Forecasting Process (with External Regressors)

Want to apply this workflow to a ***real business analysis?***
Then take the **High-Performance Forecasting Course** through **Business Science University.**

The Modeltime Ecosystem:

- **Timetk** (Time Series)
- **Modeltime** (Forecasting)
- **Modeltime Ensemble** (Blending)
- **Modeltime GluonTS** (Deep Learning)
- **Modeltime H2O** (AutoML)
- **Modeltime Resample** (Backtesting)

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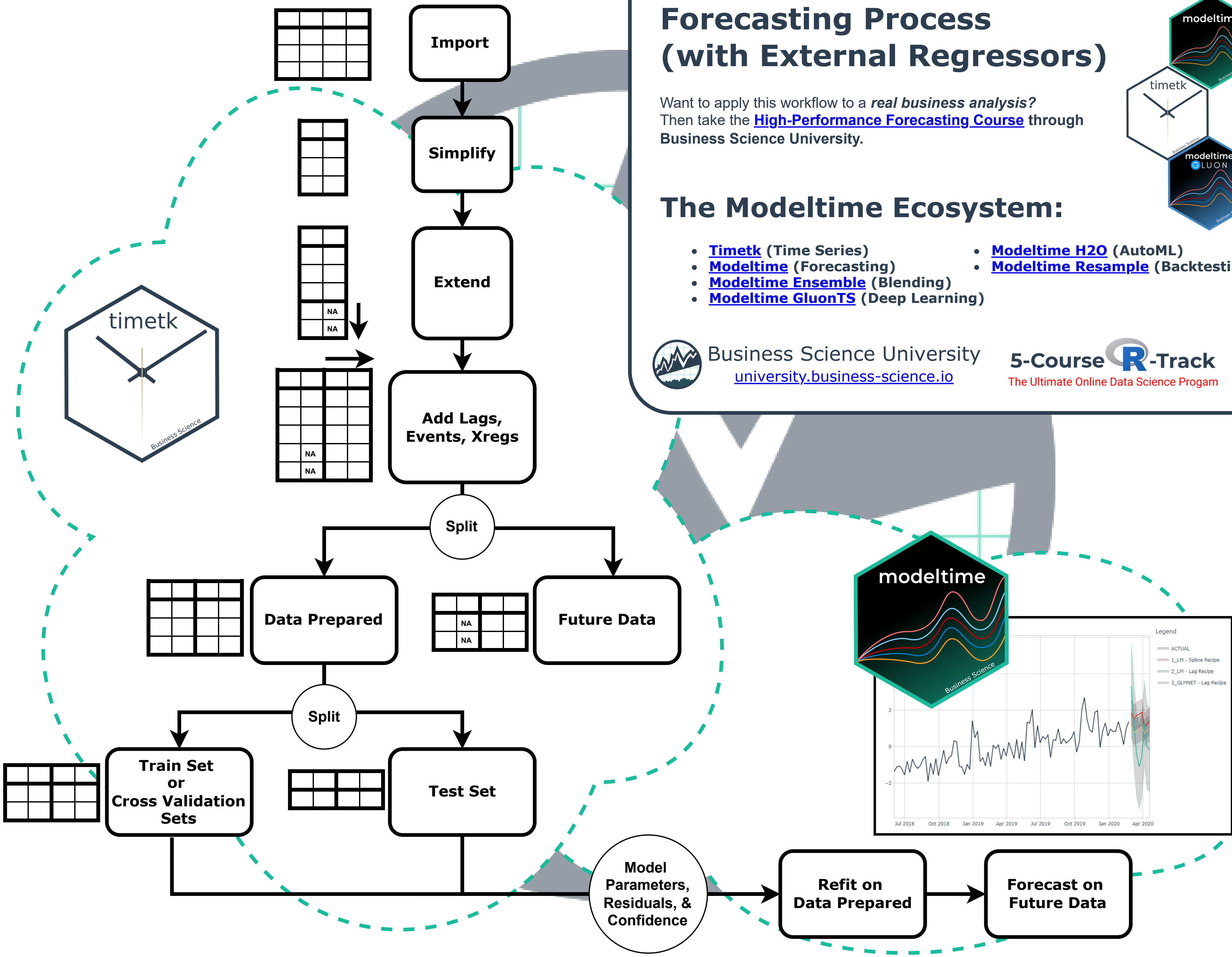


MODELTIME Workflow

Create Modeltime Table
`modeltime_table()`

```
# Modeltime Table
# A tibble: 5 x 3
  .model_id .model     .model_desc
      <int> <list>     <chr>
1         1 <fit[+]> ARIMA(0,1,1)(0,1,1)[12]
2         2 <fit[+]> ARIMA(0,1,1)(0,1,1)[12] W/ XGBOOST ERRORS
3         3 <fit[+]> ETS(M,A,A)
4         4 <fit[+]> LM
5         5 <fit[+]> EARTH
```

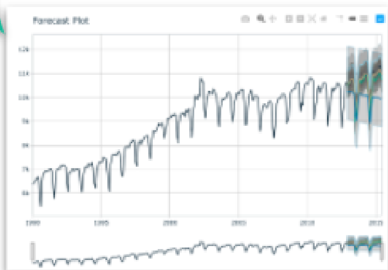
Calibrate
`modeltime_calibrate()`

```
# Modeltime Table
# A tibble: 6 x 5
  .model_id .model     .model_desc                                .type .calibration_data
      <int> <list>     <chr>                                      <chr> <list>
1         1 <fit[+]> ARIMA(0,1,1)(0,1,1)[12]                      Test  <tibble [31 × 4]>
2         2 <fit[+]> ARIMA(0,1,1)(0,1,1)[12] W/ XGBOOST ERRORS    Test  <tibble [31 × 4]>
3         3 <fit[+]> ETS(M,A,A)                                   Test  <tibble [31 × 4]>
4         4 <fit[+]> PROPHET                                      Test  <tibble [31 × 4]>
5         5 <fit[+]> LM                                           Test  <tibble [31 × 4]>
6         6 <fit[+]> EARTH                                        Test  <tibble [31 × 4]>
```

Refit
`modeltime_refit()`

```
# Modeltime Table
# A tibble: 6 x 5
  .model_id .model     .model_desc                                .type .calibration_data
      <int> <list>     <chr>                                      <chr> <list>
1         1 <fit[+]> ARIMA(0,1,1)(0,1,1)[12]                      Test  <tibble [31 × 4]>
2         2 <fit[+]> ARIMA(0,1,1)(0,1,1)[12] W/ XGBOOST ERRORS    Test  <tibble [31 × 4]>
3         3 <fit[+]> ETS(A,A,A)                                   Test  <tibble [31 × 4]>
4         4 <fit[+]> PROPHET                                      Test  <tibble [31 × 4]>
5         5 <fit[+]> LM                                           Test  <tibble [31 × 4]>
6         6 <fit[+]> EARTH                                        Test  <tibble [31 × 4]>
```

Forecast Test Set
`modeltime_forecast()`



`plot_modeltime_forecast()`

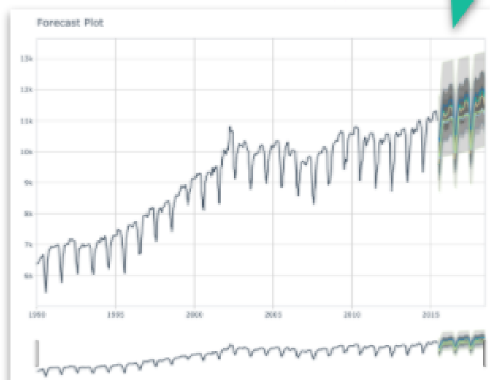
Test Accuracy
`modeltime_accuracy()`

Accuracy Table

.model_id	.model_desc	.type	mae	mape	mase	smape	rmse	rsq
1	ARIMA(0,1,1)(0,1,1)[12]	Test	151.33	1.41	0.52	1.43	197.71	0.93
2	ARIMA(0,1,1)(0,1,1)[12] W/ XGBOOST ERRORS	Test	147.04	1.37	0.50	1.39	191.84	0.93
3	ETS(M,A,A)	Test	77.00	0.73	0.26	0.73	90.27	0.98
4	PROPHET	Test	177.51	1.70	0.61	1.70	234.65	0.88
5	LM	Test	629.12	6.01	2.15	5.81	657.19	0.91
6	EARTH	Test	709.83	6.59	2.42	6.86	782.82	0.55

`table_modeltime_accuracy()`

Forecast Future
`modeltime_forecast()`



`plot_modeltime_forecast()`

Resources:

- **This workflow is covered in depth in the [High-Performance Time Series Course (Modules 7 to 18)]**
- **A beginner tutorial is available here: [Getting Started with Modeltime]**
- **The ["Global Forecasting Workflow"] is used to create scalable high-performance model(s) that forecast many time series**
- **This is NOT the "Iterative Forecasting Process" (Nested Workflow), which is used to forecast iteratively. The Iterative Forecasting Procedure is shown on Page 5.**

modeltime

1. Cross Validation Plan

Can be used for more than 1 model

START Cross Validation

Sequential Time Series CV
time_series_cv()

Ex. Arima Boost

Non-Sequential 10-Fold CV
vfold_cv()

Ex. Prophet Boost

2. Identify Tuning Parameters

Specific to Each Model

Model Spec & Recipe Identify Parameters
tune(id)

3. Make Grid for Parameters

Specific to Each Model

Grid Spec

```
grid_latin_hypercube(
   param_set
)
```

4. Hyperparameter Tune

Specific to Each Model

Use Parallel Processing to Speed Up

Tune Grid

```
tune_grid(
   resamples,
   grid,
   metrics,
   control
)
```

Review Parameters Adjust & Re-Tune (if necessary)
autoplot()

Model Parameters, Residuals, & Confidence

Split

Cross Validation

Test

Model Parameters, Residuals, & Confidence

Hyperparameter Tuning & Cross-Validation for Time Series

Cross-Validation and Hyperparameter Tuning are absolutely critical for Machine Learning algorithms.

Additional Resources:

- [**The NEW Hyperparameter Tuning & Parallel Processing Process**]()

MODELTIME ENSEMBLE

Multi-Level Stacking

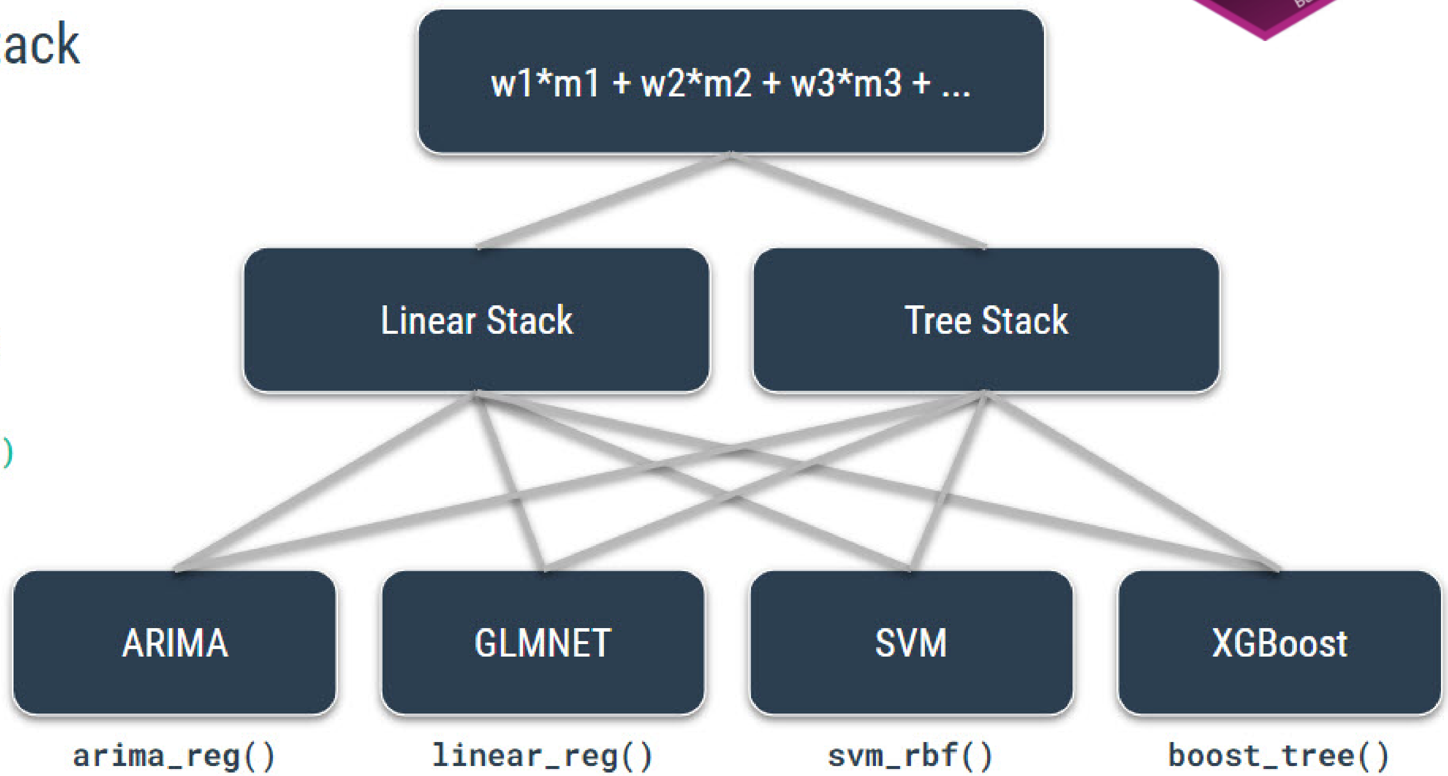
Level 3: Weighted Stack

`ensemble_weighted()`
`ensemble_average()`

Level 2:
Stacking Algorithms

`ensemble_model_spec()`
`modeltime_fit_resamples()`

Level 1:
Sub-Models



Additional Resources:

- The Modeltime Ensemble process is covered in-depth in the **[High-Performance Time Series Course Module 14]()**
- The **[Lost Time Series Module 5]()** shows how to use Ensembles to improve *Hierarchical Forecasting Performance*
- Additional Resource: **[Getting Started with Modeltime Ensemble]()**

Iterative Forecasting (Nested Workflow)

Used to make individual models for many time series. Can be more accurate than Global Forecasting, but is less scalable.

- This process is covered in-depth in the **Lost Time Series Modules (Module 2 - Iterative Forecasting at Scale) and (Module 3 - Recursive Iterative Forecasting)**
- Additional Resource: [Getting Started with Nested Forecasting](#).

Nested Time Series Data

`extend_timeseries()`
`nest_timeseries()`
`split_nested_timeseries()`

```
# A tibble: 7 × 5
  id    .actual_data       .future_data      .splits
  <fct> <list>             <list>            <list>
1 1_1   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
2 1_3   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
3 1_8   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
4 1_13  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
5 1_38  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
6 1_93  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
7 1_95  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]>
```

Many Models

- **ARIMA** — `arima_reg()`
- **PROPHET** — `prophet_reg()`
- **ETS** — `exp_smoothing()`
- **Random Forest** — `rand_forest()`
- **SVM** — `svm_rbf()`
- **XGBoost** — `boost_tree()`

`modeltime_nested_fit()`

Nested Modeltime Table

```
# Nested Modeltime Table
  Trained on: .splits | Model Errors: [0]
# A tibble: 7 × 5
  id    .actual_data       .future_data      .splits         .modeltime_tables
  <fct> <list>             <list>            <list>          <list>
1 1_1   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
2 1_3   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
3 1_8   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
4 1_13  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
5 1_38  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
6 1_93  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
7 1_95  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [2 × 5]>
```

Core Functions | Nested Forecasting

1: Nested Fitting

`modeltime_nested_fit()`

- **Trains** each model on training split
- **Logs** test accuracy, test forecast with confidence intervals on testing split
- **Logs** additional information including error reports

2: Select Best

`modeltime_nested_select_best()`

- **Selects best model** using accuracy metric
- **Filters** test forecasts to just those of best models
- **Logs** best models

3: Nested Refitting

`modeltime_nested_refit()`

- **Retrains** selected models on actual data
- **Logs** future forecast on future data

Extracting Nested Modeltime Table Logs

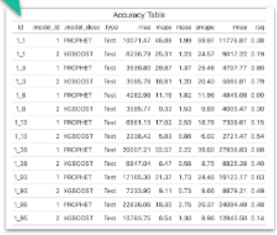
Nested Modeltime Table

```
# Nested Modeltime Table
  Trained on: .actual_data | Model Errors: [0]
# A tibble: 7 × 5
  id    .actual_data       .future_data      .splits         .modeltime_tables
  <fct> <list>             <list>            <list>          <list>
1 1_1   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
2 1_3   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
3 1_8   <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
4 1_13  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
5 1_38  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
6 1_93  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
7 1_95  <tibble [104 × 2]> <tibble [52 × 2]> <split [52/52]> <mdl_time_tbl [1 × 5]>
```

Contains Logged Attributes for fast extraction

Test Accuracy

`extract_nested_test_accuracy()`



Test Forecast

`extract_nested_test_forecast()`

Error Reporting

`extract_nested_error_report()`

```
# A tibble: 4 × 4
  id    .model_id .model_desc .error_desc
  <fct>     <int> <chr>       <chr>
1 1_1           2 BOOST_TREE  "'data' has class 'character' and length 52.\n  'data…
2 1_3           2 BOOST_TREE  "'data' has class 'character' and length 52.\n  'data…
3 1_8           1 BOOST_TREE  "`x` should be an `rsplit` object"
4 1_8           2 BOOST_TREE  "`x` should be an `rsplit` object"
```

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