations of First Differences
data/(model)

	ΔY^{us}	ΔTB^{us}	ΔY^{mex}	ΔTB^{mex}	ΔRER
ΔTB^{us}	0.346 (–0.449)				
ΔY^{mex}	0.092 (0.075)	0.651 (0.847)			
ΔTB^{mex}	–0.296 (0.449)	–0.958 (–0.970)	–0.730 (–0.849)		
ΔRER	–0.388 (0.455)	–0.820 (–0.995)	–0.730 (–0.852)	0.856 (0.990)	
ΔRER^N	0.226 (0.593)	–0.398 (–0.990)	–0.735 (–0.856)	0.518 (0.995)	0.547 (0.999)

TABLE 11
Additional Correlations of First Differences
data/(model)

	ΔM^{us}	ΔP^{us}	ΔM^{mex}	ΔP^{mex}	ΔNER
ΔY^{us}	0.144 (0.144)	–0.346 (–0.603)	–0.244 (0.003)	0.087 (–0.032)	–0.115 (0.288)
ΔTB^{us}	0.130 (–0.066)	–0.052 (0.270)	–0.353 (–0.290)	–0.110 (–0.473)	–0.502 (–0.840)
ΔY^{mex}	-0.181 (0.009)	0.161 (–0.046)	–0.335 (–0.335)	–0.571 (–0.553)	–0.811 (–0.777)
ΔTB^{mex}	–0.062 (0.066)	0.026 (–0.270)	0.282 (0.291)	0.123 (0.475)	0.532 (0.838)
ΔRER	0.239 (0.067)	–0.119 (–0.274)	0.460 (0.292)	0.233 (0.476)	0.699 (0.845)
ΔRER^N	0.115 (0.066)	–0.226 (–0.271)	0.431 (0.293)	0.593 (0.478)	0.737 (0.845)
ΔP^{us}	–0.477 (0.702)				
ΔM^{mex}	–0.075 (–0.075)	0.247 (–0.056)			
ΔP^{mex}	–0.009 (–0.068)	0.085 (–0.032)	0.637 (0.970)		
ΔNER	0.147 (–0.088)	–0.062 (–0.278)	0.694 (0.751)	0.856 (0.863)	

CONCLUSIONS

1. The more trade there is between countries, the more important are changes in the relative price of nontraded goods in determining real exchange rate fluctuations.

2. The more traded are the goods of a country with respect to a trade partner, the less important are deviations from the law of one price for real exchange rates.

3. A model that allows goods to be differentiated by degree of tradability (tradedness) does well in accounting for deviations from the law of one price and for RER fluctuations.

4. The same model does a very reasonable job of matching international business cycle facts.