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The predictive power of equilibrium exchange rate models

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Overview

Motivation

1. **Policy makers interested in equilibrium exchange rates (EqERs)**
   - Exchange rate gaps may have an important bearing on external sustainability, growth prospects, price dynamics or financial stability.
   - EqER assessments are regularly carried out by the IMF, central banks and market analysts using a variety of models.

2. **EqER models give very different results. Which one should we trust?**
   - From a normative perspective, it is important to link equilibrium exchange rates to economic fundamentals.
   - From a positive perspective, it is a desirable feature if exchange rates converge to equilibrium exchange rates.

Selected relevant papers

Equilibrium exchange rates

- MacDonald and Clark (1998); Driver and Westaway (2004); Isard (2007); Phillips et al. (2013); Fidora et al. (2017), Cubeddu et al. (2019).

Real and nominal exchange rate forecasting on the basis of PPP

- Taylor and Taylor (2004), Ca' Zorzi, Mućk & Rubaszek (2016), Ca' Zorzi, Kolasa & Rubaszek (2017), Eichenbaum, Johannsen & Rebelo (2017), Ca' Zorzi & Rubaszek (2018).

Predictive power of real time equilibria exchange rate estimates

- Abiad et al. (2009), Yesin (2016).

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Outline and key findings

What we do in this paper ?

- Discuss the three main models of equilibrium exchange rates (PPP, BEER and MB).
- Provide in-sample evidence on whether exchange rates adjusts to EqERs.
- Present out-of-sample results.

Key findings:

- PPP based forecasts are generally superior to those from the RW model.
- The relationship between exchange rates and fundamentals is feeble: adding fundamentals within the BEER model does not systematically improve forecast accuracy.
- The high sophistication of the MB model, even if appealing from a normative perspective, tends to be counterproductive out of sample.
- There is a trade-off between storytelling and predictive power for equilibrium exchange rate models.

For a full draft see Ca' Zorzi et al., ECB WP No 2358

https://www.ecb.europa.eu/pub/pdf/scpwps/ecb.wp2358~4382d88430.en.pdf?69b15f8bccded76bf868e7c7d0a418c5

Data

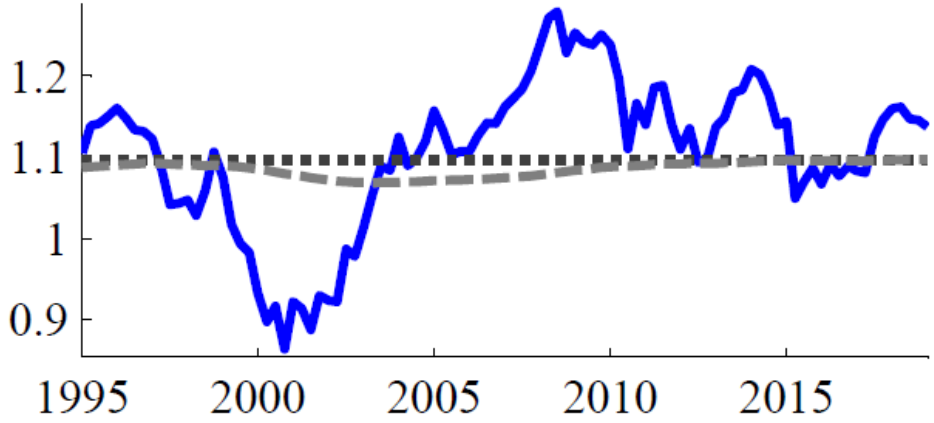
10 Countries:	USA, EA, GBP, CHE, SWE, NOR, CAD, AUS, NZL, JPN
Sample:	1975:1-2018:4 [forecasts for 1995:1-2018:4]
Time series:	Real effective ER (based on BIS weights from 1995) GDP per capita Net foreign assets (% of GDP) Terms of Trade Exports/Imports share (% of GDP) Current Account (% of GDP)
Main sources:	IMF, OECD, BIS, ECB

Equilibrium exchange rate concepts

Purchasing Power Parity

- The oldest theory of exchange rate determination.
- PPP implication: the real exchange rate is a mean reverting process.
- PPP-implied equilibrium exchange rate is calculated as the sample mean of the real.

$$rer_{it}^{PPP} = \overline{rer_i}$$



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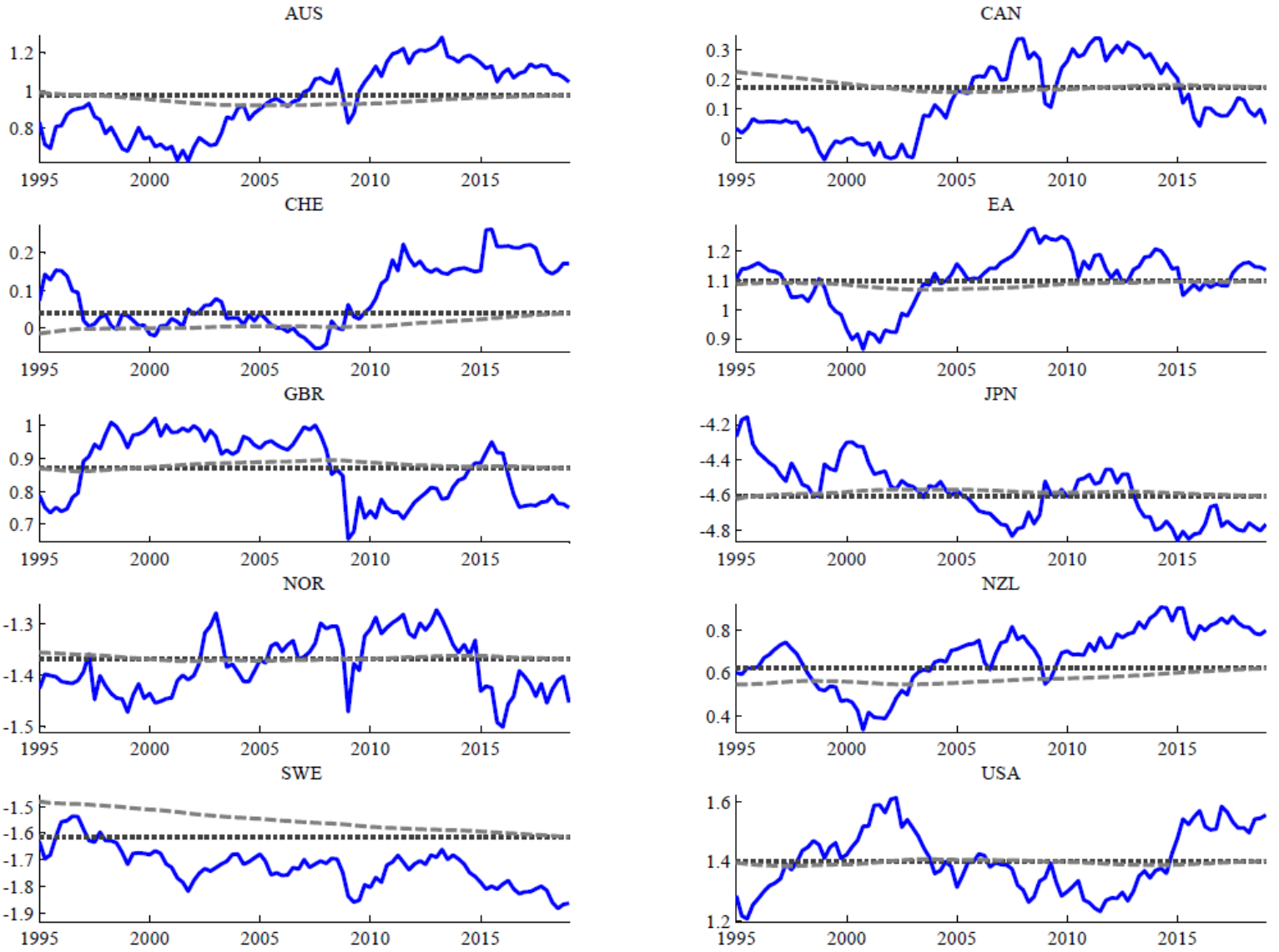
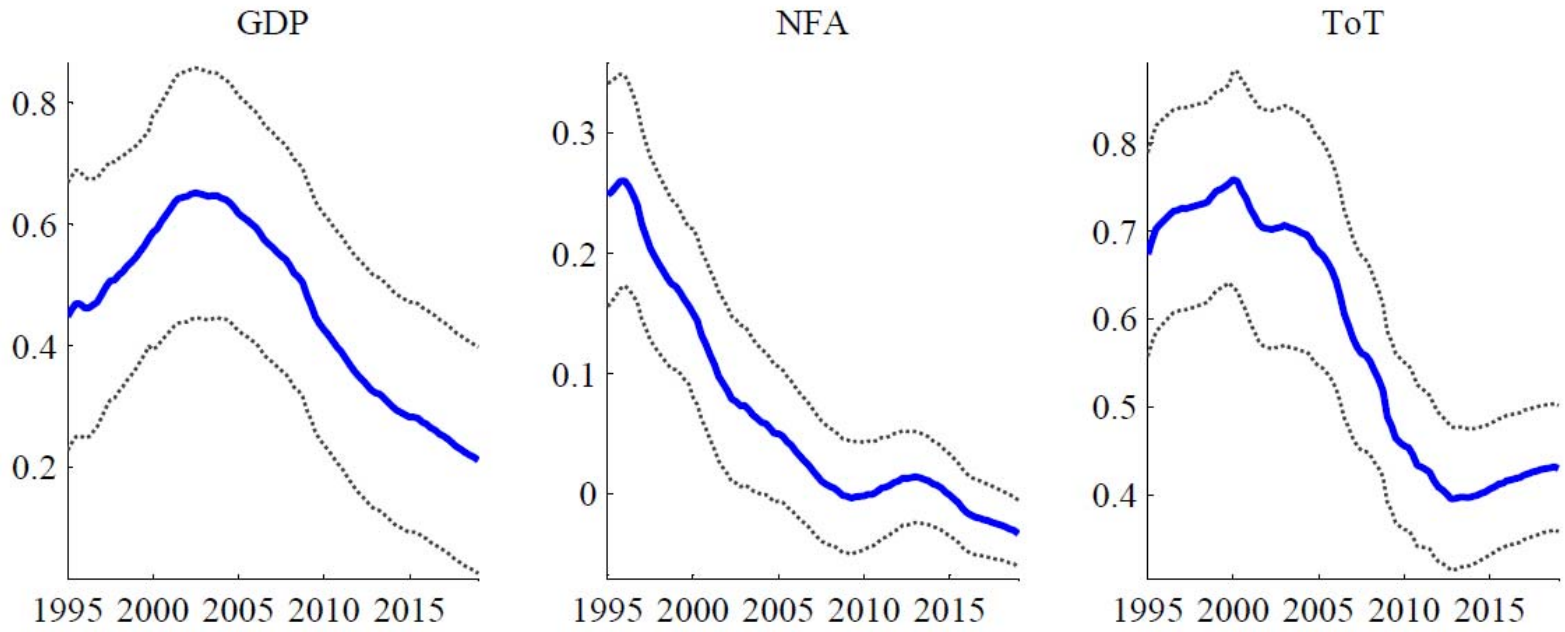
Full sample & recursive EqER: PPP model provides stable estimates



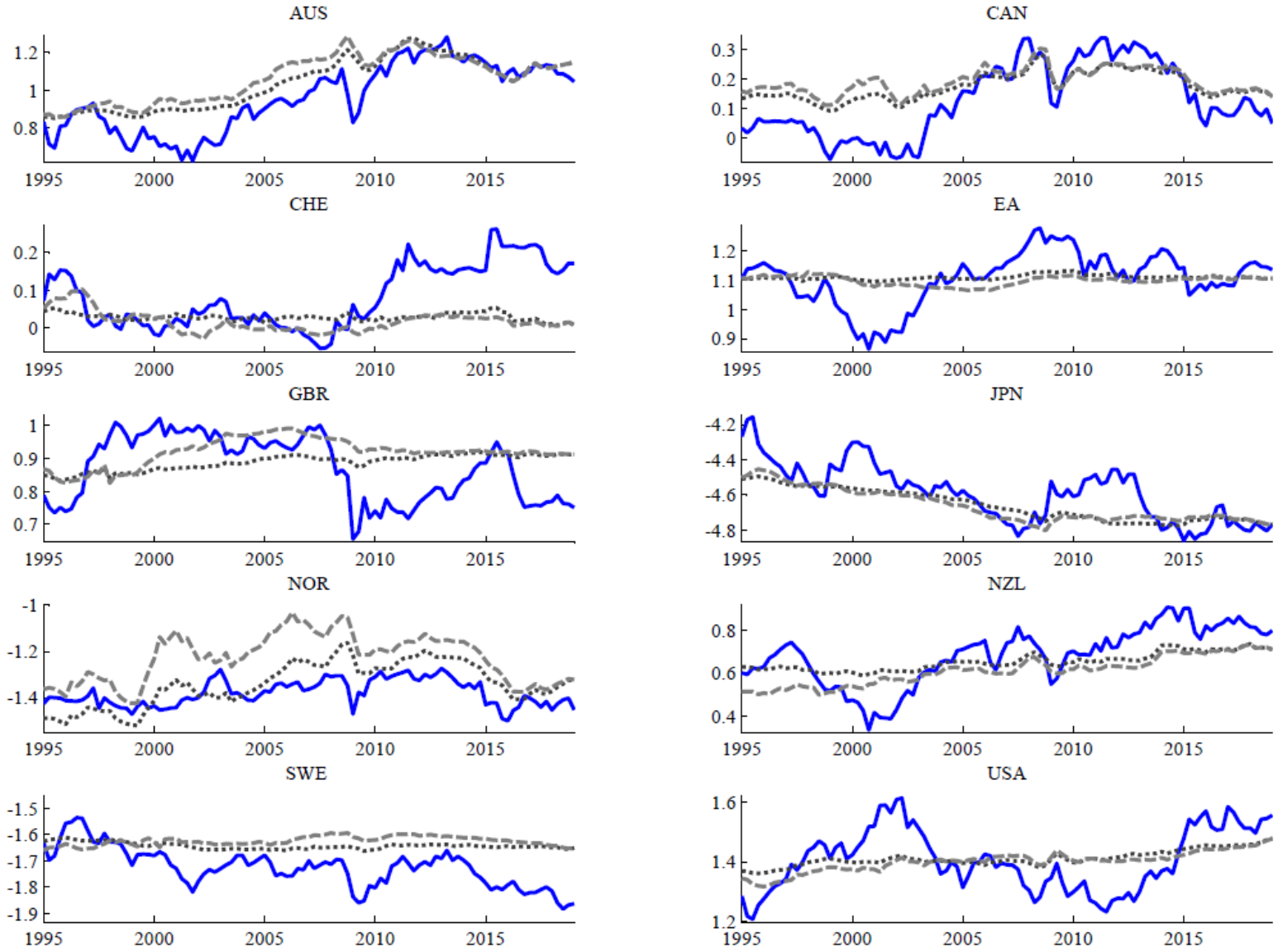
Behavioral Equilibrium Exchange Rate

- A concept popularized by MacDonald and Clark (1998).
- The real exchange rate is assumed to be I(1) and cointegrated with economic fundamentals.
- We calculate the value of BEER as the fitted value of (FM-OLS) panel regression (GDP per capita, net foreign assets and terms of trade).

$$rer_{it}^{BEER} = \mu_i + \alpha_1 gdp_{it} + \alpha_2 nfa_{it} + \alpha_3 tot_{it}$$



Full sample & recursive EqER: BEER model



Macroeconomic balance approach

A (normative) concept popularized by Williamson (1994) under the name of **Fundamental Equilibrium Exchange Rate** model.

Definition of MB EqER: Exchange rate consistent with external/internal balance.

Ingredients to calculate MB EqER:

1. **Underlying CA.** CA level if the ER remained unchanged and output gaps are closed ($\widetilde{ca}$).
2. **CA norm** (ca^{norm}).
3. **Elasticity of CA to ER.** How CA reacts to changes in ER (η).

Formula to calculate the degree of exchange rare overvaluation:

$$rer_{it} - rer_{it}^{MB} = \frac{\widetilde{ca}_{it} - ca_{it}^{norm}}{\eta_{it}}$$

Macroeconomic balance approach

Our baseline assumptions:

1. **Underlying CA.** Equal to the observed current account.
2. **CA norm.** Fitted values from panel regression $ca_{it}^{norm} = \omega + \beta_1 gdp_{it} + \beta_2 nfa_{it} + \beta_3 tot_{it}^{hp}$
3. **Elasticity of CA to ER.** Calculated using:

   - trade openness data (μ_x and μ_m)
   - trade volume price elasticities (γ_x and γ_m)
   - ER pass-through to export and import prices (δ_x and δ_m)

$$\eta_{it} = \mu_{x,it}(\delta_x + (1 + \delta_x)\gamma_x) - \mu_{m,it}(\delta_m + \delta_m\gamma_m)$$

4. Producer currency pricing (PCP): $\gamma_x = -1;\ \gamma_m = -1;\ \delta_x = 0;\ \ \delta_m = -1$

Alternative:

Imperfect pass-through (IPT): $\gamma_x = -1;\ \gamma_m = -1;\ \delta_x = -0.5;\ \delta_m = -0.5$

Macroeconomic balance approach

$$\eta_{it} = \mu_{x,it}(\delta_x + (1 + \delta_x)\gamma_x) - \mu_{m,it}(\delta_m + \delta_m\gamma_m)$$

Producer currency pricing (PCP) assumptions: $\gamma_x = -1;\ \gamma_m = -1;\ \delta_x = 0;\ \delta_m = -1$

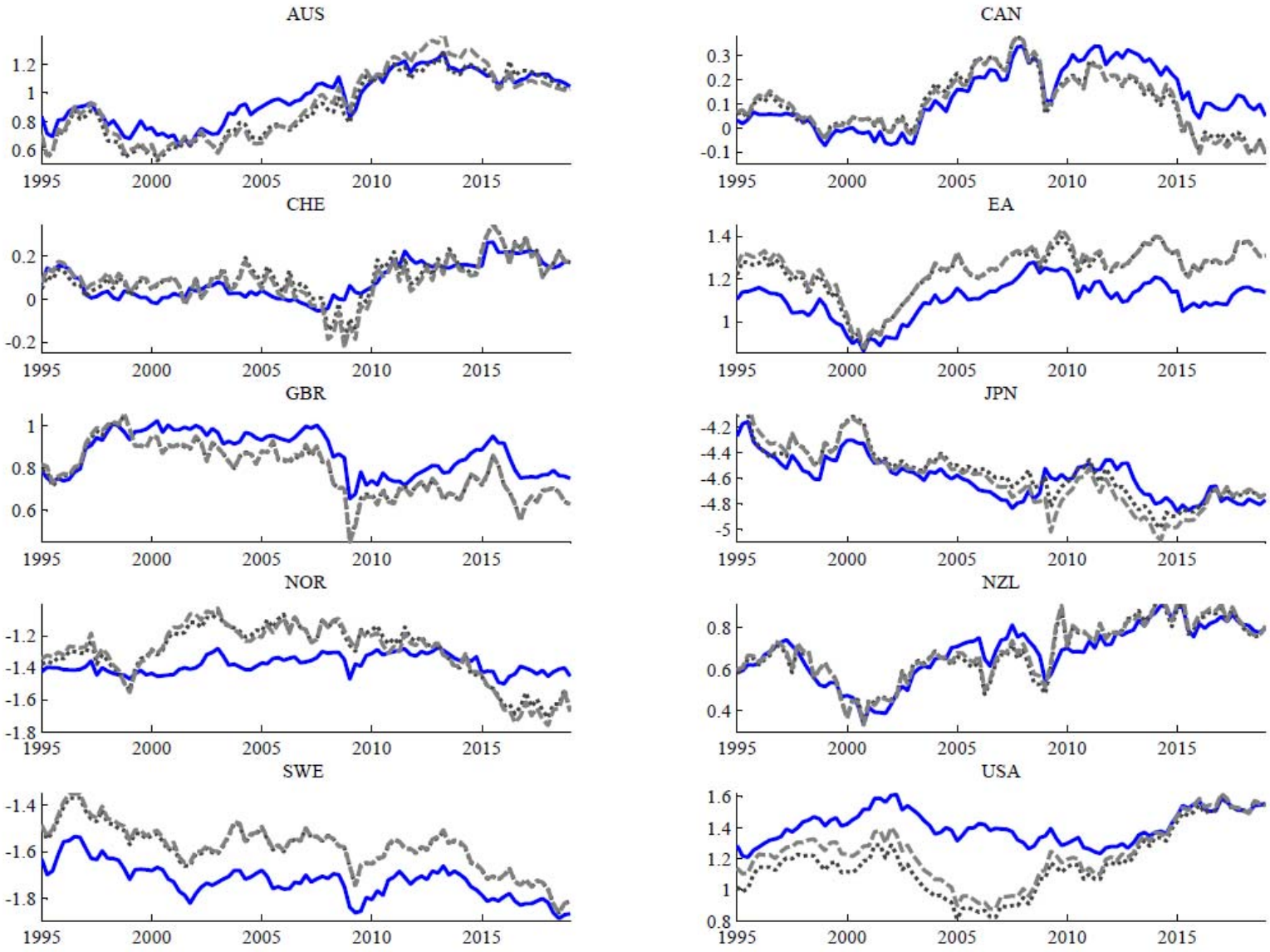
Imperfect pass-through (IPT) assumptions: $\gamma_x = -1;\ \gamma_m = -1;\ \delta_x = -0.5;\ \delta_m = -0.5$

Current account reaction to a 1% real effective exchange rate depreciation.

	Openess in 2018 (% GDP)		CA to RER elasticity ($-\eta_i$)		
	Export	Import	PCP	IPT	IMF
AUS	23	22	0.23	0.12	0.20
CAN	32	34	0.32	0.15	0.27
CHE	66	53	0.66	0.36	0.53
EA	28	25	0.28	0.15	-
GBR	30	31	0.30	0.15	0.24
JPN	18	18	0.18	0.09	0.14
NOR	38	32	0.38	0.20	0.35
NZL	28	28	0.28	0.14	0.25
SWE	47	44	0.47	0.24	0.36
USA	12	15	0.12	0.05	0.12

IPT consistent with lower values of η would imply larger misalignments.

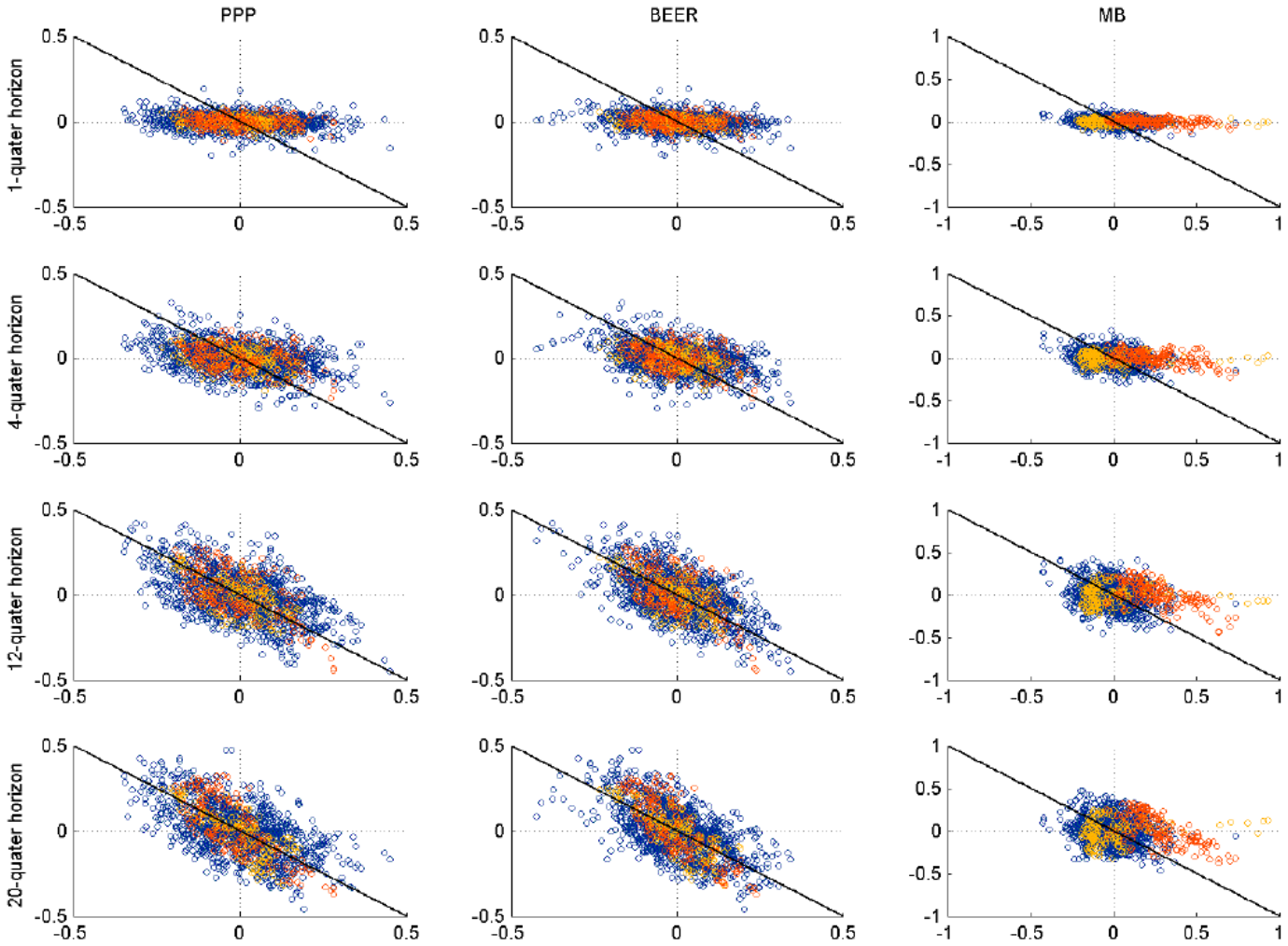
Full sample & recursive EqER: MB model provides more volatile estimates



Exchange rate adjustments
(in-sample analysis)

Adjustment of the real exchange rate toward its equilibrium

A desirable feature would be that the exchange rate adjusts toward its equilibrium. This can be illustrated by scatter-plots of exchange rate changes ($rer_{t+h} - rer_t$, Y-axis) on misalignments ($rer_t - rer_t^{eq}$, X-axis)



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Adjustment of ER to EqER

The ER convergence to EqER can also be measured by estimating regressions:

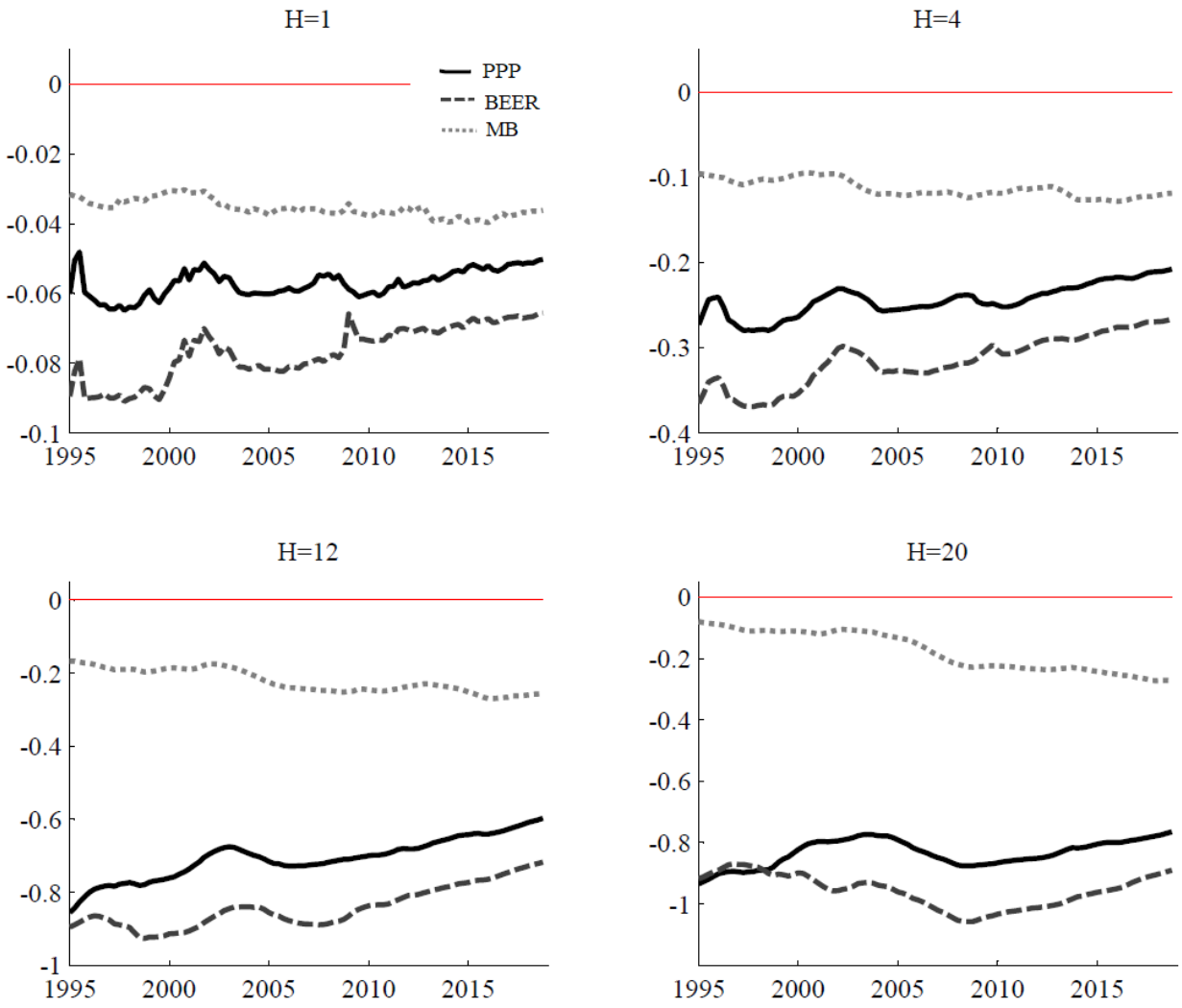
$$\Delta rer_{it,h} = \omega_{ih} + \delta_{ih}(rer_{i,t-h} - rer^{M}_{i,t-h}) + \epsilon_{it}$$

Tab. Estimates for δ_h for the ER adjustment regressions

	PPP	BEER	MB	PPP	BEER	MB
	1-quarter horizon			4-quarter horizon		
AUS	-0.04**	-0.08***	-0.06	-0.16***	-0.30***	-0.23*
CAN	-0.04**	-0.05**	-0.04	-0.18***	-0.24***	-0.15
CHE	-0.07***	-0.06**	-0.03	-0.25***	-0.21***	-0.02
EA	-0.07**	-0.07**	0.00	-0.28***	-0.31***	-0.01
GBR	-0.07***	-0.06**	-0.05	-0.31***	-0.27***	-0.21
JPN	-0.06**	-0.07***	-0.12***	-0.25***	-0.33***	-0.37***
NOR	-0.15***	-0.04*	-0.01	-0.46***	-0.15**	-0.04
NZL	-0.05**	-0.11***	-0.07**	-0.20***	-0.34***	-0.14**
SWE	-0.02	-0.04	-0.03	-0.11	-0.17**	-0.11
USA	-0.05*	-0.06*	-0.05***	-0.22**	-0.27**	-0.20***
Panel	-0.05***	-0.07***	-0.04***	-0.21***	-0.27***	-0.12***
	12-quarter horizon			20-quarter horizon		
AUS	-0.47***	-0.73***	-0.57***	-0.58***	-0.87***	-0.48*
CAN	-0.62***	-0.81***	-0.70***	-0.90***	-1.09***	-1.44***
CHE	-0.47***	-0.38***	0.15	-0.46***	-0.34**	-0.04
EA	-0.72***	-0.79***	0.01	-1.11***	-1.24***	0.10**
GBR	-0.95***	-0.82***	-0.63*	-1.25***	-1.08***	-0.62*
JPN	-0.70***	-0.84***	-0.63***	-0.72***	-0.86***	-0.76***
NOR	-0.92***	-0.22**	-0.16**	-0.91***	-0.22**	-0.18***
NZL	-0.58***	-0.95***	-0.12	-0.74***	-1.11***	-0.10
SWE	-0.29***	-0.44***	-0.26*	-0.35***	-0.55***	-0.24*
USA	-0.80***	-0.94***	-0.54***	-1.30***	-1.52***	-0.72***
Panel	-0.60***	-0.72***	-0.26***	-0.77***	-0.89***	-0.27***

Adjustment of ER to EqER

Recursive panel estimates for the adjustment coefficient δ_h



Out-of-sample analysis

Out-of-sample contest

Forecast competition settings:

- Point forecasts for horizons ranging from one to twenty quarters ahead
- EqER models estimated using recursive samples with vintages starting at 1975:1 and ending in one of the periods from 1994:4 to 2018:3
- 1Q ahead forecasts evaluated with 96 obs., 2Q ahead 95 observations, and so forth
- Random walk as a benchmark

Forecast procedure:

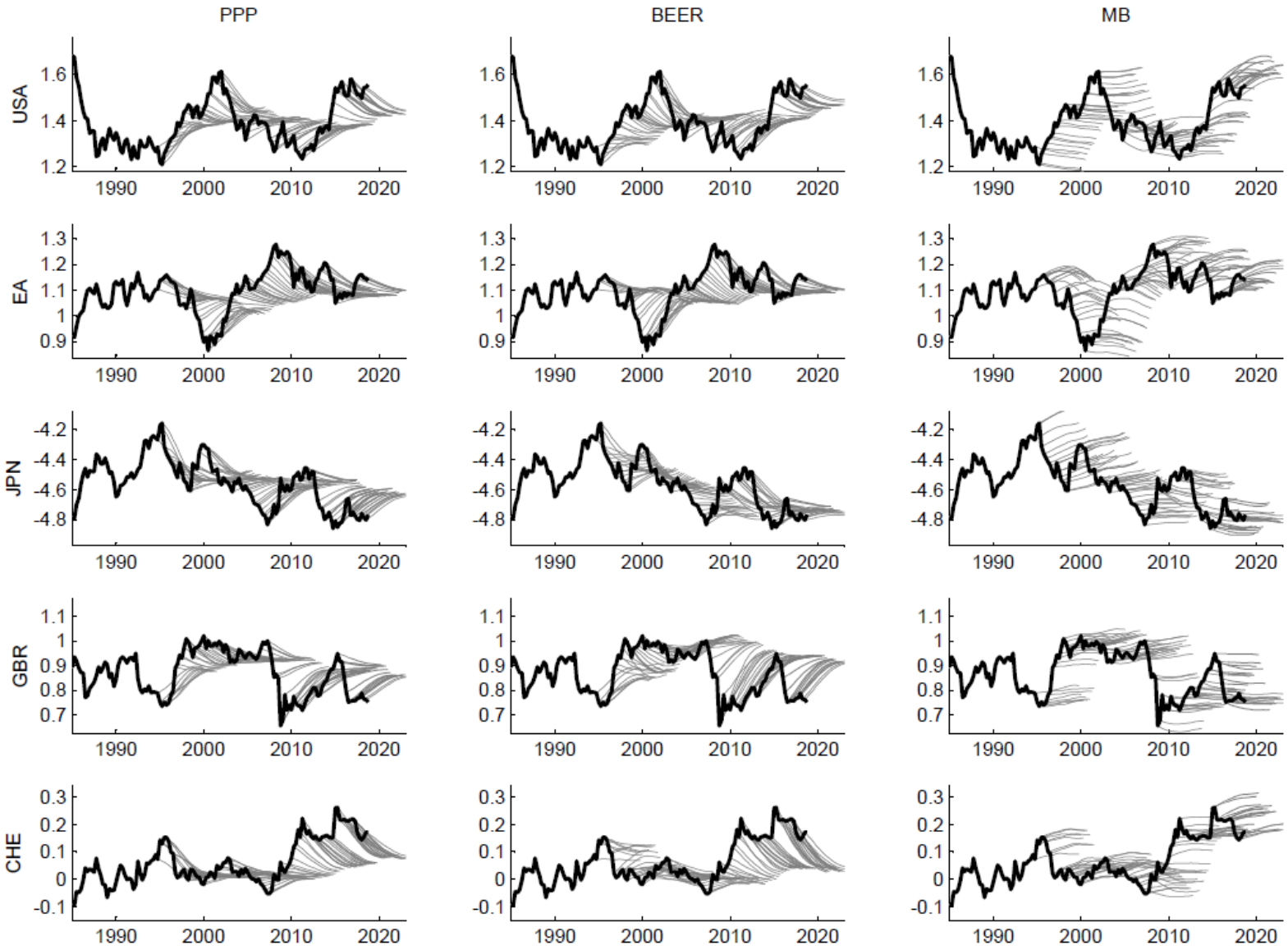
- For each EqER model M, vintage period s and forecast horizon h we estimate:

$$\Delta rer_{it,h} = \omega_{ih,s} + \delta_{h,s}(rer_{i,t-h} - rer^{M}_{i,t-h|s}) + \epsilon_{it}$$

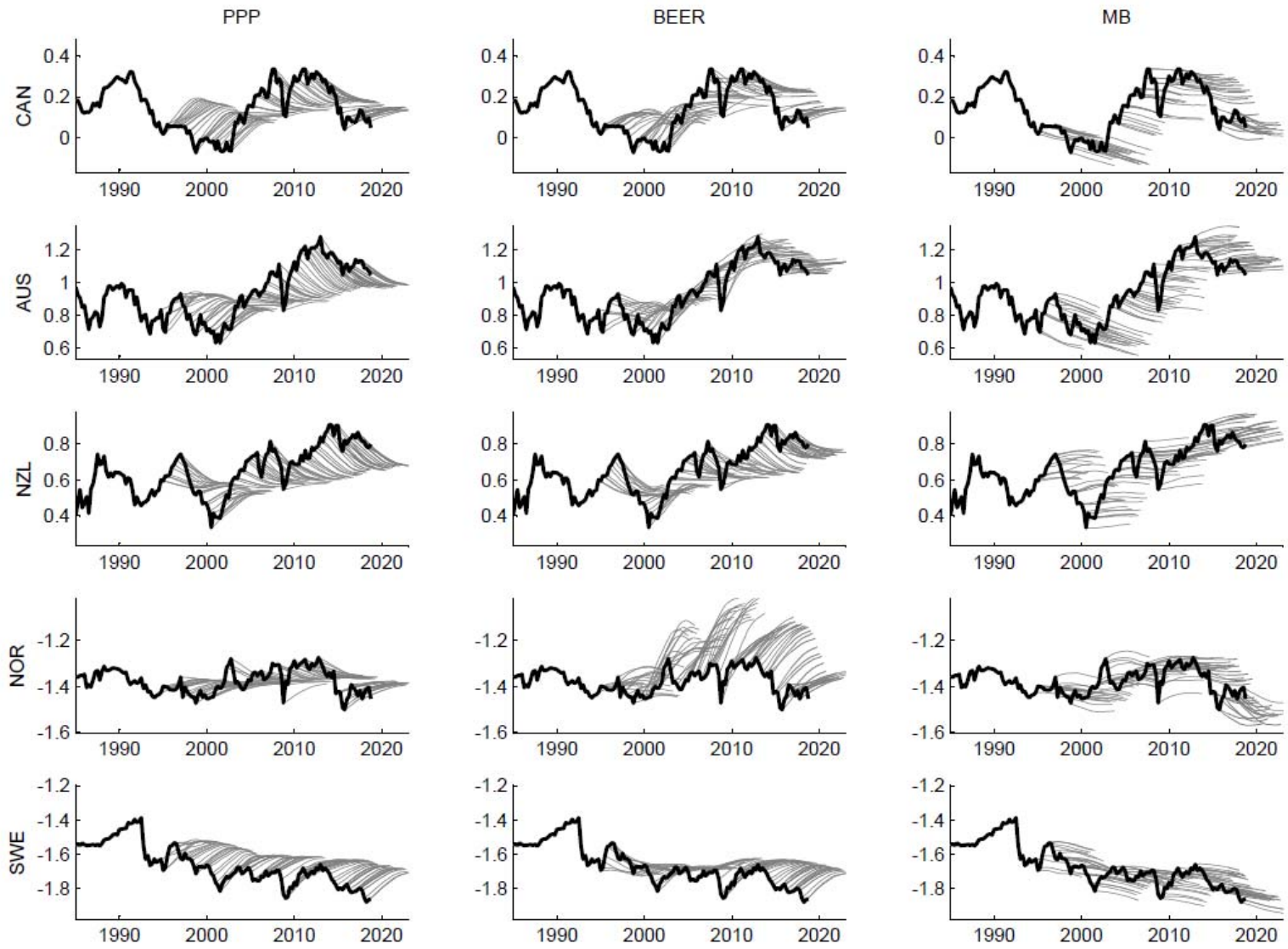
- and calculate the value of the forecast as:

$$rer^{f}_{i,s+h} = rer_{is} + \omega_{ih,s} + \delta_{h,s}(rer_{is} - rer^{M}_{is|s})$$

Sequential forecasts



Sequential forecasts

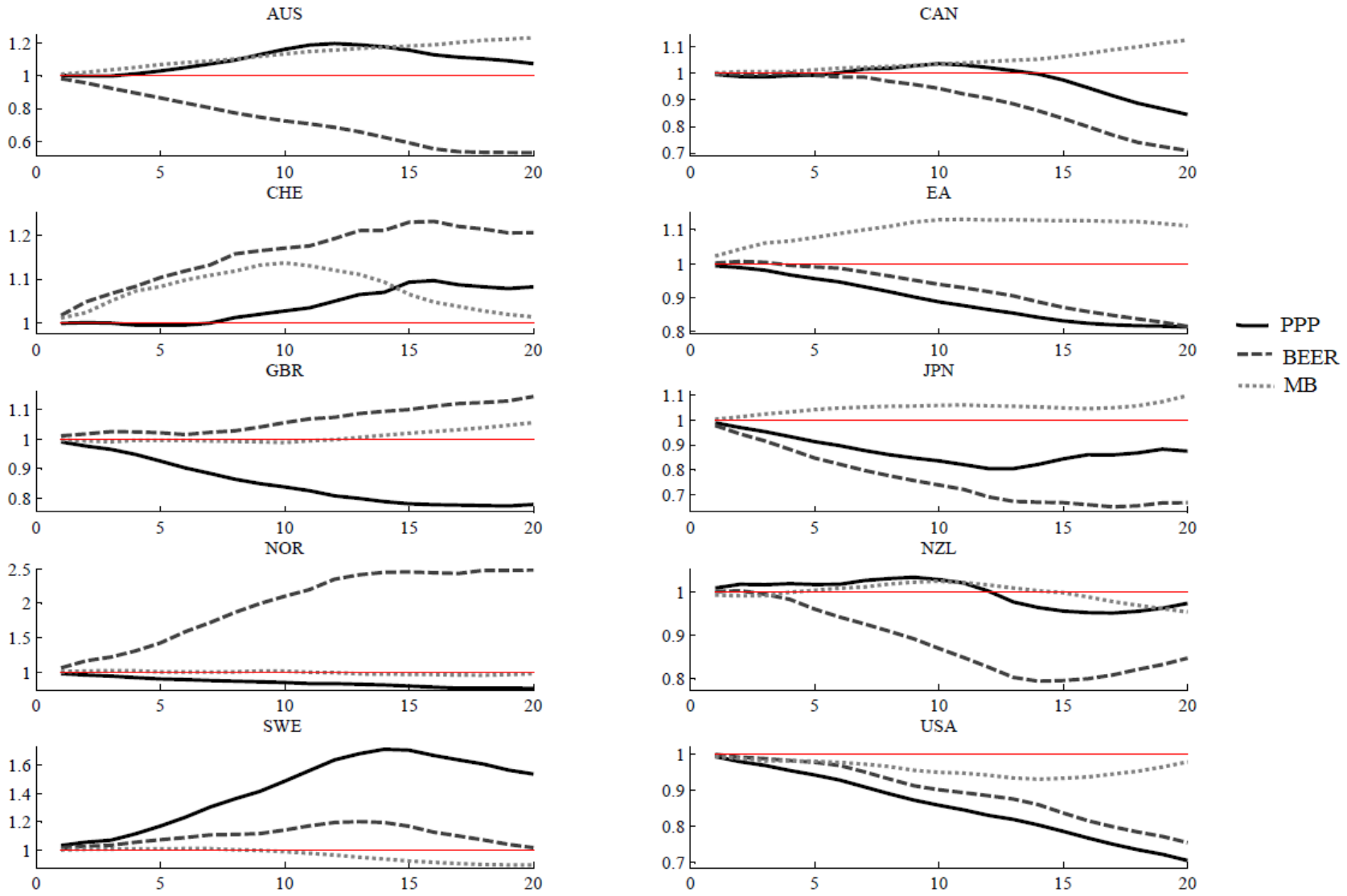


RMSE ratios relative to RW

Root mean squared forecast error (RMSFE) for the real effective exchange rates.

	PPP	BEER	MB	PPP	BEER	MB
	1-quarter horizon			4-quarter horizon		
AUS	1.00	0.98**	1.01	1.01	0.89**	1.05
CAN	1.00	1.00	1.00	0.99*	1.00*	1.01
CHE	1.00	1.02	1.01	0.99	1.08	1.07
EA	0.99	1.00	1.02	0.97**	1.00*	1.07
GBR	0.99**	1.01	1.00	0.95***	1.02	1.00
JPN	0.99*	0.98***	1.00	0.93**	0.88***	1.03
NOR	0.98***	1.06	1.01	0.92***	1.31	1.02
NZL	1.01	1.00	0.99*	1.02	0.98*	1.00
SWE	1.03	1.02	1.00	1.12	1.06	1.01
USA	0.99*	1.00	0.99*	0.95**	0.98*	0.98*
	12-quarter horizon			20-quarter horizon		
AUS	1.20	0.69***	1.16	1.07	0.53***	1.23
CAN	1.02	0.90***	1.04	0.84***	0.71***	1.12
CHE	1.05	1.19	1.12	1.08	1.21	1.01
EA	0.86***	0.92**	1.13	0.81***	0.82***	1.11
GBR	0.81***	1.07**	1.00	0.78***	1.14	1.05
JPN	0.81***	0.69***	1.06	0.88***	0.67***	1.10
NOR	0.83***	2.35	1.00	0.76***	2.49	0.98*
NZL	1.00	0.83***	1.02	0.97**	0.85***	0.95**
SWE	1.64	1.20	0.97*	1.54	1.02	0.90***
USA	0.83***	0.88**	0.94**	0.71***	0.76***	0.98

Out-of-sample forecasting race



Conclusions

Main takeaways

1. **There is a trade-off between storytelling and the predictive power of equilibrium exchange rate models:** PPP performs best, BEER not systematically better, MB in general not very satisfactory.

2. **In-sample the exchange rate converges toward PPP or BEER equilibria.** There is almost no converge to MB equilibria.

3. **Out-of-sample it is difficult to outperform PPP.** This suggests that the link between exchange rates and macroeconomic fundamentals is also feeble in the long-run if we use an out-of-sample evaluation criterion.

4. **In the robustness analysis, we show that imposing a half-life of 3 years the forecast accuracy of the PPP model improves further.** It instead worsen considerably for the MB model.

5. **In normal times it is very difficult to extrapolate from the current account an exchange rate prediction**.

Additional slides

Equilibrium exchange rate and fundamentals

Let us look at how fundamentals affect equilibrium exchange rates in 3 models

- **PPP**: EqER puts zero weight to fundamentals other than real ER
- **BEER**: EqER as a weighted average of 3 fundamentals (gdp, nfa, tot)
- **MB**: EqER as a non-linear function of $gdp, nfa, tot, ca, \mu_x, \mu_m$

PPP has little to say in normative terms. Instead the increased complexity of the BEER and MB models pays out for storytelling purposes. However, the additional fundamentals do not really help in forecasting terms.

Out-of-sample competition
Sensitivity analysis

RMSE ratios relative to RW, PPP model

PDF (panel direct forecast): EqER adjustment pace estimated with panel data (benchmark)
HL (half life): EqER adjustment pace calibrated so that half-life is 3 years
DF (direct forecast): EqER adjustment pace estimated with individual series

Sensitivity analysis with respect to the pace of equilibrium reversion. PPP model.

	PDF	HL	DF	PDF	HL	DF
	1-quarter horizon			4-quarter horizon		
AUS	1.00	1.00	1.00	1.01	0.98**	1.01
CAN	1.00	1.00	1.00	0.99*	0.98**	0.99
CHE	1.00	1.01	1.05	0.99	1.01	1.16
EA	0.99	0.99	1.00	0.97**	0.95**	0.98*
GBR	0.99**	0.99**	0.99*	0.95***	0.94***	0.95***
JPN	0.99*	0.98**	1.00	0.93**	0.90**	0.96**
NOR	0.98***	0.98***	0.97***	0.92***	0.92***	0.90***
NZL	1.01	1.01	1.05	1.02	1.01	1.11
SWE	1.03	1.06	1.02	1.12	1.16	1.05
USA	0.99*	0.99*	1.00	0.95**	0.94**	0.97**
	12-quarter horizon			20-quarter horizon		
AUS	1.20	1.03	1.13	1.07	0.93**	1.08
CAN	1.02	0.93**	1.24	0.84***	0.79***	1.08
CHE	1.05	1.04	1.21*	1.08	1.07	1.08
EA	0.86***	0.85***	0.89***	0.81***	0.77***	0.86***
GBR	0.81***	0.83***	0.85***	0.78***	0.77***	0.87***
JPN	0.81***	0.80***	0.84***	0.88***	0.78***	0.91**
NOR	0.83***	0.84***	0.91***	0.76***	0.77***	0.81***
NZL	1.00	0.98**	1.25	0.97**	0.97**	1.22
SWE	1.64	1.57	1.34	1.54	1.68	1.24
USA	0.83***	0.84***	0.84***	0.71***	0.74***	0.61***

RMSE ratios relative to RW, BEER model

Sensitivity analysis with respect to the set of regressors.BEER model.

	Full	GDP	NFA	ToT	Full	GDP	NFA	ToT
	1-quarter horizon				4-quarter horizon			
AUS	0.98**	0.99*	0.99	1.00	0.89**	0.99**	0.91*	1.01
CAN	1.00	0.99	1.00	1.00	1.00*	0.98*	0.99*	1.01
CHE	1.02	1.02	1.00	1.01	1.08	1.08	1.01	1.05
EA	1.00	1.00	1.00	1.00	1.00*	0.98*	0.97**	0.97*
GBR	1.01	0.99*	1.00*	0.99*	1.02	0.96***	0.97***	0.96***
JPN	0.98***	0.99*	0.98*	0.99***	0.88***	0.93**	0.89**	0.95***
NOR	1.06	0.98***	1.03	0.99	1.31	0.94***	1.11	1.00
NZL	1.00	1.01	1.00	1.01	0.98*	1.03	0.99	1.03
SWE	1.02	1.04	1.01	1.03	1.06	1.15	1.04	1.10
USA	1.00	0.99*	0.99	1.00	0.98*	0.94***	0.96*	0.97**
	12-quarter horizon				20-quarter horizon			
AUS	0.69***	1.14	0.77*	1.19	0.53***	0.99**	0.67**	1.07
CAN	0.90***	0.99**	0.93**	1.08	0.71***	0.82***	0.80***	0.83***
CHE	1.19	1.42	1.01	1.12	1.21	1.55	0.96*	1.07
EA	0.92**	0.89***	0.88***	0.88**	0.82***	0.83***	0.81***	0.83***
GBR	1.07	0.87***	0.92***	0.84***	1.14	0.89***	0.94***	0.80***
JPN	0.69***	0.76***	0.70***	0.84***	0.67***	0.81***	0.66**	0.94***
NOR	2.35	1.00	1.68	1.24	2.49	0.88***	1.85	1.16
NZL	0.83***	1.04	0.91**	0.98**	0.85***	1.04	0.87**	0.97**
SWE	1.20	1.72	1.22	1.54	1.02	1.57	1.08	1.41
USA	0.88**	0.81***	0.84**	0.88***	0.76***	0.70***	0.74***	0.72***

RMSE ratios relative to RW, MB model

PCP : producer currency pricing(benchmark)
IPT: imperfect pass through (lower elasticity η)
CA0: CA norm set to zero
HL: pace of EqER adjustment calibrated so that half-life is 3 years

Sensitivity analysis with respect to models assumptions. MB model.

	PCP	IPT	CA0	HL	PCP	IPT	CA0	HL
	1-quarter horizon				4-quarter horizon			
AUS	1.01	1.01	1.01	1.01	1.05	1.05	1.04	1.06
CAN	1.00	1.00	1.00	0.99*	1.01	1.01	1.01	0.97**
CHE	1.01	1.01	1.01	1.02	1.07	1.07	1.05	1.10
EA	1.02	1.02	1.01	1.04	1.07	1.06	1.03	1.13
GBR	1.00	1.00	1.00	0.99	1.00	0.99	1.01	0.98
JPN	1.00	1.00	1.01	1.00	1.03	1.03	1.06	1.03
NOR	1.01	1.01	1.01	1.03	1.02	1.02	1.03	1.12
NZL	0.99*	0.99*	1.00	0.99**	1.00	1.00	1.00	0.97**
SWE	1.00	1.00	1.00	1.06	1.01	1.01	1.01	1.18
USA	0.99*	0.99*	1.00	1.05	0.98*	0.98*	1.01	1.15
	12-quarter horizon				20-quarter horizon			
CAN	1.04	1.04	1.09	0.90***	1.12	1.12	1.18	0.86***
CHE	1.12	1.11	1.05	1.24	1.01	1.01	0.99	1.19
EA	1.13	1.13	1.08	1.25	1.11	1.11	1.13	1.25
GBR	1.00	0.99	1.03	0.93**	1.05	1.05	1.08	0.96**
JPN	1.06	1.06	1.11	1.06	1.10	1.10	1.19	1.00*
NOR	1.00*	1.00	1.08	1.40	0.98*	0.99	1.20	1.50**
NZL	1.02	1.02	1.03	0.97**	0.95**	0.95**	0.98*	0.98*
SWE	0.97*	0.96**	0.95**	1.64	0.90***	0.90***	0.92***	1.80
USA	0.94**	0.92***	1.04	1.24	0.98	0.94**	1.10	1.27