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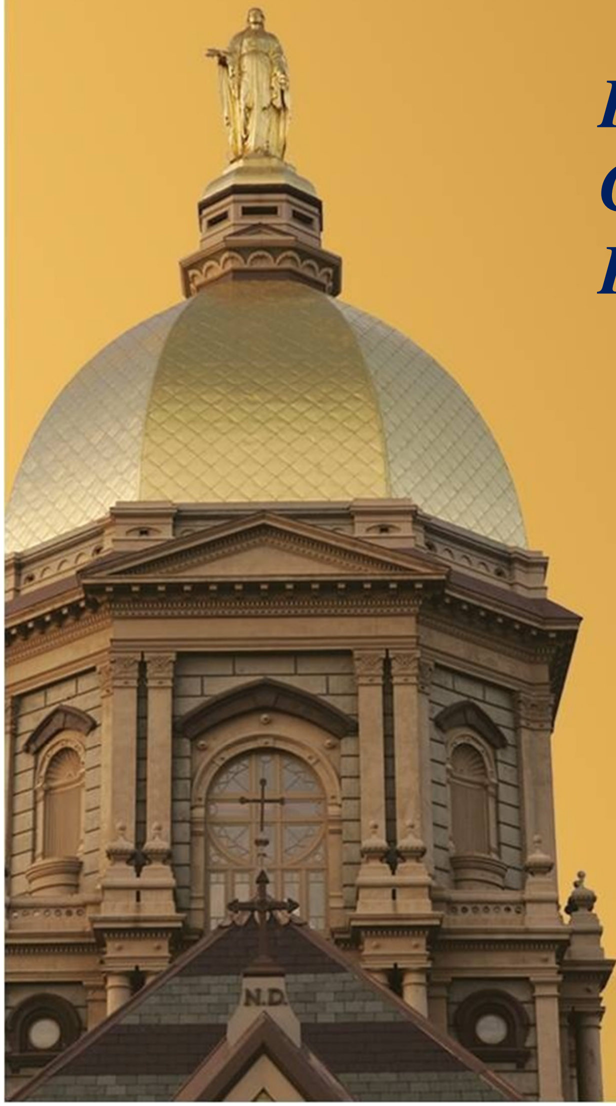
Applied and computational mathematics and statistics



Predicting Exchange Rates Out of Sample: Can Economic Fundamentals Beat the Random Walk?

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Joint work with Wei Wang and Ilias Tsiakas

R/Finance 2013

Photo: http://oneinabillionblog.com/tag/green-economy/

Bond price and Economic Fundamentals

- Mönch, E. (2008). Forecasting the yield curve in a data-rich environment: A no-arbitrage factor-augmented VAR approach. *Journal of Econometrics*, 146(1), 26-43.
- Economic fundamentals can predict yield curve.
- Economic fundamentals: more than 100 economic indicators, including industrial production, CPI, money supply, employment rate, …
- Method:

All data $\xrightarrow{\text{PCA}}$ **Factors** $\xrightarrow{\text{VAR}}$ **Short-term yield** $\xrightarrow{\text{No-arbitrage restrictions}}$ **Long- term yield**

Stock price and Economic Fundamentals

- Rapach, D. E., Strauss, J. K., & Zhou, G. (2010). Out-of-sample equity premium prediction: Combination forecasts and links to the real economy. *Review of Financial Studies*, 23(2), 821-862.
- Economic fundamentals can predict S&P500.
- Economic fundamentals: short-term yield, long-term yield, term spread, default spread, inflation, consumption/wealth, …
- Method: combined forecasts.

Combined forecasts

- *K* predictive models give *K forecasts.*
  - Option 1 (simple combination): take the mean, median, or trimmed mean
  - Option 2: take their weighted average, with the weights being determined by the past performance of individual models, or ***Discounted Mean Squared Error (DMSE)***.

$$\boldsymbol{weight_j} = \frac{\boldsymbol{DMSE_j^{-1}}}{\boldsymbol{\sum_{j=1}^{N} DMSE_j^{-1}}}$$

- Benchmark: historical average (random model) by Campbell and Thompson, *RFS*, 2007.

Rapach, Strauss, and Zhou(2010)

Model	Out-of-sample R-squared (%)
Dividend/price	0.34
Dividend/lagged price	0.26
Earnings/price	0.36
Dividend/earnings	-1.42
Variance (daily)	-12.97
Book/market	-2.6
Net equity issuance	-0.91
Short-term yield	-2.78
Long-term yield	-3.09
Long-term bond return	0.33
Term spread	-2.96
Default spread	-2.72
Default spread of returns	-1.1
Inflation	-0.84
Consumption/wealth	1.44 *

Combined forecasts	Out-of-sample R-squared (%)
Mean	3.58 **
Median	3.04 **
Trimmed mean	3.51 **
DMSE, θ=0.1	3.54 **
DMSE, θ=0.9	3.49 **

DMSE: *This forecasts combination is based on individual models' past performance, measured by* ***Discounted Mean Squared Error (DMSE)****. θ is the discounting factor.*

Benchmark: *random walk*

Whether economic fundamentals can predict other asset prices?

(Photo: Guy Parsons)

- Look abroad

Foreign exchange rates and Economic Fundamentals - Outline

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- Economic fundamentals
- Forecasting method:
  - Individual models
  - “Kitchen-sink” model
  - Combined forecasts
  - Efficient “kitchen-sink” model
- Predictability evaluation:
  - Statistical predictability
  - Portfolio returns

Economic fundamentals

- Random Walk (RW): $x_t = 0$

$$r_{t+1} = \alpha + e_{t+1}$$

$$\hat{r}_{t+1} = \hat{\alpha} = \textit{historical average}$$

Economic fundamentals

- Random Walk (RW): $x_t = 0$
- Uncovered Interest Parity (UIP):

  $x_t = x_{1t} = \Delta\ (interest\ rate)_t$

  - The difference in interest rates between two countries is equal to the expected change in exchange rates between the countries' currencies.

    Otherwise, arbitrage opportunity exists.
  - Most studies indicate the violation of this condition.
  - Carry trade strategy.

Economic fundamentals

- Random Walk (RW): $x_t = 0$
- Uncovered Interest Parity (UIP):

  $x_t = x_{1t} = \Delta\ (interest\ rate)_t$
- Purchasing Power Parity (PPP):

  $x_t = x_{2t} = \Delta\ (price\ level)_t - s_t$
  - law of one price.
  - identical goods will have the same price in different markets.


Espresso
STARBUCKS COFFEE AND TEA
Cappuccino


STARBUCKS COFFEE
RBUCKS COFFEE
104

Economic fundamentals

- Random Walk (RW): $x_t = 0$
- Uncovered Interest Parity (UIP):

  $x_t = x_{1t} = \Delta\ (interest\ rate)_t$
- Purchasing Power Parity (PPP):

  $x_t = x_{2t} = \Delta\ (price\ level)_t - s_t$
- Monetary Fundamentals (MF):

  $x_t = x_{3t} = \Delta\ (money\ supply)_t - \Delta\ (national\ income)_t - s_t$
- Taylor Rule (TR):

  $x_t = x_{4t} = 1.5\ \Delta\ (inflation)_t + 0.1\ \Delta\ (output\ gap)_t$
  $- 0.1\ \Delta\ (price\ level)_t - 0.1 s_t$

Model, Return and Econ Fundamentals

- $\boldsymbol{P_t}$ **:** nominal exchange rate (domestic price of 1 foreign currency unit)
- $\boldsymbol{r_{t+1}}$ = log($\boldsymbol{P_{t+1}}$) - log($\boldsymbol{P_t}$) is the foreign exchange rate return
- Different models have different predictor, x_t, in the predictive regression

$$\boldsymbol{r_{t+1} = \alpha + \beta\, x_t + e_{t+1}}$$

- Economic fundamentals: $\boldsymbol{x_t}$

Foreign exchange rates and Economic Fundamentals - method

1. Individual models: $r_{t+1} = \alpha + \beta x_t + e_{t+1}$
2. "Kitchen sink" regression: include $x_{1t}, x_{2t}, x_{3t}, x_{4t}$ in a multiple regression
3. Combined forecasts: generate forecasts from individual models.

   - Simple combined forecasts: take the mean, median, or trimmed mean
   - Take their weighted average, with the weights are determined by the past performance of individual models (DMSE).

Data

- Monthly FX data ranging from January 1976 to June 2012 (~ 35 years).

- The 10 most liquid (G10) currencies in the world:

  Australian dollar

  Canadian dollar

  Swiss franc

  Deutsche mark

  British pound

  Japanese yen

  Norwegian kroner

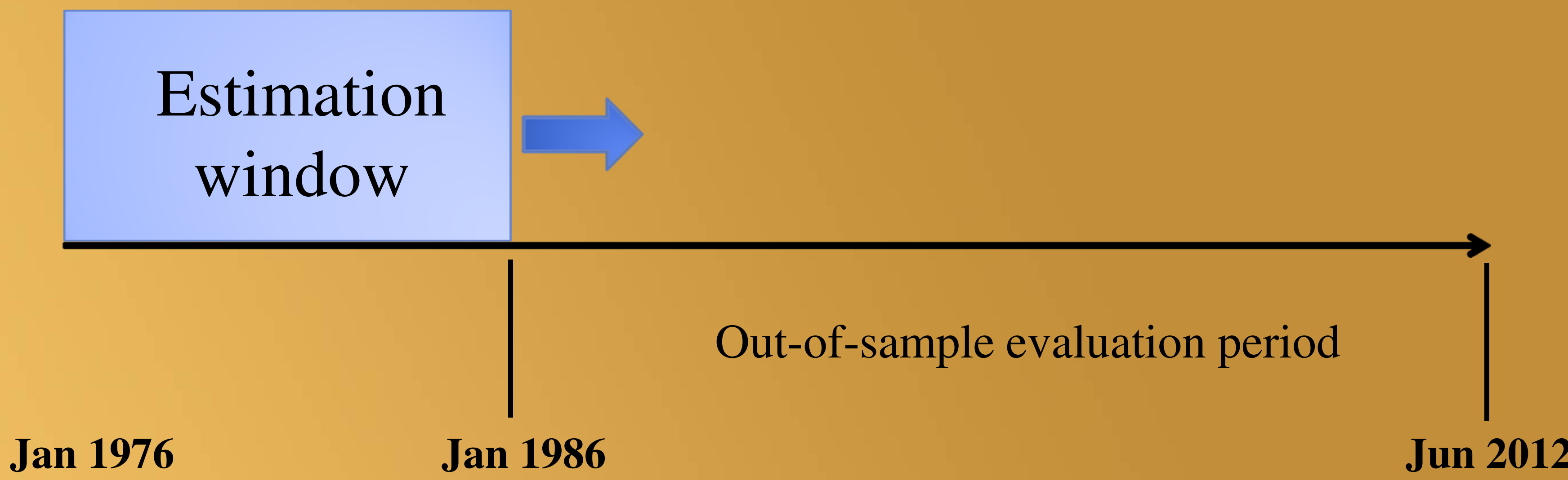
  New Zealand dollar

  Swedish kronor

  US dollar

- 9 exchange rates.

Out-of-sample forecasts



- The first FX return to be predicted is in January 1986 (using a 10 year estimation window)
- Keep updating estimation window.

Statistical evaluation

- Out-of-sample R^2

$$R^2_{os} = 1 - \frac{\sum_{t=1}^{T-1}(\hat{r}_{t+1} - r_{t+1})^2}{\sum_{t=1}^{T-1}(\bar{r}_{t+1} - r_{t+1})^2}.$$

$\hat{r}_{t+1}$ is the model's forecast, $\bar{r}_{t+1}$ is the benchmark's forecast (historical average).

- Positive out-of-sample R^2

⇔the lower alternative model's error

⇔the better the alternative model

Out-of-sample R square (benchmark: random walk)

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	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
Combined - DMSE(0.9)	-0.068	0.060	0.468	-0.591	0.028	0.990	-0.392	-0.023	-1.010
Combined - DMSE(1.0)	-0.403	-0.196	0.605	-0.429	0.244	0.777	-0.495	-0.137	-0.915
Combined - Mean	-0.382	-0.245	0.615	-0.414	0.181	0.795	-0.468	-0.110	-0.938
Combined - Median	-0.195	0.071	-0.613	-0.535	-0.370	0.563	-0.738	0.702	-0.108
Uncovered interest rate parity	-0.968	0.528	-1.806	-3.337	-3.387	-0.417	-2.736	-0.851	-6.376
Purchasing power parity	-1.831	-1.308	-0.964	-1.380	0.490	-0.110	-1.336	-1.550	-0.443
Taylor rule	-1.553	-2.115	-2.385	-2.134	-2.959	-1.019	-1.745	-0.543	-1.671
Monetary fundamentals	-1.879	-1.643	-0.513	-2.751	-0.881	-1.487	-2.639	-1.809	-0.496
"Kitchen sink"	-11.226	-13.052	-15.918	-22.587	-9.579	-18.812	-14.267	-22.109	-16.433

Economic evaluation

- Mean-variance strategy

Predictive regression → 9 return forecasts → Mean-variance strategy → 1 portfolio return

- Mean-variance strategy: target volatility (annualized) = 10%
- Covariance estimates: sample covariance
- We also implement 1/N strategy and momentum strategy

Sharpe Ratio

	Mean (%)	Volatility (%)	Sharpe Ratio	Performance Fee (bps)
Combined - DMSE(0.9) (the best one)	11.083	12.761	0.498	71
Uncovered interest rate parity	9.597	12.521	0.389	-134
Purchasing power parity	8.886	12.500	0.333	-282
Taylor rule	8.226	11.685	0.300	-196
Monetary fundamentals	9.851	12.328	0.416	-102
"Kitchen sink"	8.553	11.537	0.332	-224
Random walk	11.039	12.770	0.494	
1/N strategy	6.653	7.111	0.271	-177
Momentum strategy	6.867	7.897	0.271	-177

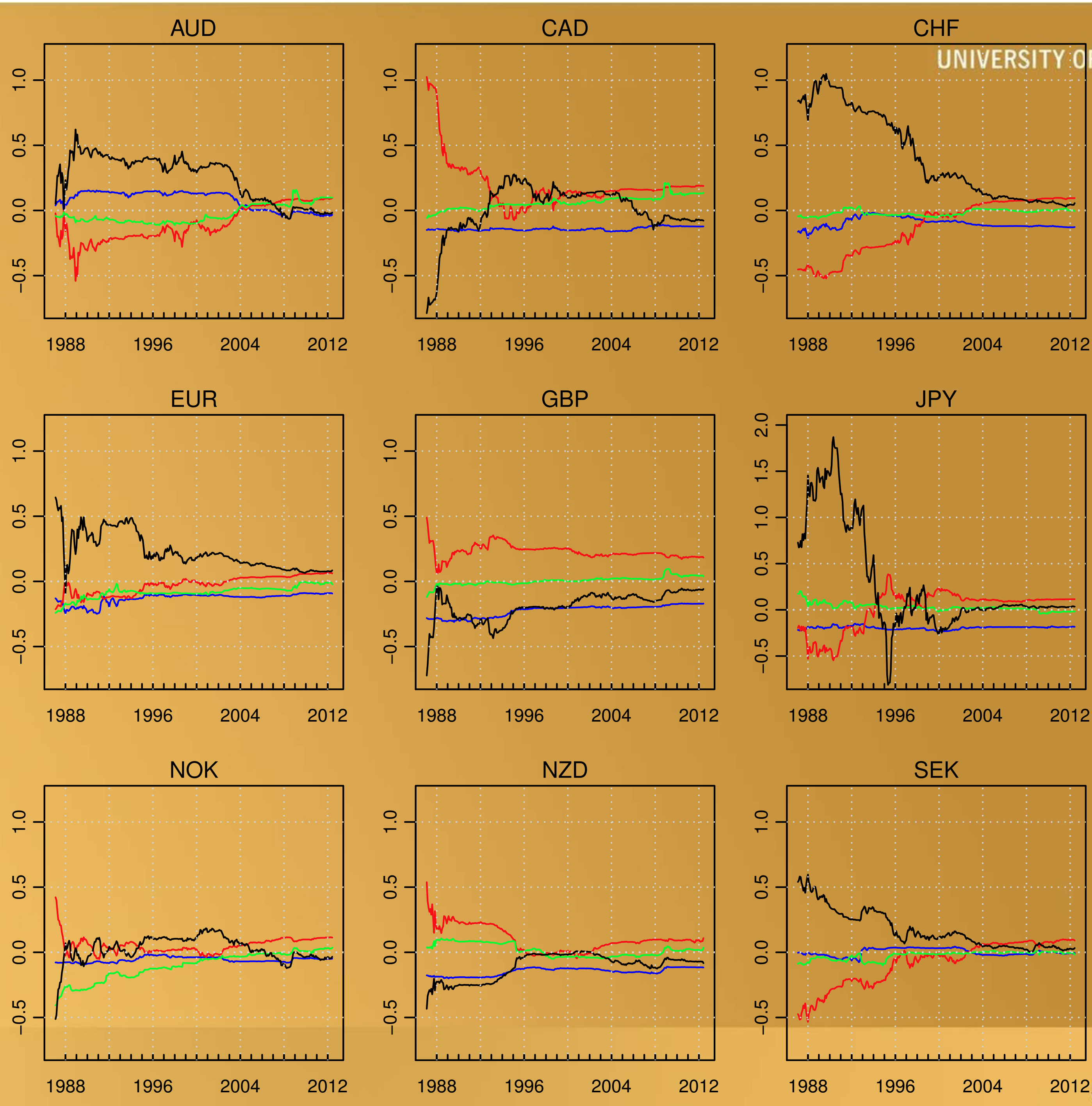
“Efficient kitchen-sink” model

- What is the problem with “kitchen-sink” model?

$$\boldsymbol{r_{t+1} = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} + \beta_3 x_{3t} + \beta_4 x_{4t} + e_{t+1}}$$

- More information leads to bad forecasts ??

- Let’s examine $\boldsymbol{\beta_1, \ldots, \beta_4}$ in the predictive regression of each currency



AUD
CAD
CHF
EUR
GBP
JPY
NOK
NZD
SEK
1988
1996
2004
2012
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"Efficient kitchen-sink" model

- What is the problem with "kitchen-sink" model?

$$\boldsymbol{r_{t+1} = \alpha + \beta_1 x_{1t} + \beta_2 x_{2t} + \beta_3 x_{3t} + \beta_4 x_{4t} + e_{t+1}}$$

- $\boldsymbol{\beta_1}, \ldots, \boldsymbol{\beta_4}$ are inflated.

- This motivates shrinkage estimation.

"Efficient kitchen-sink" model

- Constraint least squares that minimizes

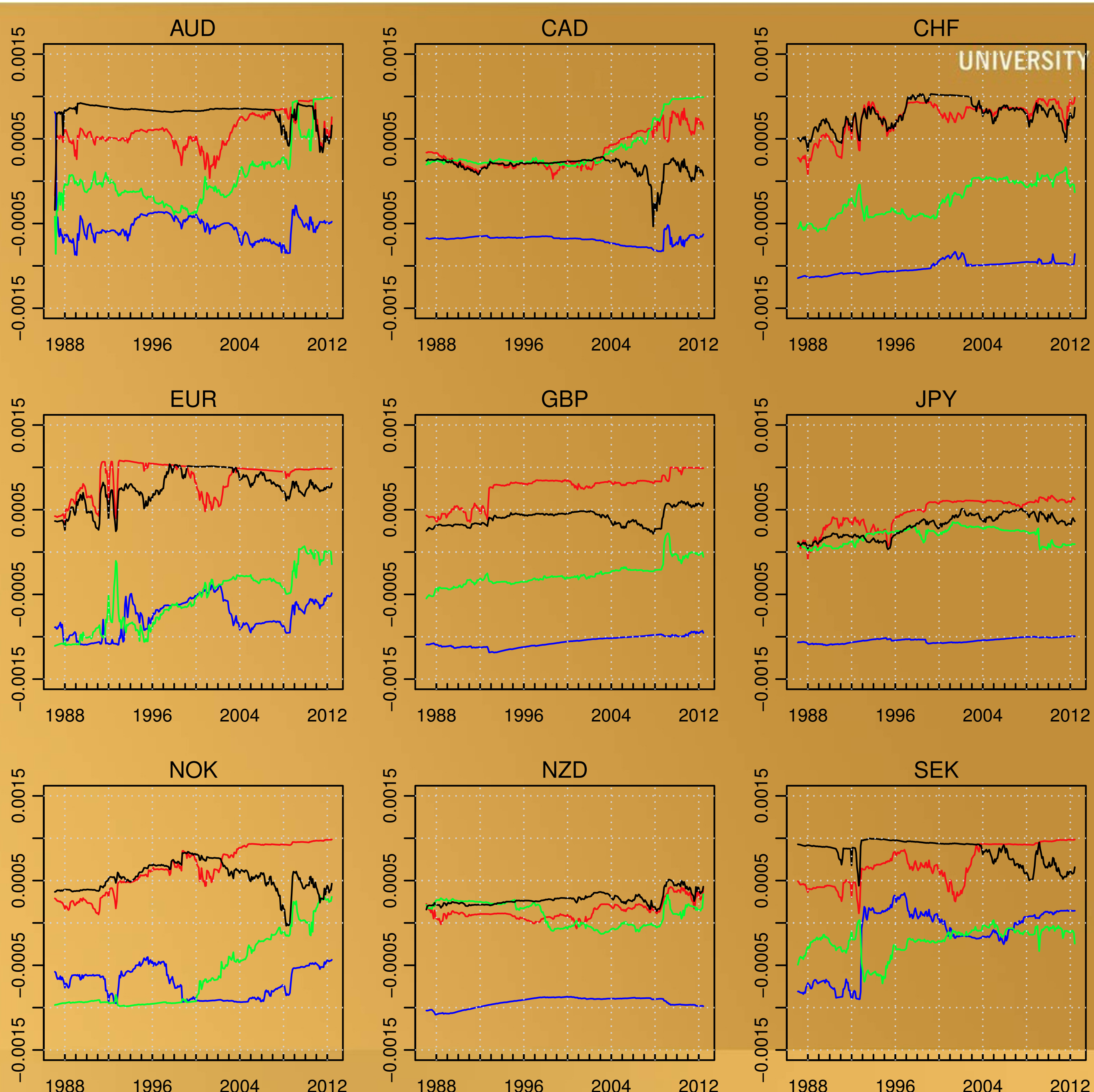
$$\sum_{t=1}^{T}(r_{t+1} - \alpha - \beta_1 x_{1t} - \beta_2 x_{2t} - \beta_3 x_{3t} - \beta_4 x_{4t})^2$$

subject to constraints: $\sum_{j=1}^{4}|\beta_j| < s_1$ and $\sum_{j=1}^{4}(\beta_j^2) < s_2$

- This is the elastic-net regression.
- Consequence: The estimated regression coefficients $(\boldsymbol{\beta}_1, \dots, \boldsymbol{\beta}_4)$ are shrunk towards $\boldsymbol{0}$.

"Efficient kitchen-sink" model

- More robust and stable compared to traditional ones
- Forecasting error-oriented procedure
- Linear model – consistent with many empirical models in economics and finance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EUR
GBP
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NOK
NZD
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0.0005
−0.0005
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1988
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Out-of-sample R square (benchmark: random walk)

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	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK
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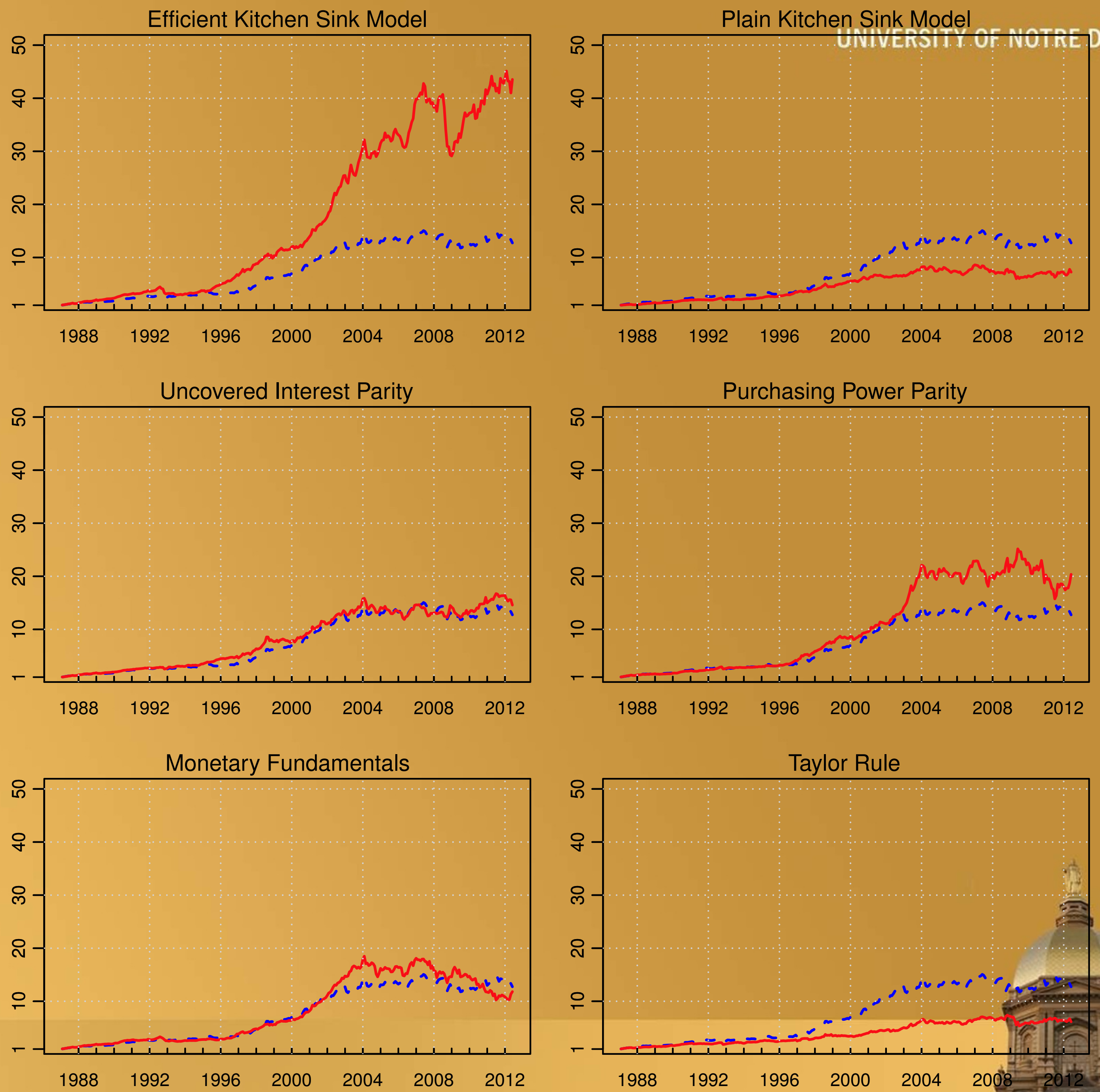
Cumulative Wealth:

what if you invested $1 in January 1976 ?



Cumulative Wealth:

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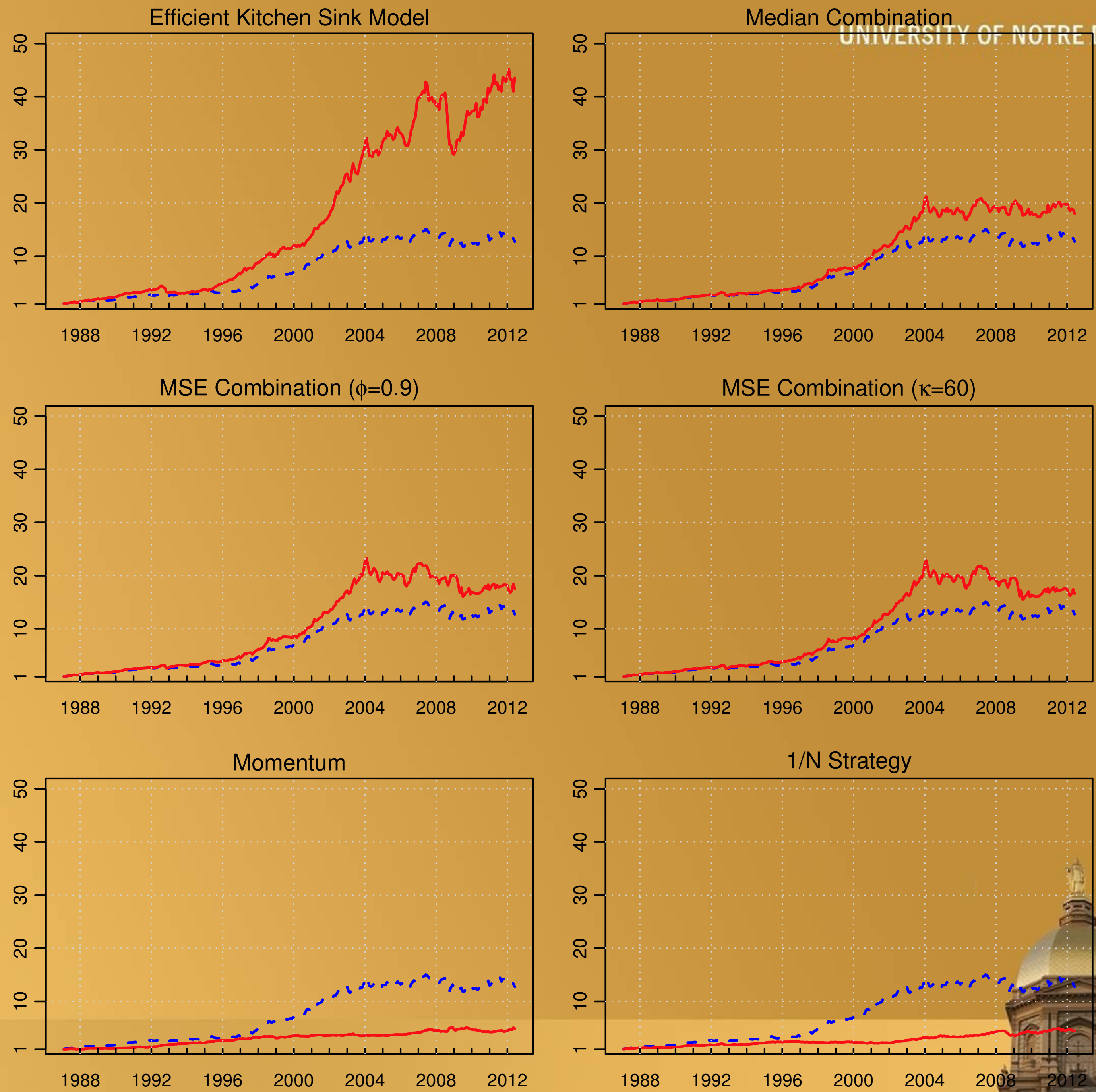

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Take-home message..

- It’s all about how to process information.
- Traditional regression is in-sample explanatory power-oriented, not forecasting-oriented.
- Remedies: forecasts combinations; shrinkage estimation
- **R package:** lars, elasticnet, glmnet, grpreg

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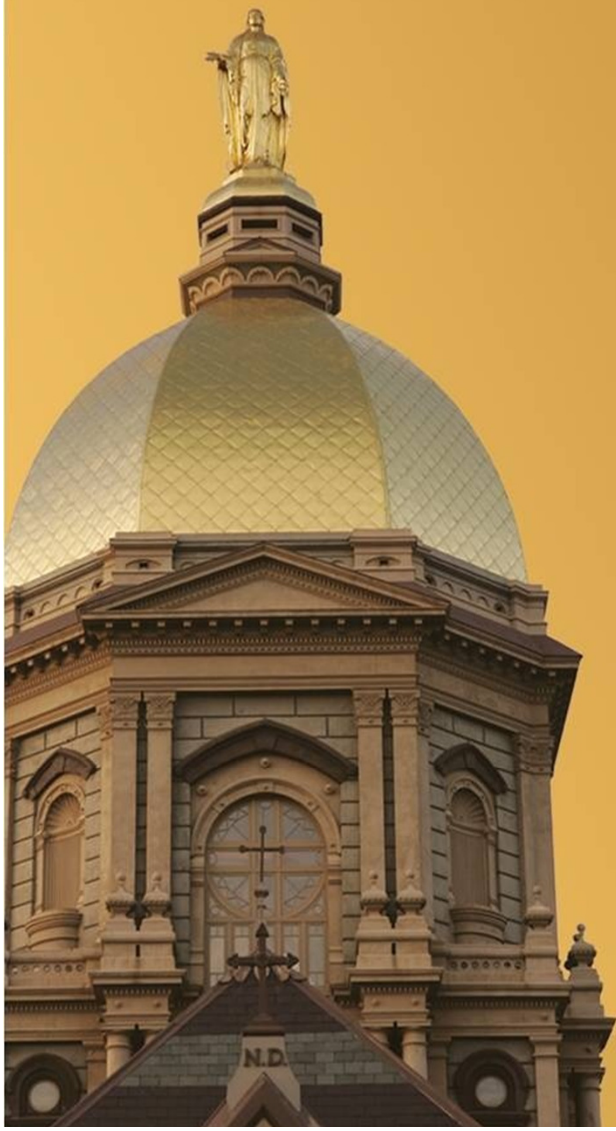

THANK YOU!