Macroeconomic Forecasting in Times of Crises

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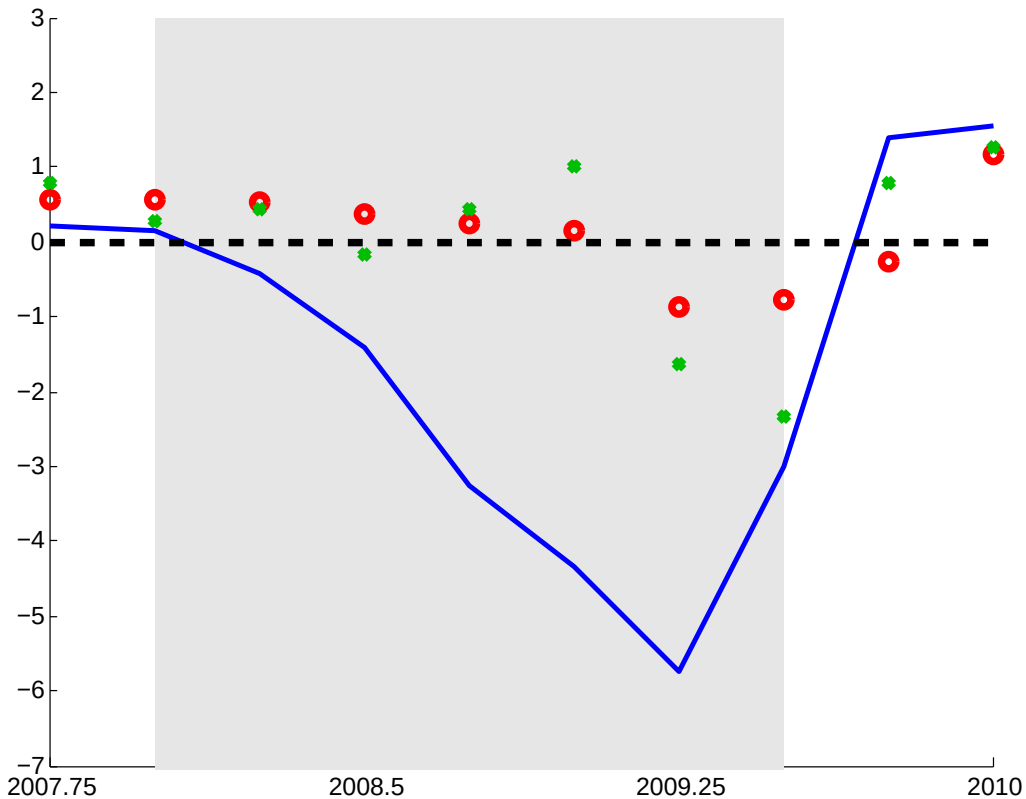
[1] The views expressed in this paper are solely the responsibility of the authors and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or of any other person associated with the Federal Reserve System.

Motivation

- Great Recession difficult time for macroeconomic forecasters (Potter, 2011)

U.S. Industrial production 1-quarter ahead forecasts



Blue: Data, Green: Greenbook, Red: SPF

What we do

Based on **nearest-neighbor** (NN) techniques, we propose methods that:

1. **Match** recent pattern of data series from current time period with similar patterns in past

2. **Forecast** future movements in data series from its realizations following matched time periods in the past

We apply these methods to forecast 13 postwar U.S. macro and financial data series.

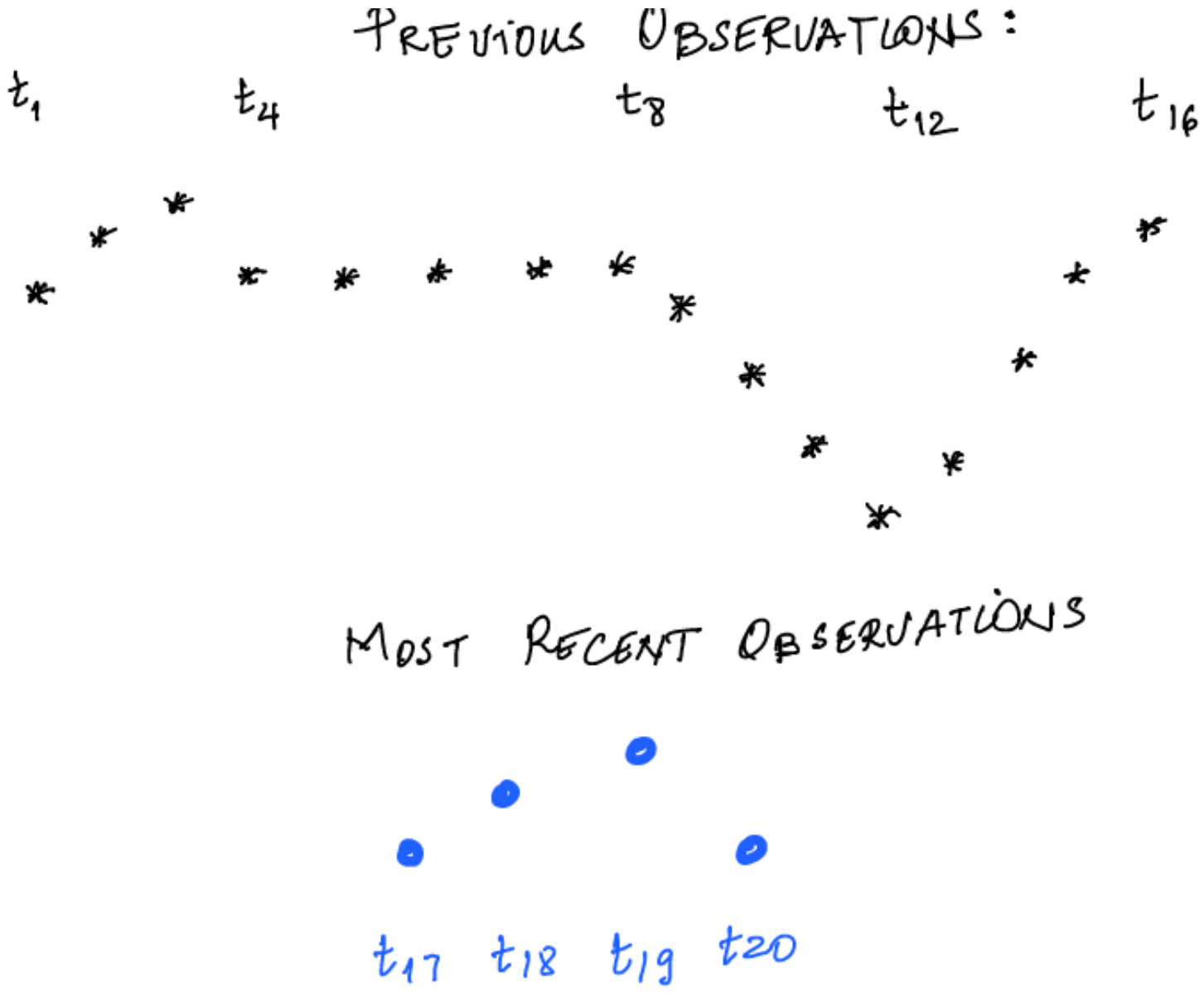
What we find

- Forecasts using nearest-neighbor methods ...
  - **Significantly** outperform optimally-selected ARIMA models for many data series
  - **Almost always** better than linear alternatives
  - Do particularly well during the Great Recession
- Incorporating **house price information** helps a lot (significant gains over ARIMA models for 60% of the data series)
  - **Financial factors** are also important (although less so)
  - **Oil prices** do not seem to help

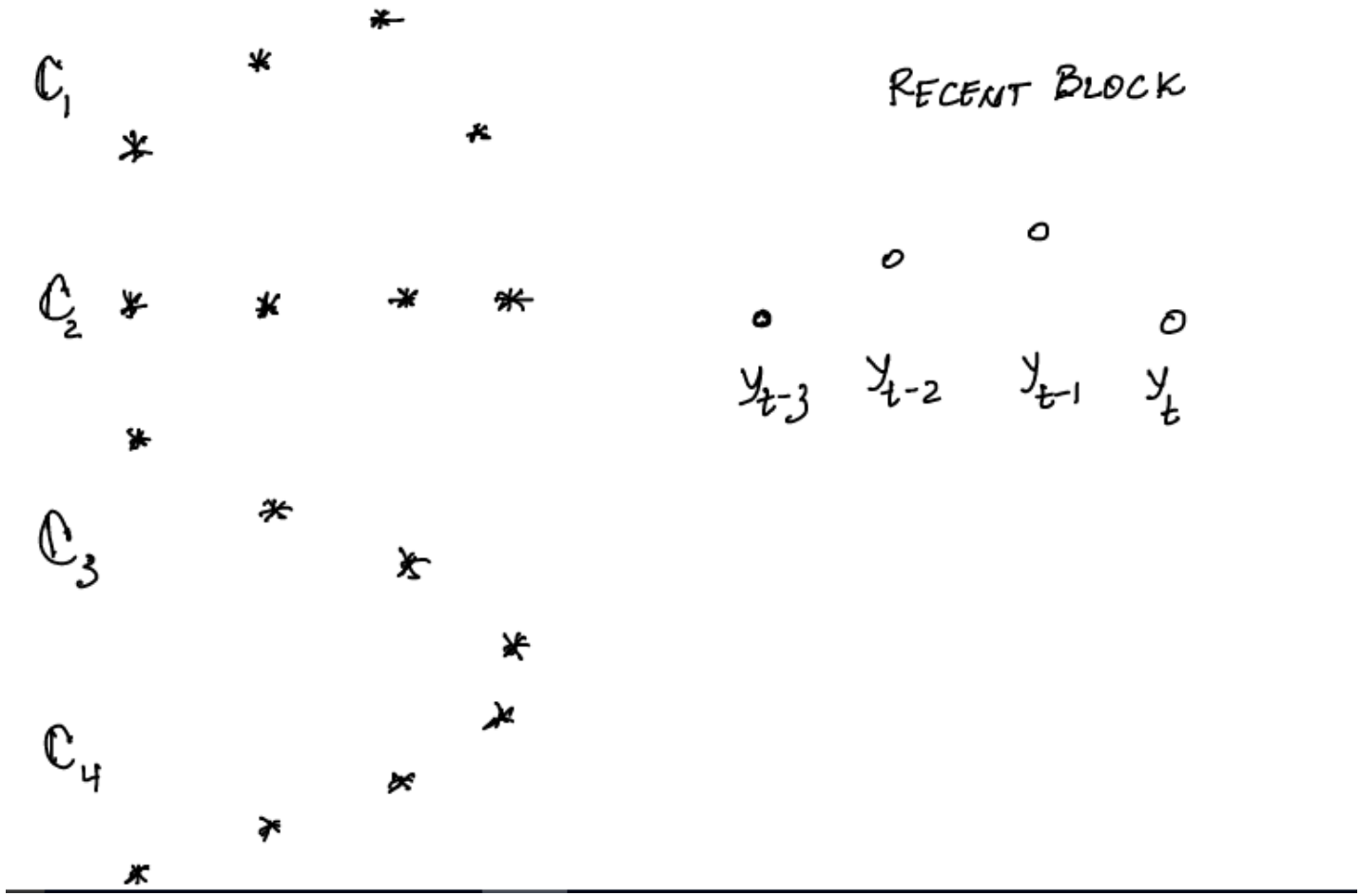
Literature

- Nearest-neighbor methods (Farmer and Sidorowich (1987), Diebold and Nason (1990))
- Uses in economics:
  - Exchange rates (Mizrach (1992), Fernandez-Rodriguez and Sosvilla-Rivero (1998), Meade (2002))
  - GDP (Ferrara et. al. (2010))
  - Unemployment (Golan and Perloff (2004))
  - Interest rates (Barkoulas et. al. (2003))
  - Commodity prices (Agnon et. al. (1999))
- Intercept corrections (Clements and Hendry (1996))
- No systematic evaluation of nearest-neighbor methods on a wide variety of macro and financial time series
- **No work on the Great Recession**

Framework: Graphical Representation



Framework: Graphical Representation



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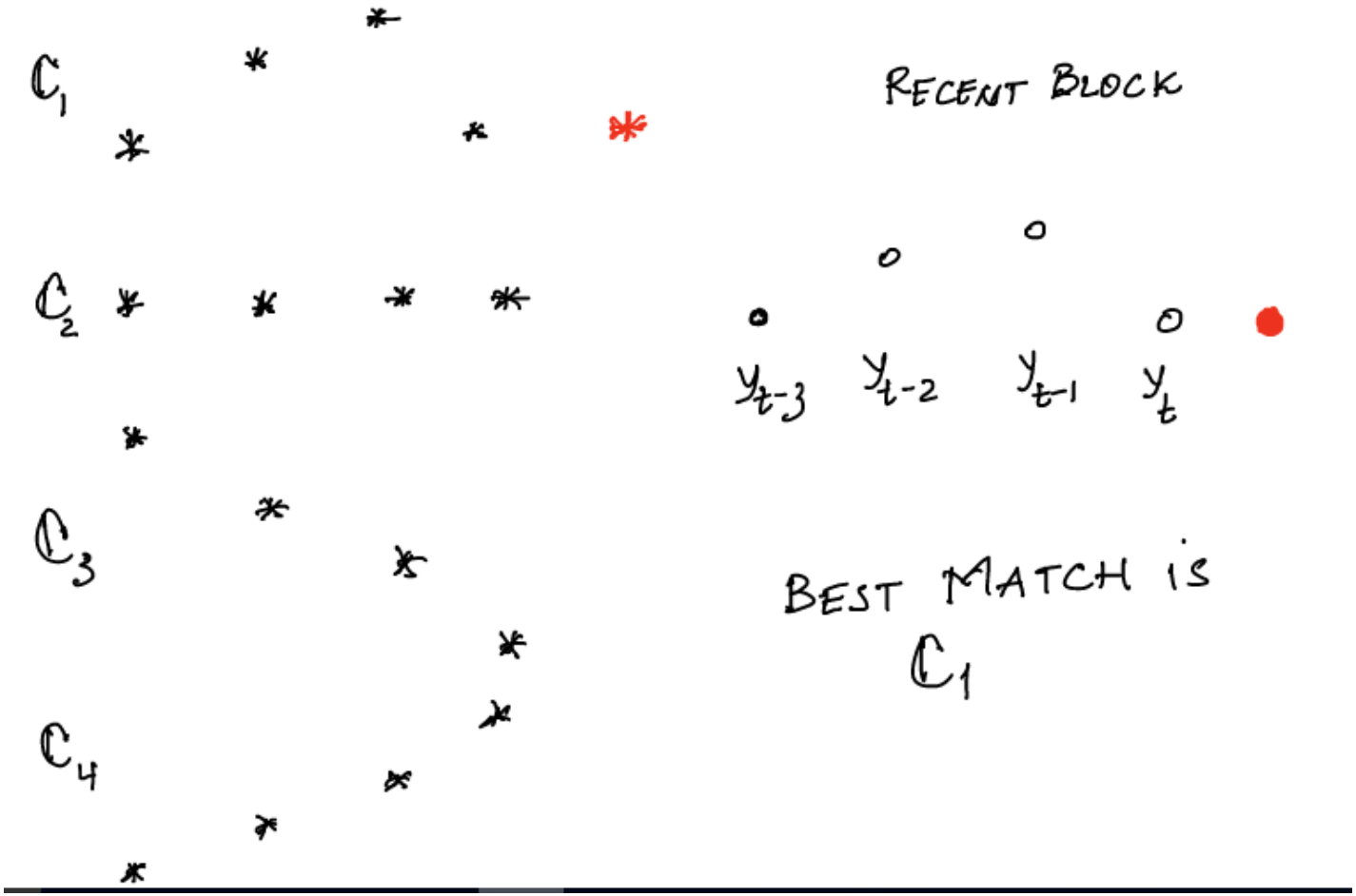


Framework

In our proposal,

Baseline model: ARIMA selected using BIC and unit root pretests

- Produce forecasts $\hat{y}_{t+1,ARIMA}$

Goal: Adjust forecasts produced from baseline model to take into account past systematic errors

- e.g. suppose baseline model has consistently overpredicted y_t entering into recessions

Remarks:

- Bayesian flavor: ARIMA $\rightarrow$ likelihood. Prior: systematic correction
- Flexible approach, choose your preferred baseline model.

Question: How do we find "similar" time periods?

Nearest-neighbor methods

Two main classes of matching algorithms

- **Match to levels**

  Suppose we match to the first time period $(y_1, ..., y_k)$:

$$dist(k) = \sum_{i=1}^{k} w(i) \left(y_{t-k+i} - y_i\right)^2 .$$

- **Match to deviations from local mean**

$$dist(k) = \sum_{i=1}^{k} w(i) \left((y_{t-k+i} - \overline{y}_t) - (y_i - \overline{y}_k)\right)^2 .$$

where w is an **increasing** function in i: $w(i) = \frac{1}{k-i+1}$

Key parameter to choose is k: match length

Adjusted forecasting model

Suppose first sequence is one that is matched

$$\hat{y}_{t+1} = \underbrace{(y_{k+1} - \hat{y}_{k+1,ARIMA})}_{\text{Error from matched time period}} + \hat{y}_{t+1,ARIMA},$$

We can also take the first m matched sequences ranked by distance to current $\{y_t, ..., y_{t-k+1}\}$ to do this correction

$$\hat{y}_{t+1} = \frac{1}{m} \sum_{i}^{m} \left(y_{l(i)+1} - \hat{y}_{l(i)+1,ARIMA}\right) + \hat{y}_{t+1,ARIMA}$$

where $\{y_{l(i)}, y_{l(i)-1}, ..., y_{l(i)-k+1}\}$ is the ith closest match to $\{y_t, ..., y_{t-k+1}\}$

Model selection

There are 2 free parameters in our approach:

- k (Match length): Grid from $2 - 70$ (by 10)
- m (Number of averages): Grid from $2 - 80$ (by 10)

Use past recursive out-of-sample mean squared error to select optimal k and m (predictive least squares)

$$MSE = \frac{1}{t - t_1} \sum_{s=t_1}^{t} \left(\hat{y}_{s|s-1} - y_s \right)^2$$

Data series

We consider 13 monthly U.S. macroeconomic and financial data series from $1959M1 - 2015M5$

Macro variables

- Inflation
- Federal funds rate
- Unemployment
- Payroll employment
- Industrial production
- Personal consumption expenditures
- Real personal income
- Average hourly earnings
- Housing starts
- Capacity utilization

Financial variables

- S&P500
- Real estate loans
- Commercial and industrial loans

Recursive out-of-sample forecasting exercise

Forecasting details

- Begin forecasting at $1990M1$, one-step ahead
- Forecast monthly, reestimating model every period
- $t_1 = 1975M1$
- Forecast comparison to **baseline linear model** using Diebold and Mariano (1995) test statistic

Baseline model details

- Select ARIMA model using BIC

Forecast comparison overview

Match to deviations forecasts better for...

- Inflation
- Federal funds rate
- Unemployment**
- Payroll employment
- Industrial production**
- Personal consumption expenditures*
- Real personal income**
- Average hourly earnings
- Housing starts
- Capacity utilization

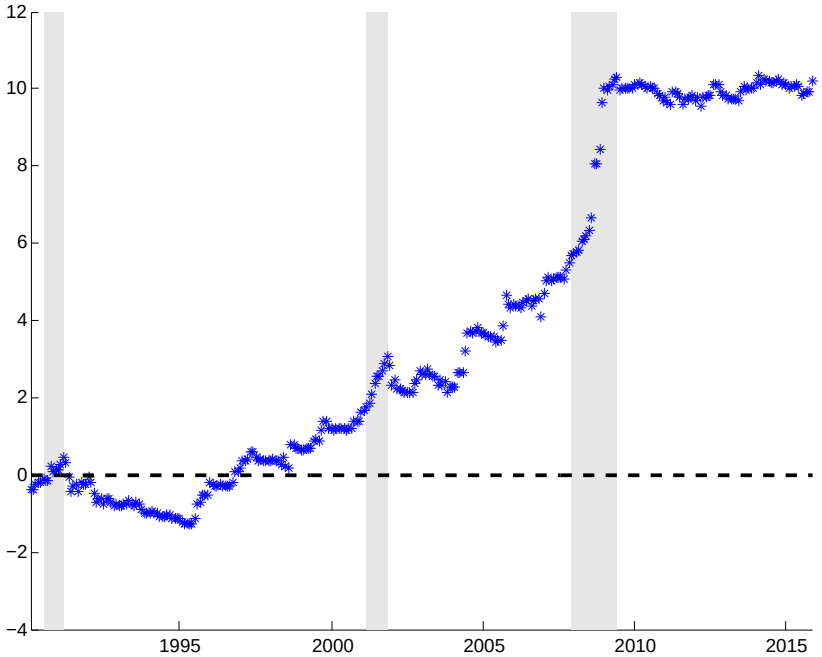
RMSE

- S&P500
- Real estate loans**
- Commercial and industrial loans

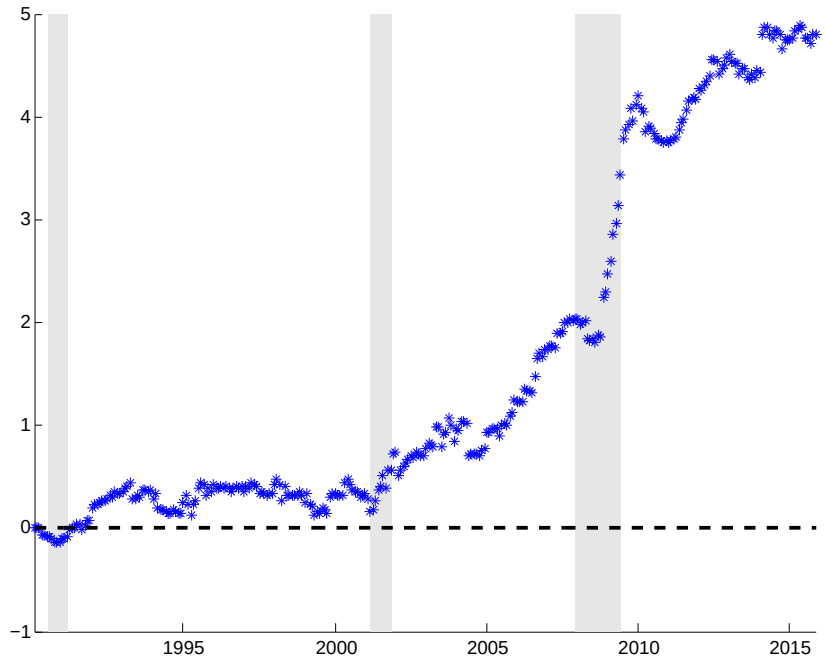
Forecasting in the Great Recession

$$RCSd = \sum error_B^2 - \sum error_{NN}^2$$

Recursive cum sum of squares diff (IP)



Recursive cum sum of squares diff (C&I loans)



- Relative RMSE IP: 0.92
- Relative RMSE C&I: 0.95

Comparison to rolling-window ARMA(1,1)

Match to deviations forecasts better for...

- Inflation
- Federal funds rate
- Unemployment**
- Payroll employment
- Industrial production
- Personal consumption expenditures**
- Real personal income**
- Average hourly earnings
- Housing starts**
- Capacity utilization
- S&P500**
- Real estate loans**
- Commercial and industrial loans

RMSE

AR(1)

Drivers of the Great Recession

Question: Do potentially important (nonlinear) drivers of the Great Recession help improve forecasting performance?

Theories:

- Financial factors – Christiano, Motto, Rostagno (2014), Gilchrist and Zakrajsek (2012)
- Housing – Iacoviello (2005), Liu, Wang, Zha (2013), Guerrieri and Iacoviello (2015)
- Oil prices – Hamilton (2009)

What are reasonable "X"?

- Financial factors Results
  - Gilchrist and Zakrajsek (2012) excess bond premium
- Housing
  - Case-Shiller House Price Index growth
- Oil prices Results
  - West Texas Intermediate, deflated by PCE prices

House Price Index

Nearest neighbor X vs ARIMA

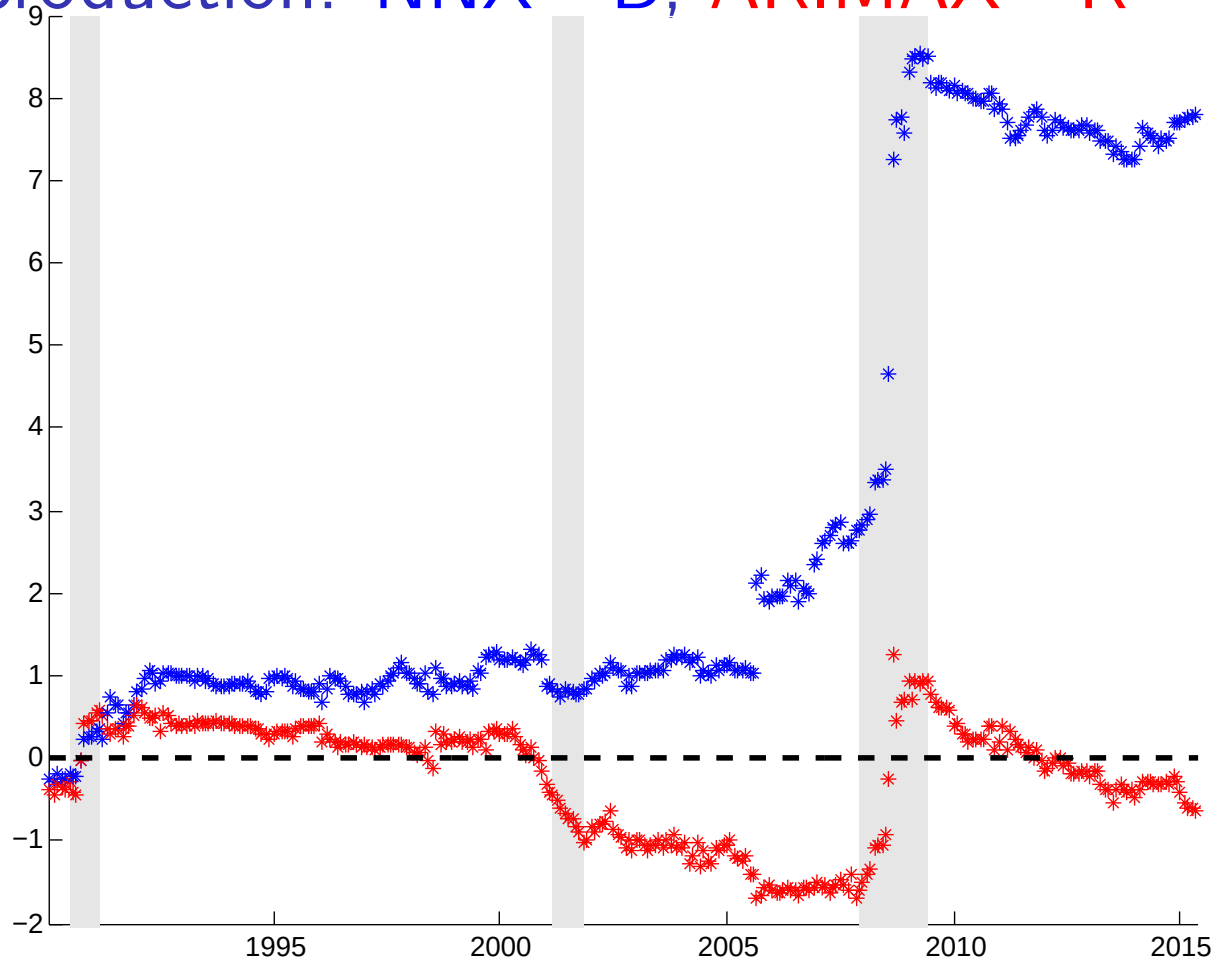
- Inflation**
- Federal funds rate
- Unemployment**
- Payroll employment*
- Industrial production*
- Personal consumption expenditures*
- Real personal income**
- Average hourly earnings
- Housing starts**
- Capacity utilization
- S&P500
- Real estate loans**
- Commercial and industrial loans

RMSE

ARIMAX vs ARIMA

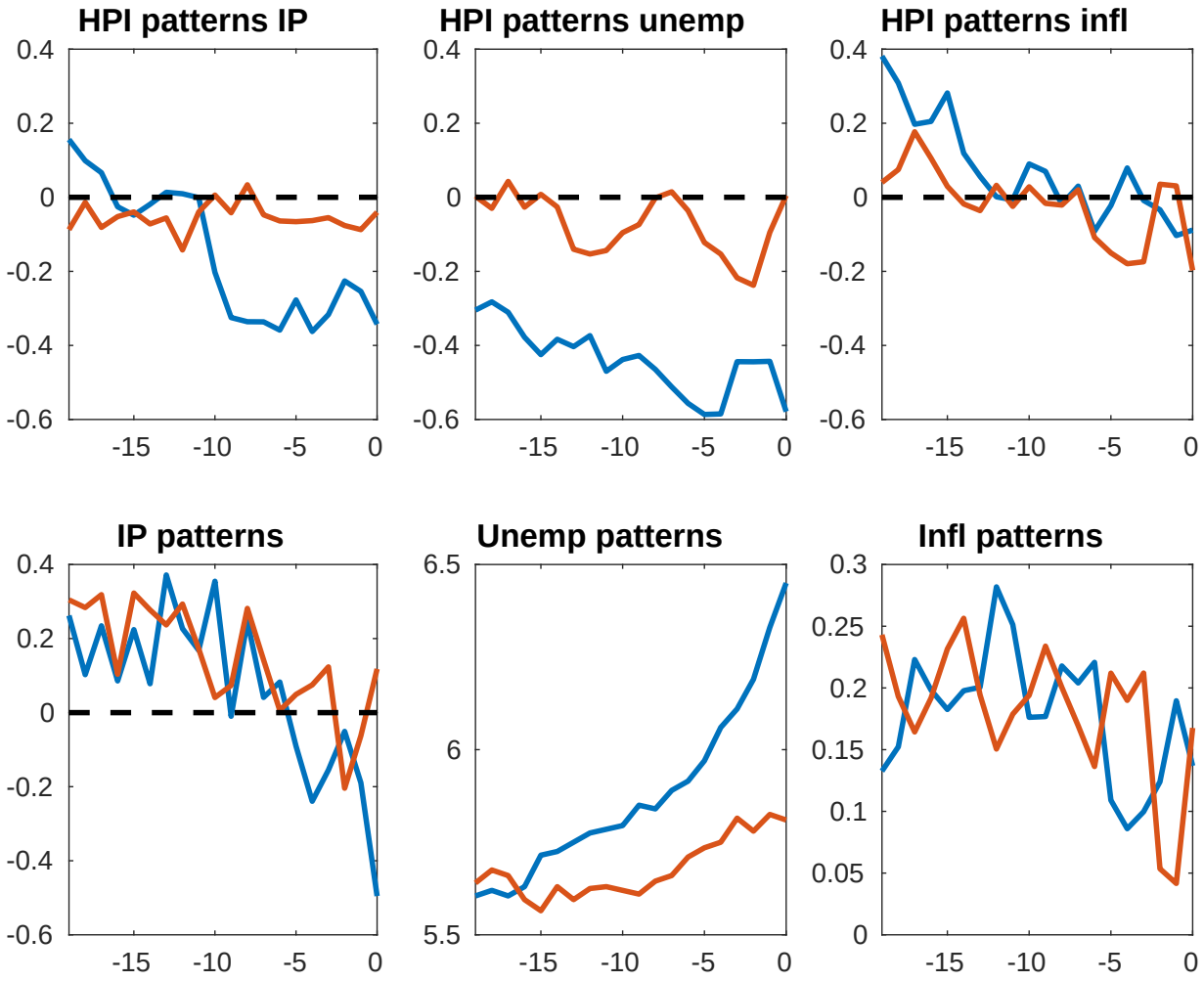
- Inflation
- Federal funds rate
- Unemployment
- Payroll employment
- Industrial production
- Personal consumption expenditures
- Real personal income
- Average hourly earnings
- Housing starts
- Capacity utilization
- S&P500
- Real estate loans
- Commercial and industrial loans

Industrial production: NNX - B, ARIMAX - R



- Relative RMSE NNX: 0.96
- Relative RMSE ARIMAX: 1.00

Patterns after which we tend to do well



House Price Index

- House price index important factor in macroeconomic/financial variable forecasting
  - Strong forecasting gains in the Great Recession
- Strong nonlinear forecasting relationship between house price index and many variables
- Little evidence of linear forecasting relationship

Survey comparison

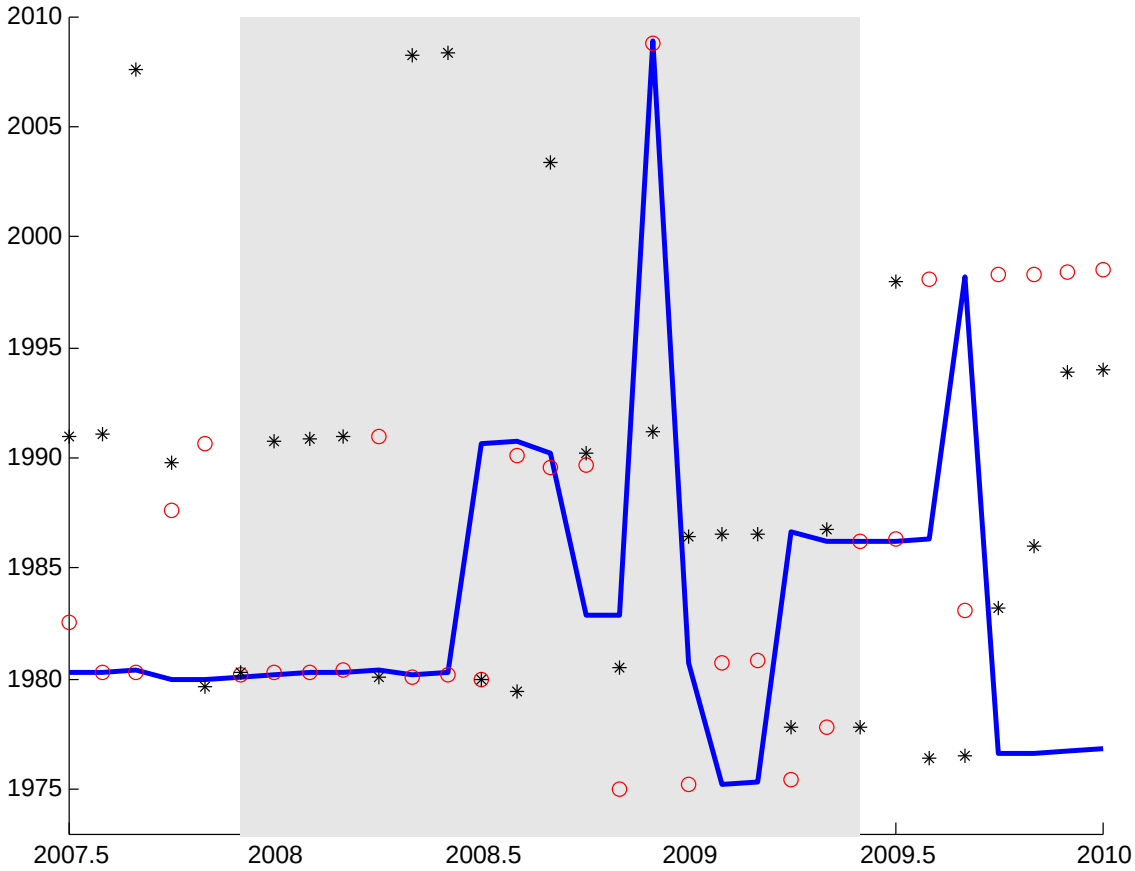
Multiple horizons

Multivariate

Conclusion

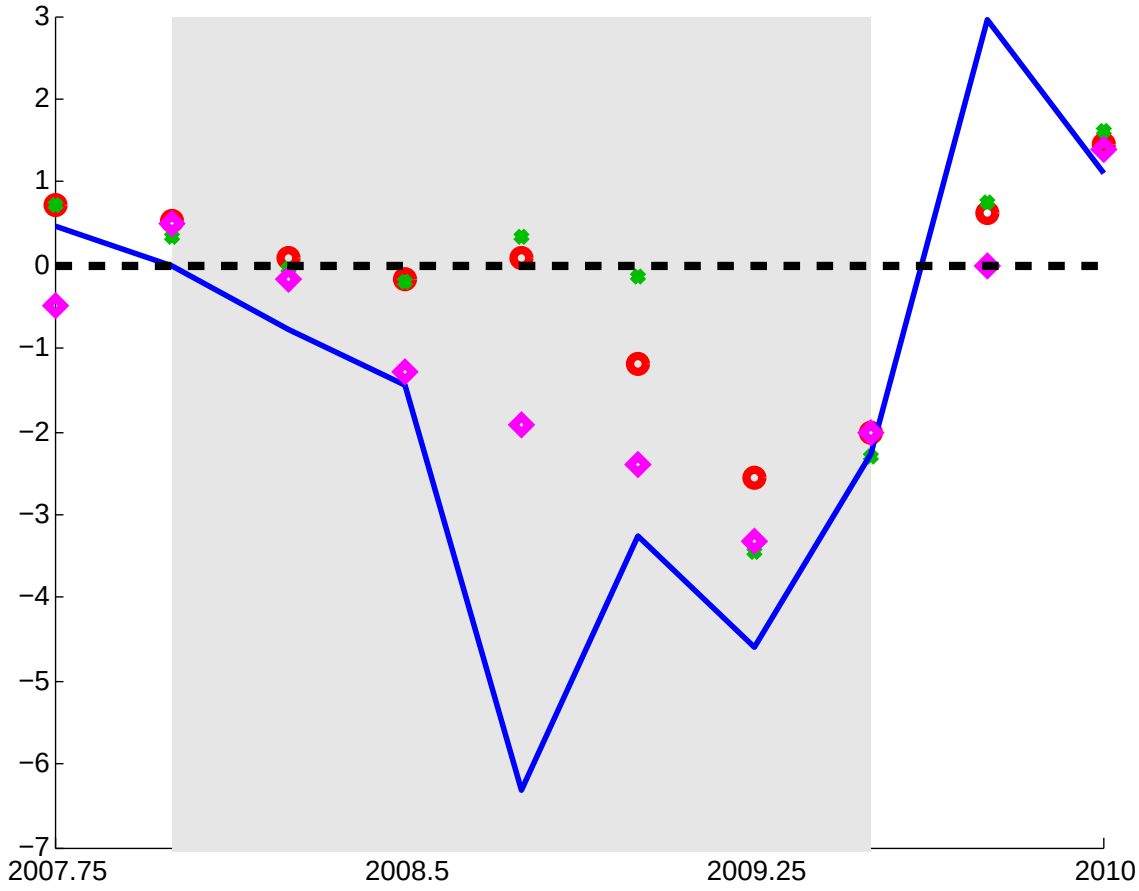
- We propose and evaluate the **nearest neighbor** method as a forecasting tool on 13 U.S. macro and financial time series
- We find that the method delivers significantly better forecasts when compared to optimally-selected ARIMA models
  - Especially large gains in the Great Recession
- House price information can improve forecasts
- Interesting extension: DSGE model as auxiliary model.

What information is being used to forecast IP?



Blue: Top match, Red: 2nd, Black: 3rd

Industrial production: Data-blue, Greenbook, SPF-red, NNX-pink



Return

Multi-step forecasting

NN - X versus ARMA/ARIMA model forecast comparison based on RMSE for multiple horizons (months) (RMSE ratio relative to ARMA/ARIMA model forecast)

	3	6	12
Inflation	0.97	0.98	0.98
Federal funds rate	0.96	0.96	0.94
Unemployment	0.94	0.88*	0.80**
Payroll employment	0.95	0.92*	0.91
Industrial production	0.96	0.98	0.98
Personal consumption	0.99	0.98*	–
Real personal income	0.99	1.00	0.97**
Average hourly earnings	0.99	1.00	0.99
Housing starts	0.99**	0.98**	0.99
Capacity utilization	0.97	0.99	0.99
S&P500	0.99	0.99	0.99
Real estate loans	0.98	0.98	0.96
Commercial and industrial loans	0.97*	0.96**	0.96*

Return

Multivariate extension

2−variable nearest-neighbor versus VAR model forecast comparison based on RMSE (1 step ahead) (RMSE ratio relative to VAR model forecast)

Inflation	0.94^{**}
Federal funds rate	1.03
Unemployment	0.99
Payroll employment	0.99
Industrial production	0.98^{**}
Personal consumption	0.99
Real personal income	0.95
Average hourly earnings	1.00
Housing starts	0.98^{**}
Capacity utilization	0.98^{**}
S&P500	0.99
Real estate loans	0.98^{*}
Commercial and industrial loans	0.97^{**}

Return

RMSE NN-2 versus Rolling-window ARMA(1,1)

Inflation	1.00
Federal funds rate	1.07
Unemployment	0.87**
Payroll employment	0.97
Industrial production	0.98
Personal consumption	0.94**
Real personal income	0.90**
Average hourly earnings	0.98
Housing starts	0.96**
Capacity utilization	0.95
S&P500	0.96**
Real estate loans	0.95**
Commercial and industrial loans	1.00

Return

RMSE NN-2 versus Rolling-window AR(1)

Inflation	0.99
Federal funds rate	1.06
Unemployment	0.86**
Payroll employment	0.87**
Industrial production	0.95*
Personal consumption	0.95**
Real personal income	0.91**
Average hourly earnings	0.98
Housing starts	0.95**
Capacity utilization	0.94
S&P500	0.97**
Real estate loans	0.95**
Commercial and industrial loans	0.93**

Return

Excess bond premium

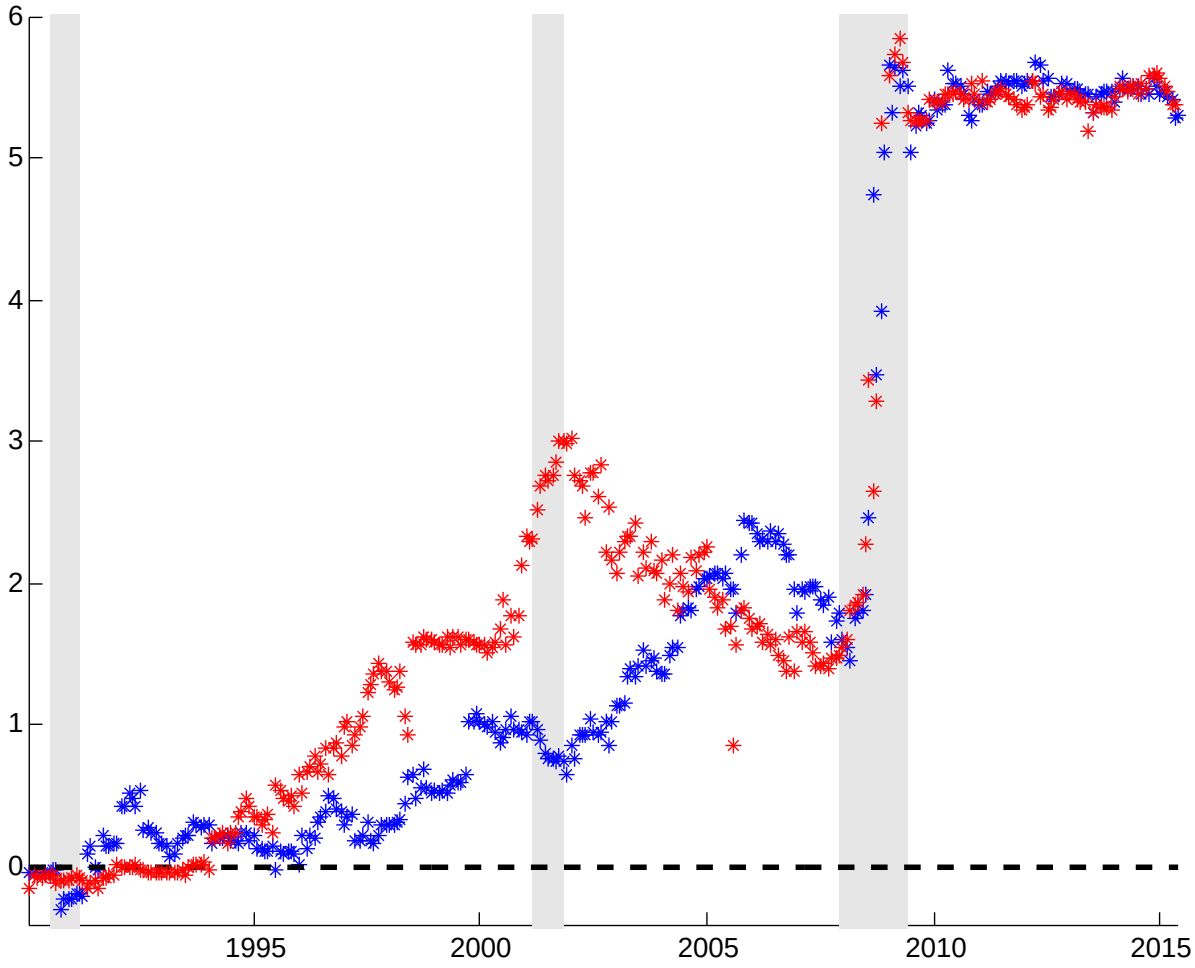
Nearest neighbor X vs ARIMA

- Inflation*
- Federal funds rate
- Unemployment*
- Payroll employment
- Industrial production
- Personal consumption expenditures
- Real personal income
- Average hourly earnings**
- Housing starts*
- Capacity utilization
- S&P500
- Real estate loans**
- Commercial and industrial loans**

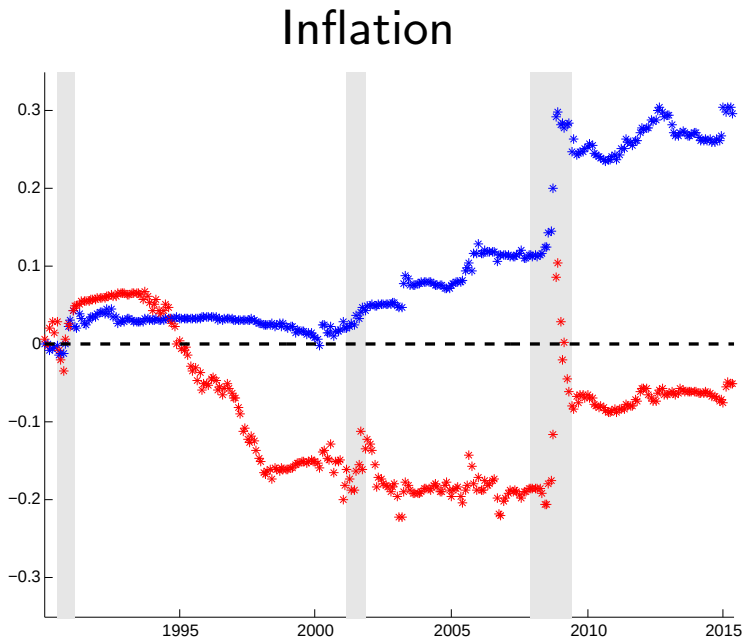
ARIMAX vs ARIMA

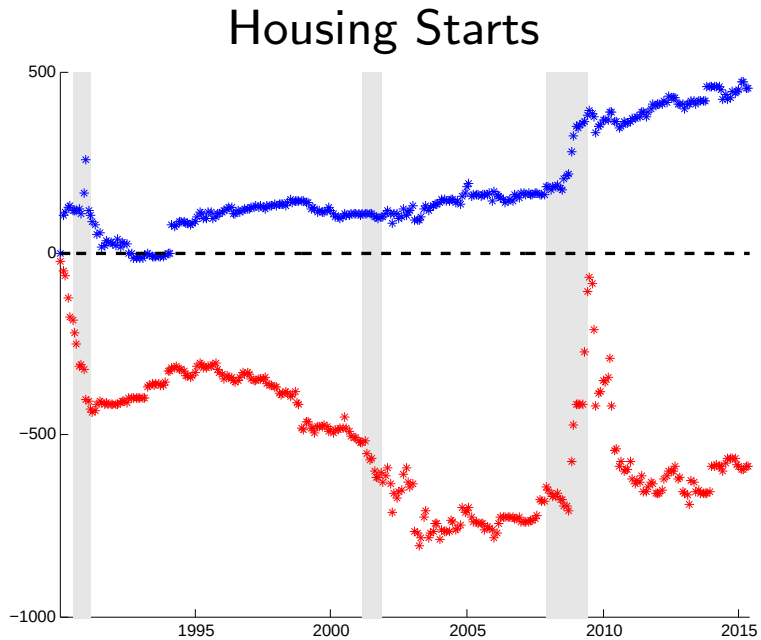
- Inflation
- Federal funds rate**
- Unemployment
- Payroll employment
- Industrial production
- Personal consumption expenditures
- Real personal income
- Average hourly earnings
- Housing starts
- Capacity utilization
- S&P500
- Real estate loans
- Commercial and industrial loans**

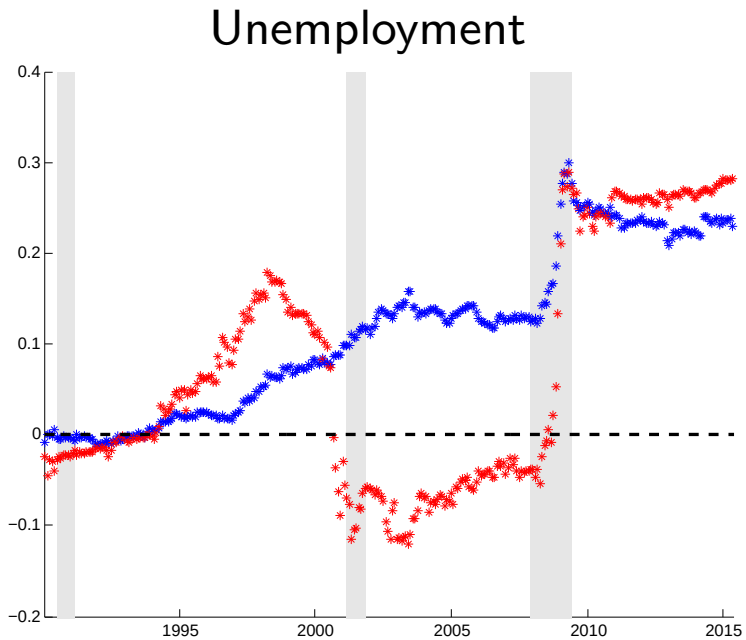
Industrial production: NNX - B, ARIMAX - R

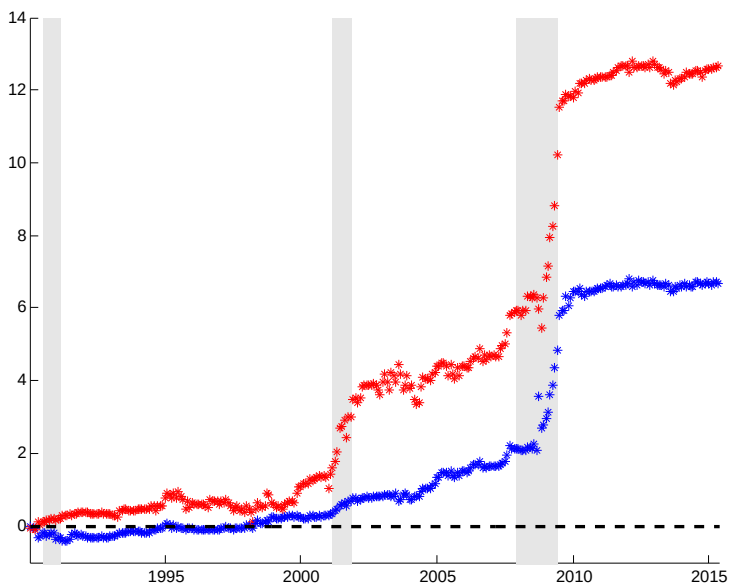


Forecast comparisons: NNX - B, ARIMAX - R









EBP Summary

- Including EBP does improve macroeconomic/financial variable forecasting performance
  - Oftentimes large forecasting gains in the Great Recession
- Nearest neighbor X produces more series with significant forecasting difference versus ARIMA than ARIMAX does
  - HOWEVER: overall forecasting gains often similar
- Strong evidence of nonlinear forecasting relationship:
  - Inflation
  - Average hourly earnings
  - Housing starts
  - Real estate loans

Return

Real oil price

Nearest neighbor X vs ARIMA

- Inflation**
- Federal funds rate
- Unemployment
- Payroll employment
- Industrial production
- Personal consumption expenditures
- Real personal income*
- Average hourly earnings**
- Housing starts
- Capacity utilization
- S&P500
- Real estate loans**
- Commercial and industrial loans

ARIMAX vs ARIMA

- Inflation**
- Federal funds rate
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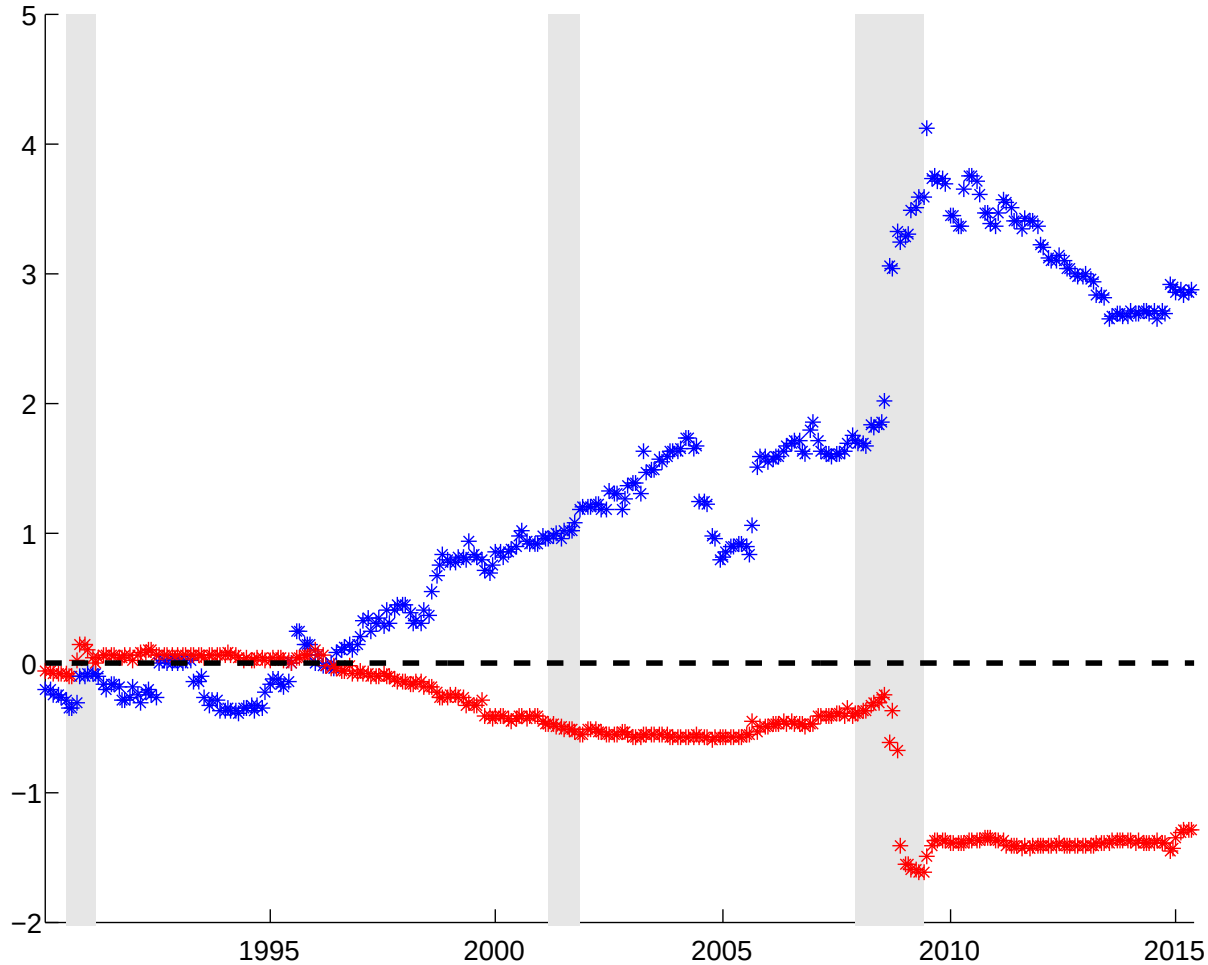
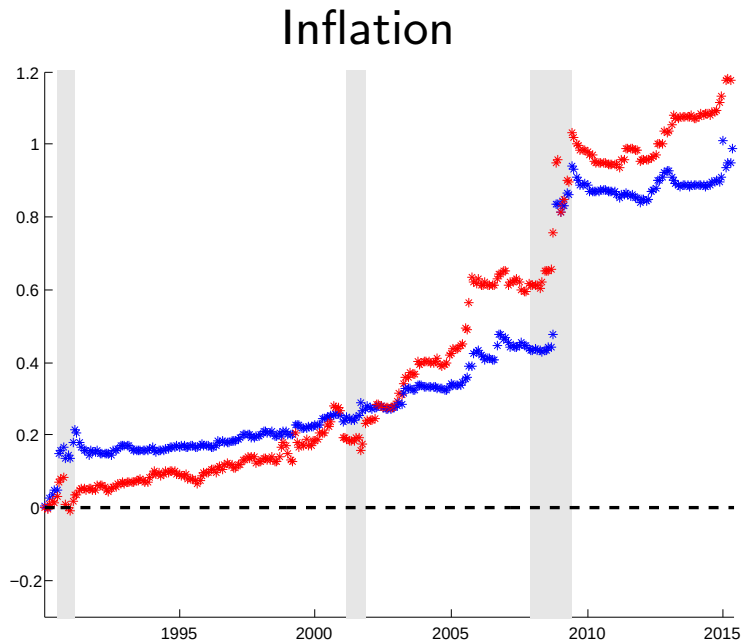
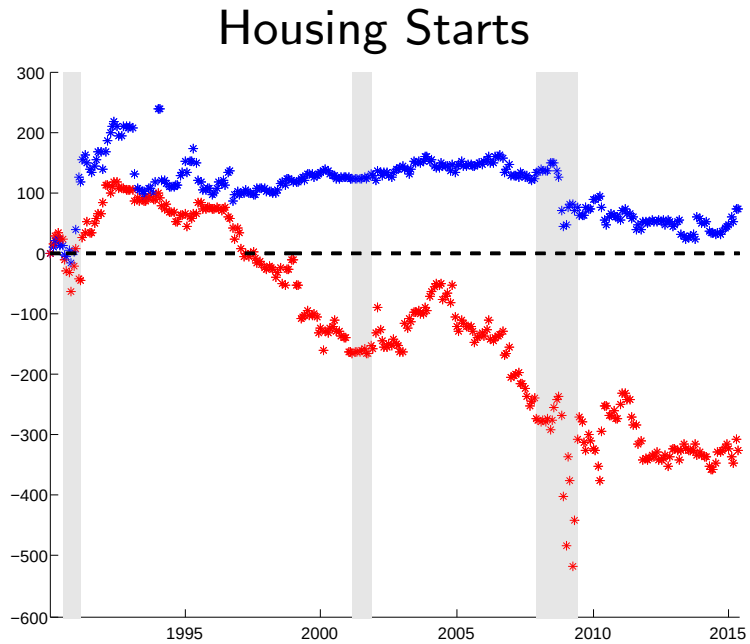
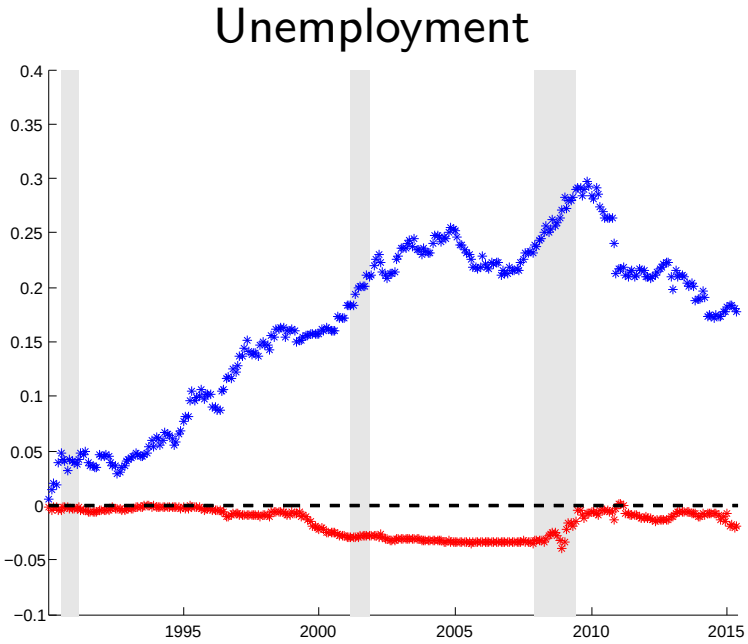
Industrial production: NNX - B, ARIMAX - R

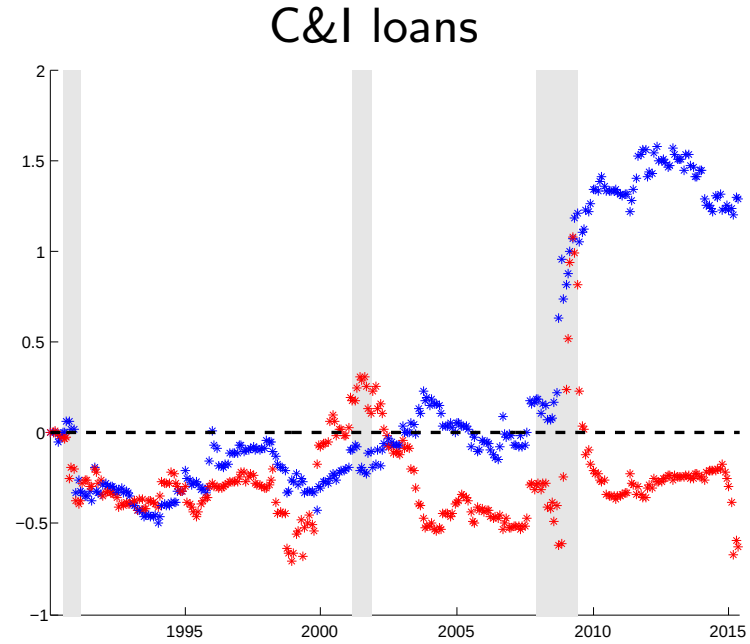


Forecast comparisons: NNX - B, ARIMAX - R









Real oil price Summary

- Nearest neighbor X with oil prices oftentimes forecasts better than ARIMA model. Significant for:
  - Inflation
  - Average hourly earnings
  - Real estate loans
- ARIMAX with oil prices does well for inflation, FFR, and average hourly earnings
  - Oftentimes forecasts worse than ARIMA model
- Weaker evidence of nonlinear forecasting relationship

Return

RMSE Results

Forecast comparison based on RMSE (1-step ahead) (RMSE ratio relative to ARMA/ARIMA model forecast)

	NN		MS-AR	NNX			ARMAX		
	1	2		B	H	O	B	H	O
Inflation	0.98^{**}	0.99	1.02	0.98^{*}	0.96^{**}	0.95^{**}	1.00	0.99	0.93^{**}
Federal funds rate	1.03	0.95	–	0.97	0.97	1.01	1.43	0.98	0.99
Unemployment	1.00	0.95^{**}	1.02^{**}	0.98^{*}	0.97^{**}	0.98	0.98	0.99	1.00
Payroll employment	0.96^{*}	0.97	1.04	0.98	0.96^{*}	0.99	0.96	1.00	1.02
Industrial production	0.96^{**}	0.96^{**}	0.98	0.97	0.96^{*}	0.98	0.97	1.00	1.00
Personal consumption	0.98	0.98^{*}	1.03^{**}	0.99	0.96^{*}	0.99	1.00	1.00	1.02
Real personal income	0.91^{**}	0.95^{**}	1.01	0.98	0.98^{**}	0.98^{*}	0.98	0.99	0.99
Average hourly earnings	1.00	1.00	1.01	0.97^{**}	0.97	0.96^{**}	1.00	1.01	0.96^{*}
Housing starts	0.99	0.99	0.99	0.98^{*}	0.98^{**}	1.00	1.02	1.01	1.01
Capacity utilization	0.99	0.98	0.98	0.97	0.98	0.99	0.98	1.00	1.00
S&P500	0.99	0.99	1.00	0.99	1.01	0.99	0.99	1.00	1.04
Real estate loans	0.99	0.98^{**}	1.00	0.98^{**}	0.98^{**}	0.98^{**}	1.00	0.99	1.00
Commercial and industrial loans	0.97^{**}	0.99	0.96^{**}	0.96^{**}	0.99	0.99	0.94^{**}	1.00	1.00

Return