A machine learning approach to House Price Indexes with the `hpiR` package

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Outline

1. ‘hpiR’ package and data
2. Conceptual Model + Motivation
3. A Random Forest House Price Index
4. Performance Comparison
5. Discussion

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‘hpiR’ package

- R package for house price indexes :https://cran.r-project.org/web/packages/hpiR/index.html
- Methods for generating ‘coefficients’ and converting to index
  - Hedonic + Repeat Sales
  - Random Forests (Github/development version only)
- Methods for index validation and comparison
  - Accuracy
  - Revision
  - Volatility
- Generic Functionality
  - Smoothing
  - Imputation
  - Series Creation
- Data Set
  - Seattle home sales from 2010 through 2016 (43k, 5k repeat)
  - Rich hedonic characteristics

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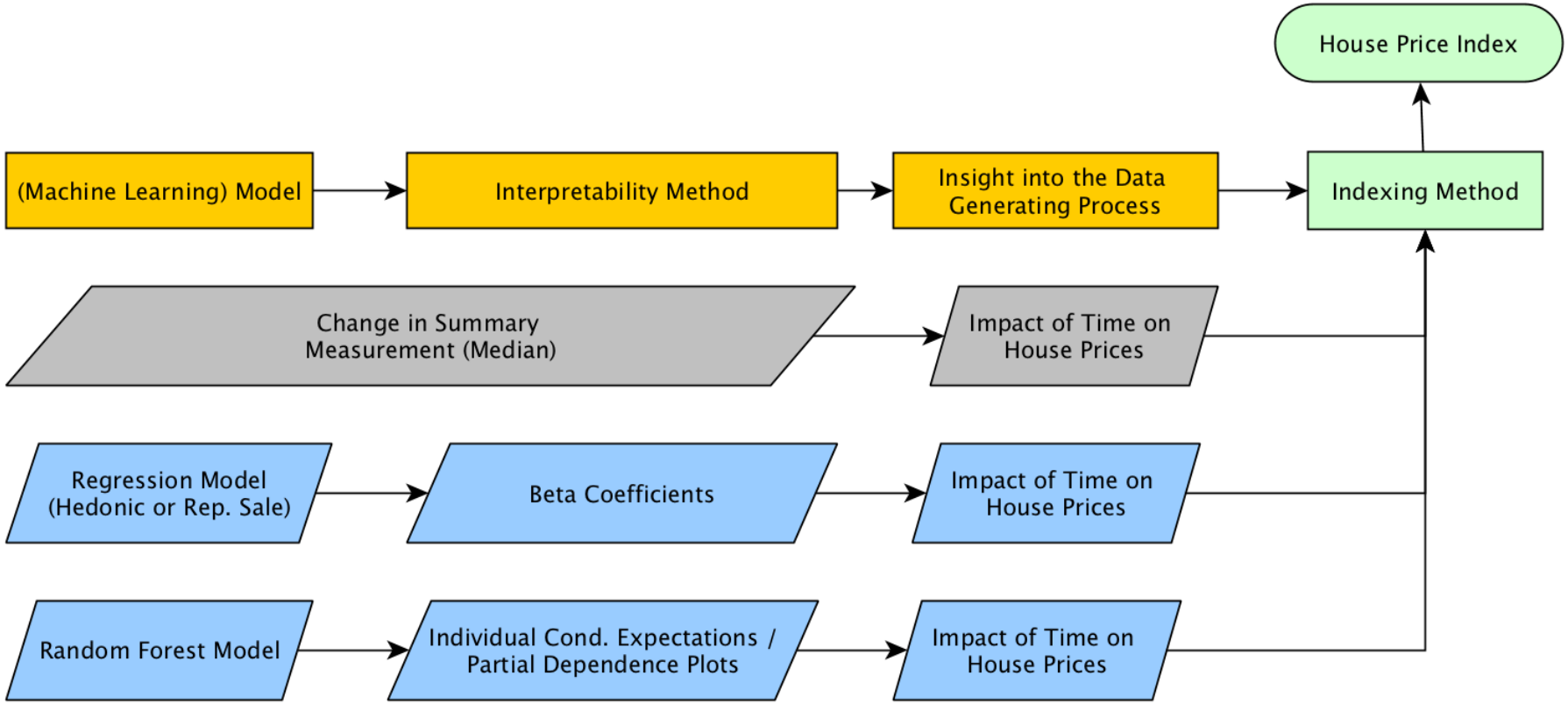
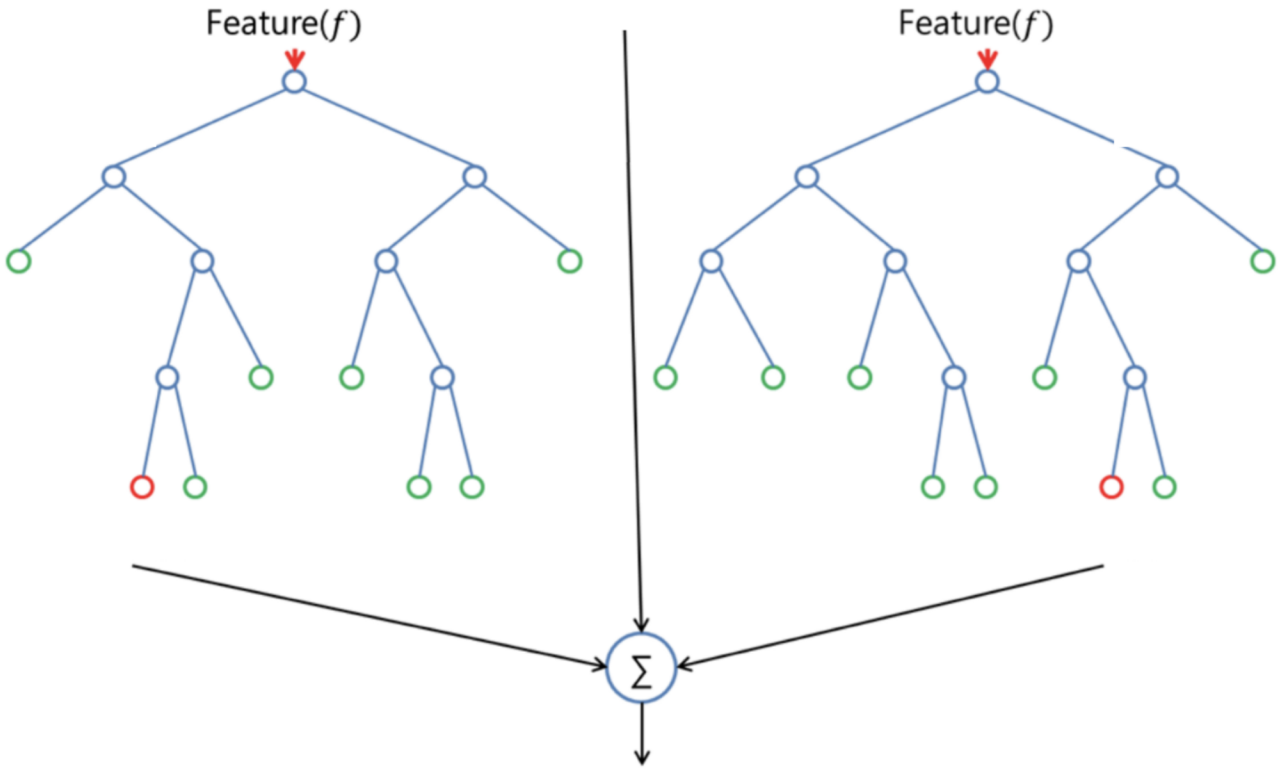
Conceptual Model + Motivation



What is a Random Forest?

- Subsetting process
- Multiple decision trees trained on randomized sub-samples of data/features
  - Each split in tree is a single feature (e.g. Is Waterfront. Yes (left) / No (right)
- Prediction is (weighted) result of each tree



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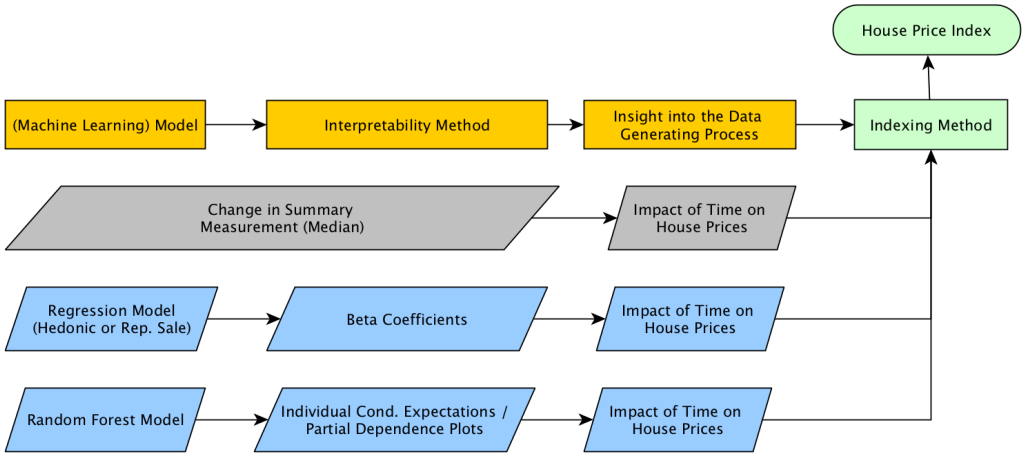
A House Price Index via Random Forest

- House price indexes generation require an estimate of the impact of time on prices
- Random Forests do not produce readily interpretable coefficients
  - But we can simulate these with a Model Agnostic Interpretability Methods (Molner 2019)



- Individual Conditional Expectations / Partial Dependence Plots
  - Build RF Model
  - (ICE) Value or simulate property Z with RF Model at period t, t+1, t+2, t+k
  - Convert this price trend to an index
  - (PDP) Apply the above to all instances/observations and average

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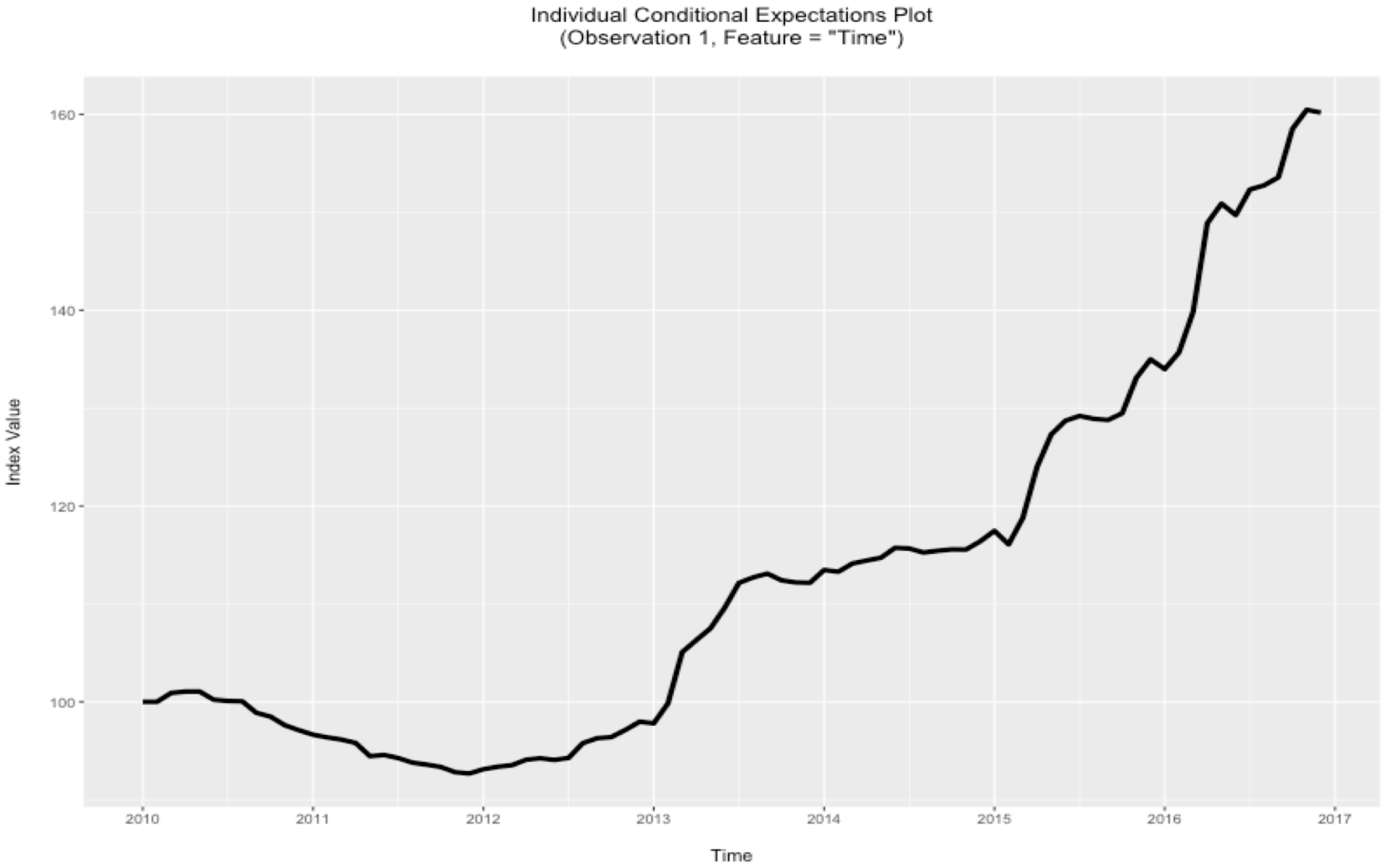
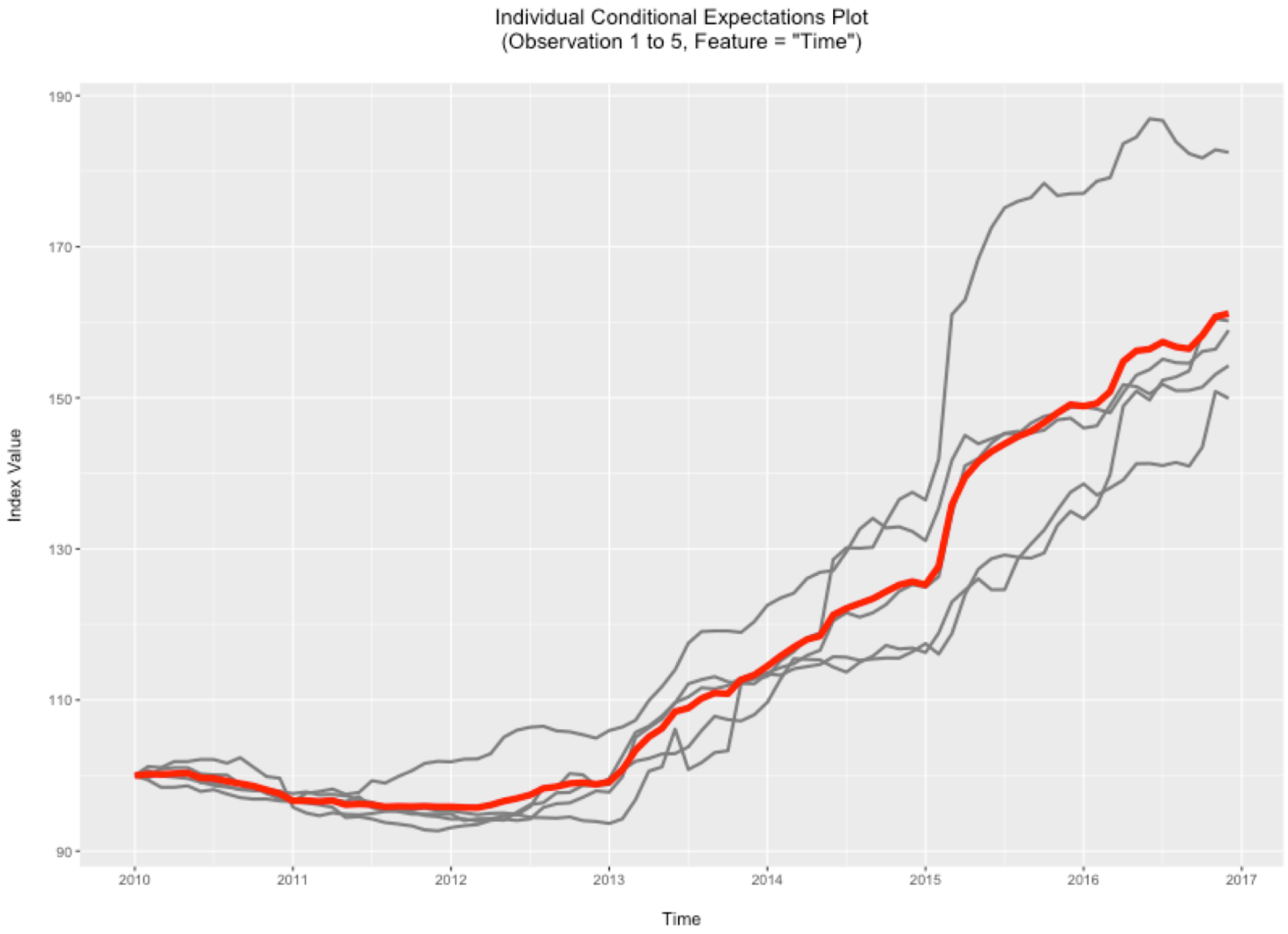
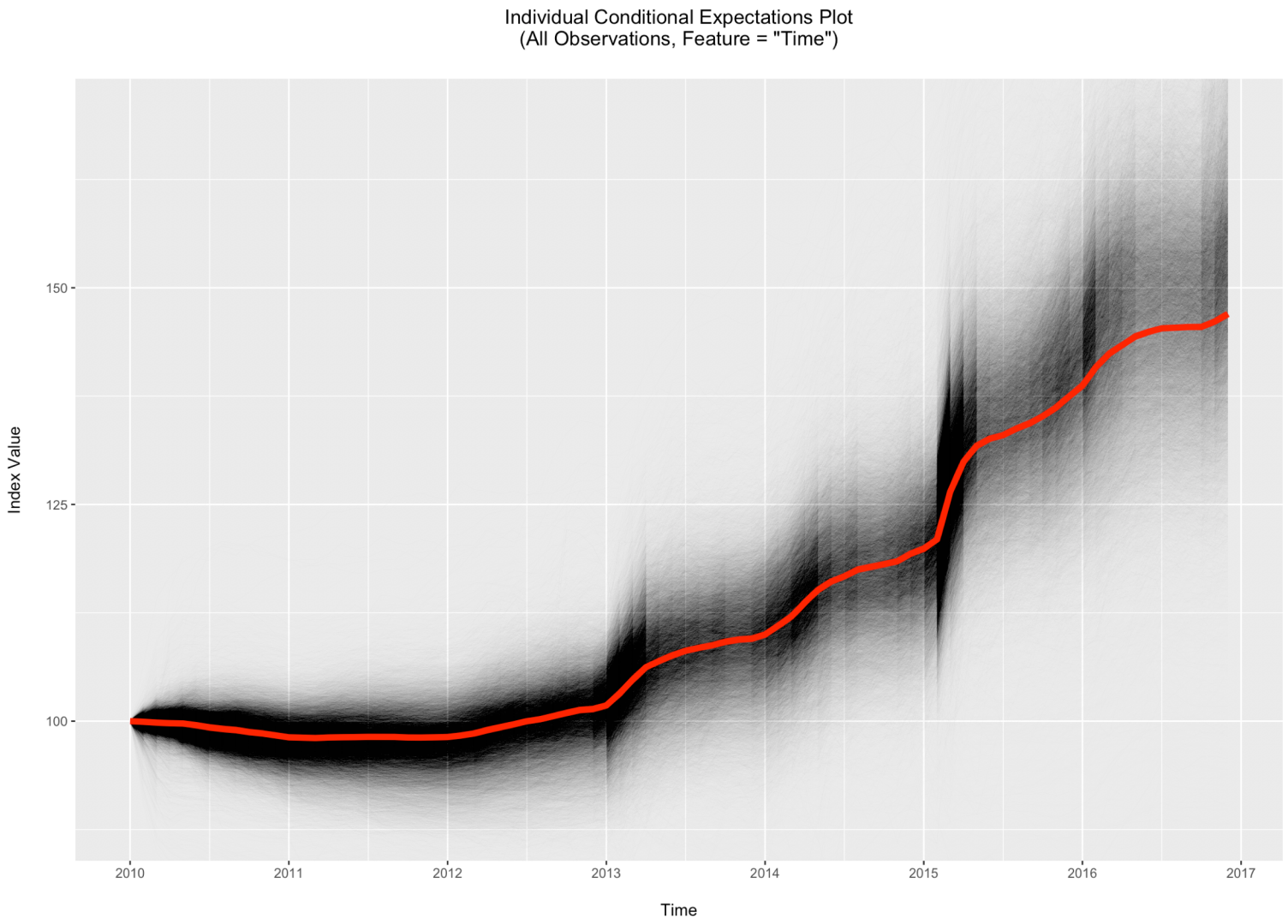
A Single ICE Example



5 ICEs + Average



~43,000 ICEs -> PDP



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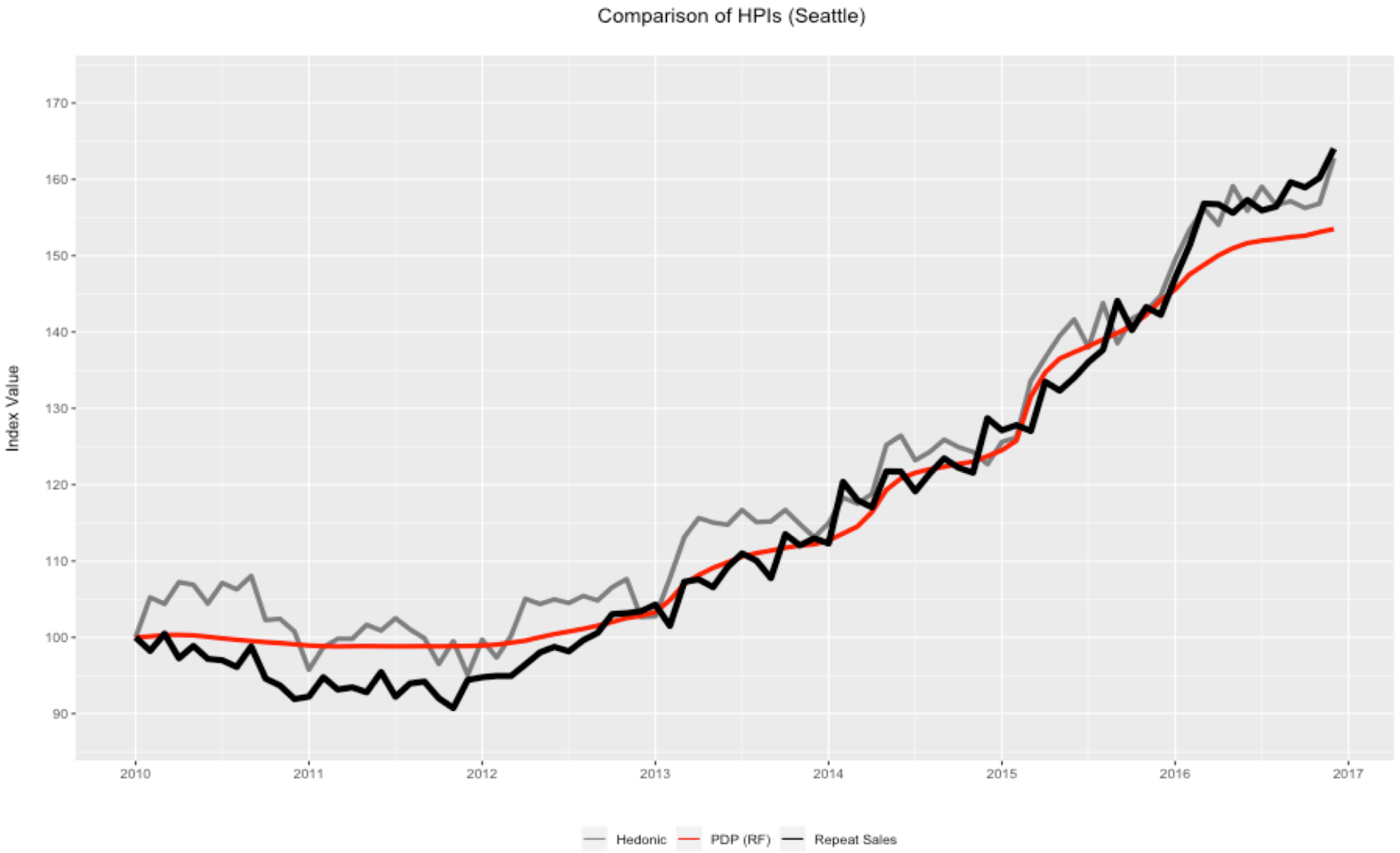
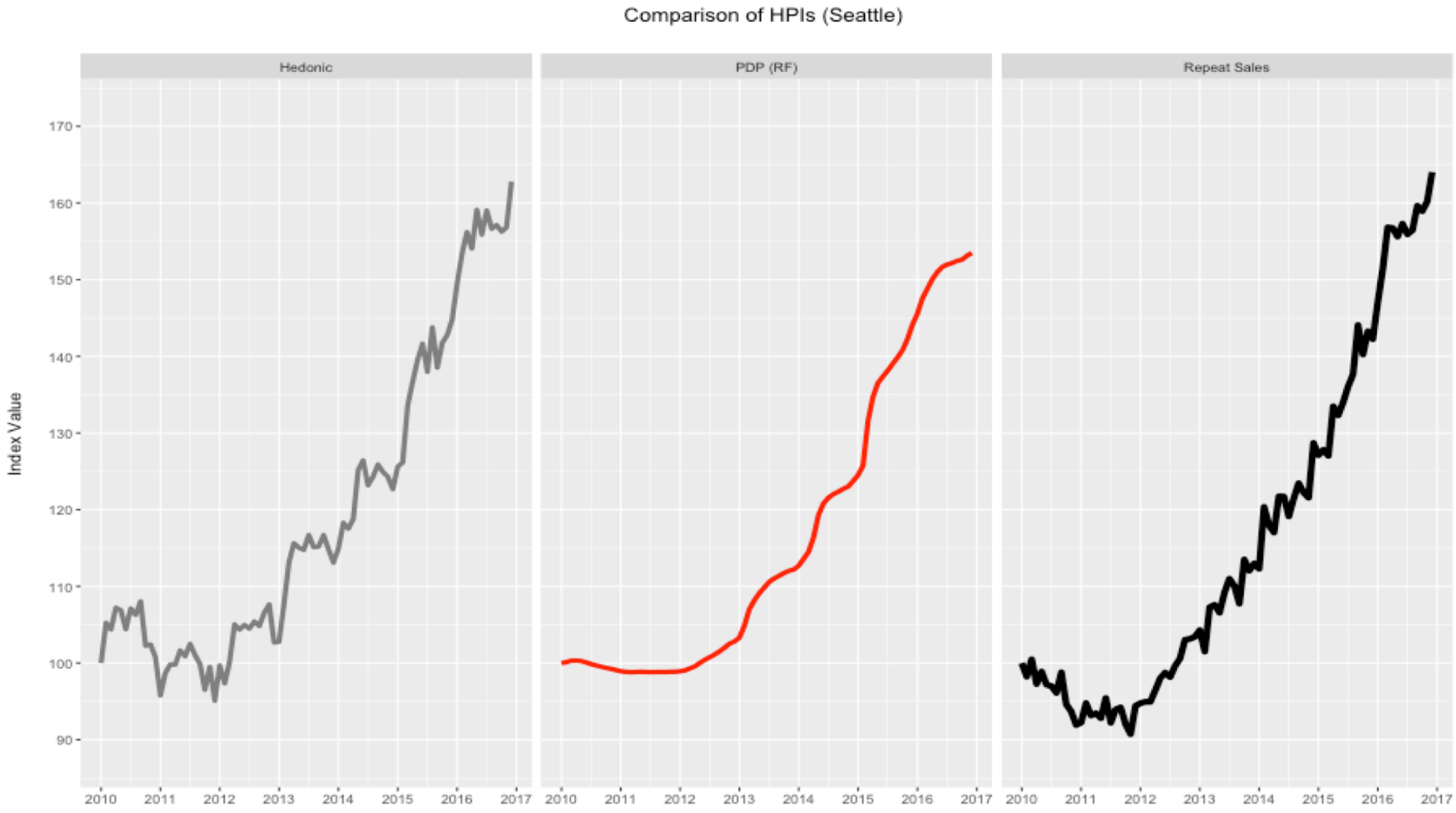
Comparison


Comparison of HPIs (Seattle)
Index Value
170
160
150
140
130
120
110
100
90
2010
2011
2012
2013
2014
2015
2016
2017
Hedonic
PDP (RF)
Repeat Sales

Comparison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Comparison to Existing Methods

- Looks competitive (and certainly smoother), but is it better?
- ‘hpiR’ allows comparison by:
- 1) Volatility – Standard Deviation of three month moving average
- 2) Revision – Level of change in initial index values as index series grown over time
- 3) Accuracy – How well can we predict second transaction in a repeat sales pair?
  - In Sample – How well does it fit data?
  - Out of Sample – How well does it prediction in a K-Fold situation?
  - Future Prediction – How well does it predict at t+1?
    - `forecast` package, simple exponential smoothing

Comparison to Existing Methods

- Compute index and series for full data set (~43k transactions, ~5k repeat)
- Full 2010 through 2016 time period (84 months)
- Robust RS and Hedonic Models

Method	Volatility	Revision	In Sample Accuracy	K-Fold Accuracy	Prediction Accuracy
Repeat Sales	.020	.398	.094	.096	.117
Hedonic	.021	**.010**	.095	.097	**.095**
RF – PDP	**.001**	.062	**.093**	**.093**	.100

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Small Geographic Area Comparison

- 25 King County Assessment Zones
- ~ 2000 sales in each over the 7 year period
- ~ 250 repeat transactions in each

Method	Volatility	Revision	In Sample Accuracy	K-Fold Accuracy	Prediction Accuracy
Repeat Sales	.119	.086	.123	.201	.217
Hedonic	.061	**.013**	.101	.105	**.099**
RF – PDP	**.002**	.077	**.093**	**.095**	.110

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Takeaways

- Random Forest with Interpretability
  - Smoothest
  - Most accurate In and Out of sample
  - Intuitive explanation (value property X as if sold repeatedly)
  - Computationally expensive
- Repeat Sales
  - High revision + worse accuracy
  - Faster + least data intensive
- Hedonic model
  - Least Revision, Best Prediction accuracy
- ML interpretability models offer some competitive performance
  - At the expense of compute time
  - Struggle at the ‘leading end’ of the index
  - Only tried one model type (RF) and one interpretability method (PDP)
- ‘hpiR’ offer quick way to test a model/method
  - Dataset, benchmark and a framework for comparison