EUROPEAN CENTRAL BANK

EUROSYSTEM

Exchange Rate Forecasting on a Napkin

NBP Workshop on Forecasting, 26-27 November

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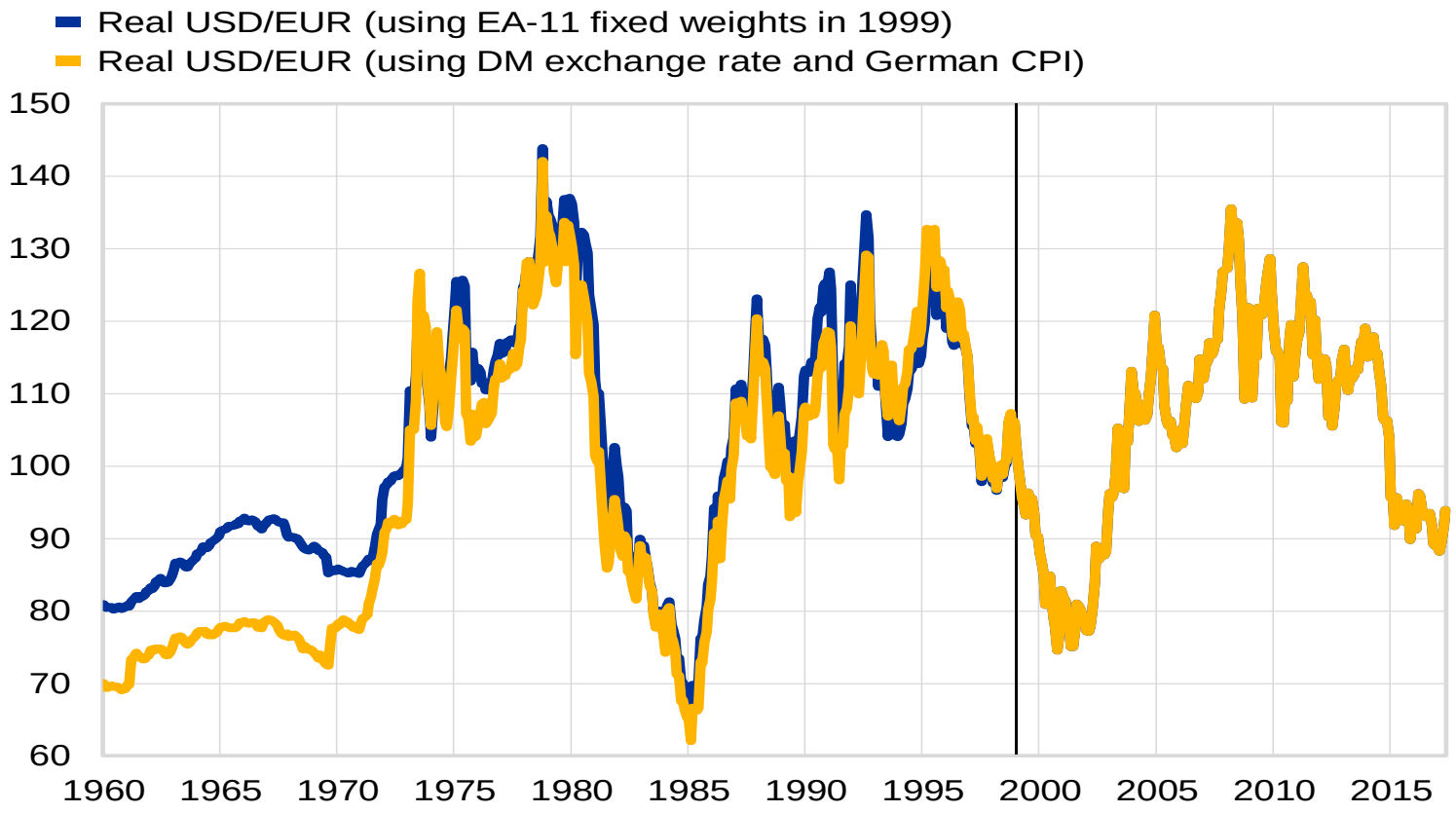
The views here expressed are ours and do not necessarily represent those of the ECB

Introduction

The euro before 1999



ER forecasting horse race: bird's eye view on the literature

Meese & Rogoff (1983):

exchange rates are not forecastable: start of the ER forecasting race

Mark (1995); Chinn & Meese (1995):

RW can be beaten at longer horizons by theoretical models

Cheung, Chinn & Pascual (2005):

none of standard models able to consistently outperform RW

Engel, Mark & West (2008):

ER models are not as bad as you think: part of the dismal forecasting performance of macro models can be attributed to estimation rather than mis-specification error

Rogoff (2009), Rossi (2013), Cheung et al. (2018):

the unpredictability of (nominal) exchange rates is likely to remain the consensus view for the conceivable future. Some hope/evidence in favour of PPP.

Ca' Zorzi, Muck and Rubaszek (2016), Ca' Zorzi, Kolasa and Rubaszek (2017)

mean reversion of the real exchange rates is key to understand predictability of the exchange rate over medium and long-term horizons.

Outline of the presentation

1. Discuss regularities on the exchange rate market
2. Present the evidence that RERs are predictable, especially in the long run
3. Show that RER forecasts can be exploited for predicting NERs
4. Main takeaways and final thoughts

In-sample regularities of FX markets

Data

Monthly data over the period 1975:1-2017:5 for each country:

- end-of-period NER against the USD
- consumer price index (CPI)
- end-of-period RER against the USD

Countries:

- Australia (AUD)
- Canada (CAD)
- Japan (JPY)
- New Zealand NZD)
- Switzerland (CHF)
- United Kingdom (GBP)
- euro area (EUR)
- South Korea (KRW)
- Norway (NOK)
- Sweden (SEK)

In sample regularities on the FX markets

1. Mean reversion of RER to PPP level ($\lim_{h\to\infty} \alpha_{1h} = -1$)

$$\Delta rer_{t,h} = \alpha_{0h} + \alpha_{1h} rer_{t-h} + \epsilon_t$$

2. Adjustment of RER through NER ($\beta_{1h} = 1$)

$$\Delta ner_{t,h} = \beta_{0h} + \beta_{1h} \Delta rer_{t,h} + \epsilon_t$$

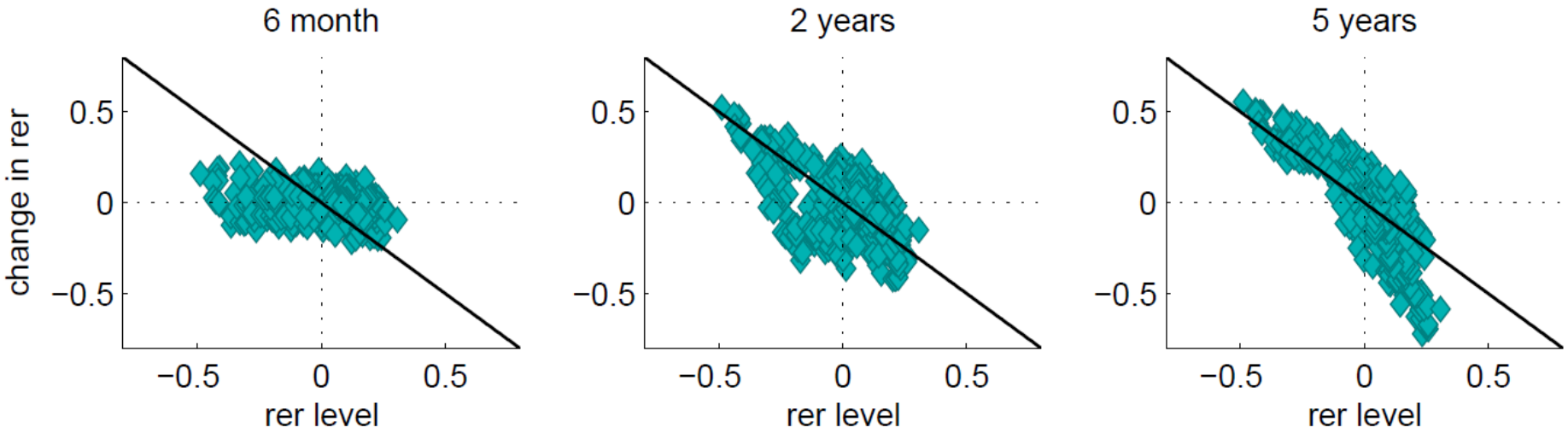
3. No adjustment through relative price indices RPI ($\gamma_{1h} = 0$)

$$\Delta rpi_{t,h} = \gamma_{0h} + \gamma_{1h} \Delta rer_{t,h} + \epsilon_t$$

Regularity 1: Mean reversion of RER

$$\Delta rer_{t,h} = \alpha_{0h} + \alpha_{1h} rer_{t-h} + \epsilon_t$$

Exchange rate regularities for the euro dollar



Regularity 1: Mean reversion of RER

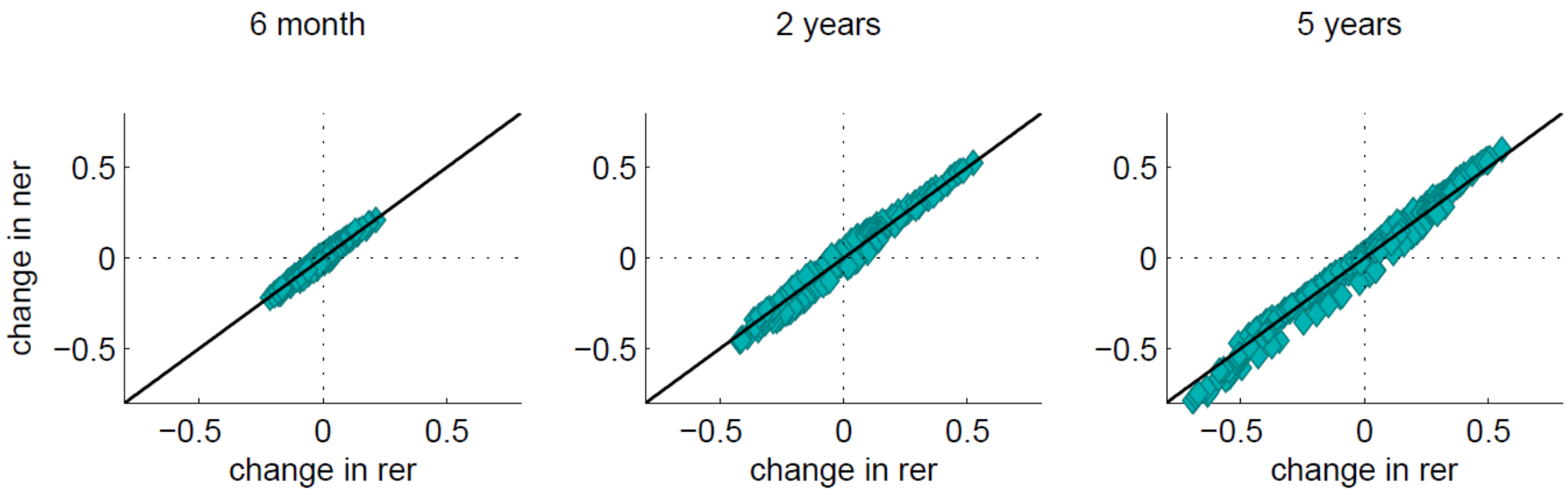
$$\Delta rer_{t,h} = \alpha_{0h} + \alpha_{1h} rer_{t-h} + \epsilon_t$$

	6 months			2 years			5 years		
	α_{0h}	α_{1h}	R^2	α_{0h}	α_{1h}	R^2	α_{0h}	α_{1h}	R^2
AUD	0.00	-0.11	0.06	-0.01	-0.41	0.22	-0.02	-0.92	0.44
CAD	0.00	-0.08	0.04	-0.01	-0.38	0.21	-0.02	-0.98	0.51
JPY	0.00	-0.12	0.06	0.01	-0.52	0.27	0.02	-0.85	0.43
NZD	0.00	-0.11	0.05	0.01	-0.51	0.25	0.00	-1.07	0.48
CHF	0.00	-0.14	0.07	0.01	-0.57	0.29	0.00	-1.05	0.52
GBP	0.00	-0.20	0.09	0.00	-0.84	0.39	0.00	-1.41	0.69
EUR	0.00	-0.13	0.06	-0.01	-0.59	0.29	-0.02	-1.35	0.70
KRW	0.00	-0.17	0.08	0.00	-0.63	0.31	-0.01	-1.16	0.62
NOK	0.00	-0.15	0.07	-0.01	-0.58	0.26	-0.01	-1.36	0.65
SEK	-0.01	-0.09	0.04	-0.02	-0.45	0.21	-0.04	-1.04	0.55
Panel		-0.12	0.06		-0.52	0.26		-1.08	0.54

Regularity 2: Adjustment of RER via NER

$$\Delta ner_{t,h} = \beta_{0h} + \beta_{1h}\Delta rer_{t,h} + \epsilon_t$$

Exchange rate regularities for the euro dollar



Regularity 2: Adjustment of RER via NER

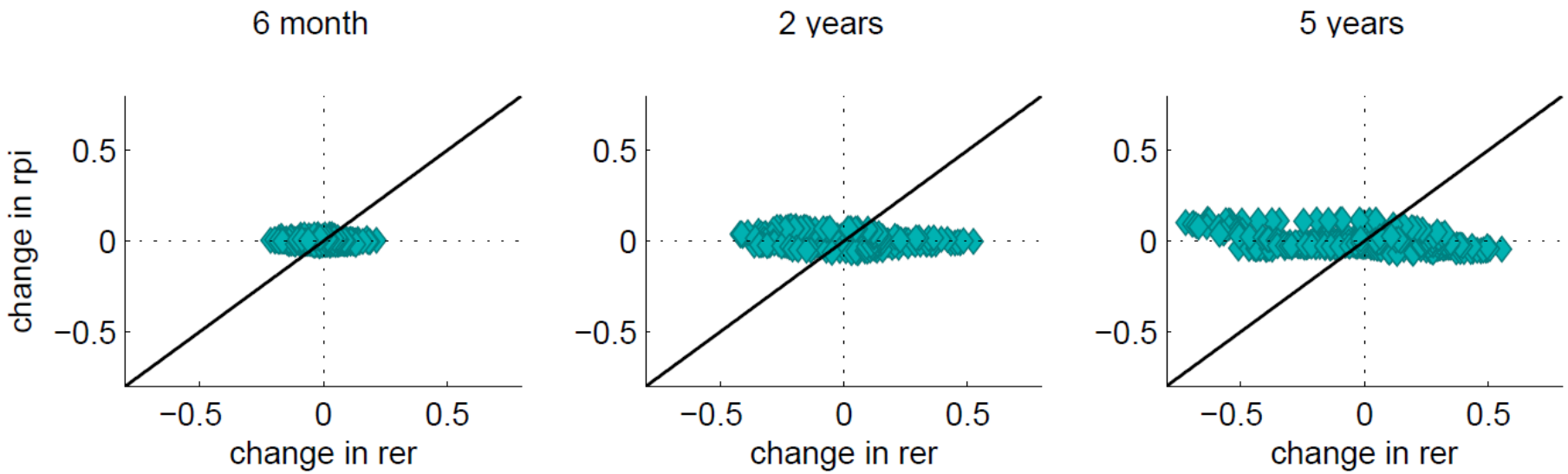
$$\Delta ner_{t,h} = \beta_{0h} + \beta_{1h}\Delta rer_{t,h} + \epsilon_t$$

	6 months			2 years			5 years		
	β_{0h}	β_{1h}	R^2	β_{0h}	β_{1h}	R^2	β_{0h}	β_{1h}	R^2
AUD	-0.01	1.01	0.96	-0.02	0.99	0.93	-0.04	1.00	0.92
CAD	0.00	1.00	0.96	0.00	0.97	0.94	0.00	0.98	0.95
JPY	0.01	0.97	0.98	0.04	0.98	0.97	0.12	0.99	0.97
NZD	-0.01	0.99	0.94	-0.03	0.91	0.87	-0.08	0.94	0.76
CHF	0.01	1.00	0.98	0.04	0.99	0.95	0.09	0.93	0.91
GBP	0.00	1.02	0.96	-0.01	1.01	0.95	-0.02	1.01	0.93
EUR	0.00	1.02	0.98	0.00	1.03	0.98	0.01	1.05	0.98
KRW	-0.01	1.03	0.94	-0.04	1.04	0.89	-0.09	1.05	0.81
NOK	0.00	1.01	0.96	-0.01	1.01	0.93	-0.02	1.00	0.90
SEK	0.00	1.01	0.97	-0.01	0.99	0.95	-0.02	0.97	0.91
Panel		1.00	0.96		0.99	0.94		0.99	0.90

Regularity 3: No adjustment of RER via RPI

$$\Delta rpi_{t,h} = \gamma_{0h} + \gamma_{1h}\Delta rer_{t,h} + \epsilon_t$$

Exchange rate regularities for the euro dollar



Regularity 3: No adjustment of RER via RPI

$$\Delta rpi_{t,h} = \gamma_{0h} + \gamma_{1h}\Delta rer_{t,h} + \epsilon_t$$

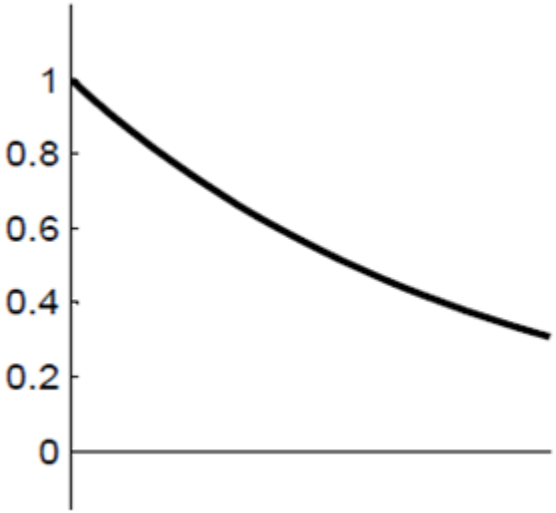
	6 months			2 years			5 years		
	γ_{0h}	γ_{1h}	R^2	γ_{0h}	γ_{1h}	R^2	γ_{0h}	γ_{1h}	R^2
AUD	0.01	-0.01	0.00	0.02	0.01	0.00	0.04	0.00	0.00
CAD	0.00	0.00	0.00	0.00	0.03	0.01	0.00	0.02	0.01
JPY	-0.01	0.03	0.05	-0.04	0.02	0.02	-0.12	0.01	0.00
NZD	0.01	0.01	0.00	0.03	0.09	0.06	0.08	0.06	0.01
CHF	-0.01	0.00	0.00	-0.04	0.01	0.00	-0.09	0.07	0.05
GBP	0.00	-0.02	0.01	0.01	-0.01	0.00	0.02	-0.01	0.00
EUR	0.00	-0.02	0.02	0.00	-0.03	0.04	-0.01	-0.05	0.13
KRW	0.01	-0.03	0.01	0.04	-0.04	0.01	0.09	-0.05	0.01
NOK	0.00	-0.01	0.00	0.01	-0.01	0.00	0.02	0.00	0.00
SEK	0.00	-0.01	0.00	0.01	0.01	0.00	0.02	0.03	0.01
Panel		0.00	0.00		0.01	0.00		0.01	0.00

Out-of-sample evidence: Real Exchange Rates

What we call a half-life model

A simple, calibrated AR(1) model that assumes gradual reversion to historical mean, with the adjustment pace:

- 10% in 6 months
- 20% in 1 year
- 50% (half-life) in 3 years (Rogoff, 1996)



$$rer_{t+h}^{f} = \hat{\mu} + \bar{\rho}^{h}\,(rer_t - \hat{\mu})$$

Interpretation: a simple gliding path between an initial value and an end point, long-term forecast (PPP proxied by the sample mean)

Real exchange rates models

Mean-reverting model for RER:

Autoregression (AR): $rer^{f}_{it+h} = \hat{\mu}_i + \hat{\rho}^{h}_{i}(rer_{it} - \hat{\mu}_i)$

Direct forecast (DF): $\Delta rer^{f}_{it+h,h} = \hat{\alpha}_{i0h} + \hat{\alpha}_{i1h} rer_{it}$

Panel DF (PDF): $\Delta rer^{f}_{it+h,h} = \hat{\alpha}_{i0h} + \hat{\alpha}_{1h} rer_{it}$

Half-life (HL): $rer^{f}_{it+h} = \hat{\mu}_i + \bar{\rho}^{h}_{i}(rer_{it} - \hat{\mu}_i)$

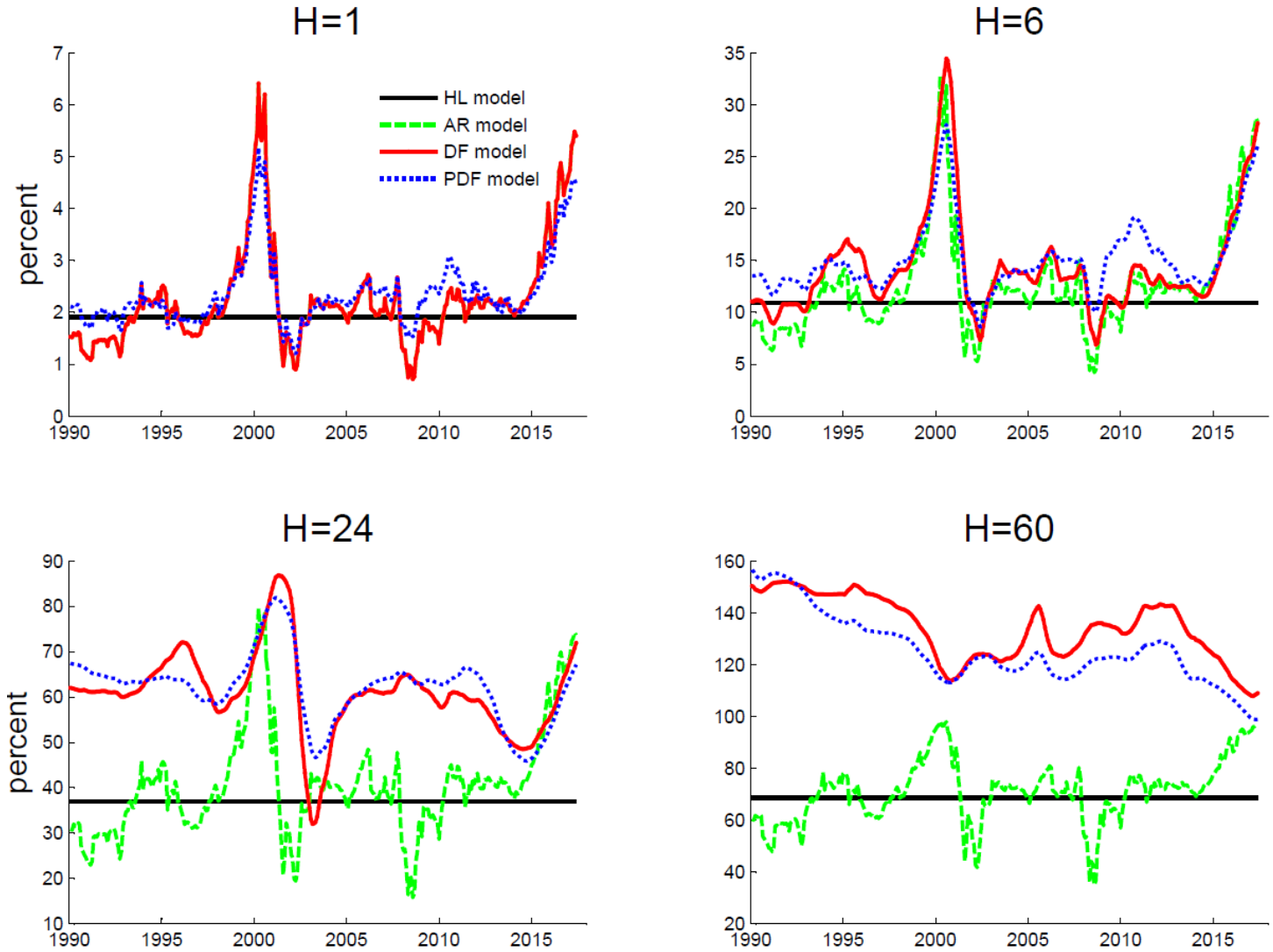
Benchmark: Random walk

USD rates against: AUD, CAD, JPY, NZD, CHF, GBP, EUR, KRW, NOK, SEK

Sample: 1975-2017, forecasts for 1995-2017

Forecasting scheme: rolling (15-years window)

Rolling estimates of the fraction of adjustment to PPP achieved at horizon H



RERs are forecastable:
RMSFE for the RER with respect to the RW

	AR	DF	PDF	HL	AR	DF	PDF	HL
	1 month				**6 months**			
AUD	1.01	1.01	1.01	1.00	1.03	1.04	1.05	1.00
CAD	1.01	1.01	1.01	1.00	1.05	1.05	1.08	1.01
JPY	1.01	1.01	1.00	1.00	1.04	1.05	1.02	1.00
NZD	1.01	1.01	1.01	1.00	1.05	1.05	1.05	0.99
CHF	1.01	1.01	1.01	1.00	1.06	1.06	1.04	0.98
GBP	1.01	1.01	1.00	1.00	1.01	1.02	1.00	0.97*
EUR	1.02	1.01	1.01	1.00	1.07	1.07	1.04	0.97
KRW	1.00	1.00	1.00	0.99	1.01	0.98**	0.98*	0.96**
NOK	1.01	1.01	1.01	1.00	1.05	1.05	1.03	0.97
SEK	1.01	1.01	1.01	1.00	1.04	1.05	1.04	0.98
	2 years				**5 years**			
AUD	1.02	1.11	1.05*	0.96	0.97*	1.08**	1.04**	0.92
CAD	1.07	1.15	1.16*	0.99	1.16	1.15**	0.99**	0.88*
JPY	1.05	1.15	1.02*	0.97	1.01	1.19*	1.23**	0.88*
NZD	1.03	0.96**	0.96**	0.90*	0.87**	0.98**	0.85**	0.81**
CHF	1.04	1.04**	0.98**	0.90*	0.85**	1.01**	0.96**	0.75**
GBP	0.85**	0.76**	0.79**	0.85**	0.66**	0.68**	0.67**	0.71**
EUR	1.03	0.92**	0.92**	0.87**	0.76**	0.67**	0.68**	0.69**
KRW	1.05	0.87**	0.86**	0.86**	1.60	0.79**	0.74**	0.75**
NOK	0.99*	0.93**	0.92**	0.89**	0.78**	0.71**	0.70**	0.73**
SEK	1.05	0.93**	0.91**	0.88*	0.94**	0.91**	0.88**	0.79**

Out-of-sample evidence: Nominal Exchange Rates

Relative price indices models

Models for RPI (see Faust and Wright, 2013):

Autoregression (AR): $\Delta rpi_{it+h}^{f} = \hat{\mu}_i + \hat{\rho}_i^h(\Delta rpi_{it} - \hat{\mu}_i)$

Direct forecast (DF): $\Delta rpi_{it+h,h}^{f} = \hat{\alpha}_{i0h} + \hat{\alpha}_{i1h} rer_{it}$

Panel DF (PDF): $\Delta rpi_{it+h,h}^{f} = \hat{\alpha}_{i0h} + \hat{\alpha}_{1h} rer_{it}$

Half-life (HL): $\Delta rpi_{it+h}^{f} = \hat{\mu}_i + \bar{\rho}_i^h(\Delta rpi_{it} - \hat{\mu}_i)$

Benchmark: Random walk

CPI against CPI in US: AUD, CAD, JPY, NZD, CHF, GBP, EUR, KRW, NOK, SEK

Sample: 1975-2017, forecasts for 1995-2017

Forecasting scheme: rolling (15-years window)

RPI are not forecastable:
RMSFE for the RPI with respect to the RW

	AR	DF	PDF	HL	AR	DF	PDF	HL
	1 month				**6 months**			
AUD	1.04	1.05	1.03	1.01	1.22	1.39	1.25	1.06
CAD	1.01	1.03	1.03	1.02	1.06	1.19	1.13	1.09
JPY	0.92**	0.94**	0.95**	0.93**	0.76**	0.78**	0.82**	0.76**
NZD	1.19	1.12	1.10	1.02	1.80	1.75	1.70	1.08
CHF	0.97**	1.01**	1.01**	0.96**	0.88**	1.10**	1.04**	0.79**
GBP	1.01	1.01	1.00	1.00	1.05	1.06	1.05	0.99
EUR	1.02	1.00	1.00	1.01	1.01	1.05	1.06	1.08
KRW	0.91**	0.99**	0.96**	0.98	0.91**	0.94**	0.94**	0.95
NOK	1.01	1.02	1.01	1.02	1.10	1.11	1.08	1.04
SEK	1.00	1.02	1.02	0.99	1.09	1.16	1.14	0.94
	2 years				**5 years**			
AUD	1.71	2.42	1.84	1.07	2.52	3.49	3.00	1.08
CAD	1.21	1.73	1.37	0.93	1.34	2.23	1.60	0.95
JPY	0.58**	0.66**	0.72**	0.77**	0.39**	0.49**	0.46**	0.87**
NZD	3.23	3.71	3.29	1.03	5.00	6.52	5.96	1.03
CHF	0.79**	1.09**	1.00**	0.77**	0.59**	0.79**	0.72**	0.90**
GBP	1.23	1.32	1.29	0.91*	1.57	1.70	1.71	0.96
EUR	1.02**	1.07**	1.02**	1.04	1.12*	1.31	1.24	1.01
KRW	0.78**	0.88**	0.90**	0.87*	0.76**	0.89**	1.00**	0.88**
NOK	1.40	1.66	1.41	1.02	1.92	2.83	2.43	1.05
SEK	1.42	1.49	1.58	0.85**	1.80	2.22	2.17	0.94**

Nominal exchange rate models

RER adjustment occurs through NER changes:

Direct forecast (DF): $\Delta ner^{f}_{it+h,h} = \hat{\alpha}_{i0h} + \hat{\alpha}_{i1h} rer_{it}$

Panel DF (PDF): $\Delta ner^{f}_{it+h,h} = \hat{\alpha}_{i0h} + \hat{\alpha}_{1h} rer_{it}$

Half-life (HL): $\Delta ner^{f}_{it+h} = \Delta rer^{f,HL}_{it+h}$

Double half-life (2HL): $\Delta ner^{f}_{it+h} = \Delta rer^{f,HL}_{it+h} - \Delta rpi^{f,HL}_{it+h}$

Benchmark: Random walk

NER against US: AUD, CAD, JPY, NZD, CHF, GBP, EUR, KRW, NOK, SEK

Yes, we can outperform the RW in NER forecasting: RMSFE for the NER with respect to the RW

	DF	PDF	HL	2HL	DF	PDF	HL	2HL
	1 month				**6 months**			
AUD	1.01	1.01	1.00	1.01	1.04	1.05	0.99	1.01
CAD	1.01	1.01	1.00	1.01	1.05	1.07	1.01	1.03
JPY	1.01	1.00	1.00	1.00	1.05	1.01	1.01	1.00
NZD	1.01	1.01	1.00	1.00	1.04	1.05	0.99	1.01
CHF	1.01	1.00	1.00	1.00	1.04	1.03	0.99	0.99
GBP	1.01	1.01	1.00	1.00	1.03	1.01	0.97*	0.99
EUR	1.02	1.01	1.00	1.00	1.07	1.04	0.97	0.99
KRW	1.00	1.00*	0.99	1.00	0.97**	0.98**	0.97**	0.97*
NOK	1.01	1.01	1.00	1.00	1.05	1.03	0.98	0.98
SEK	1.01	1.01	1.00	1.00	1.05	1.03	0.97	1.00
	2 years				**5 years**			
AUD	1.05	1.01**	0.95	0.97	0.99**	0.99**	0.89*	0.90*
CAD	1.08	1.11*	1.00	1.01	0.94**	0.88**	0.87*	0.87*
JPY	1.12*	0.98**	0.97	0.98	1.08**	1.12**	0.89	0.88*
NZD	0.98**	0.98**	0.91*	0.92	1.28*	1.14**	0.80**	0.81**
CHF	0.93**	0.90**	0.94	0.93	0.80**	0.78**	0.87*	0.85**
GBP	0.78**	0.81**	0.85**	0.84**	0.86**	0.84**	0.75**	0.74**
EUR	0.91**	0.90**	0.87**	0.88**	0.68**	0.67**	0.68**	0.68**
KRW	0.85**	0.83**	0.88**	0.88**	0.63**	0.58**	0.80**	0.78**
NOK	0.93**	0.92**	0.91**	0.91**	0.77**	0.77**	0.75**	0.76**
SEK	0.88**	0.85**	0.86**	0.88*	0.67**	0.67**	0.69**	0.71**

Main takeaways

- The consensus view that `*ER theories are of little help in ER forecasting*' should be re-assessed. At least for advanced countries relative PPP is a good framework of analysis.

- We can forecast RERs with ``conservative'' and mean-reverting models. HL model is a good candidate (also for its simplicity).

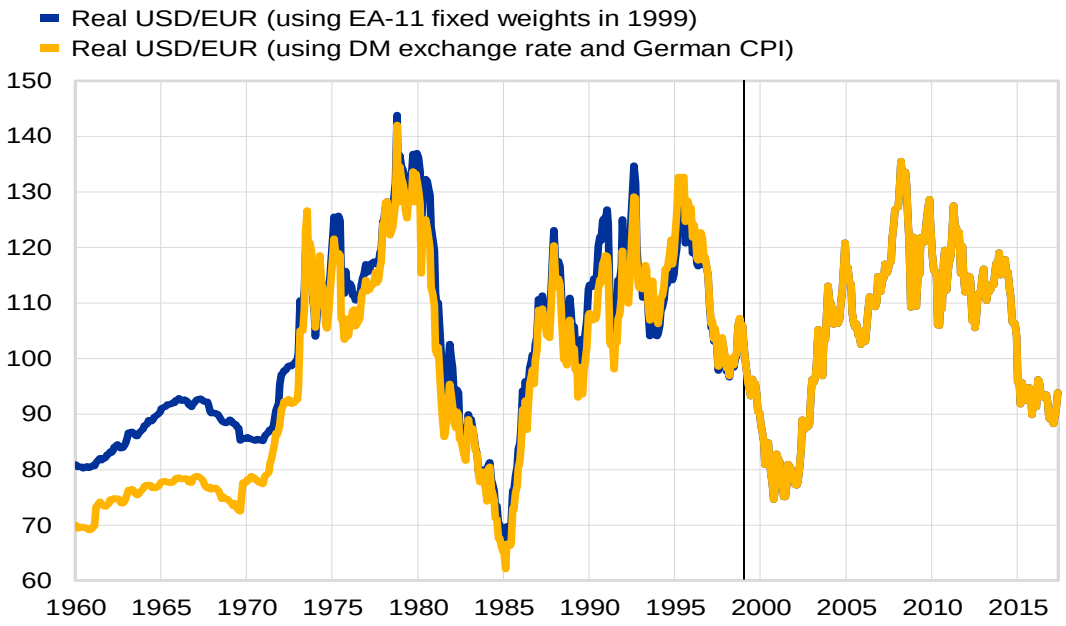
- The best forecast for the NER is to assume that in the forecast horizon its change will be equal to our forecasted change in the RER. This is the predictable part of future NER movements.

- Our proposed method is very easy to the point that it can be implemented on the back of a napkin, i.e. 10% in 6 months, 20% in 1 year, 50% in 3 years.

$$\Delta ner^{f}_{t+h,h} = \rho^{h}(rer_{t} - \overline{rer}),$$

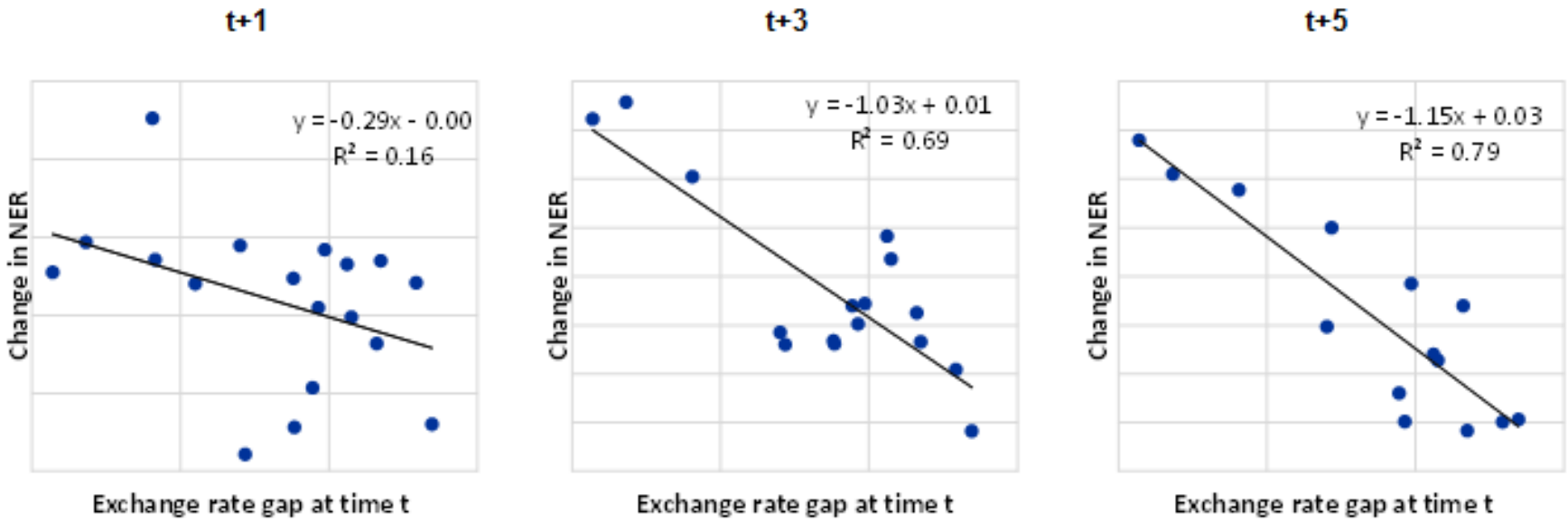
Final thoughts

A final look at the RER USD/EUR

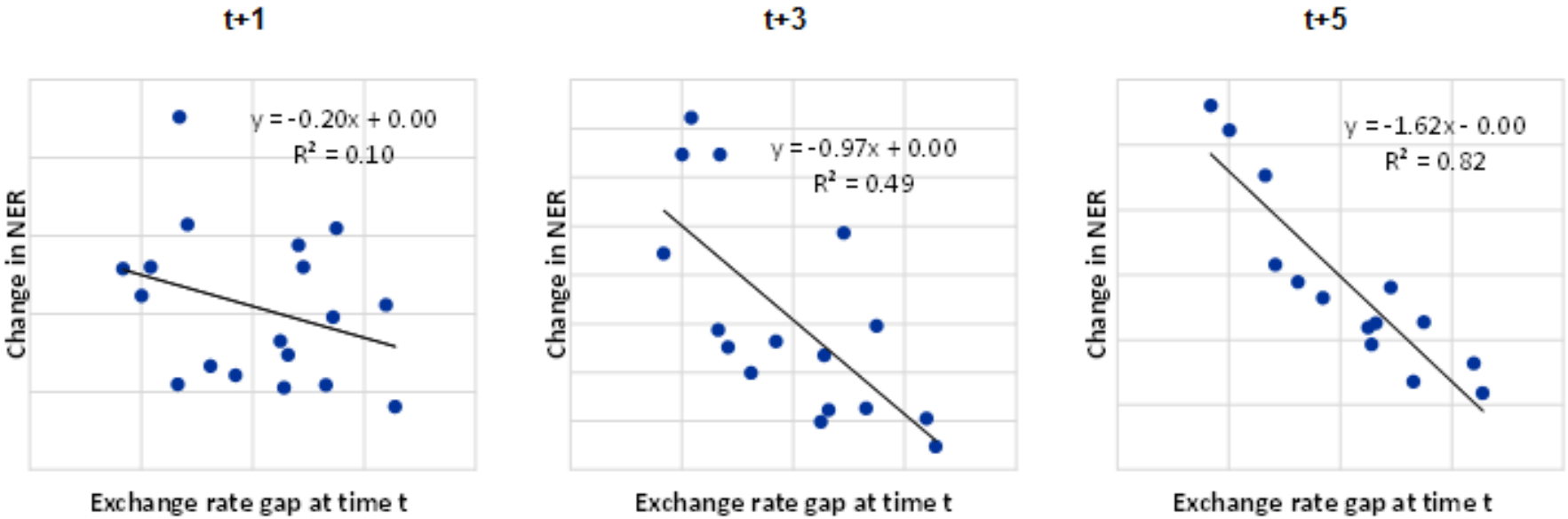


Equilibrium and predictability

EURO: Predictive power of the EBA approach for different time horizons



USD: Predictive power of the EBA approach for different time horizons



Sources: BIS and ECB staff calculations
Notes: NER refers to the BIS Nominal Broad Index

End

Extensions to more complex models

Forecasting
RER: BVAR and DSGE competitors

Exchange rate forecasting with DSGE models, JIE 017

Two Macro models:	2 DSGEs Justiniano and Preston, JAE (allowing / not allowing for RER trend)
Three time series models:	LBVAR - level BVAR DBVAR - differenced BVAR MBVAR - mean-reverting BVAR
A-theoretical benchmarks:	Random Walk AR fixed / HL model
Five countries:	US, EA, UK, CAN, AUS
Data for DSGE/BVAR:	y,y*,p,p*,i,i*,ca,rer
Sample:	1975-2013, forecasts for 1995-2013
Forecasting scheme:	recursive

RMSFE for RER

Main findings:

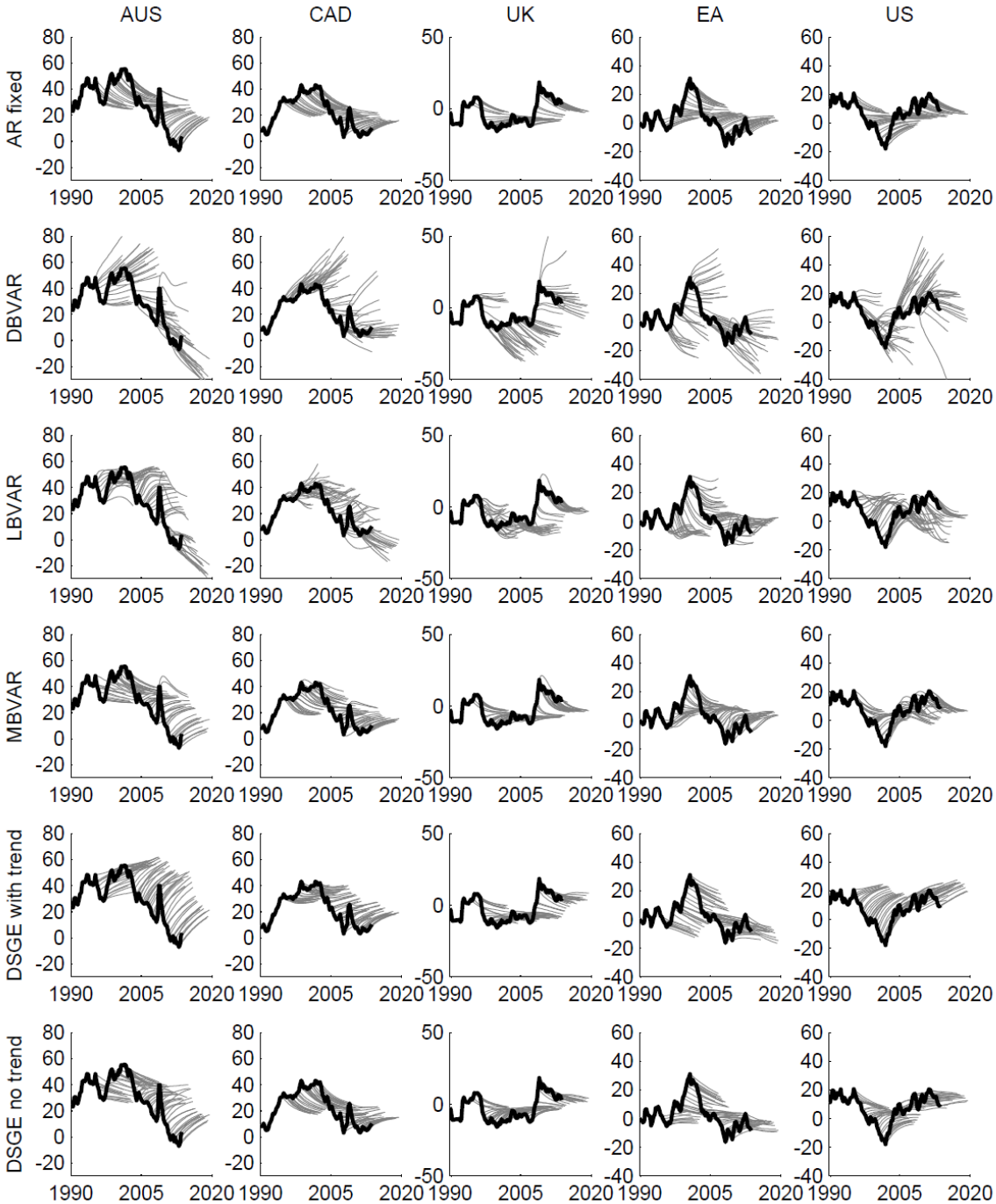
- *AR fixed* and *DSGE no trend* are clear winners
- Both models are mean-reverting and forecast `conservative' dynamics
- MBVAR also performs well (at longer horizons)

	H=1	H=2	H=4	H=8	H=12	H=24
			United States			
AR fixed	0.99	0.98	0.94	0.89	0.87	0.73**
DBVAR	1.04	1.15	1.13	1.19	1.13	1.28
LBVAR	1.01	1.09	1.15	1.29*	1.36*	1.03
MBVAR	0.99	1.02	0.96	0.86	0.77	0.68**
DSGE with trend	1.12*	1.15	1.22	1.21	1.21	1.01
DSGE no trend	1.03	1.02	1.00	0.92	0.83	0.66***
			Euro Area			
AR fixed	1.00	1.00	0.97	0.92	0.87	0.76**
DBVAR	1.05	1.12*	1.20***	1.30***	1.36***	1.36**
LBVAR	1.05	1.12	1.22	1.31	1.25	0.93
MBVAR	1.02	1.05	1.07	1.01	0.93	0.75**
DSGE with trend	0.99	0.98	0.98	1.01	1.00	0.90
DSGE no trend	0.99	0.98	0.96	0.95	0.91	0.77**
			United Kingdom			
AR fixed	1.00	0.98	0.95	0.88**	0.86**	0.83***
DBVAR	1.06	1.18	1.23**	1.31**	1.43***	1.82***
LBVAR	1.12**	1.21**	1.24*	1.14	1.13	1.23*
MBVAR	1.02	1.06	1.00	0.89	0.86*	0.82**
DSGE with trend	1.01	0.98	0.94	0.84**	0.80***	0.86**
DSGE no trend	1.02	0.99	0.94	0.84	0.78**	0.67***
			Canada			
AR fixed	1.01	1.00	1.00	1.03	1.02	0.80
DBVAR	0.99	1.07*	1.15*	1.31*	1.41**	1.61**
LBVAR	1.04	1.09*	1.13**	1.09	1.03	1.10
MBVAR	0.99	1.03	1.05	1.07	1.07	0.88
DSGE with trend	1.02	1.02	1.03	1.08	1.08	1.04
DSGE no trend	1.03	1.03	1.04	1.08	1.05	0.79
			Australia			
AR fixed	1.01	1.00	1.00	1.02	1.03	0.88
DBVAR	1.03	1.10	1.12	1.05	0.98	1.18
LBVAR	1.02	1.06	1.09	1.07	1.07	1.22**
MBVAR	1.04*	1.08*	1.10*	1.07	1.06	0.92
DSGE with trend	1.07*	1.10	1.18**	1.34***	1.46***	1.55***
DSGE no trend	1.03	1.03	1.04	1.10	1.14	1.01

Hedgehog graphs

Models are inaccurate if:

- A lot of weight to dynamics in-sample, which deteriorates the out-of-sample accuracy (BVAR models)
- They ignore mean reverting tendencies of the RER and extrapolate too much past trends (DBVAR, LBVAR, DSGE with trend)



DSGE fails to forecast RPI well…

$$\widetilde{rpi}^{f}_{t+h} - \widetilde{rpi}_t = h\underbrace{(\mu_\pi - \mu^*_\pi)}_{trend} + \sum_{i=1}^{h}\underbrace{\left(\pi^f_{t+i} - \pi^{*f}_{t+i}\right)}_{cycle}$$

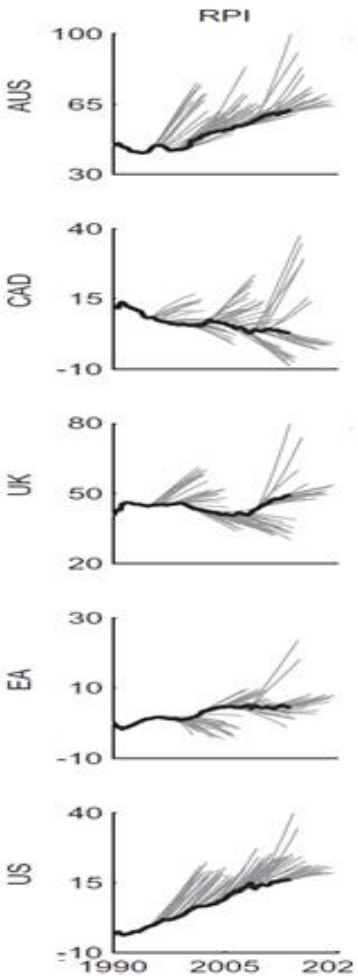
DSGE (no RPI trend): includes only the *cycle*,

DSGE (no RPI cycle): includes only the *trend*,

RW: excludes both the *trend* and the *cycle*.

Table : RMSFE for the RPI

	H=1	H=2	H=4	H=8	H=12	H=24
				United States		
DSGE	0.92	0.97	0.95	1.11	1.28	1.50***
DSGE (no RPI trend)	0.92	0.97	0.93	1.08	1.26	1.47***
DSGE (no RPI cycle)	1.01	1.03	1.04	1.04	1.02	0.99
				Euro area		
DSGE	1.28	1.58	1.87	1.93*	2.04**	2.32***
DSGE (no RPI trend)	1.28	1.56	1.83	1.85	1.97*	2.10***
DSGE (no RPI cycle)	1.20***	1.31***	1.55***	1.72***	1.76***	1.97***
				United Kingdom		
DSGE	1.19	1.35*	1.51**	1.76***	1.97***	2.47***
DSGE (no RPI trend)	1.16	1.29*	1.42**	1.60***	1.75***	2.17***
DSGE (no RPI cycle)	1.05	1.09	1.12	1.19	1.25*	1.64***
				Canada		
DSGE	1.29**	1.59**	2.13**	2.96***	3.71***	4.06***
DSGE (no RPI trend)	1.28**	1.56**	2.06**	2.82***	3.53***	3.68***
DSGE (no RPI cycle)	1.09**	1.15**	1.26**	1.34***	1.41***	1.71***
				Australia		
DSGE	1.03	1.12	1.32	1.60	1.78	1.54
DSGE (no RPI trend)	1.01	1.07	1.21	1.40	1.50	1.09
DSGE (no RPI cycle)	0.93	0.93	0.93	0.90	0.84	0.54***



... because of the lack in price co-movement.

	DSGE model					Data				
	H=1	H=4	H=8	H=12	H=24	H=1	H=4	H=8	H=12	H=24
correlation of changes in price indices: $cor(\widetilde{p}^*_t - \widetilde{p}^*_{t-h}, \widetilde{p}_t - \widetilde{p}_{t-h})$										
United States	0.06	0.08	0.10	0.11	0.13	0.80	0.87	0.90	0.93	0.98
Euro area	0.03	0.05	0.06	0.06	0.06	0.87	0.92	0.93	0.94	0.97
United Kingdom	0.09	0.14	0.17	0.19	0.21	0.80	0.90	0.93	0.94	0.97
Canada	0.13	0.19	0.21	0.22	0.23	0.81	0.89	0.92	0.95	0.97
Australia	0.13	0.18	0.20	0.21	0.22	0.67	0.77	0.80	0.84	0.89
Standard deviation of RPI changes: $std(\widetilde{rpi}_t - \widetilde{rpi}_{t-h})$										
United States	1.1	3.4	6.0	8.4	15.1	0.5	1.4	2.3	2.7	3.2
Euro area	1.1	3.8	7.1	10.3	19.4	0.4	1.2	2.1	2.8	3.6
United Kingdom	1.4	3.9	6.6	9.2	16.3	0.8	2.1	3.5	4.4	6.4
Canada	1.1	3.2	5.6	7.8	14.1	0.5	1.4	2.2	2.8	4.4
Australia	1.1	3.2	5.6	7.9	14.2	0.8	2.2	3.7	4.8	7.4