Real Exchange Rates and Primary Commodity Prices

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- This is a data paper.
- We show that an important fraction of the volatility of RER between Japan, UK and Germany against the US can be accounted for by shocks that affect a few PCP.
- Why writing a paper about it?
- RER disconnect puzzle for these RER. (Engel (1999) and Betts and Kehoe (2004))
    1. RER unrelated to fundamentals.
    2. "Very" volatile.
    3. "Very" persistent.

- The puzzle is not present in **Small Open Economies** that specialize in the production of one primary commodity.
- Betts and Kehoe (2004), Chen and Rogoff (2003) and Hevia and Nicolini (2013), Ricci, Milessi-Ferreti and Lee (2013).
- RER responds to exogenous movements in PCP.

- The relationship is also present for some **Large** economies like Brazil.
- We explore this relationship for pairs of **Large Developed** economies: Japan, UK, Germany against the US.
- Is the dichotomy in the literature that stresses PC for SOE, but ignores them for LDE justified?

Why PCP?

- The top 10 commodities account for 18% of world trade in 2012 (12% in 1990). Only the **direct** measure.
- Primary commodities are at the bottom of the production structure.
- They are traded in competitive markets, where the law of one price holds.
- Very volatile and persistent.

Potential mechanism:

- Movements in PCP change costs.
- Assume input-output matrices of the two countries are different enough.
- Then, PCP changes affect final good prices asymmetrically: the RER ought to change.

Plan

- Discuss the empirical strategy.
- For US and UK, we analyze

$$r_t^{USA,UK} = \ln\left(\frac{P_t^{USA}}{P_t^{UK}} S_t\right) = \beta' \mathbf{p}_t^{X,USA} + v_t. \quad (1)$$

1. Endogeneity problems.
2. Selection of commodities.
3. Time varying coefficients.

Plan

- Descriptive statistics.
- Regressions (levels and four year differences) and focus on R^2.
- Alternative way to select commodities.
- Out-of-sample fit.
- Monte-Carlo simulations.

Plan

- A model that illustrates a mechanism.
- A model-based exercise.

Endogeneity problems

- PCP are very likely correlated with the RER between these four big economies.
- No hope to get consistent estimators of parameters.
- Our focus is on R^2.

- How much of the variability of the RER can be accounted for by shocks that affect a set of PCP?
- According to theory the RER and PCP are determined simultaneously.

- Let $\xi_t \in R^n$ be a vector representing the state of the economy.
- In equilibrium

$$\begin{aligned} r_t^{USA,UK} &= f(\xi_t), \\ \mathbf{p}_t^{X,USA} &= g(\xi_t). \end{aligned} \tag{2}$$

- Using a linear approximation

$$\begin{aligned} r_t^{USA,UK} &= \theta' \xi_t, \\ \mathbf{p}_t^{X,USA} &= \Omega \xi_t, \end{aligned} \tag{3}$$

- Consider the projection

$$Proj(r_t^{USA,UK} | \mathbf{p}_t^{X,USA}) = \beta' \mathbf{p}_t^{X,USA}.$$

$$\beta' = (\theta'\Omega')(\Omega\Omega')^{-1}.$$

- Using

$$\mathbf{p}_t^{X,USA} = \Omega\xi_t,$$

- can write

$$r_t^{USA,UK} = \beta'\Omega\xi_t + (\theta' - \beta'\Omega)\xi_t. \tag{4}$$

- The underlying (implicit) assumption in much of the literature on bilateral RER between developed countries is that $\beta'\Omega\xi_t$, can be safely ignored.

- Let state variables be divided in two sets as $\xi_t = [\xi_{1t}' \ \xi_{2t}']'$, so that

$$\begin{aligned} r_t^{USA,UK} &= \theta_1' \xi_{1t} + \theta_2' \xi_{2t} \\ \mathbf{p}_t^{X,USA} &= \Omega_1 \xi_{1t} + \Omega_2 \xi_{2t}. \end{aligned}$$

- A sufficient condition for the R^2 of the regression to be zero is thus

$$\theta_1 = 0 \text{ and } \Omega_2 = 0$$

- Implies an equilibrium with a block-recursive structure.

Selection of commodities

- We chose the 10 most traded commodities in 1990, for which we have data from 1960.
- We run the regression with those commodities.
- We select the 4 (tried also 5 and 3) with highest t-stats.
- Run the regression again with only those 4 PCP.

Time varying coefficients

- Constants in linearization depend on equilibrium you are approximating around.
- Production, imports and exports of commodities change over time.
- Run the regressions for 4 sub-periods.

Results

- Monthly data from 1960 to 2015.
- We start by showing moments of RER and PCP
- Both for the whole period and for sub-periods.
- In levels and in 4-year differences

Table: Volatilities of real exchange rates and primary commodity prices

(a) LEVEL

	1960–2014	1960–1972	1973–1985	1986–1998	1999–2014
Real Exchange Rates					
US-UK	0.12	0.06	0.15	0.08	0.08
US-DEU	0.18	0.07	0.21	0.09	0.13
US-JPN	0.37	0.13	0.13	0.12	0.11
Average across commodities					
Simple	0.44	0.13	0.31	0.22	0.36
Trade weighted	0.57	0.13	0.37	0.23	0.46

(b) 4-YEAR DIFFERENCES

	1960–2014	1960–1972	1973–1985	1986–1998	1999–2014
Real Exchange Rates					
US-UK	0.18	0.11	0.26	0.17	0.14
US-DEU	0.22	0.07	0.31	0.16	0.21
US-JPN	0.23	0.07	0.27	0.26	0.17
Average across commodities					
Simple	0.38	0.17	0.44	0.30	0.36
Trade weighted	0.46	0.17	0.55	0.35	0.36

FIGURE: 10-years rolling volatilities of real exchange rates and commodity prices (United Kingdom)

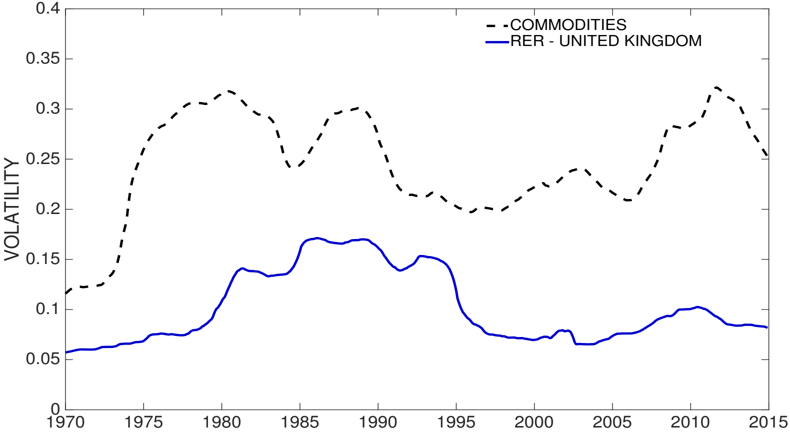


Figure: 10-years rolling volatilities of real exchange rates and commodity prices (Germany)

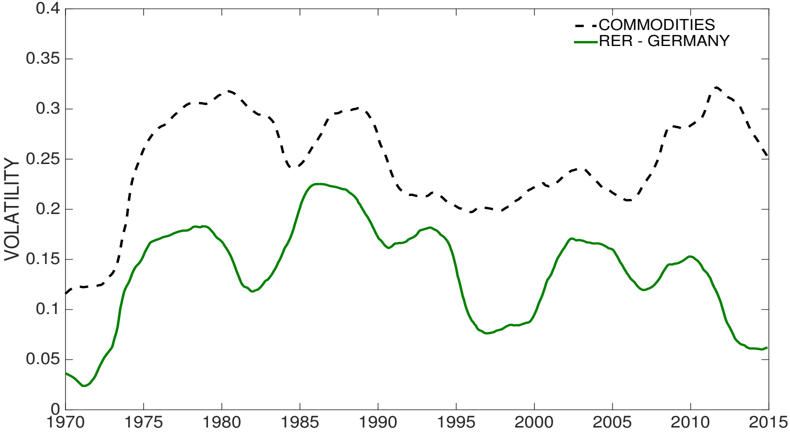
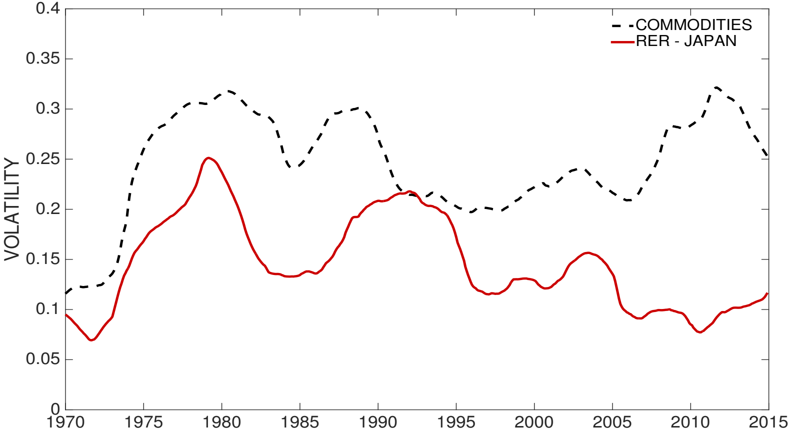


FIGURE: 10-years rolling volatilities of real exchange rates and commodity prices (Japan)



- Autocorrelation for 4-year differences between 0.95 an 0.98 for the 3 RER and the 10 PCP.
- The simple correlations are high.
- Tables with the R^2 follow.

Table: Regressions in 4-year differences with 10 commodities - R^2

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
United Kingdom	0.48	0.90	0.90	0.81	0.60
Germany	0.63	0.95	0.87	0.83	0.75
Japan	0.57	0.92	0.84	0.92	0.82

Table: Regressions in 4-year differences with 4 commodities (best-fit) - R^2

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
United Kingdom	0.33	0.72	0.82	0.63	0.58
Germany	0.56	0.84	0.87	0.81	0.74
Japan	0.48	0.88	0.76	0.86	0.80

FIGURE: Real exchange rates and fitted values, in 4-year differences with 4 commodities, best fit, 1960–2014, United Kingdom

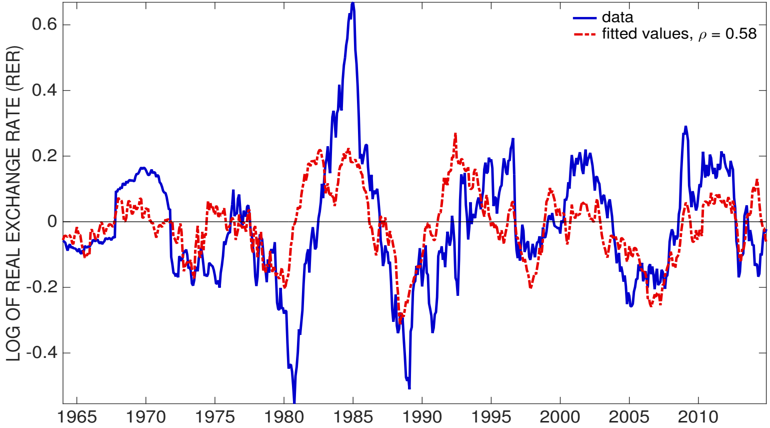


FIGURE: Real exchange rates and fitted values, in 4-year differences with 4 commodities, best fit, 1960–2014, Germany

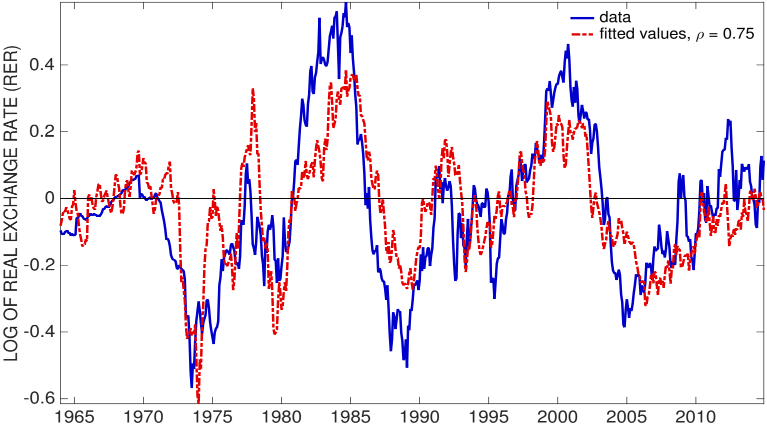
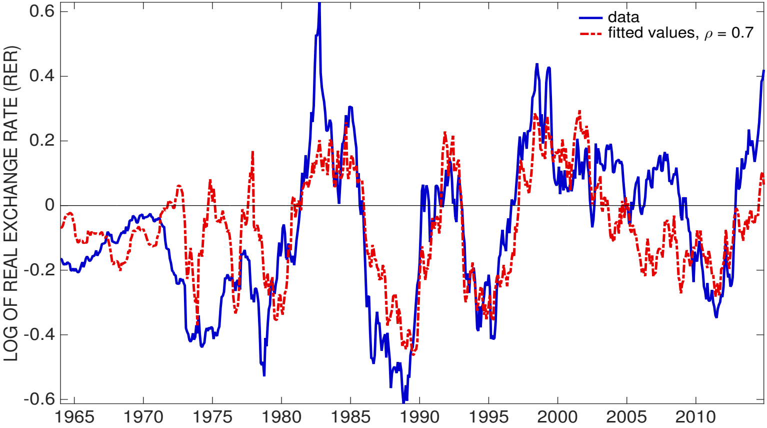


FIGURE: Real exchange rates and fitted values, in 4-year differences with 4 commodities, best fit, 1960–2014, Japan



Robustness Exercises

- Now we perform an out-of-sample exercise.
- Run the regression from Jan-1960 to Dec-1972. Choose the 4 commodities with the highest t-stats.
- Use data for those 4 PCP from Jan-1973 to Jan-1973 $+ T$, and the estimated coefficients, to fit value of the RER.
- Compare with data.

FIGURE: Out-of-sample fit 6 months ahead, with 4 best-fit commodities,United Kingdom

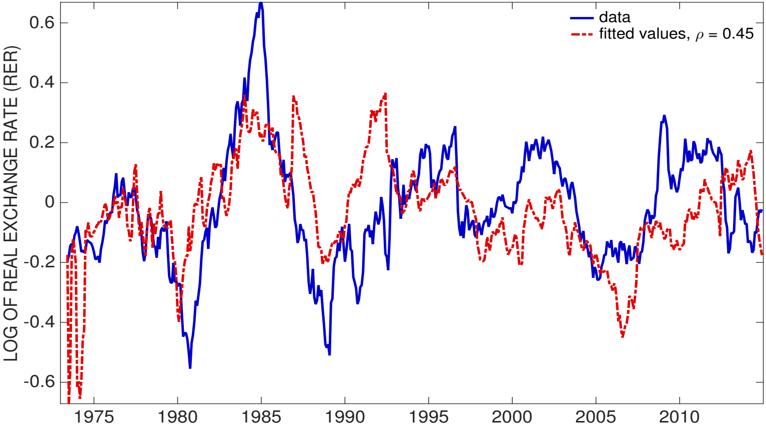


FIGURE: Out-of-sample fit 6 months ahead, with 4 best-fit commodities, Germany

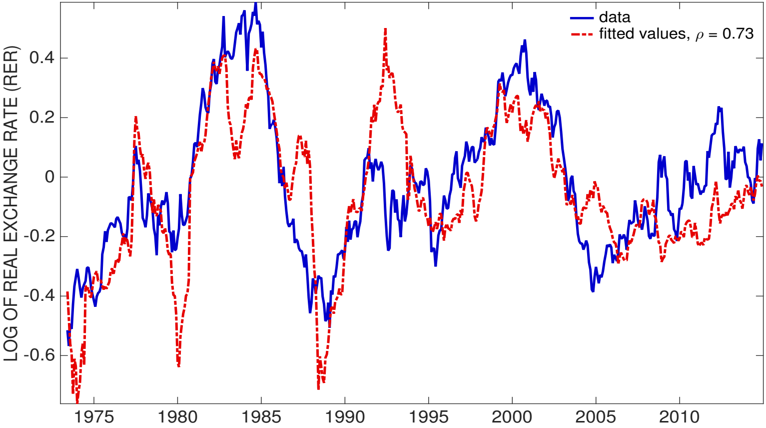


FIGURE: Out-of-sample fit 6 months ahead, with 4 best-fit commodities, Japan

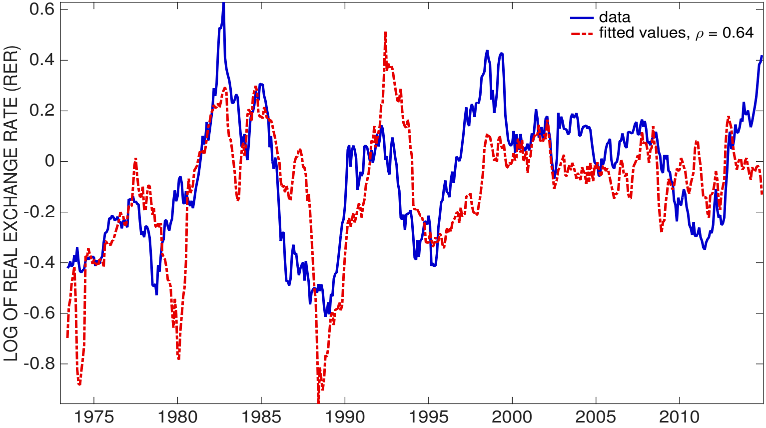
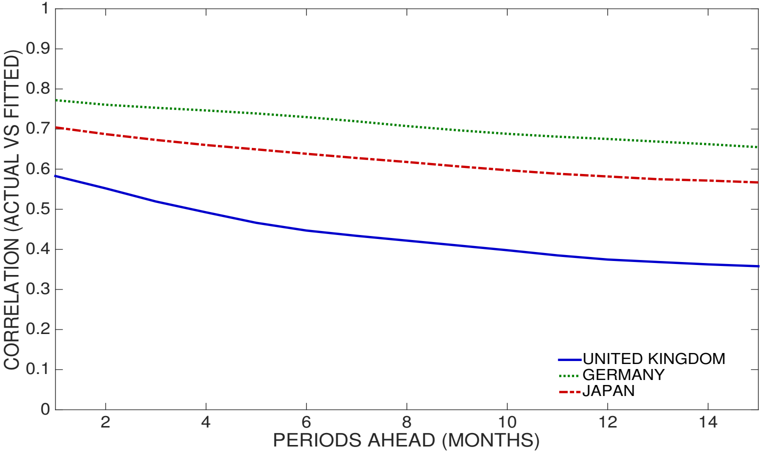


FIGURE: Out-of-sample fit, 4 best-fit commodities, correlations as a function of r (months ahead)



Are the results spurious?

- Estimate time series process for each RER
- Estimate a VAR for the 10 PCP
- Simulate series using orthogonal shocks and reproduce our regressions.
- The $R^2 \to 0$ as the sample size goes to ∞.
- Get 10.000 samples of size 660 and compute the distribution of the R^2.

Figure: Small sample distribution of the R^2 over the period 1960–2014, with 4 best-fit commodities, United Kingdom

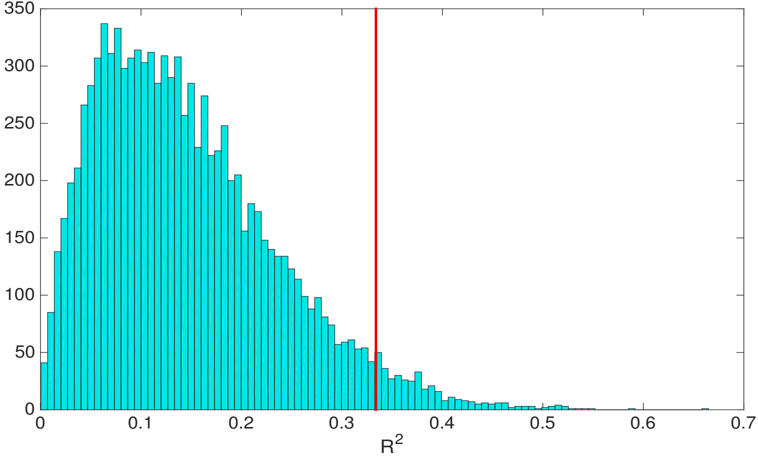


FIGURE: Small sample distribution of the R^2 over the period 1960–2014, with 4 best-fit commodities, Germany

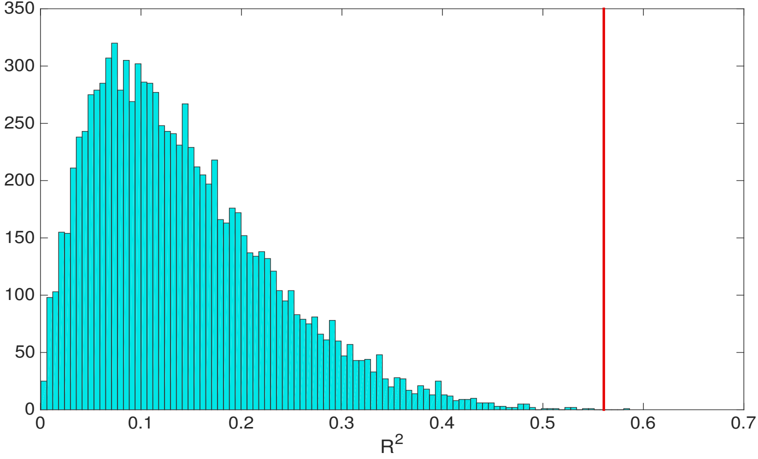


FIGURE: Small sample distribution of the R^2 over the period 1960–2014, with 4 best-fit commodities, Japan

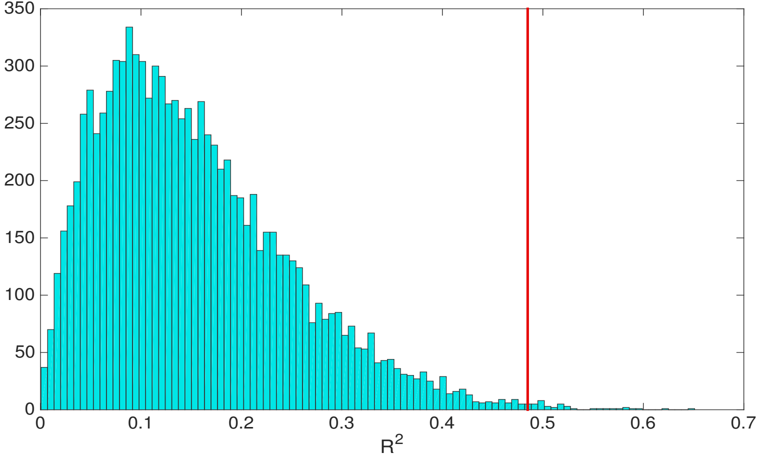


FIGURE: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 best-fit commodities, United Kingdom

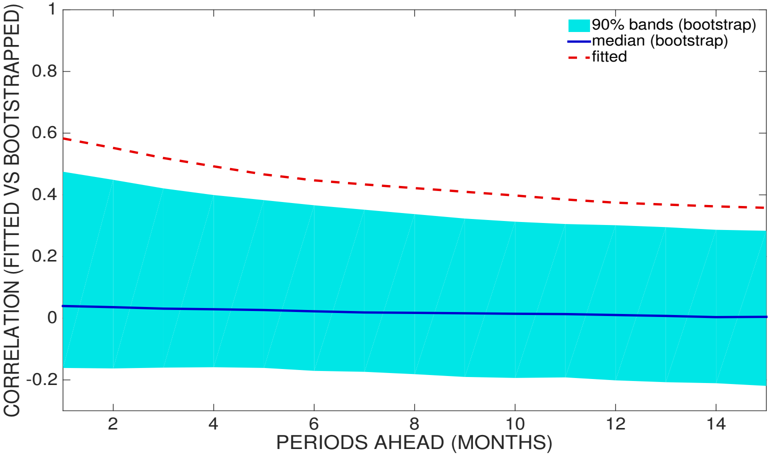


FIGURE: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 best-fit commodities, Germany

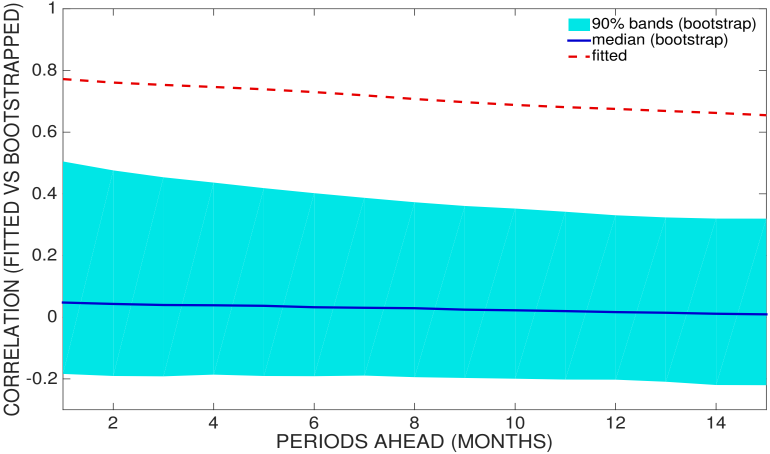
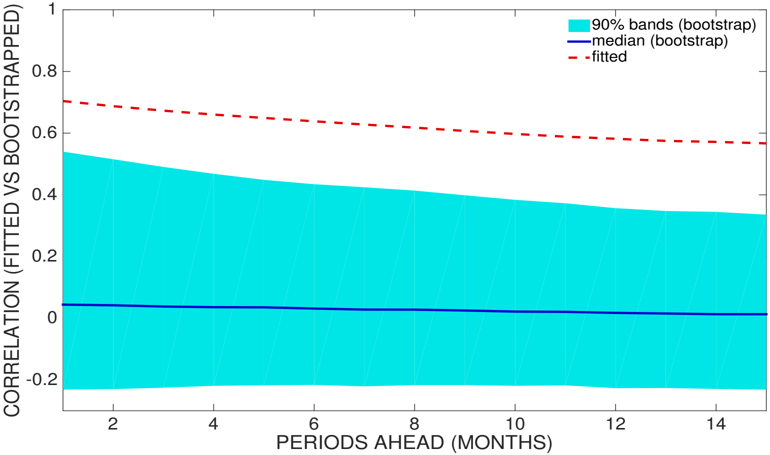


Figure: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 best-fit commodities, Japan



Model

- Imagine a world with many countries, which have different technologies and different endowments.
- We will describe the environment for country i. (for simplicity, we omit superscript i for the moment)
- Preferences

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t),$$

where C_t represents consumption of a **non-traded** final good (think of many!).

- All we exploit from the model comes from its production structure.
- We use Cobb-Douglas, for simplicity.
- Let

$$Y_t = C_t = Z_t^y (n_t^y)^\alpha (q_t)^{1-\alpha}$$

- where q_t is a domestic, intermediate good

$$Q_t = Z_t^q [n_t^q]^{\beta_n} [x_t]^{\beta_x} [m_t]^{\beta_m}.$$

- Technology to produce the primary commodity x_t,

$$X_t = Z_t^h [n_t^x]^\eta E^{1-\eta}$$

- The primary commodity m_t must be imported.

- The marginal cost of the final good can be expressed as

$$P_t = \frac{\kappa^y}{Z_t^y}(W_t)^{\alpha}(P_t^q)^{1-\alpha}.$$

But

$$P_t^q = \frac{\kappa^q}{Z_t^h}[W_t]^{\beta_n}[P_t^x]^{\beta_x}[P_t^m]^{\beta_m},$$

so

$$P_t = \frac{\kappa^y}{Z_t^y}(W_t)^{\alpha}(\frac{\kappa^q}{Z_t^h}[W_t]^{\beta_n}[P_t^x]^{\beta_x}[P_t^m]^{\beta_m})^{1-\alpha}$$

- Taking logs,

$$\ln P_t = \ln \frac{\kappa^y}{Z_t^y} + (\alpha + (1-\alpha)\beta_n) \ln W_t + (1-\alpha)(\ln \frac{\kappa^q}{Z_t^h} + \beta_x \ln P_t^x + \beta_m \ln P_t^m)$$

- From the cost minimization conditions of the primary commodity sector, we have

$$W_t = P_t^x \eta Z_t^h \left[\frac{E}{n_t^x} \right]^{1-\eta}$$

- Using this to replace the wage above

$$\begin{aligned} \ln P_t &= \ln \frac{\kappa^y}{Z_t^y} + (1-\alpha) \ln \frac{\kappa^q}{Z_t^h} + (\alpha + (1-\alpha)\beta_n) \ln \eta Z_t^h \\ &+ (\alpha + (1-\alpha)\beta_n)(1-\eta) \ln \left[\frac{E}{n_t^x} \right] \\ &+ (1-\alpha)\beta_m \ln P_t^m + (\alpha + (1-\alpha)\beta_n + (1-\alpha)\beta_x) \ln P_t^x \end{aligned}$$

- Note that $(1-\alpha)\beta_m + \alpha + (1-\alpha)\beta_n + (1-\alpha)\beta_x = 1$.

- If we collect productivity shocks and labor input in a single term Z_t,

$$\ln P_t = (1-\alpha)\beta_m \ln P_t^m + (\alpha + (1-\alpha)\beta_n + (1-\alpha)\beta_x) \ln P_t^x + Z_t$$

- Not a unique representation in economy with many goods.

- In general, then, we can write the solution for the price level in the US as

$$\ln P_t^{US} = k + \sum_{h=1}^{N} a_h^{US} \ln P^{US}(h)_t + Z_t^{US}$$

where

$$\sum_{h=1}^{N} a_h^{US} = 1,$$

- Similarly, for a different country we have

$$\ln \widetilde{P}_t = \widetilde{k} + \sum_{h=1}^{N} \widetilde{a}_h \ln \widetilde{P}_t(h) + \widetilde{Z}_t.$$

- The law of one price

$$P_t^{US}(h)\widetilde{S}_t = \widetilde{P}_t(h),$$

where $\widetilde{S}_t$ is the nominal exchange rate.

- Then

$$\ln \widetilde{P}_t - \ln \widetilde{S}_t = \widetilde{k} + \sum_{h=1}^{N} \widetilde{a}_h \ln P_t^{US}(h) + \widetilde{Z}_t$$

so

$$\ln \frac{P_t^{US}\widetilde{S}_t}{\widetilde{P}_t} = \left(k - \widetilde{k}\right) + \sum_{h=1}^{N-1} \left(a_h^{US} - \widetilde{a}_h\right) \ln P_t^{US}(h) + \left(Z_t^{US} - \widetilde{Z}_t\right).$$

- This regression equation is used in the empirical section.
- Key:

$$\left(a_h^{US} - \widetilde{a}_h\right) \neq 0.$$

- We now select the 4 commodities with the largest trade share in the USA
- There are sizeable differences in the amounts traded with the other three countries, specially for Germany and Japan.

TABLE: Share of imports and exports in each country (% average in 1990–1999)

	United States		United Kingdom		Germany		Japan	
	imp.	exp.	imp.	exp.	imp.	exp.	imp.	exp.
Petroleum	**8.5**	**1.2**	**3.4**	**6.0**	**5.2**	**0.7**	**13.1**	**0.4**
Fish	**1.0**	**0.6**	**0.7**	**0.5**	**0.5**	**0.2**	**5.0**	**0.2**
Timber	**0.9**	**1.0**	**0.8**	**0.0**	**0.5**	**0.2**	**3.5**	**0.0**
Gold	**0.3**	**0.9**	**0.0**	**0.1**	**0.3**	**0.2**	**0.8**	**0.1**
Meat	0.3	0.9	0.7	0.6	1.1	0.4	2.4	0.0
Maize	0.0	1.1	0.1	0.0	0.1	0.0	0.8	0.0
Aluminium	0.4	0.2	0.3	0.2	0.5	0.1	1.5	0.0
Wheat	0.0	0.8	0.1	0.3	0.1	0.2	0.4	0.0
Copper	0.2	0.2	0.3	0.0	0.4	0.1	1.2	0.1
Cotton	0.0	0.5	0.0	0.0	0.1	0.0	0.3	0.0
SUM	**11.8**	**7.2**	**6.5**	**7.7**	**8.7**	**2.1**	**29.0**	**0.8**

Table: R^2 using 4 commodities with largest US-trade share, 1960–2014

	Number of Commodities		
	10	4 (best-fit)	4 (largest US-trade share)
United Kingdom	0.48	0.33	0.25
Germany	0.63	0.56	0.53
Japan	0.57	0.48	0.44

Conclusions

- A simplifying - and somehow unfair - summary of the literature on exchange rates is that it has evolved according to a certain dichotomy.
- The role of trade in primary commodities has been explicitly modeled in studying developing economies.
- But models used to analyze large developed economies focuses on trade in differentiated final products exclusively and ignore trade in primary commodities.
- Maybe they should not.....

APPENDIX

Table: Unit root tests (p-values)

	Level	3-years diff.	4-years diff.	5-years diff.
Real Exchange Rates				
US-UK	0.018	0.001	0.003	0.003
US-DEU	0.117	0.005	0.028	0.027
US-JPN	0.809	0.001	0.018	0.027
Commodities				
Oil	0.485	0.079	0.128	0.356
Fish	0.352	0.001	0.027	0.009
Meat	0.523	0.019	0.047	0.304
Aluminium	0.145	0.001	0.001	0.003
Copper	0.319	0.009	0.025	0.103
Gold	0.508	0.001	0.016	0.025
Wheat	0.226	0.001	0.005	0.009
Maize	0.269	0.001	0.010	0.013
Timber	0.047	0.003	0.018	0.047
Cotton	0.592	0.005	0.016	0.015

Table: Correlations (1960–2014)

	Oil	Fish	Meat	Alum.	Copper	Gold	Wheat	Maize	Timber	Cotton
RER										
US-UK	-0.47	0.00	0.30	0.11	0.09	-0.53	0.26	0.36	-0.40	0.30
US-DEU	-0.51	-0.24	0.16	0.08	-0.08	-0.62	0.06	0.14	-0.58	0.11
US-JPN	-0.49	0.25	0.59	0.52	0.41	-0.63	0.59	0.63	-0.44	0.55
Commodities										
Oil	1.00									
Fish	0.28	1.00								
Meat	-0.17	0.45	1.00							
Alum.	-0.20	0.36	0.73	1.00						
Copper	0.07	0.72	0.57	0.52	1.00					
Gold	0.88	0.25	-0.16	-0.22	0.03	1.00				
Wheat	-0.05	0.57	0.78	0.70	0.60	-0.07	1.00			
Maize	-0.11	0.58	0.81	0.70	0.62	-0.13	0.94	1.00		
Timber	0.39	0.10	0.18	0.17	0.10	0.56	0.21	0.15	1.00	
Cotton	-0.23	0.39	0.83	0.78	0.43	-0.21	0.84	0.86	0.24	1.00

TABLE: Bootstrap distributions of the R^2 under the null hypothesis of orthogonality, with 4 best-fit commodities

	$\hat{R}^2$	Percentiles distribution of R^2				$\Pr(R^2 \geq \hat{R}^2)$
		Median	75	90	95	
United Kingdom						
1964-2014	0.33	0.13	0.20	0.27	0.31	0.037
1964-1972	0.72	0.52	0.66	0.75	0.80	0.143
1973-1985	0.82	0.37	0.52	0.64	0.70	0.004
1986-1998	0.63	0.37	0.50	0.61	0.67	0.077
1999-2014	0.58	0.29	0.41	0.53	0.59	0.059
Germany						
1964-2014	0.56	0.13	0.19	0.26	0.31	0.000
1964-1972	0.84	0.56	0.69	0.79	0.83	0.032
1973-1985	0.87	0.49	0.63	0.73	0.78	0.005
1986-1998	0.81	0.40	0.54	0.65	0.71	0.007
1999-2014	0.74	0.30	0.43	0.55	0.61	0.007
Japan						
1964-2014	0.48	0.14	0.21	0.29	0.34	0.003
1964-1972	0.88	0.59	0.72	0.81	0.85	0.022
1973-1985	0.76	0.46	0.60	0.70	0.75	0.045
1986-1998	0.86	0.41	0.55	0.66	0.71	0.001
1999-2014	0.80	0.33	0.46	0.57	0.63	0.002

TABLE: Share of imports and exports in each country (% average in 1990–1999)

	United States		United Kingdom		Germany		Japan	
	imp.	exp.	imp.	exp.	imp.	exp.	imp.	exp.
Petroleum	8.5	1.2	3.4	6.0	5.2	0.7	13.1	0.4
Fish	1.0	0.6	0.7	0.5	0.5	0.2	5.0	0.2
Meat	0.3	0.9	0.7	0.6	1.1	0.4	2.4	0.0
Aluminium	0.4	0.2	0.3	0.2	0.5	0.1	1.5	0.0
Copper	0.2	0.2	0.3	0.0	0.4	0.1	1.2	0.1
Gold	0.3	0.9	0.0	0.1	0.3	0.2	0.8	0.1
Wheat	0.0	0.8	0.1	0.3	0.1	0.2	0.4	0.0
Maize	0.0	1.1	0.1	0.0	0.1	0.0	0.8	0.0
Timber	0.9	1.0	0.8	0.0	0.5	0.2	3.5	0.0
Cotton	0.0	0.5	0.0	0.0	0.1	0.0	0.3	0.0
SUM	**11.8**	**7.2**	**6.5**	**7.7**	**8.7**	**2.1**	**29.0**	**0.8**

TABLE: Regressions in 4-year differences, selecting 3 commodities - R^2

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
United Kingdom	0.24	0.68	0.78	0.63	0.39
Germany	0.53	0.84	0.80	0.72	0.72
Japan	0.46	0.81	0.58	0.73	0.69

Table: Regressors from previous sub-period, selecting 3 commodities - R^2

	1973-1985	1986-1998	1999-2014
United Kingdom	0.45	0.56	0.39
Germany	0.68	0.57	0.66
Japan	0.27	0.31	0.42

TABLE: Regression coefficients, in 4-year differences - United Kingdom

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
Oil				-0.012	
Fish	-0.213***	-0.252***		-0.218***	-0.162**
Meat		-0.176**	-0.322***	-0.457***	-0.139***
Aluminium	-0.197***	-0.456***			
Copper			0.402***	-0.127***	-0.196***
Gold			-0.329***		0.290***
Wheat					
Maize	0.121**				
Timber			-0.211***		
Cotton	0.027	-0.439***			

TABLE: Regression coefficients, in 4-year differences - Germany

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
Oil					
Fish	-0.319***	-0.095***	-0.194**		-0.375***
Meat			-0.005		
Aluminum			-0.541***		
Copper				-0.231***	
Gold				-0.138**	-0.186***
Wheat	-0.137*		-0.233***		-0.279***
Maize	0.223*	-0.032		0.252***	0.316**
Timber	-0.314***	0.282***		-0.149***	
Cotton		-0.537***			

Table: Regression coefficients, in 4-year differences - Japan

	1960-2014	1960-1972	1973-1985	1986-1998	1999-2014
Oil	0.173**			0.270***	
Fish			-0.318***	0.241***	0.346***
Meat			-0.027		
Aluminium	-0.170**		-0.434***	-0.260***	
Copper		-0.029***	0.109		
Gold		-0.290***			-0.532***
Wheat					0.205***
Maize		-0.244***			
Timber	-0.396***			-0.352***	
Cotton	-0.124*	-0.318***			-0.130***

TABLE: Bootstrap distributions of R^2 under the null hypothesis of orthogonality, with 4 com. (largest US-trade share) in 4-year diff

		Percentiles distribution of R^2				
	$\hat{R}^2$	Median	75	90	95	$\Pr(R^2 \geq \hat{R}^2)$
United Kingdom						
1960-2014	0.25	0.13	0.20	0.27	0.31	0.134
1960-1972	0.63	0.51	0.64	0.74	0.79	0.274
1973-1985	0.73	0.44	0.59	0.70	0.76	0.070
1986-1998	0.25	0.37	0.50	0.62	0.68	0.734
1999-2014	0.46	0.30	0.43	0.54	0.59	0.188
Germany						
1960-2014	0.53	0.13	0.20	0.27	0.33	0.000
1960-1972	0.89	0.53	0.68	0.77	0.81	0.005
1973-1985	0.71	0.45	0.60	0.72	0.77	0.106
1986-1998	0.50	0.40	0.54	0.66	0.71	0.313
1999-2014	0.69	0.33	0.47	0.58	0.64	0.024
Japan						
1960-2014	0.44	0.13	0.20	0.27	0.32	0.007
1960-1972	0.71	0.54	0.67	0.77	0.82	0.190
1973-1985	0.52	0.47	0.62	0.74	0.79	0.421
1986-1998	0.82	0.42	0.56	0.67	0.73	0.007
1999-2014	0.68	0.35	0.48	0.59	0.65	0.033

FIGURE: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 commodities (largest US-trade share), United Kingdom

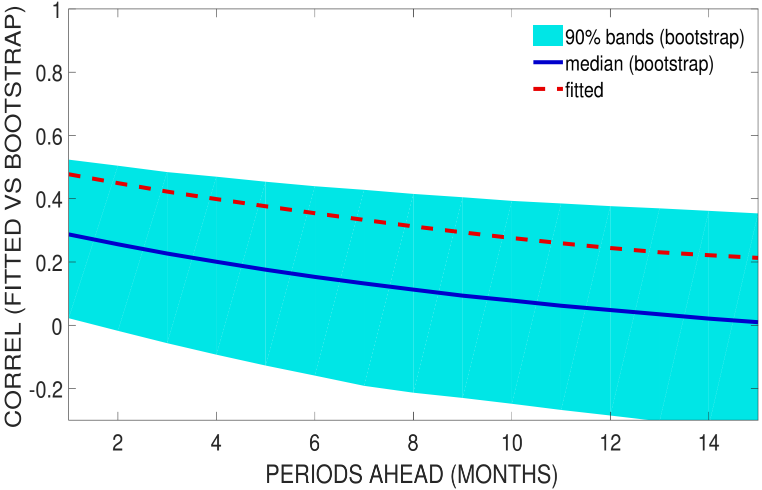


Figure: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 commodities (largest US-trade share), Germany

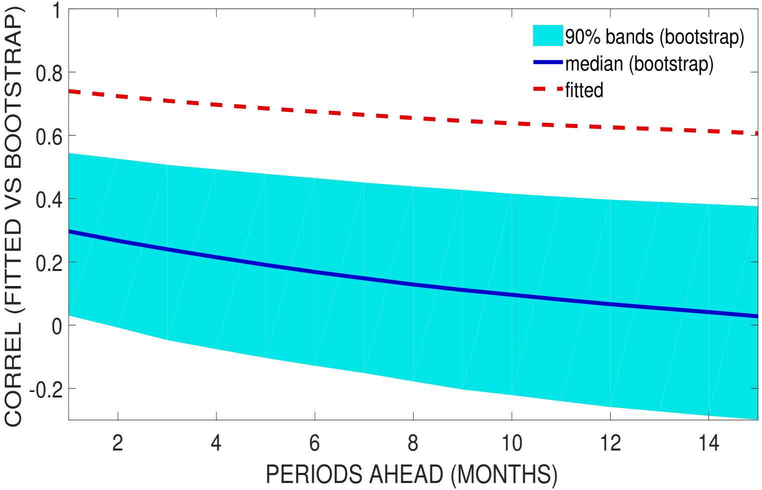


FIGURE: Fitted correlations and bootstrap bands under the null hypothesis of orthogonality, with 4 commodities (largest US-trade share), Japan