Euro area GDP forecasting using large survey datasets
A random forest approach

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Views expressed represent exclusively the positions of the authors and do not necessarily correspond to those of the European Commission

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Introduction

- ✓ **Increasing interest in forecasting methods that utilise large datasets**
- ✓ **Not only an issue of academic interest**

  Eklund and Kapetanios, 2008
- ✓ **Factor methods in the forefront of developments**

  Stock and Watson, 2002; Forni *et al.*, 2005; Giannone *et al.*, 2008
- ✓ **Factor analysis combined with linear modelling**

Introduction

- **A new statistical approach to forecasting macro-economic aggregates, based on the Random Forests technique**

  Breiman, 2001, 2002

- **RF algorithm is widely applied in medical research and biological studies, becomes more and more popular and appears to be very powerful**

  Arun and Langmead, 2006; Díaz-Uriarte and Alvarez de Andrés, 2006; Ward *et al.*, 2006

- **RF is largely unknown in economics**

  Biau. G, Biau. O and Rouvière, 2007

Introduction

- ✓ **RF enjoys good prediction properties, is robust to noise and can handle a very large number of input variables**
- ✓ **RF is considered to be one of the most accurate general-purpose learning techniques available, independent of any functional and distributional assumptions**
- ✓ **However, from a mathematical point of view, the mechanism of RF algorithms remains largely unknown and is not clearly explained**

  Breiman, 2002; Lin and Jeon, 2006; Biau. G *et al.*, 2008, Biau. G and Devroye, 2008; Biau. G, 2010

Introduction

- ✓ **A specific application for short-term GDP forecasting in the euro area is shown using (*only*) the harmonized European Union Business and Consumer surveys dataset**
- ✓ **A typical high-dimensional regression problem ($n << p$)**
- ✓ **The RF technique is explored with two aims in mind:**
  1. to obtain a non-parametric forecast of GDP
  2. to obtain a ranking of the explanatory variables, and then select those variables to build a linear model to forecast GDP
- ✓ **The forecast performance is assessed through an out-of-sample exercise**

Outline

- ✓ Data
- ✓ RF algorithm
- ✓ Benchmark
- ✓ Results

Data

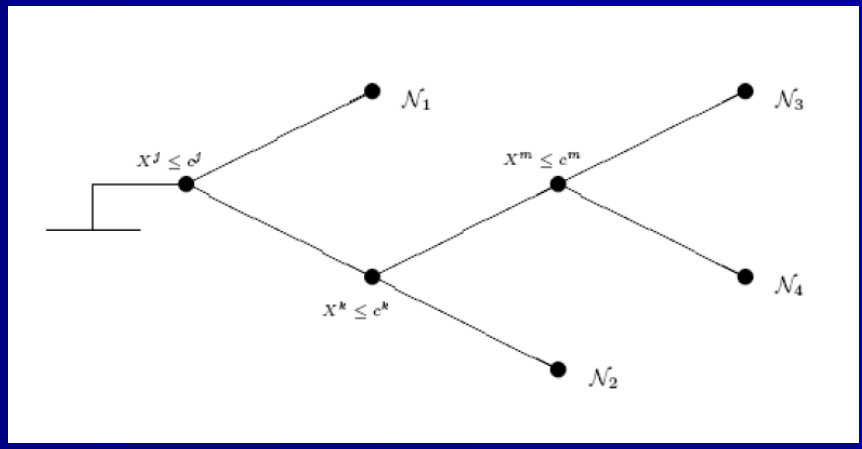
- ✓ Based on the Joint Harmonized EU Programme of Business and Consumer Surveys (manufacturing industry, services, retail trade, construction, and consumers)
- ✓ Qualitative surveys
- ✓ It covers all the 27 Members States, Croatia, the FYROM and Turkey
- ✓ More than 125 000 firms and over 40 000 consumers surveyed every month

Data

- The dataset mainly consists of the euro area balances of opinion (% positive - % negative)
- The time series used in the analysis are those available at the end of the third month of each quarter:
  - the level series: monthly *St* or quarterly *Sq*,
  - the difference series: (*St* - *St-1*), (*St* - *St-2*), (*St* - *St-3*) and (*Sq* - *Sq-1*)
- The dataset is composed of $p = 172$ 'soft' series: X_i
- The only 'hard' variable is the euro area GDP qoq growth series: Y_i
- Finally, we have a « learning set » $L = \{(X_1, Y_1) \ldots (X_n, Y_n)\}$ $n = 57$ (1995Q3 - 2009Q3)

From binary trees to Random Forest

- ✓ What is a binary tree?



- ✓ How to grow a tree?

- ✓ What is the tree predictor (or tree regressor)?

How to grow a tree? with CART

How to predict the income of a newcomer (entering the room) based on observed characteristics X_i (gender, size, weight, age, …) and income Y_i of people attending the conference?

- **For the first node, we seek the first splitting variable X^j and the first split point s which discriminate the most, by solving:**

$$\min_{j,s}\left[\min_{c_1}\sum_{X_i\in N_1[j,s]}(Y_i-c_1)^2+\min_{c_2}\sum_{X_i\in N_2[j,s]}(Y_i-c_2)^2\right]$$

- **For any choice j and s, the inner minimization is solved by:**

$$c_i = average(Y_i / i\in N_i)$$

$$where \quad N_1=[X^j\le s] \quad and \quad N_2=[X^j>s]$$

- **Having found the best split, we partition the data into the two resulting regions and repeat the splitting process until each node reaches a user-specified minimum *nodesize* and becomes a terminal node**

What is the tree predictor?

Once the tree is built, a new *X* arrives…

… it ‘falls’ into a terminal node N(X),

… the tree regressor *h(X)* is computed by averaging the observed Y_i over the observations *i* ‘falling’ in that node:

$$h(X) = \frac{1}{Card\{i/X_i \in N(X)\}} \sum_{i/X_i \in N(X)} Y_i$$

RF algorithm

- **Breiman's idea: instead of finding the best tree, build a large number (*K*) of simpler regression trees and aggregate them**

- **RF algorithm (Hastie and Tibshirani, 2009)**

  1. For $k = 1$ to ***K***:

  (a) Draw a bootstrap sample from the learning dataset $L = \{ (X_1, Y_1) \ldots (X_n, Y_n) \}$.

  (b) Grow a random-forest tree h_k to the bootstrapped data, by recursively repeating the following steps for each terminal node of the tree, until the minimum ***nodesize*** is reached.

  - Select ***mtry*** variables at random from the ***p*** variables
  - Pick the best variable/split-point among the ***mtry***
  - Split the node into two daughter nodes

  2. the predicted outcome (final decision) is obtained as the average value over the ***K*** trees:

$$h(X) = \frac{1}{K} \sum_{k=1}^{K} h_k(X)$$

- **For the free parameters *K*, *nodesize* and *mtry*, we used the default values 500, 5 and *p*/3 of the random forest R-package**

RF algorithm

- ✓ **RF posses one important feature to reduce data dimensionality**
- ✓ **Breiman (2001) suggests a measure called 'variable importance' to discriminate between informative and noninformative variables**
- ✓ **For each variable, the idea is to compare the prediction error with the prediction error where the variable is randomly permuted**
  - Large positive values for a variable indicate that this variable is predictive
  - zero or negative importance values indicate non-predictive variables

Benchmark

- We predict GDP growth for quarter Q (nowcast), based on data available at the end on quarter Q

- Out-of-sample analysis:
  - 2004Q1-2009Q3, using GDP vintage data
  - Criterion: Mean Square Error (MSE)

- Two competitors:
  - AR model
  - *euro zone economic outlook*
    - Quarterly publication, published in the first days of quarter Q+1
    - Nowcast (Q), 2-steps-ahead projections (Q+1 and Q+2) for GDP, IP, Cons., Inflation
    - But also economic links explaining these forecasts

- How does a data-driven model like the RF perform relative to competitors for GDP nowcasting?

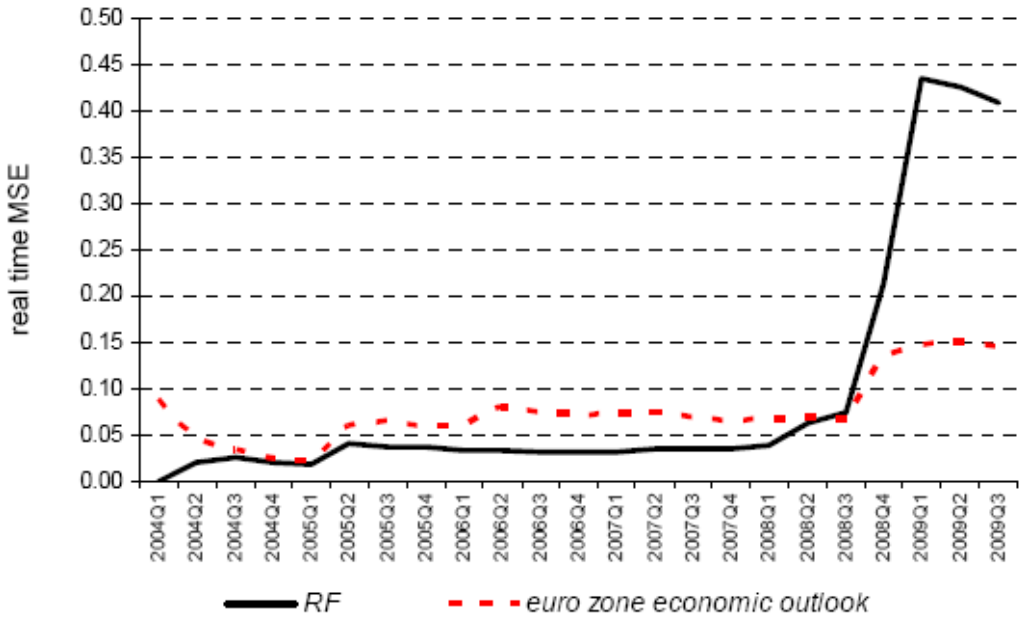
Results (1)

RF: pure Random Forest

- RF outperforms the AR but not the *euro zone economic outlook*
- Good performance of RF before the crisis
- Poor performance during the crisis… however, by construction!

Mean Square Error - MSE	
AR	*0.64*
RF	*0.43*
euro zone economic outlook	*0.15*

Note: MSEs are computed on the whole out-of-sample period in the table, while the chart shows how these values develop over time (real time MSEs)



Results (2)

- ✓ **To square the problem of non negative values in the learning set, a two steps procedure:**
  - **Select the 25 most *important variables* (RF feature)**
  - **Choose the « best » linear model to explain GDP (Gets)**

- ✓ **RF_LINMOD: model retained**

$$100.GDP_t = \underset{(12.033)}{0.615} + \underset{(2.683)}{0.011} V12_t + \underset{(3.248)}{0.032} V24_t + \underset{(3.152)}{0.020} V41_t + \underset{(4.153)}{0.044} V62_t + \underset{(1.933)}{0.025} V101_t$$

OLS results — estimation period 1995Q3 -2009Q2 — Standard error of the regression = 0.246

Values of t-statistic in brackets — R^2=0.858, adjusted R^2= 0.844, DW(0) = 2.18.

V12: Orders development over past 3 months - INDU

V24: Expectation about household financial positions over next 12 months - CONS

V41: Orders development expected over next 3 months - RETA

V62: Export orders development expected over next 3 months — difference series (t – t-1) - INDU

V101: Assessment of current order book — difference series (t – t-2) - INDU

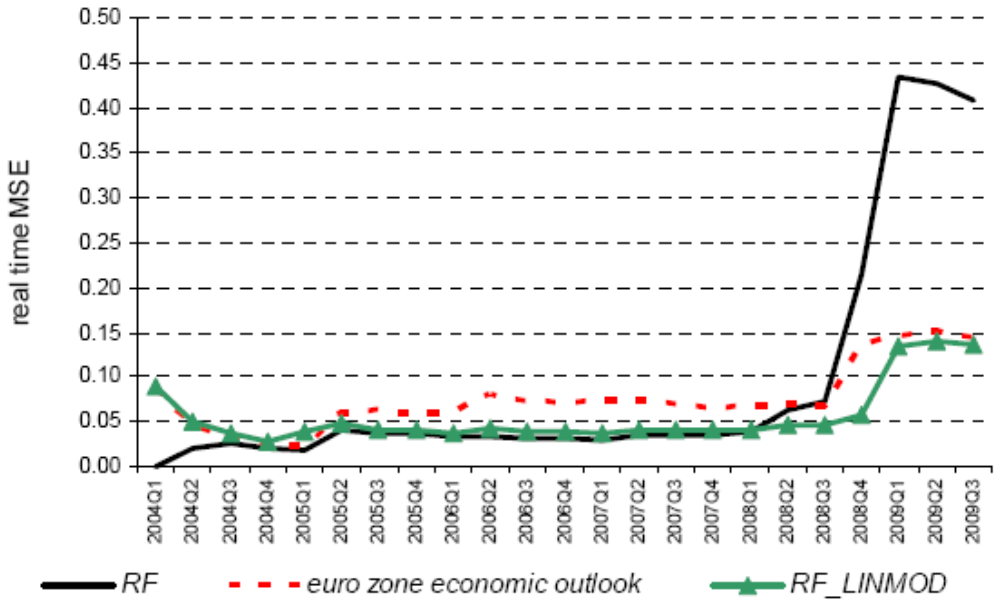
Results (2)

RF_LINMOD

- performs as well as the *euro zone economic outlook*
- outperforms the pure RF and compares well to the *euro zone economic outlook* during the 'crisis'

Mean Square Error - MSE	
RF	*0.43*
euro zone economic outlook	*0.15*
RF_LINMOD	*0.14*

Note: MSEs are computed on the whole out-of-sample period in the table, while the chart shows how these values develop over time (real time MSEs)



Conclusion

- ✓ RF: a new approach for short-term analysis
  - to forecast macroeconomic variables
  - to reduce data dimensionality
- ✓ RF is fast and easy to implement
- ✓ RF outperforms AR and compares well with reliable forecasts
- ✓ RF is worth adding to the economists' toolbox