Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Toronto Home Price Index

A Time Series Analysis

S. Ozel

AISC Time Series Discussion Group, 2021

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Outline

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Home Price Index (HPI)

Home Price Index

- Based on the sold prices of residential real estate.
- Corrects for the estate's features to make it less volatile, compared to averages.
- https://trreb.ca/index.php/market-news/mls-home-price-index/

Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
	Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
	Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
	Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
	Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
	Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
	Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
	Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
	Townhouse	288.2	294.7	299.8	299.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
	Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
	Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
	Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
	Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

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Home Price Index (HPI)

Granularity

- Area: Defined by the Toronto Region Real Estate Board (TRREB). (Toronto C10, Mississauga, Milton, etc...)
- Type: Housing type
- Date: Monthly, first of every month

	Area	Date / Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
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Home Price Index (HPI)

Panel Data

- Each panel is an Area x Type pair, i.e. each row in the below table.
- Each panel has either 103 or 69 data points (months)
- We can run multivariate analysis or multiple univariate analyses.

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
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Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
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Forecasts & Validation
Future Work

Goal

Forecast HPI

- Come up with the best forecast of HPI possible.
- Refresh knowledge of time series models in the process.
- Present results to spark discussion.

Research Questions

- Can we beat a basic benchmark?
- Which approach will work best?
- Can we develop a better approach?

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Validation: Moving Window, Next Month Forecast MSE

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Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
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Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
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Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
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Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
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Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Month After

Area		Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
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		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Month After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Month After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Month After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Quarter After

Area		Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Quarter After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Quarter After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

Validation: Moving Window, Next Month Forecast MSE

Moving Window

4-month Training Sample Validation 1 Quarter After

	Area	Date Type	2020-06-01	2020-07-01	2020-08-01	2020-09-01	2020-10-01	2020-11-01	2020-12-01	2021-01-01	2021-02-01	2021-03-01	2021-04-01
HPI	Milton	Apartment	287.6	289.8	290.9	287.8	288.9	288.7	NaN	292.4	298.8	306.6	320.2
		Composite	289.5	285.5	289.1	294.5	297.8	301.7	NaN	325.5	341.9	346.0	347.6
		Single-Family Attached	303.2	297.4	303.4	308.9	314.2	320.5	NaN	349.1	367.8	368.1	369.0
		Single-Family Detached	283.2	284.7	287.9	294.2	297.5	301.8	NaN	329.3	346.5	349.4	348.7
		Townhouse	291.9	302.8	309.3	319.3	317.3	319.9	NaN	324.5	344.2	362.5	363.2
	Mississauga	Apartment	307.2	308.5	309.4	310.6	308.0	307.1	303.0	302.6	309.2	321.3	329.5
		Composite	287.4	291.1	294.3	296.0	295.8	296.2	296.9	301.5	313.8	327.0	332.6
		Single-Family Attached	275.3	280.0	285.2	288.0	290.1	292.4	295.7	302.7	320.1	333.3	336.5
		Single-Family Detached	273.5	278.5	282.9	285.8	287.3	288.8	292.3	300.0	316.3	330.2	334.9
		Townhouse	288.2	294.7	298.8	298.8	298.0	297.9	299.2	301.8	312.7	326.7	332.2
	Toronto C10	Apartment	315.5	307.4	306.7	305.6	302.1	305.0	303.0	298.9	305.6	313.8	326.2
		Composite	299.4	298.5	297.8	295.6	292.7	295.7	294.0	293.3	300.5	306.1	317.0
		Single-Family Attached	254.0	271.8	272.2	266.5	262.9	269.3	269.4	279.0	287.9	288.8	292.2
		Single-Family Detached	265.6	283.1	282.1	277.2	275.0	278.2	277.1	287.3	295.6	295.3	301.8
		Townhouse	279.9	279.1	281.8	277.0	282.5	282.2	279.0	266.5	272.5	273.2	284.8

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

AR(2) Model

$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \epsilon_t$

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

AR(2) Model on One Panel

I added the subscript 1 to show that this is panel 1 among many.

$$Y_{1,t} = \beta_0 + \beta_{1,1} Y_{1,t-1} + \beta_{1,2} Y_{1,t-2} + \epsilon_t$$

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

AR(2) Model on One Panel

Now I added two more terms from <u>another</u> panel.

$$Y_{1,t} = \beta_0 + \beta_{1,1} Y_{1,t-1} + \beta_{1,2} Y_{1,t-2} + \beta_{2,1} Y_{2,t-1} + \beta_{2,2} Y_{2,t-2} + \epsilon_t$$

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

VAR(2) Model on Two Panels

Finally, I do the same for Panel 2.

$$Y_{1,t} = \beta_0 + \beta_{11,1} Y_{1,t-1} + \beta_{11,2} Y_{1,t-2} + \beta_{12,1} Y_{2,t-1} + \beta_{12,2} Y_{2,t-2} + \epsilon_{1,t}$$

$$Y_{2,t} = \beta_0 + \beta_{21,1} Y_{1,t-1} + \beta_{21,2} Y_{1,t-2} + \beta_{22,1} Y_{2,t-1} + \beta_{22,2} Y_{2,t-2} + \epsilon_{2,t}$$

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

Why VAR Models?

- Why not: we have additional data, so why not use it?

- Explanatory power: Impulse Response Functions (IRF)

- Granger Causality

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

Why VAR Models?

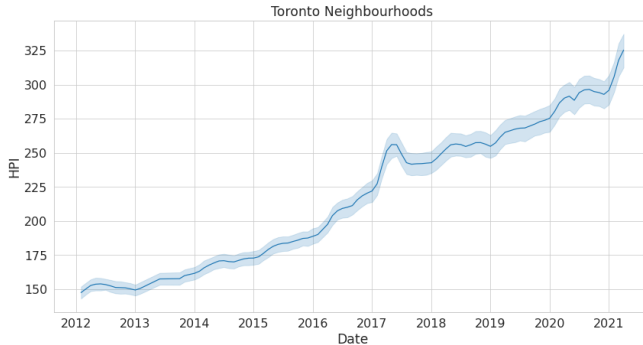- Why not: we have additional data, so why not use it?
- Explanatory power: Impulse Response Functions (IRF)
- Granger Causality

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
Forecasts & Validation
Future Work

AR(2) $\longrightarrow$ 2-panel VAR(2)

Why VAR Models?

- Why not: we have additional data, so why not use it?
- Explanatory power: Impulse Response Functions (IRF)
- Granger Causality

Data: Home Price Index (HPI)
Problem Statement: Forecast the HPI
Validation Framework
Model Framework: Vector AutoRegressive (VAR)
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Are the panels stationary?

- Visually, it is clear that the panels are not stationary.

- For each panel, I run the Augmented Dickey-Fuller test

- I reject non-stationarity for over 99% of the panels.

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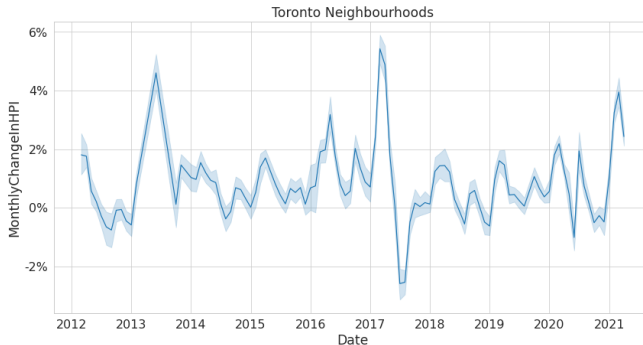Problem Statement: Forecast the HPI
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A Good Example

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MSE: Benchmark vs VAR model

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I would like to repeat the work with the following sets of models:

- ARMA and derivative models (ARIMA, ARIMAX, etc...)
- VECM
- ARCH & GARCH models
- LSTM networks
- Idea: A bootstrapping of VAR models with different sets of neighbourhoods and years.