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ABSTRACT

Household Heterogeneity and the Real Exchange Rate: Still a Puzzle

Kocherlakota and Pistaferri (EJ, 2007) [KP] develop a model of a world economy with private-information Pareto optimal (PIPO) risk sharing; in that model, the real exchange rate tracks relative domestic/foreign cross-sectional distributions of consumption. KP claim that the PIPO model fits the UK/US real exchange rate well. This paper shows that the PIPO model is inconsistent with the UK/US data. Minor specification changes overturn KP's regression results. I also document that the relevant (relative) cross-sectional consumption moment is orders of magnitude more volatile than the real exchange rate, and less persistent. The link between the real exchange rage and consumption (heterogeneity) remains a puzzle.

JEL Classification: F36 and F41
Keywords: heterogeneity, international risk sharing and real exchange rate

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1. Introduction

Standard models of the world economy that postulate full international risk sharing (complete asset markets) predict that a country's aggregate consumption is high, relative to foreign consumption, when the relative price of domestic final consumption is low. Yet, as first documented by Kollmann (1991, 1995) and Backus and Smith (1993), CPI-based real exchange rates are essentially uncorrelated with cross-country aggregate consumption differences. This 'consumption-real exchange rate anomaly' is one of the major puzzles in international macroeconomics (Obstfeld and Rogoff, 2000).

In their widely discussed *Economic Journal Lecture* at the 2006 Royal Economic Society meetings, Kocherlakota and Pistaferri (2007) [KP] develop a model of a world economy in which individuals cannot fully insure against individual-specific shocks that are only privately observable. KP show that a private-information Pareto-optimal (PIPO) insurance scheme entails that the log real exchange rate tracks one-to-one the logged ratio of the $\gamma-$th non-central moments of the cross-sectional distributions of consumption in the domestic and foreign economies, where γ is the coefficient of relative risk aversion. Thus, inequality matters for the real exchange rate. If $\gamma>1$, the real exchange rate is influenced by the right tail of the within-country consumption distribution (i.e. by the consumption of the rich).

Let $e_t^{j,k}$ be the date *t* real exchange rate between countries *j* and *k*, defined as the ratio of *k*'s CPI to *j*'s CPI (in same currency);[1] let $C_{\gamma,t}^{j}$ be the $\gamma-$th (non-central) moment of the cross-sectional consumption distribution in country *j*. The PIPO model implies:

$$\ln e_t^{j,k} = \ln(C_{\gamma,t}^{j}/C_{\gamma,t}^{k}) + \nu_{\gamma}^{j,k}, \quad \text{for some constant } \nu_{\gamma}^{j,k}. \tag{1}$$

KP test this prediction for the UK and US, using monthly time series on cross-sectional moments of consumption (1980-1999) estimated from household-level data (US CEX and UK FES surveys). KP create an error term by subtracting the logged relative sample consumption moment from the log real exchange rate; they regress *quarterly first differences* of that 'model error' on *quarterly first differences* of the real exchange rate. If the PIPO model is true, the regression coefficient should be zero. KP find that the slope coefficient is zero, when $\gamma\approx 5$. This is the basis of KP's claim that the PIPO model 'is able to account for movements in the real exchange rate' (p.C3). (Kocherlakota and

[1] A rise in $e_t^{j,k}$ is a depreciation of the country *j* real exchange rate.

Pistaferri (2005) claim that the PIPO model also solves the equity premium puzzle for $\gamma=5.)$ This is a noteworthy claim, as standard macro fundamentals fail to explain the real exchange rate, in the short/medium run (e.g., Obstfeld and Rogoff, 2000).

This paper shows that the PIPO model is inconsistent with the behavior of the UK/US real exchange rate, and with KP's household-level consumption data.

Section 2 documents that the logged ratio of UK/US high-order *sample* consumption moments is vastly more volatile than the logged real exchange rate, and much less persistent. Thus, the real exchange rate does *not* track the relevant relative sample consumption moment. KP do not report these striking facts.

To formally test the PIPO model, I extend KP's regression analysis (summarized in Section 3). Section 4 shows that minor specification changes overturn KP's regression results. E.g., KP only test the model using *quarterly first differenced* variables. I show that regression results based on *annual first differences* are inconsistent with the model. I also extend KP's empirical analysis by regressing the model error on additional macro variables. I document that the model error is correlated with relative UK/US industrial production and stock prices, as well as with future values of the real exchange rate, which likewise implies a rejection of the PIPO model. KP's results are sensitive to extreme observations; estimation techniques that are more robust to outliers yield clear rejections of the model.

In Section 5, I use Kocherlakota and Pistaferri's (2008) idea that the fraction of aggregate consumption due to the richest households is a proxy for higher cross-sectional consumption moments. Based on KP's data, I show that this proxy is not correlated with the UK-US real exchange rate, which casts further doubts on the PIPO model.

2. Properties of UK/US cross-sectional consumption moments and of model error

Let $\overline{C^j_{\gamma,t}}$ be the **sample** $\gamma-$th non-central moment of the consumption distribution in country *j*, based on survey data. Table 1 reports the standard deviation and autocorrelation of the time series of $\ln(\overline{C^{UK}_{\gamma,t}}/\overline{C^{US}_{\gamma,t}}),$ as well as its correlation with the logged real exchange rate $\ln(e_t^{UK,US})$, for $\gamma=1,2,..,9.$ All data used in this paper are monthly, for 1980-99, and are from KP's data set (unless stated otherwise).

The standard deviation and autocorrelation of the monthly logged real exchange rate are 13.9% and 0.99%, respectively. For all values of γ considered in Table 1, the relative sample cross-sectional consumption moments are less persistent than the real exchange rate, and negatively or weakly positively correlated with the real exchange rate. When $\gamma \geq 2$ the relative consumption moment is several times more volatile than the real exchange rate. These facts cast doubts on the PIPO model. KP do not discuss the facts in Table 1.

KP claim that for $\gamma \approx 5$ the PIPO model fits the data well. For $\gamma = 5,$ the standard deviation of $\ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}})$ is 245.4%, while its autocorrelation and correlation with $\ln(e_t^{UK,US})$ are 0.08 and 0.06, respectively; thus, the logged relative consumption moment is 17.6 (!) times more volatile than the log real exchange rate, and much less persistent. [2]

Figure 1 plots $\ln(e_t^{UK,US}),$ and $\ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}})$ for $\gamma=1$ and $\gamma=5$. Visually, the real exchange rate is 'disconnected' from relative consumption moments.

As shown in Table 1 (Row 4), the 'model error' $\Psi_{\gamma,t}^{j,k} \equiv \ln e_t^{j,k} - \nu_\gamma^{j,k} - \ln(\overline{C_{\gamma,t}^{j}}/\overline{C_{\gamma,t}^{k}})$ is roughly as volatile as $\ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}}).$ E.g. for $\gamma=5$ the standard deviation of the model error is 244.9%.

Under the null hypothesis that the PIPO model is true, the model error just reflects cross-sectional *sampling* error:

$$\Psi_{\gamma,t}^{j,k} = \ln(\overline{C_{\gamma,t}^{j}}/C_{\gamma,t}^{j}) + \ln(\overline{C_{\gamma,t}^{k}}/C_{\gamma,t}^{k}) \approx -\varepsilon_{\gamma,t}^{j}/C_{\gamma,t}^{j} + \varepsilon_{\gamma,t}^{k}/C_{\gamma,t}^{k}, \qquad (2)$$

where $\varepsilon_{\gamma,t}^{j} \equiv \overline{C_{\gamma,t}^{j}} - C_{\gamma,t}^{j}$ is the country j sampling error. If $\varepsilon_{\gamma,t}^{j}, \varepsilon_{\gamma,t}^{k}$ have mean zero, the mean model error is thus (approximately) zero, under the null hypothesis.

I use bootstrap simulations (5000 random samples of UK and US households) to approximate the sampling distribution of the logged relative γ-th cross-sectional consumption moment, at each date *t.* [3] Table 2 reports the fraction of months in the

[2] KP's empirical analysis is based on *quarterly first differenced* time series. The standard deviation and autocorrelation of the quarterly first differenced log real exchange rate are 5.0% and 0.87, respectively. For $\gamma=5$ the standard dev. and autocorr. of the quarterly first differenced log relative consumption moment are 322.8% (!) and 0.01, respectively (correlation with first differenced log real exchange rate: 0.01).

[3] Each of the 5000 bootstrap samples for date t is drawn with replacement from the sets of UK and US households in KP's data base, for t (and includes the same number of households as in the data base). Krueger and Perri (2007) also use bootstraps to evaluate the distribution of cross-sectional consumption moments.

sample (1980-1999) in which the log real exchange rate adjusted for an estimate of $\nu_\gamma^{j,k}$ (see (1)), $\ln e_t^{j,k} - \widehat{\nu_\gamma^{j,k}}$, lies outside the 99% bootstrap confidence interval for the date *t* logged relative consumption moment;[4] if the PIPO model is true, that fraction should be close to 1%. In fact, the fraction is much higher: e.g., 35.3% for γ=2; and 10.9% for γ=5. [5] $\ln e_t^{j,k} - \widehat{\nu_\gamma^{j,k}}$ lies *outside* the range of the simulated 5000 logged relative consumption moments, in 17.6% [5.9%] of the periods, when γ=2 [γ=5]. This suggests that the historical real exchange rate is inconsistent with the sampling distribution of relative UK/US consumption moments.

3. KP's regression analysis

KP note that if the PIPO model is true, then the model error is uncorrelated with any variables that are uncorrelated with cross-sectional sampling error. KP regress the first-differenced model error on the first-differenced log real exchange rate:

$$\Delta_u\{\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j} / \overline{C_{\gamma,t}^k})\} = b\,\Delta_u \ln e_t^{j,k} + \eta_t \ , \qquad (3)$$

where $\Delta_u x_t \equiv x_t - x_{t-u}$; η_t is a regression error. The PIPO model implies $b = 0$.

KP **only** work with u=3, i.e. they solely test the model using monthly observations of **quarterly** first differences. They do *not* consider regressors other than the real exchange rate. KP report that the estimate of *b* is zero when $\gamma \approx 5$.

Table 3 (Col. (2)) reports slope estimates obtained by fitting (3) to KP's data, for u=3 and γ=1, 2, .., 9. I did not manage to reproduce KP's regression results *exactly* (see their Table 1), but results here are similar. The estimate of *b* is zero for γ=5.47; for smaller [larger] values of γ, the slope estimate is positive [negative]. As in KP, the estimates of *b* are not statistically significant, when γ>2. For γ=5 one cannot reject the hypothesis that the slope coefficient is zero, but (at conventional significance levels) one also fails to the reject the hypothesis that the slope coefficient equals any other value between -7 and +7.

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[4] $\widehat{\nu_\gamma^{j,k}} \equiv \frac{1}{T}\sum_{t=1}^{T}\{\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j}/\overline{C_{\gamma,t}^k})\}$. Under the null hypothesis, $\widehat{\nu_\gamma^{j,k}}$ is a consistent estimate of $\nu_\gamma^{j,k}$. A very similar estimate of $\nu_\gamma^{j,k}$ is obtained by subtracting the mean simulated log relative consumption moment (averaged over all simulations and over all sample periods) from the mean log real exchange rate.

[5] Table 2 also shows that the fraction of months in which $\ln e_t^{j,k} - \widehat{\nu_\gamma^{j,k}}$ lies outside α% confidence intervals is markedly larger than $100\% - \alpha\%$, for α=95%, 90% and 80%.

As shown above, the model error is very volatile. It is thus important to investigate the robustness of KP's regression results.

4. Sensitivity analysis

4.1. Regressions based on *annual* 1st differences, levels, and moving averages

Column (3) of Table 3 reports slope estimates based on regression (3) with *u*=12 (monthly time series of annual first differences), while Column (4) reports estimates from a regression based on variables in (log) levels:

$$\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j} / \overline{C_{\gamma,t}^k}) = a + b \ln e_t^{j,k} + \eta_t \, . \tag{4}$$

(An intercept is included in (4), to capture the term $\nu_\gamma^{j,k}$ in equation (1).) Column (5) reports slope coefficients based on a regression of a 12-month moving average of $\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j} / \overline{C_{\gamma,t}^k})$ on a 12-month moving average of the real exchange rate:

$$\tfrac{1}{12}\sum_{h=0}^{11} \{\ln e_{t-h}^{j,k} - \ln(\overline{C_{\gamma,t-h}^j} / \overline{C_{\gamma,t-h}^k})\} = a + b \tfrac{1}{12}\sum_{h=0}^{11} \ln e_{t-h}^{j,k} + \eta_t \, . \tag{5}$$

Using moving averages may lower the influence of measurement error and outliers. All regressions are run for $\gamma = 1, 2, .., 9$.

The 'levels' regression (equation (4)) yield results that are roughly in line with KP's result: for γ close to 5, the estimate of the slope coefficient *b* is zero.

By contrast, the 'annual 1st differences' and 'moving averages' regressions both overturn the KP findings, in the sense that the slope coefficient is positive for *all* values of γ. However the slope coefficient *b* is again estimated imprecisely when γ is large. I thus investigate whether other regressors yield more precisely estimated slope coefficients.

4.2. Other regressors

Lags and Leads of the real exchange rate

If the PIPO model is true, then a regression of the model error on *past* and *future* values of the exchange rate should also yield zero slope estimates. I added the first 12 lags and leads of the logged real exchange rate as regressors to equations (3) and (4). [6] The coefficients of *lagged* exchange rates are never jointly significant, in the 'quarterly 1st

[6] $\Delta_u \{\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j} / \overline{C_{\gamma,t}^k})\} = b \sum_{s=-12}^{s=12} \Delta_u \ln e_{t-s}^{j,k} + \eta_t$; $\ln e_t^{j,k} - \ln(\overline{C_{\gamma,t}^j} / \overline{C_{\gamma,t}^k}) = a + b \sum_{s=-12}^{s=12} \ln e_{t-s}^{j,k} + \eta_t$.

differences' and 'levels' regressions; they are jointly significant (at a 10% level), in the 'annual 1st differences' regressions, for $\gamma \geq 3$.

However, the model error is strongly correlated with *future* values of the real exchange rate. Table 4 reports p-values (from Wald tests) of the null hypothesis that all leads of the exchange rate have zero coefficients. In the 'quarterly 1st differences' regressions, the p-values are smaller than 10% when $\gamma \geq 2$; for $\gamma = 1$, the leads of the real exchange rate do not enter significantly in the regression—however, for $\gamma = 1$ the *contemporaneous* real exchange rate has a highly significant slope coefficient (see Table 3, Col. (2)); thus, either the current *or* the future values of the real exchange rate have significant coefficients, in the 'quarterly 1st differences' regressions—which implies rejection of the PIPO model.

In the 'annual 1st differences' regressions, the p-values of leads of the real exchange rate are all smaller than 1.3%, for all values of γ considered in Table 4. In the and 'levels' regressions, the p-values are all smaller than 7.4%. This again is a clear rejection of the PIPO model. The real exchange rate does *not* track the relevant relative cross-sectional consumption moments in the manner predicted by the PIPO model.

Relative industrial production and stock indices

Table 5 reports slope estimates from regressions of the model error on log relative UK/US industrial production (Panel a), and on the logged relative UK/US stock price (Panel b). (See Table 5 for data sources.)

In the 'levels' and 'moving averages' regressions (Columns (4),(5)), **relative industrial production** has negative slope coefficients, for all values of γ; those estimates are significant, at a 1% level, for $\gamma \geq 2$ and $\gamma \geq 3$, respectively.

The slope estimates of the **relative stock price** are negative, for all four regression specifications, and for all values γ. In the 'quarterly/annual 1st differences' regressions, the slope coefficient is statistically significant for $\gamma \leq 4$. In the 'levels' and 'moving averages' regressions, the slope coefficient is statistically significant (often very highly) for all values of γ. This too implies rejection of the PIPO model.

4.3. Alternative estimates of cross-sectional moments of consumption

Higher-order cross-sectional consumption moments are largely driven by the consumption of the richest households, and may thus be especially sensitive to measurement error in the right-tail of the distribution. In the US [UK] sample, the largest observation accounts for 26.2% [38.7%] of the *sum* of the fifth power of *all* household consumptions for that country, over the *entire* sample period 1980-1999.

Trimmed and winsorized estimates of cross-sectional moments of consumption

In order to reduce the influence of extreme observations, I estimated the cross-sectional $\gamma-$th consumption moment for each country using trimmed means and winsorized means of individual consumptions raised to the power γ; I set the truncation points at the smallest and largest 1% observations. (The trimmed mean is obtained by discarding the top and bottom 1% observations; the winsorized mean 'accumulates' the top and bottom 1% observations at the truncation point.) Trimming and winsorizing may provide more robust estimates of moments of heavy tailed distributions (Amemiya (1985). As both approaches yield very similar results, I only report results for winsorized moments.

Winsorizing greatly reduces the volatility of the relative cross-sectional consumption moments. E.g., for $\gamma=5$, the standard deviation and autocorrelation of the logged relative winsorized cross-sectional consumption moments are 72.4% and 0.51, respectively, and its correlation with the logged real exchange rate is -0.25 (corresponding statistics without winsorizing: 245.4%, 0.08 and 0.06; see above).

Table 6 reports slope estimates from regressions of model errors based on winsorized cross-sectional moments. The Table provides further evidence against the PIPO model. The slope coefficients of *relative industrial production* are significant (at the 10% level or below) in the 'levels' regressions for $\gamma\geq 2$, and in the 'moving averages' regressions, for $\gamma\geq 3$. The slope estimates of the *real exchange rate* and of the *relative stock price* are statistically significant in all four regression specifications and that for almost all values of γ;[7] in the 'levels' and 'moving average' regressions, those slope estimates are all significant at the 0.1% level or below.

[7] In the 'quarterly 1st differences' regressions, the real exchange rate is not significant for $\gamma\geq 6$.

5. Regressions based on the consumption share of the biggest spenders

A key prediction of the PIPO model is that the real exchange rate is linked to the right-tail of the consumption distribution (provided γ>1). Kocherlakota and Pistaferri (2008) argue that the proportion of aggregate consumption accounted for by the richest household can be used as a proxy for right-tail consumption inequality. Let $\overline{R^j_{\alpha,t}}$ be the fraction of total consumption in country *j* at date *t*, among the households included in KP's sample, that is accounted for by the top α % households (ranked by spending at *t*). I run these regressions:

$$\ln e_t^{j,k} = a + b\ln(\overline{R^j_{\alpha,t}}/\overline{R^k_{\alpha,t}}) + c\ln(\overline{C^j_{1,t}}/\overline{C^k_{1,t}}) + \eta_t\,, \qquad (6a)$$

$$\Delta_u \ln e_t^{j,k} = a + b\,\Delta_u \ln(\overline{R^j_{\alpha,t}}/\overline{R^k_{\alpha,t}}) + c\Delta_u \ln(\overline{C^j_{1,t}}/\overline{C^k_{1,t}}) + \eta_t\,, \text{ for u=3, 12} \qquad (6b)$$

where $\overline{C^j_{1,t}}$ is per capita consumption in country *j* (based on KP's household data). *b*>0 can be viewed as evidence for the PIPO model; a complete markets model predicts *c*>0.

Table 7 reports estimates of *b* and *c*, for $\alpha = 50\%$, 25%, 10% and 5%. The estimates of *c* are all negative; Table 7 is thus consistent with the rejections of the complete markets model reported in the literature. The estimates of *b* are positive for only half of the regressions; the estimates are numerically small and never statistically significant. [8] Thus, there is no significant relation between the UK/US real exchange rate and relative right-tail consumption inequality. This again suggests that the PIPO model is inconsistent with the UK/US data.

6. Conclusion

This paper has shown that the PIPO model is inconsistent with the behavior of the UK/US real exchange rate, and with household-level consumption data for these countries. The real exchange rate does *not* track the relevant domestic vs. foreign cross-sectional consumption moments. The link between the real exchange rate and consumption (heterogeneity) remains a puzzle.

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[8] Kocherlakota and Pistaferri (2008) report significant slope coefficients, in panel regressions of the real exchange rates on *income* shares received by the richest 10% households. The *consumption* shares of the top households used here are relevant for testing the PIPO model (not the income shares).

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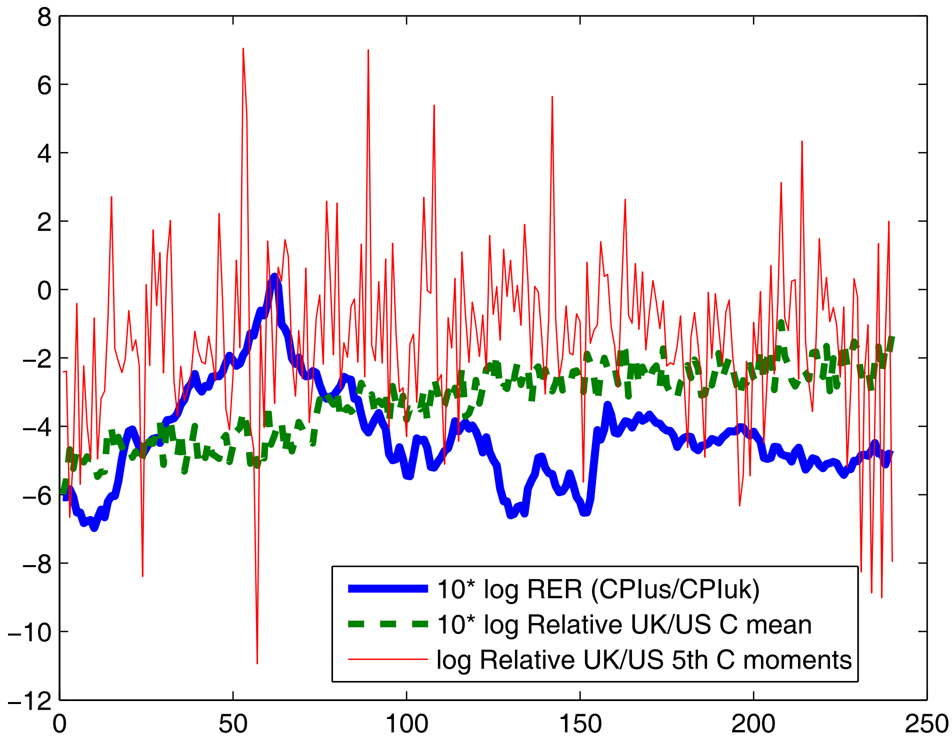

Figure 1—The Figure shows monthly time series (1980-1999) of the logged real exchange rate $e_t^{UK,US}$ ('RER'), and of logged relative UK/US cross-sectional consumption moments of orders $\gamma=1$ (line labeled 'Relative UK/US Cmean') and $\gamma=5$ ('Relative UK/US 5th C moments'). **Note: the logged real exchange rate, and logged relative mean consumption $(\gamma=1)$ are both scaled by the factor 10.**

Table 1. Properties of relative cross-sectional consumption moments and of model errors

	γ							
	1	2	3	4	5	6	7	8
Std. of $\ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}})$	10.3%	29.7%	88.5%	166.8%	245.4%	320.2%	391.8%	461.1%
Autocorrel. of $\ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}})$	0.84	0.43	0.14	0.09	0.08	0.07	0.07	0.07
$Corr(\ln(\frac{\overline{C_{\gamma,t}^{UK}}}{\overline{C_{\gamma,t}^{US}}}), \ln(e_t^{UK,US}))$	-0.31	-0.17	-0.02	0.04	0.06	0.06	0.06	0.06
Std. of model error	19.7%	35.0%	89.9%	166.8%	244.9%	319.7%	391.2%	460.4%

Note—The Table reports the standard deviation (Row 1) and autocorrelation (Row 2) of monthly time series (1980-1999) of the logged relative UK/US cross-sectional $\gamma-$th consumption moment (for $\gamma=1,2,..,9$) as well as its correlation with the logged real exchange rate $e_t^{UK,US}$ (Row 3). Also shown is the standard deviation of the model error, $\ln e_t^{UK,US} - \ln(\overline{C_{\gamma,t}^{UK}}/\overline{C_{\gamma,t}^{US}}) - \nu_\gamma^{UK,US}$ (Row 4).

Table 2. Fractions of periods in which $\ln e_t^{j,k} - \widehat{\nu_\gamma^{j,k}}$ does *not* lie in $\alpha\%$ bootstrap confidence interval

	γ							
	1	2	3	4	5	6	7	8
$\alpha = 99\%$	60.9%	35.3%	16.4%	14.3%	10.9%	10.5%	10.5%	10.1%
$\alpha = 95\%$	72.7%	43.3%	26.1%	21.4%	20.2%	21.0%	21.4%	21.0%
$\alpha = 90\%$	78.2%	50.0%	33.6%	31.1%	28.6%	29.4%	29.0%	29.4%
$\alpha = 80\%$	84.5%	59.7%	44.1%	42.9%	43.3%	43.3%	44.5%	45.4%

Note—The Table reports the fraction of months (1980-1999) in which the adjusted log real exchange rate $\ln e_t^{j,k} - \widehat{\nu_\gamma^{j,k}}$ lies outside the $\alpha\%$ bootstrap confidence interval for the logged relative UK/US $\gamma-$th cross-sectional consumption moment. Bootstrap confidence intervals are constructed using the 'modified percentile method', i.e. the $\alpha\%$ confidence interval is the shortest interval that includes $\alpha\%$ of the simulated statistics (Davidson and MacKinnon (1993, p.766)).

Table 3. Slope estimates in regressions of model errors on real exchange rate

γ	Quarterly 1^{st} differences	Annual 1^{st} differences	Levels	Moving averages
(1)	*(2)*	*(3)*	*(4)*	*(5)*
1	**1.04** (0.08)	**1.04** (0.05)	**1.23** (0.04)	**1.31** (0.13)
2	**1.34** (0.45)	**1.16** (0.21)	**1.38** (0.13)	**1.57** (0.27)
3	1.67 (1.55)	**1.30** (0.71)	**1.12** (0.41)	**1.48** (0.46)
4	1.29 (2.97)	1.17 (1.36)	0.54 (0.77)	**1.11** (0.75)
5	0.45 (4.29)	0.93 (2.00)	-0.02 (1.14)	0.78 (1.06)
6	-0.52 (5.60)	0.69 (2.61)	-0.47 (1.49)	0.56 (1.35)
7	-1.48 (6.87)	0.48 (3.20)	-0.85 (1.82)	0.41 (1.64)
8	-2.39 (8.09)	0.29 (3.76)	-1.19 (2.15)	0.28 (1.91)
9	-3.23 (9.30)	0.12 (4.31)	-1.51 (2.46)	0.18 (2.17)

Note—The Table reports slope coefficients of regressions of model errors (for $\gamma = 1, 2, .., 9$) on the logged real exchange rate. Figures in parentheses are standard errors. The regressions are run in quarterly 1^{st} differences (Col. (2)), annual 1^{st} differences (Col. (3)), levels (Col. (4)), and moving averages (Col. (5)). The standard errors are of the Newey-West (1987) form; the number of lags used is three in Col. (2), twelve in Cols. (3) and (5), and zero in Col. (4).

Coefficients in **bold** font that are underlined by a continuous [dotted] line are significant at the 5% [10%] level (one-sided test).

Table 4. p-values of first 12 leads of real exchange rate

γ	Quarterly 1^{st} differences	Annual 1^{st} differences	Levels
(1)	(2)	(3)	(4)
1	0.43	0.00	0.00
2	0.09	0.01	0.00
3	0.06	0.01	0.07
4	0.04	0.00	0.07
5	0.02	0.00	0.06
6	0.02	0.00	0.04
7	0.01	0.00	0.04
8	0.01	0.00	0.03
9	0.01	0.00	0.03

Note—This Table is based on regressions of model errors (for $\gamma = 1, 2, .., 9$) on the current logged real exchange rate, as well as on the first 12 lags and leads of the logged real exchange rate. The Table reports p-values of Wald tests that the first 12 leads of the logged real exchange rate all have zero coefficients. The regressions are run in quarterly 1^{st} differences (Col. (2)), annual 1^{st} differences (Col. (3)) and levels (Col. (4)). The Wald test is based on a covariance matrix of estimated coefficients of the Newey-West (1987) form; the number of lags used is three in Col. (2), twelve in Col. (3), and zero in Col. (4).

Table 5. Slope estimates in regressions of model errors on additional macro variables

γ	Quarterly 1st differences	Annual 1st differences	Levels	Moving averages
(1)	(2)	(3)	(4)	(5)
(a) Regressions on relative industrial production				
1	0.07 (0.33)	0.14 (0.51)	-0.18 (0.25)	-0.49 (0.89)
2	0.24 (1.23)	0.39 (0.80)	**-1.29** (0.44)	-1.56 (1.20)
3	-0.58 (4.12)	0.63 (2.09)	**-3.85** (1.13)	**-3.42** (1.45)
4	-4.78 (7.73)	-0.20 (3.88)	**-6.94** (2.10)	**-5.46** (1.95)
5	-10.64 (11.35)	-1.81 (5.70)	**-9.92** (3.09)	**-7.35** (2.65)
6	-16.64 (14.81)	-3.58 (7.43)	**-12.71** (4.04)	**-9.11** (3.39)
7	-22.32 (18.14)	-5.29 (9.05)	**-15.37** (4.95)	**-10.81** (4.10)
8	**-27.67** (21.37)	-6.88 (10.69)	**-17.95** (5.83)	**-12.47** (4.80)
9	**-32.74** (24.54)	-8.39 (12.26)	**-20.48** (6.68)	**-14.12** (5.48)
(b) Regressions on relative stock price				
1	**-0.39** (0.08)	**-0.64** (0.10)	**-0.97** (0.04)	**-1.05** (0.13)
2	**-0.86** (0.31)	**-0.91** (0.19)	**-1.46** (0.10)	**-1.54** (0.15)
3	**-1.88** (1.07)	**-1.48** (0.60)	**-1.90** (0.33)	**-1.87** (0.26)
4	**-2.76** (2.03)	**-1.88** (1.17)	**-2.12** (0.65)	**-1.95** (0.52)
5	-3.40 (2.99)	-2.14 (1.74)	**-2.26** (0.96)	**-1.99** (0.80)
6	-3.93 (3.91)	-2.38 (2.28)	**-2.42** (1.26)	**-2.07** (1.07)
7	-4.40 (4.80)	-2.62 (2.81)	**-2.62** (1.55)	**-2.19** (1.31)
8	-4.87 (5.65)	-2.86 (3.31)	**-2.38** (1.82)	**-2.34** (1.55)
9	-5.33 (6.49)	-3.11 (3.80)	**-3.05** (2.10)	**-2.50** (1.77)

Note—The Table reports slope coefficients in regressions of model errors (for $\gamma=1,2,..,9$) on logged relative UK/US industrial production (Panel (a)), and on the logged relative UK/US stock price (Panel (b)). Figures in parentheses are standard errors. The regressions are run in quarterly 1st differences (Col. (2)), annual 1st differences (Col. (3)), levels (Col. (4)), and moving averages (Col. (5)). The standard errors are of the Newey-West (1987) form; the number of lags used is three in Col. (2), twelve in Cols. (3) and (5), and zero in Col. (4).

Coefficients in **bold** font that are underlined by a continuous [dotted] line are significant at the 5% [10%] level (one-sided test).

Industrial production (IP) series are from International Financial Statistics. Relative UK/US IP has a strong downward trend. I thus use linearly detrended logged relative IP as a regressor. Stock prices are cumulated dollar stock returns for the US and the UK, taken from Kenneth French's website.

Table 6. Regressions results based on model errors constructed from winsorized cross-sectional moments of consumption

γ	Quarterly 1st differences	Annual 1st differences	Levels	Moving averages
(1)	(2)	(3)	(4)	(5)
(a) Regression of model error on real exchange rate				
1	**1.05** (0.07)	**1.03** (0.05)	**1.24** (0.04)	**1.32** (0.13)
2	**1.13** (0.19)	**1.11** (0.12)	**1.51** (0.10)	**1.69** (0.27)
3	**1.25** (0.39)	**1.22** (0.24)	**1.78** (0.16)	**2.07** (0.42)
4	**1.36** (0.65)	**1.34** (0.40)	**2.04** (0.24)	**2.43** (0.55)
5	**1.44** (0.96)	**1.47** (0.58)	**2.29** (0.32)	**2.80** (0.68)
6	1.49 (1.28)	**1.59** (0.77)	**2.53** (0.41)	**3.15** (0.82)
7	1.52 (1.59)	**1.70** (0.96)	**2.78** (0.50)	**3.51** (0.96)
8	1.52 (1.90)	**1.80** (1.15)	**3.02** (0.60)	**3.87** (1.09)
9	1.52 (2.21)	**1.90** (1.33)	**3.26** (0.69)	**4.23** (1.23)
(b) Regression of model error on relative industrial production				
1	0.12 (0.32)	0.12 (0.51)	-0.15 (0.25)	-0.47 (0.90)
2	0.08 (0.57)	-0.06 (0.62)	**-0.79** (0.38)	-1.26 (1.29)
3`	0.04 (1.06)	-0.42 (0.87)	**-1.65** (0.54)	-2.21 (1.70)
4	-0.02 (1.75)	-0.96 (1.27)	**-2.60** (0.74)	**-3.19** (2.10)
5	-0.12 (2.54)	-1.62 (1.74)	**-3.57** (0.96)	**-4.16** (2.49)
6	-0.25 (3.37)	-2.31 (2.25)	**-4.51** (1.20)	**-5.10** (2.90)
7	-0.38 (4.20)	-3.02 (2.76)	**-5.43** (1.45)	**-6.02** (3.30)
8	-0.52 (5.02)	-3.70 (3.27)	**-6.33** (1.69)	**-6.93** (3.71)
9	-0.64 (5.82)	-4.37 (3.77)	**-7.22** (1.93)	**-7.82** (4.13)
(c) Regression of model error on relative stock price				
1	**-0.37** (0.07)	**-0.63** (0.10)	**-0.97** (0.05)	**-1.05** (0.13)
2	**-0.54** (0.14)	**-0.72** (0.14)	**-1.44** (0.07)	**-1.57** (0.18)
3	**-0.82** (0.27)	**-0.83** (0.22)	**-1.94** (0.11)	**-2.12** (0.23)
4	**-1.21** (0.44)	**-0.97** (0.35)	**-2.43** (0.17)	**-2.64** (0.29)
5	**-1.65** (0.65)	**-1.10** (0.50)	**-2.91** (0.24)	**-3.15** (0.36)
6	**-2.11** (0.87)	**-1.23** (0.66)	**-3.37** (0.32)	**-3.64** (0.44)
7	**-2.57** (1.09)	**-1.36** (0.82)	**-3.84** (0.39)	**-4.12** (0.52)
8	**-3.02** (1.30)	**-1.49** (0.98)	**-4.29** (0.46)	**-4.60** (0.60)
9	**-3.46** (1.51)	**-1.61** (1.13)	**-4.75** (0.53)	**-5.08** (0.69)

Note—The Table reports slope coefficients in regressions of model errors, constructed using winsorized cross-sectional consumption moments (of order $\gamma=1,2,..,9$) on the logged real exchange rate (Panel (a)), on logged relative industrial production (Panel (b)), and on the logged relative stock price (Panel (c)). Figures in parentheses are standard errors.

The regressions are run in quarterly 1st differences (Col. (2)), annual 1st differences (Col. (3)), levels (Col. (4)), and moving averages (Col. (5)). The standard errors are of the Newey-West (1987) form; the number of lags used is three in Col. (2), twelve in Cols. (3) and (5), and zero in Col. (4).

Coefficients in **bold** font that are underlined by a continuous [dotted] line are significant at the 5% [10%] level (one-sided test).

Table 7. Regressions of real exchange rate on relative share of α % largest consumptions and on relative per capita consumption

	b	c	R^2
(1)	(2)	(3)	(4)
(i) Regression in quarterly first differences			
$\alpha = 50\%$	-0.07 (0.19)	-0.02 (0.06)	0.002
$\alpha = 25\%$	-0.01 (0.08)	-0.03 (0.07)	0.002
$\alpha = 10\%$	0.01 (0.03)	-0.04 (0.06)	0.002
$\alpha = 5\%$	0.01 (0.02)	-0.05 (0.06)	0.002
(ii) Regression in annual first differences			
$\alpha = 50\%$	-0.27 (0.54)	-0.14 (0.20)	0.01
$\alpha = 25\%$	-0.03 (0.22)	-0.18 (0.19)	0.01
$\alpha = 10\%$	-0.01 (0.10)	-0.18 (0.18)	0.01
$\alpha = 5\%$	0.02 (0.06)	-0.22 (0.18)	0.01
(iii) Regression in levels			
$\alpha = 50\%$	-0.11 (1.12)	-0.41 (0.28)	0.10
$\alpha = 25\%$	0.12 (0.45)	-0.44 (0.26)	0.10
$\alpha = 10\%$	0.13 (0.19)	-0.44 (0.25)	0.10
$\alpha = 5\%$	0.11 (0.11)	-0.45 (0.25)	0.11

Note—The Table reports slope estimates in regressions of the logged real exchange rate on the logged relative share of total consumption accounted for by the $\alpha\%$ largest consumptions (coefficient b) and on logged relative per capita consumption (coefficient c). See equations (6a) and (6b). Figures in parentheses are standard errors. The regressions are run in quarterly first differences (Panel (i)), annual first differences (Panel (ii)) and in levels (Panel (iii)). The standard errors are of the Newey-West (1987) form; the number of lags used is twelve.