Regression by Eye: Estimating Trends in Bivariate Visualizations

Michael Correll

Jeffrey Heer

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Regression by Eye

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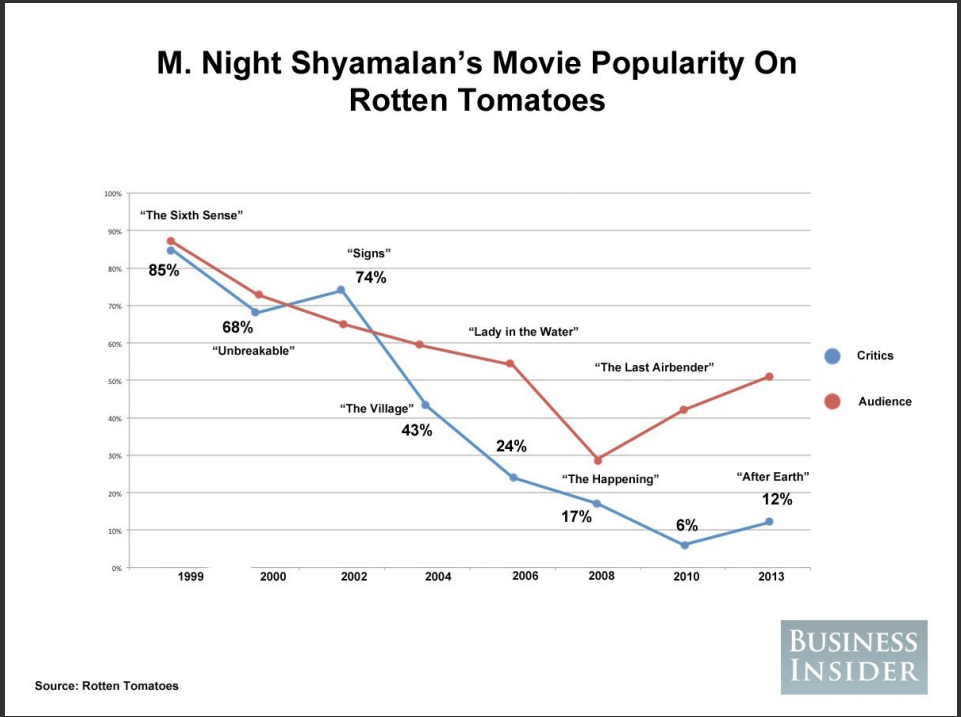
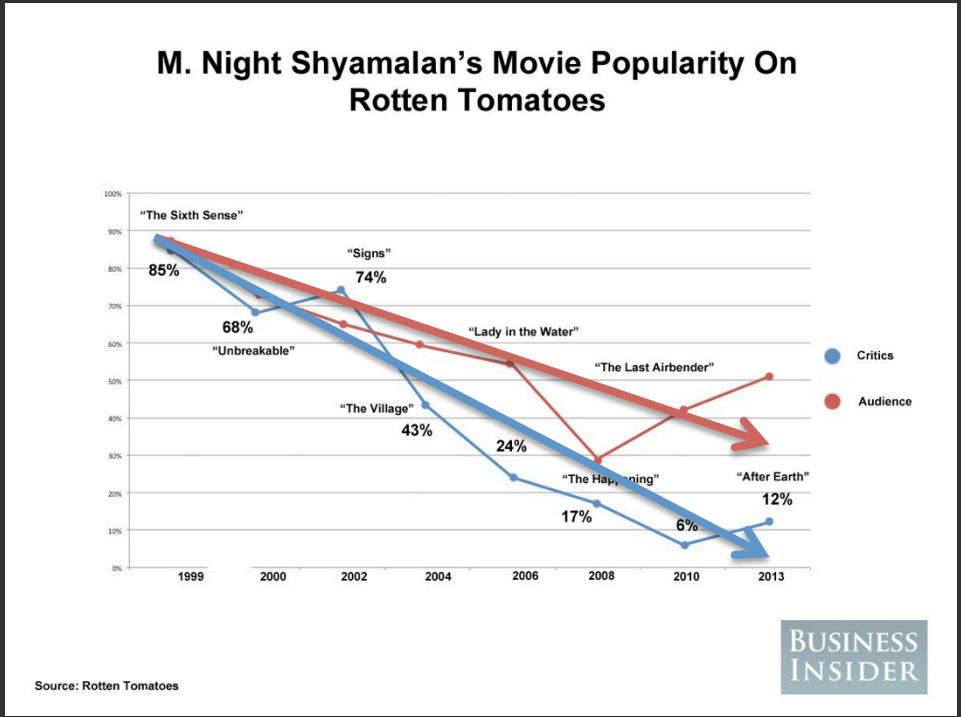
We visually estimate trends all the time.

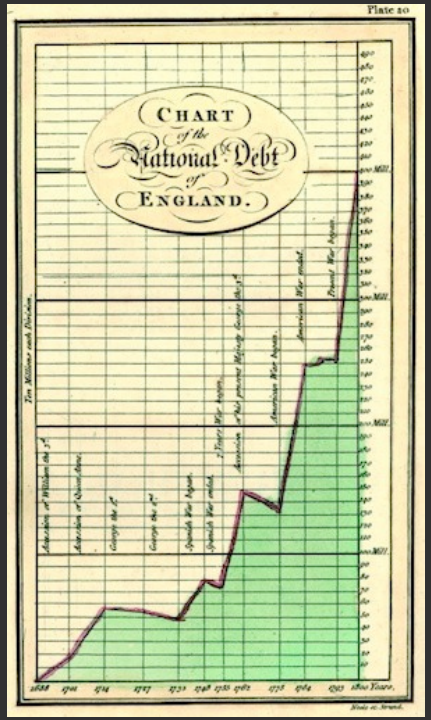
Visual Trends



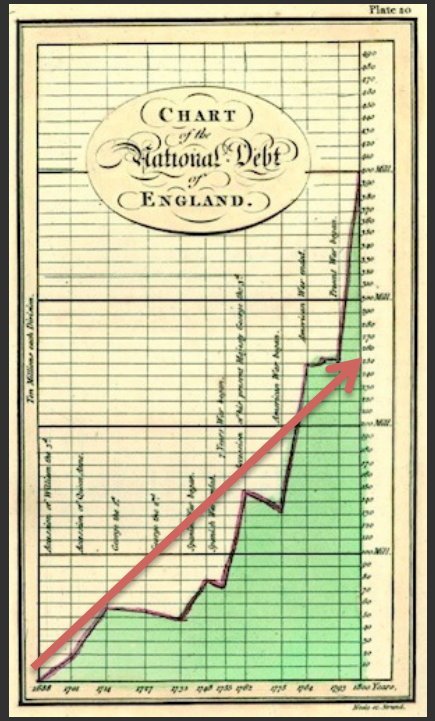
Visual Trends



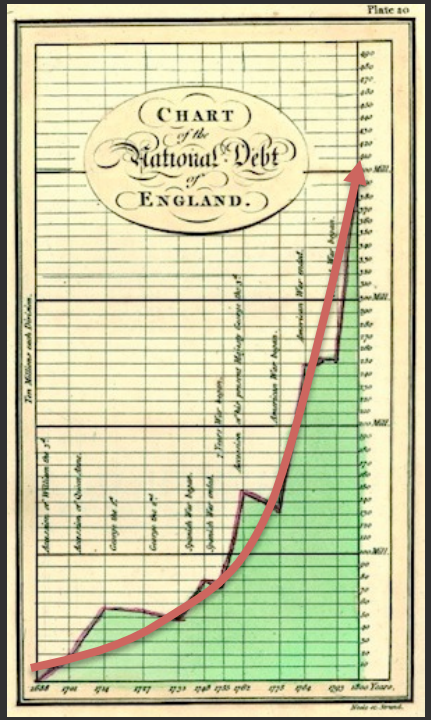
Non-linear Fits



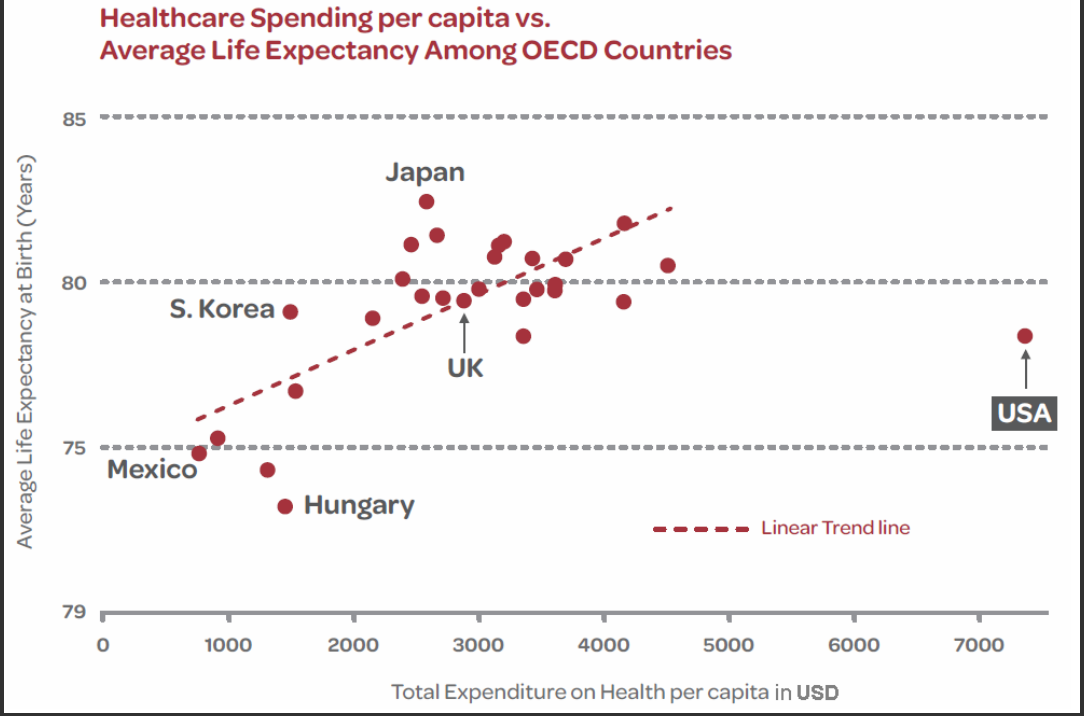
Non-linear Fits



Non-linear Fits



Outlier Detection



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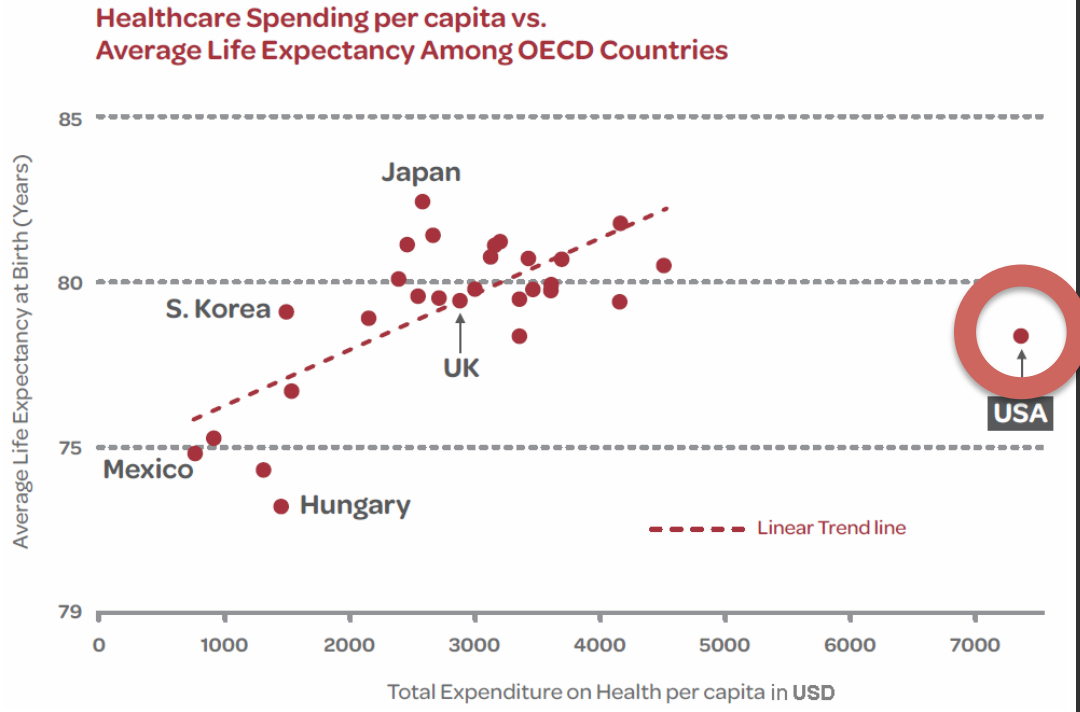

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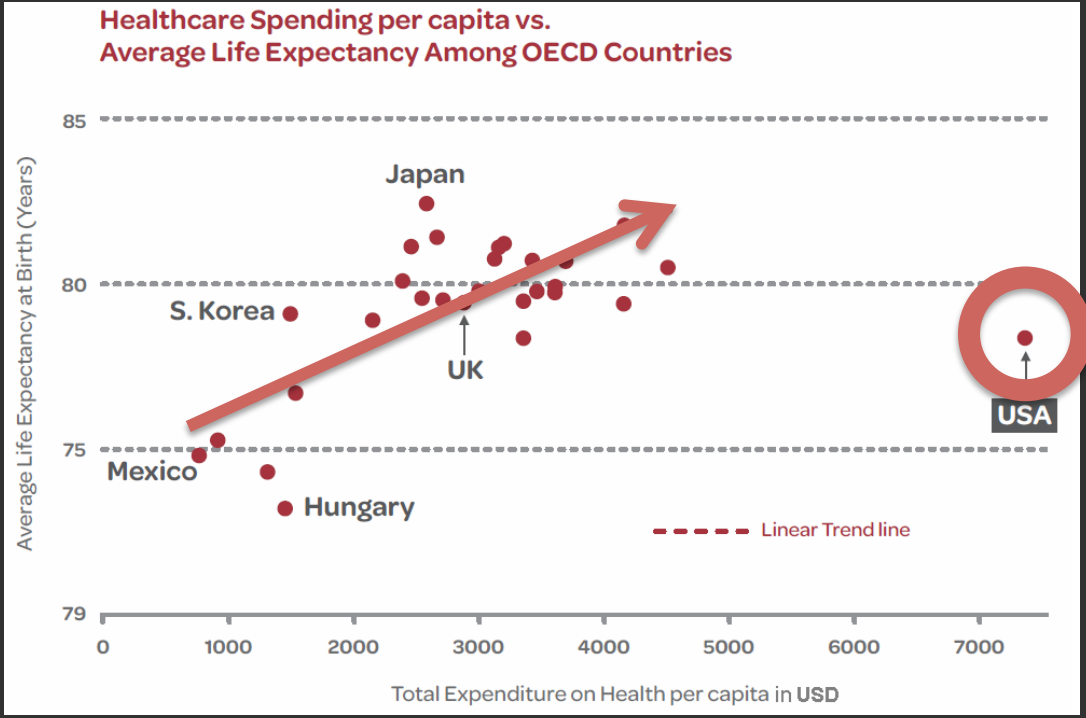
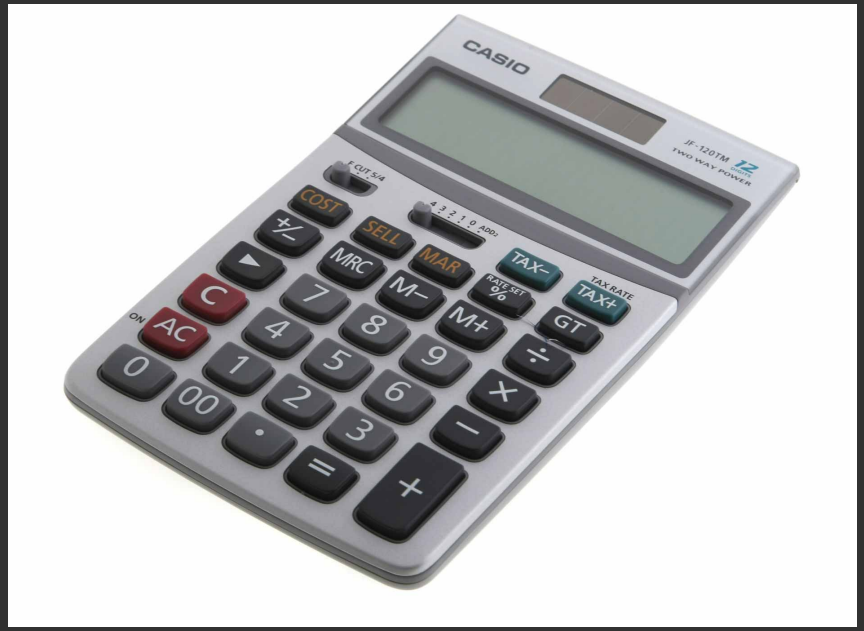
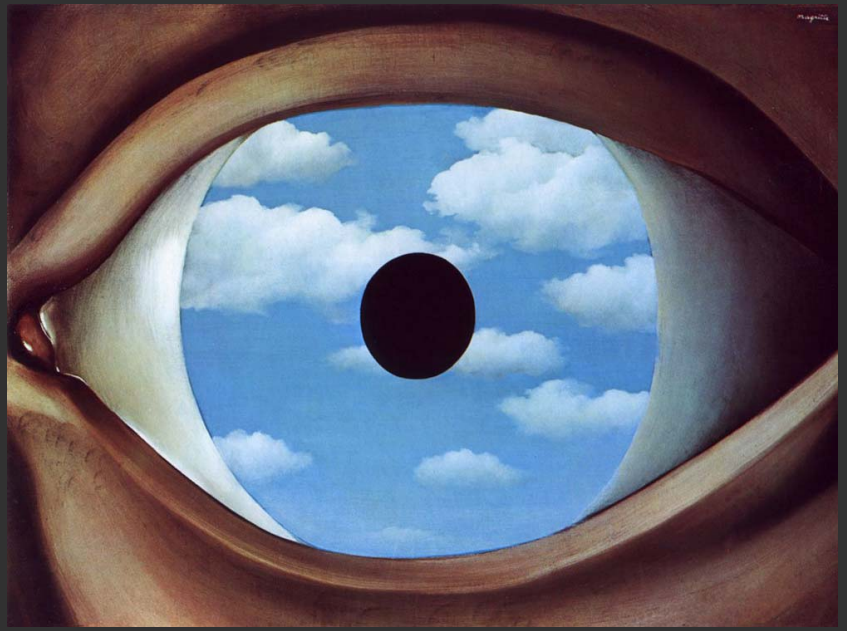


Estimating Trends

Explicit Calculation



Visual Estimation



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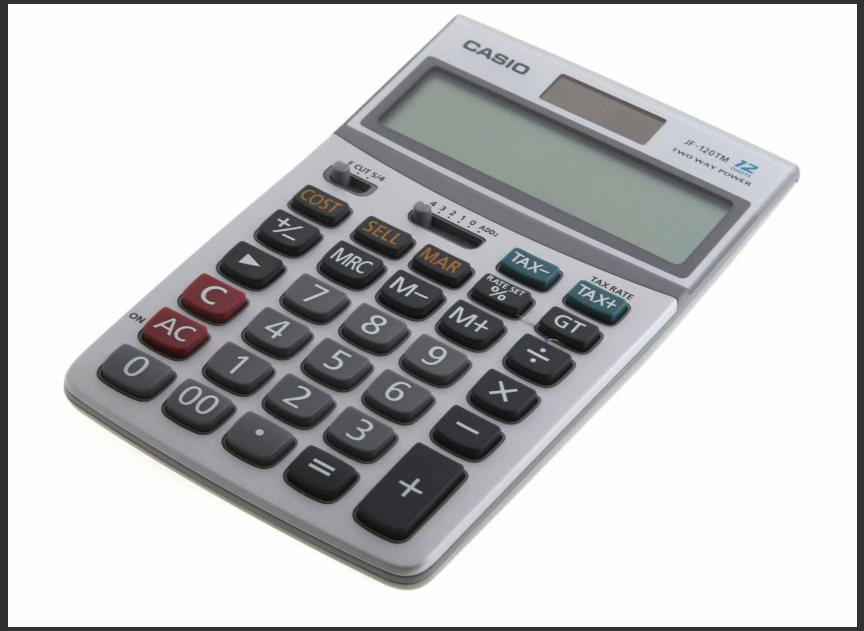
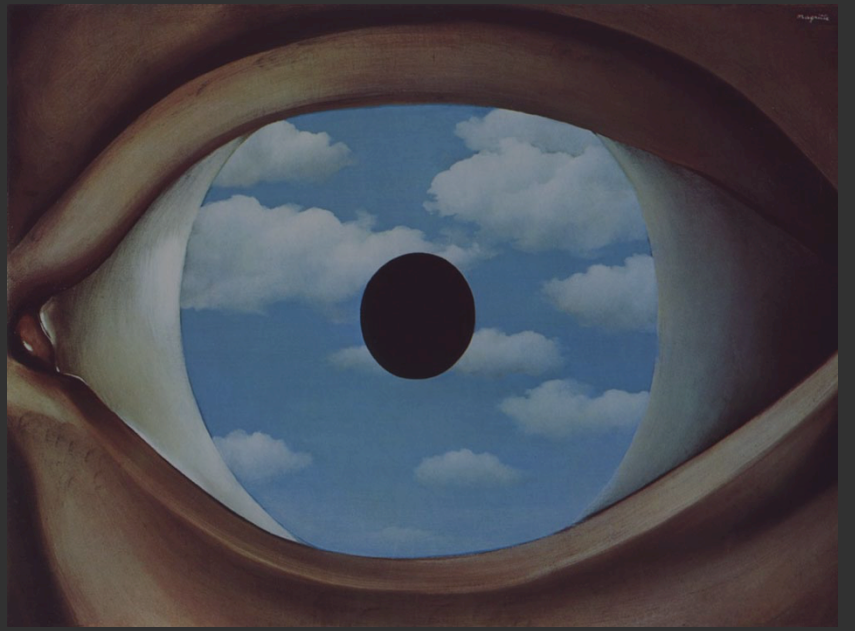
Explicit Calculation

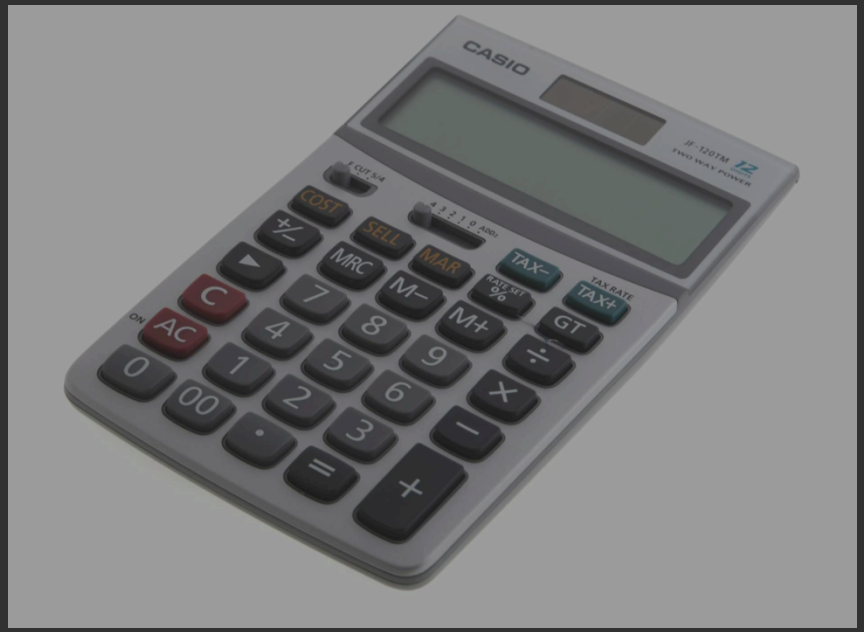


Visual Estimation

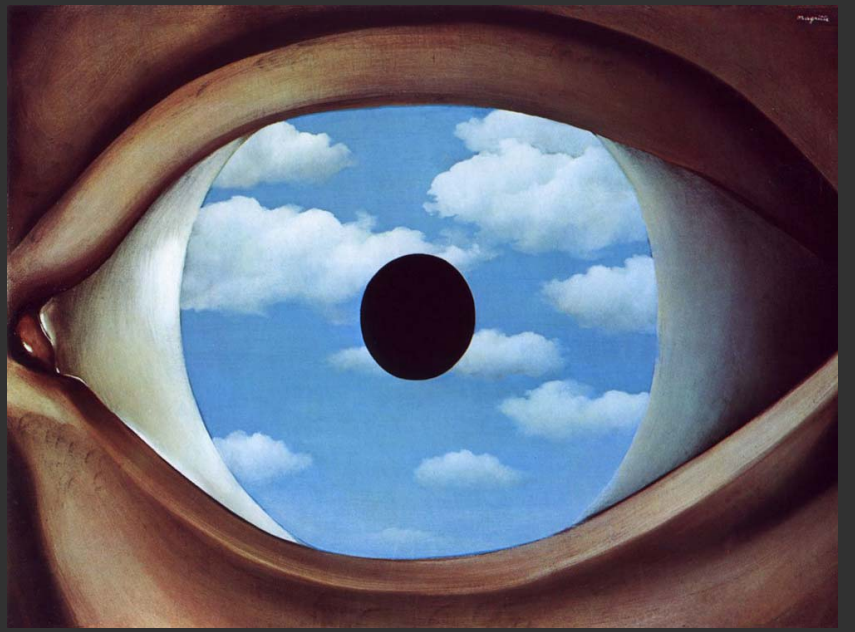


Estimating Trends

Explicit Calculation



Visual Estimation



Regression by Eye

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BUT

Are we good at it?

Does it line up with the stats?

Should designers intervene?

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SOMETIMES

Detour

Why not just always show the trend line?

Detour

Why not just always show the trend line?

1. Regression by Eye is Parsimonious
2. Regression by Eye is Robust

Detour

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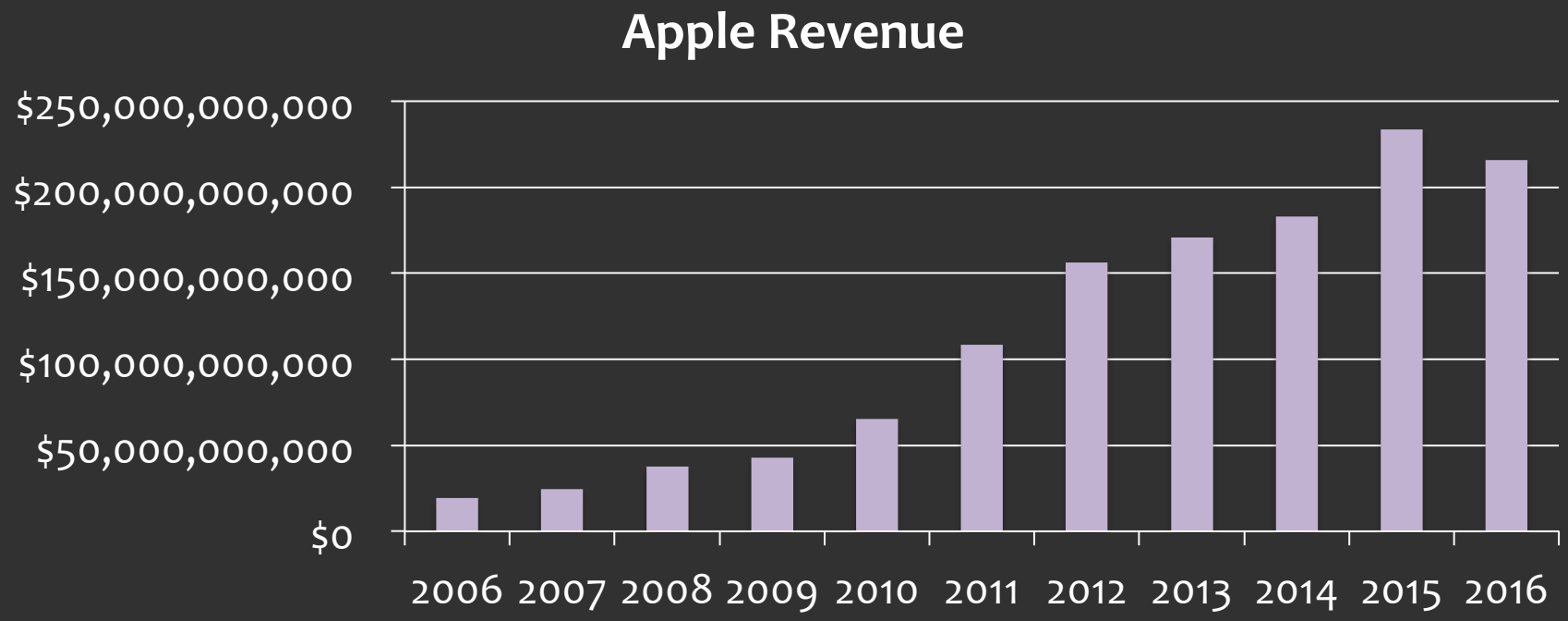
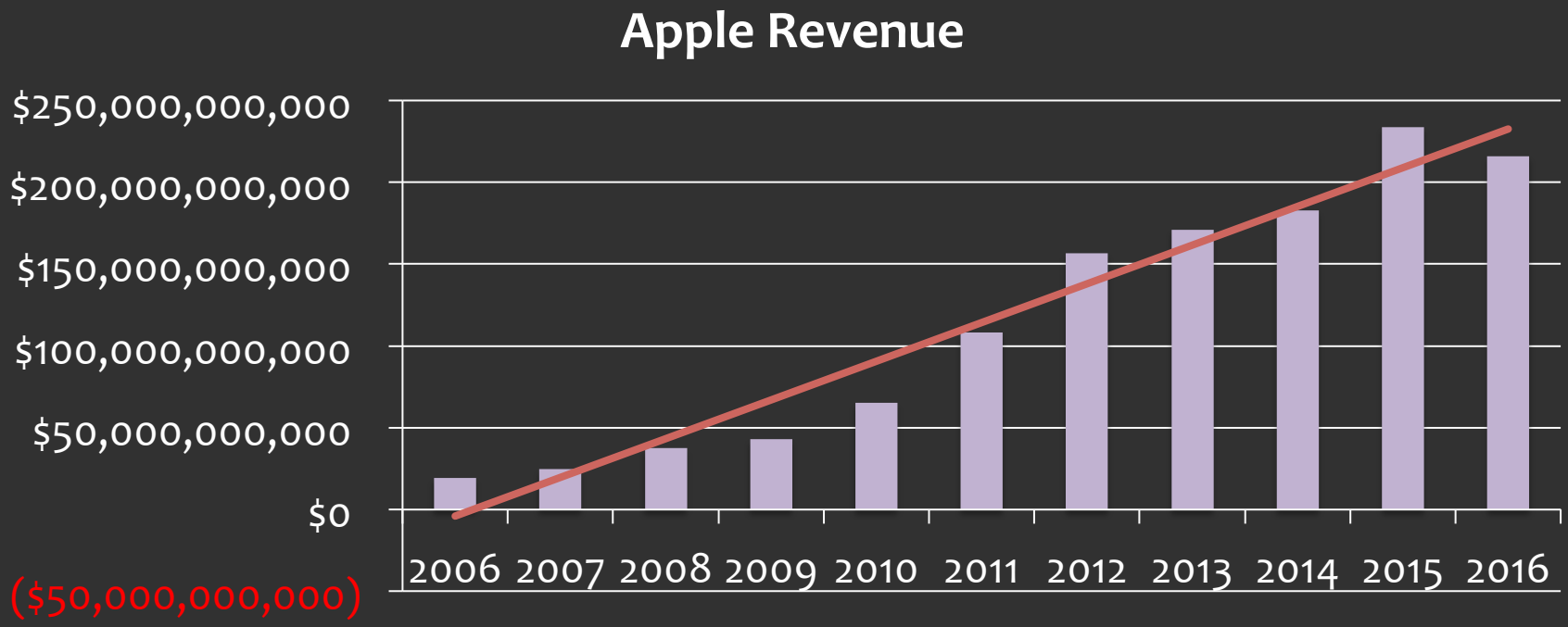
1. Regression by Eye is Parsimonious
2. Regression by Eye is Robust

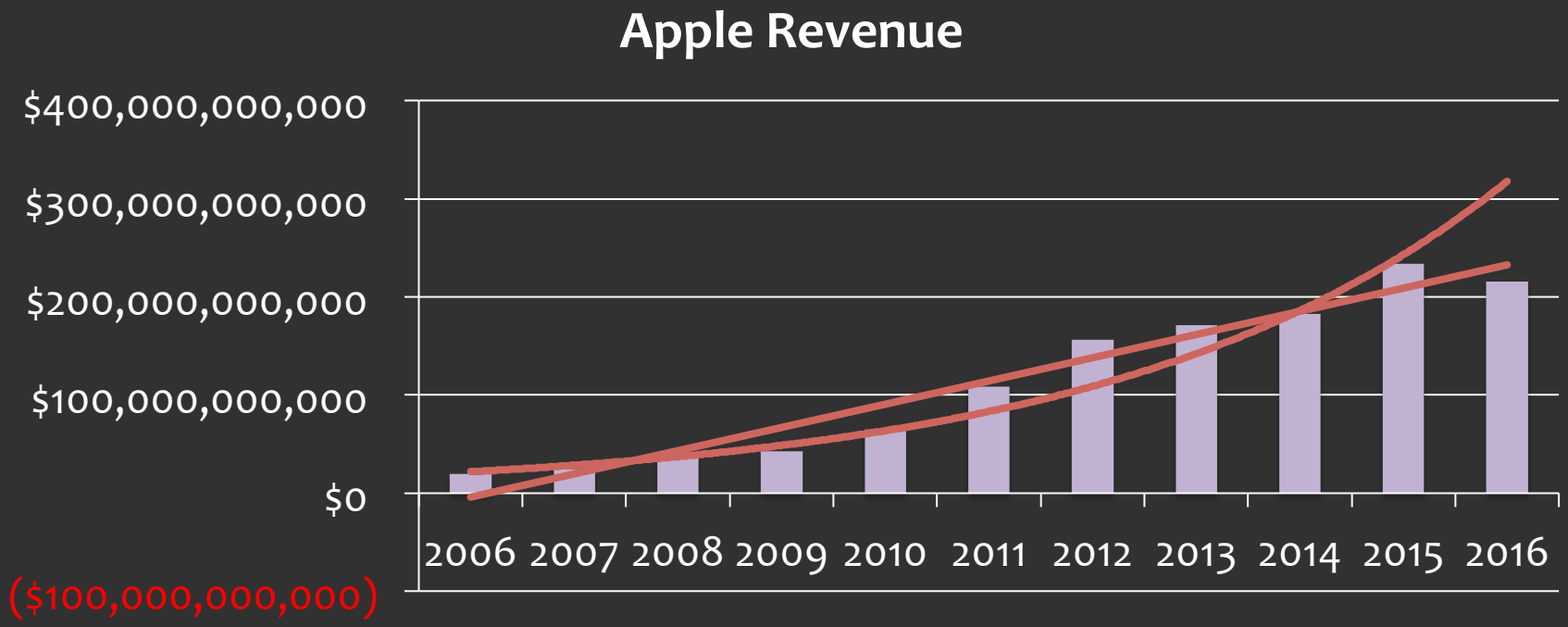
Parsimonious?



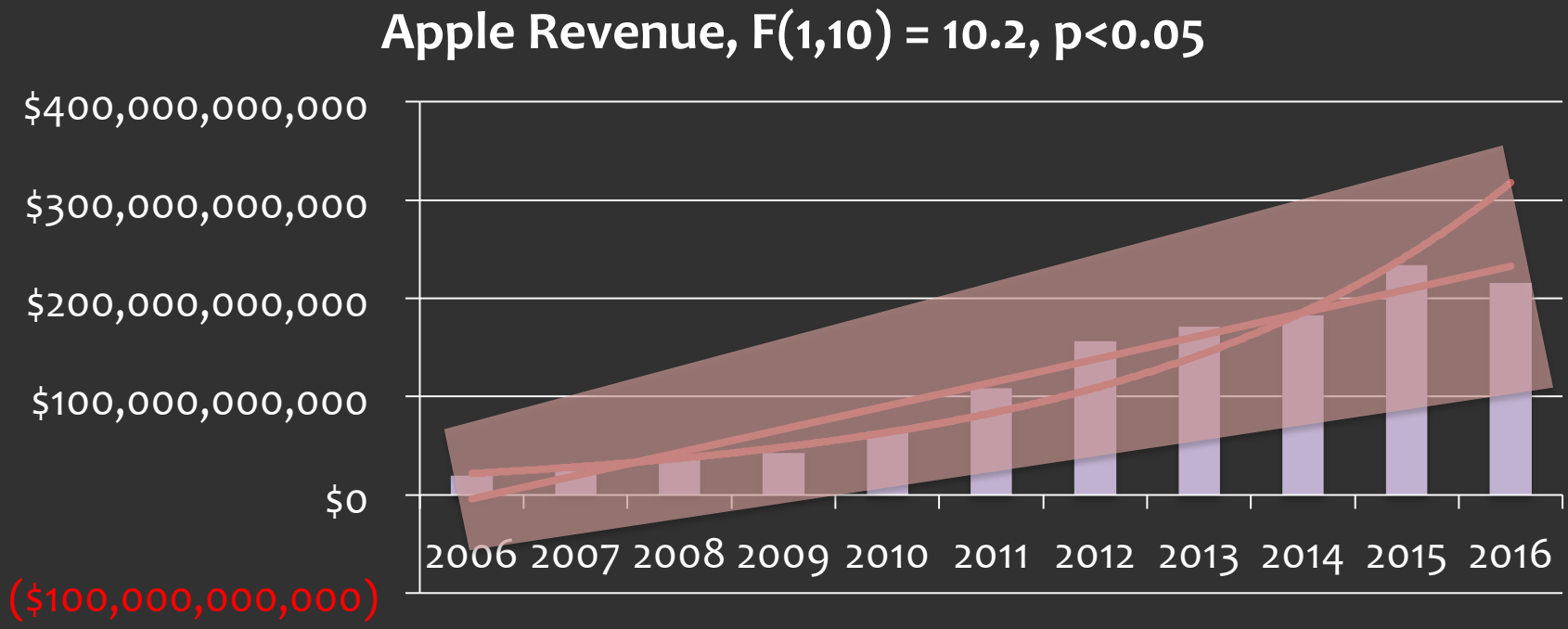
Parsimonious?



Parsimonious?

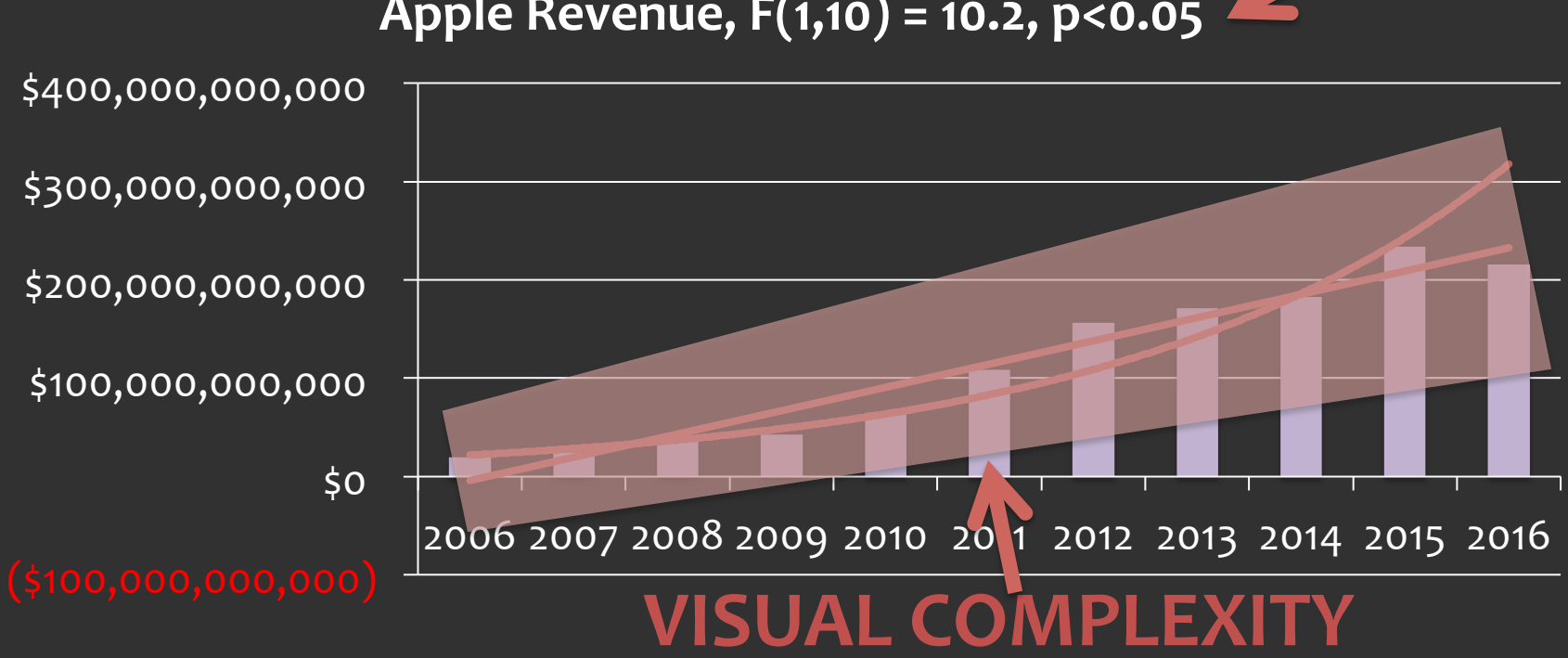


Parsimonious?

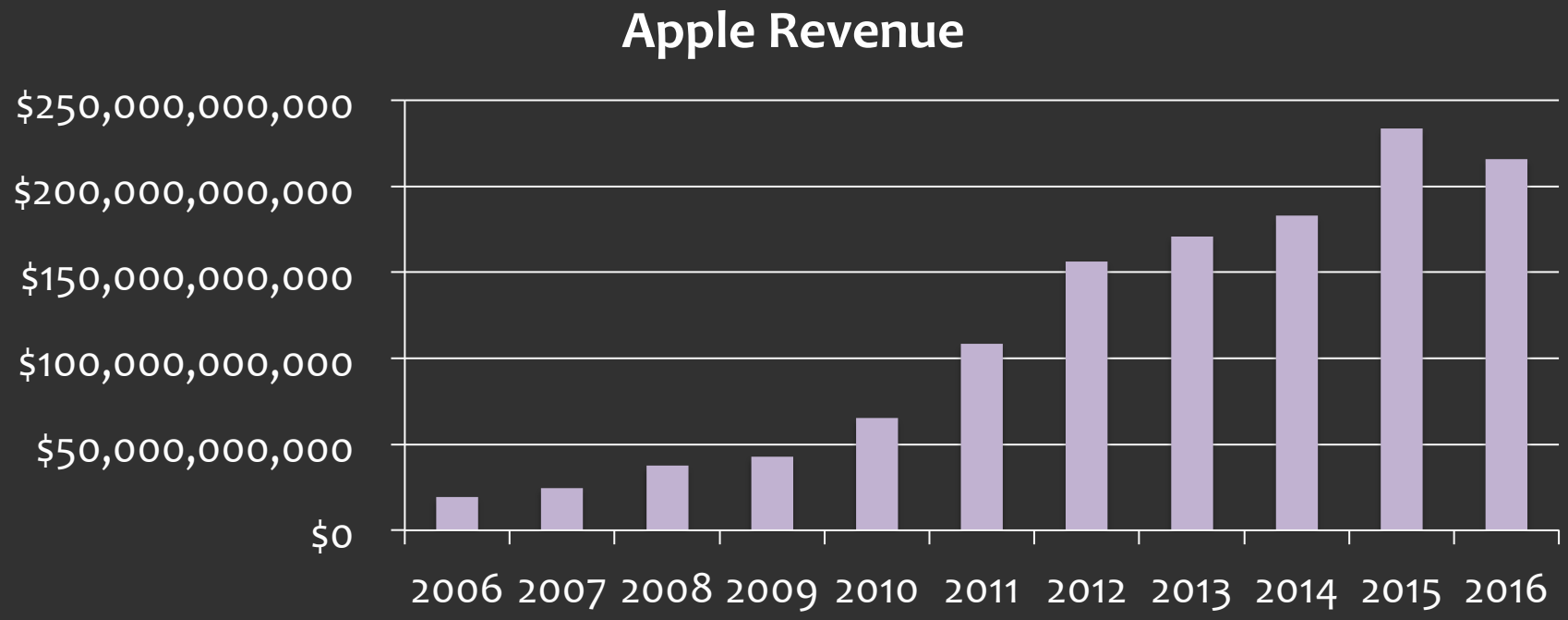


Parsimonious?

STATISTICAL COMPLEXITY



Parsimonious



Detour

Why not just always show the trend line?

1. Regression by Eye is Parsimonious
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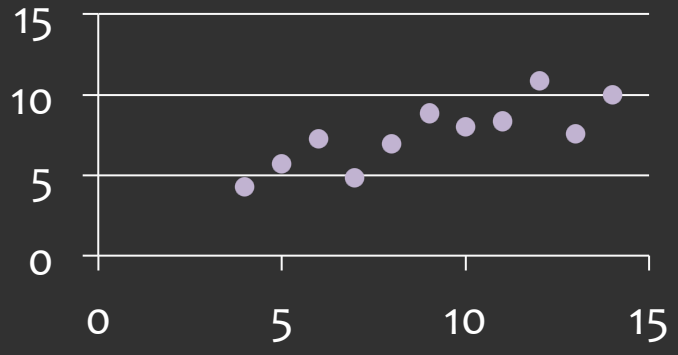
Robust?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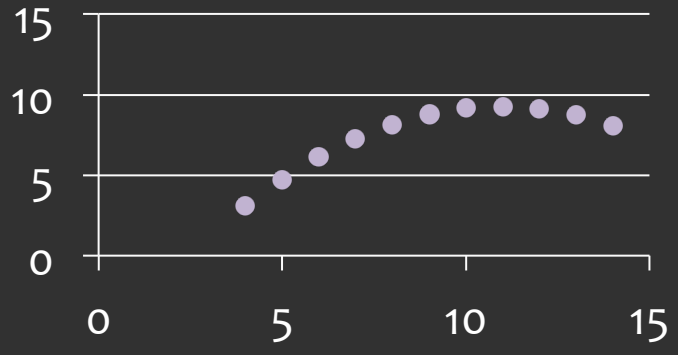
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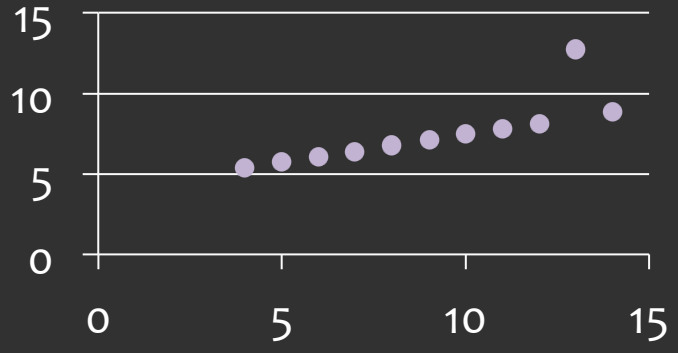
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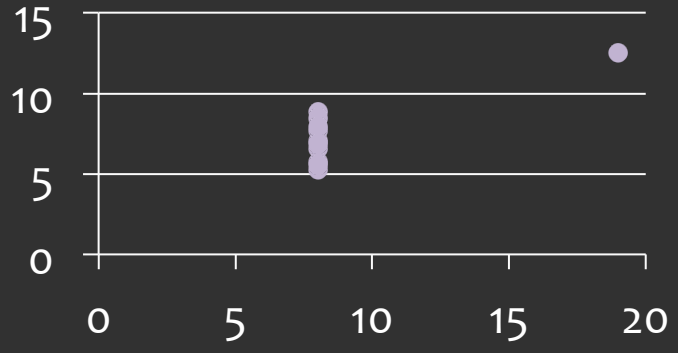
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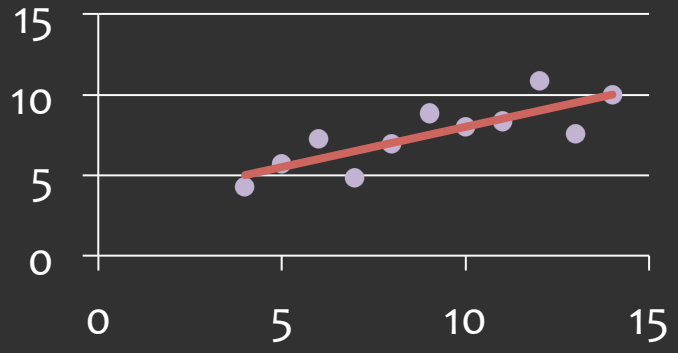
Robust?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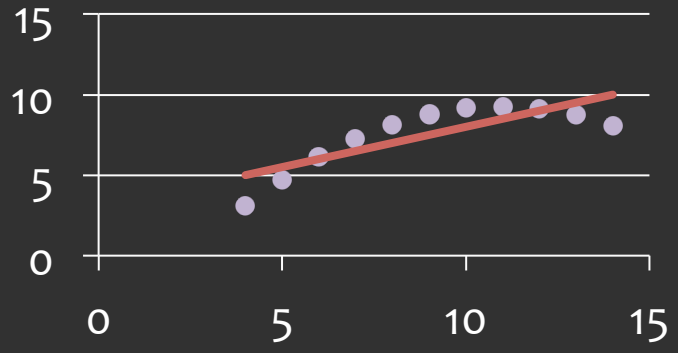
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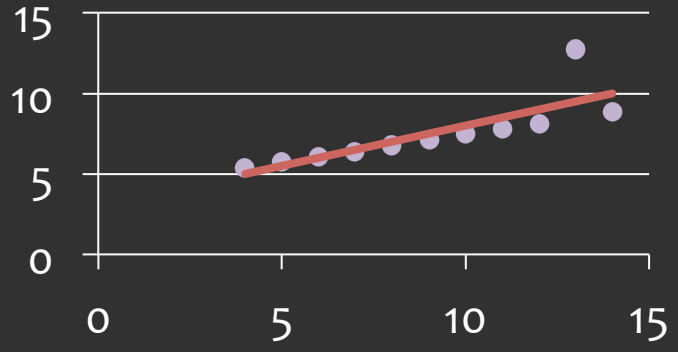
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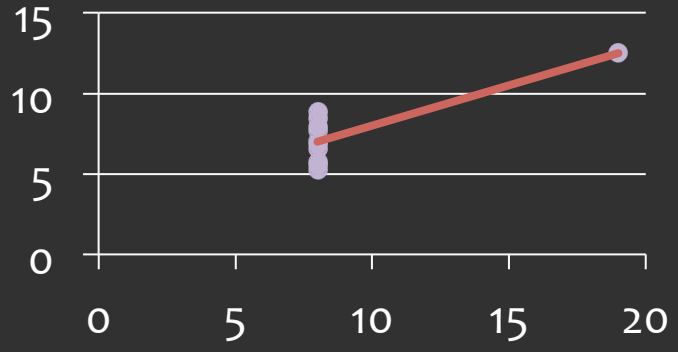
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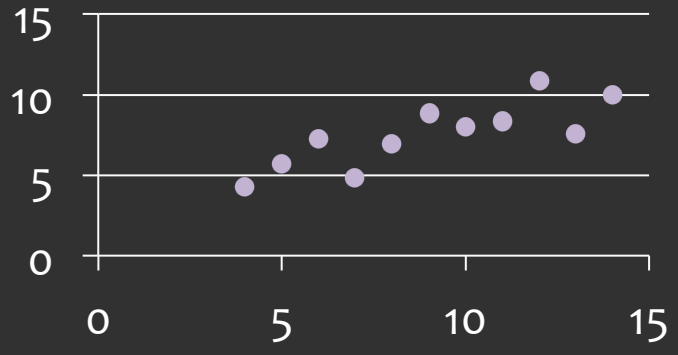
Robust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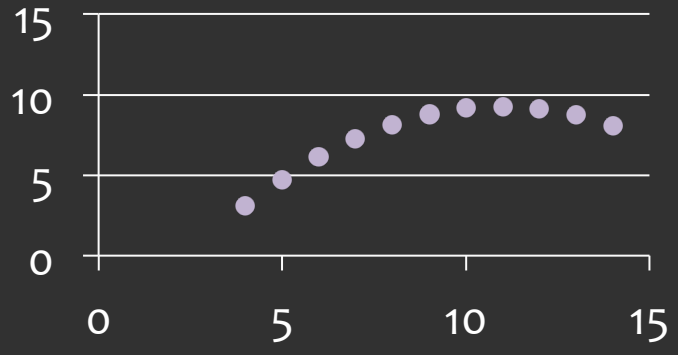
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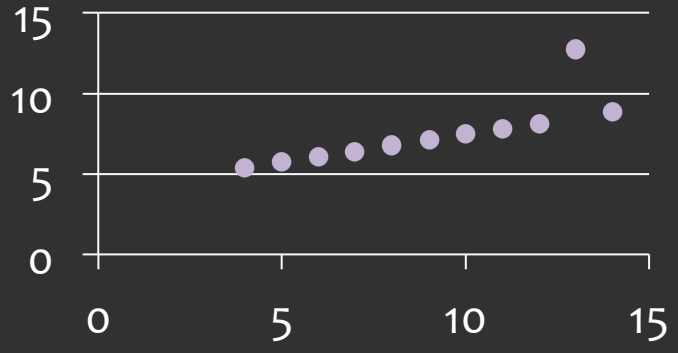
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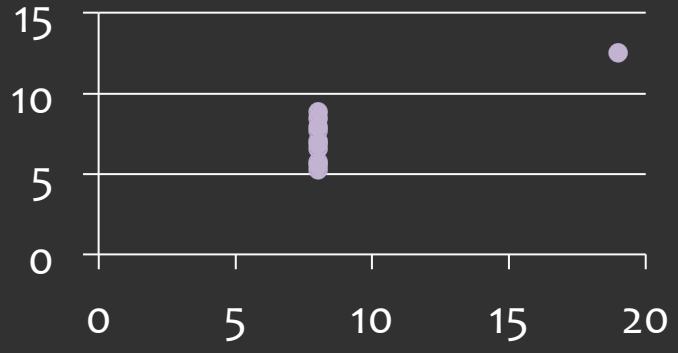
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End Detour

Regression by Eye

Are we good at it?

Does it line up with the stats?

Should designers intervene?

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Measuring Regression by Eye

Measuring Regression by Eye

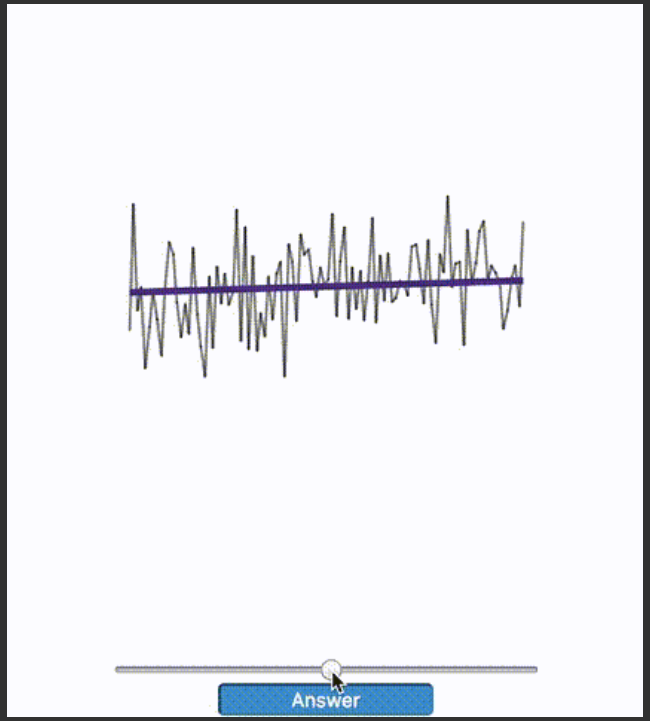
Can we disambiguate model fitting from model selection?

Measuring Regression by Eye

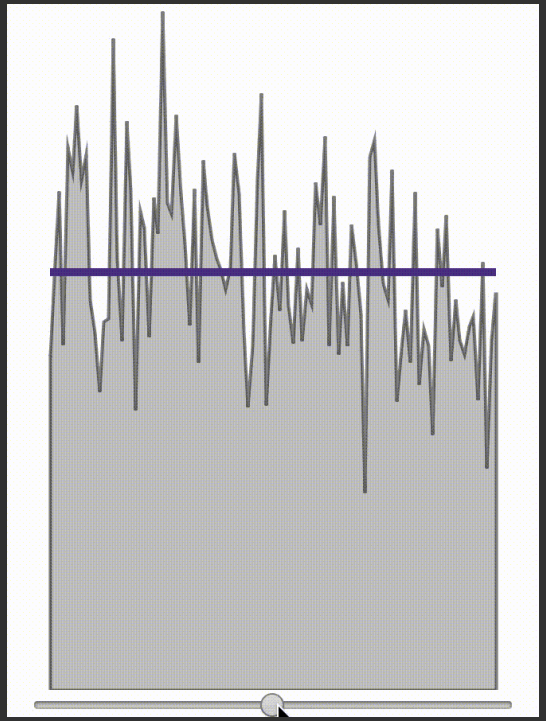
Can we disambiguate model fitting from model selection?

Can we make a task for the general audience?

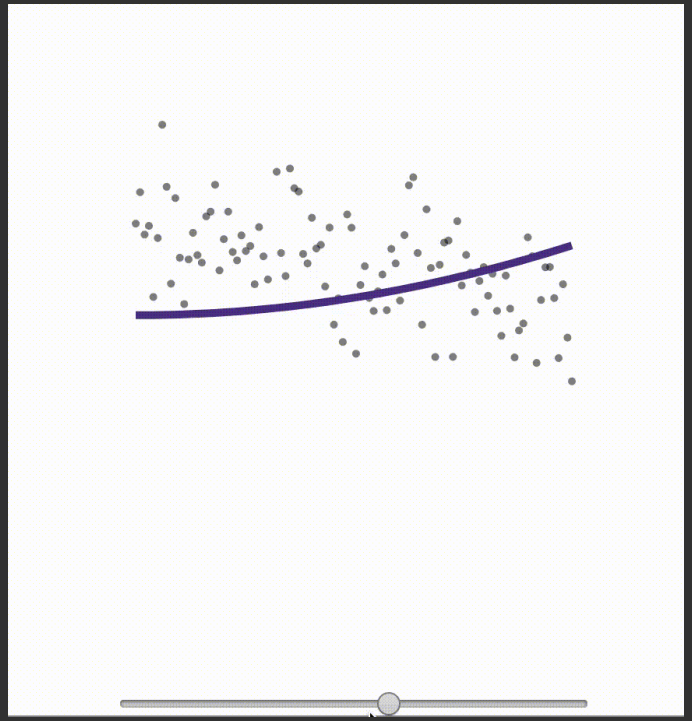
Experimental Task



Experimental Task

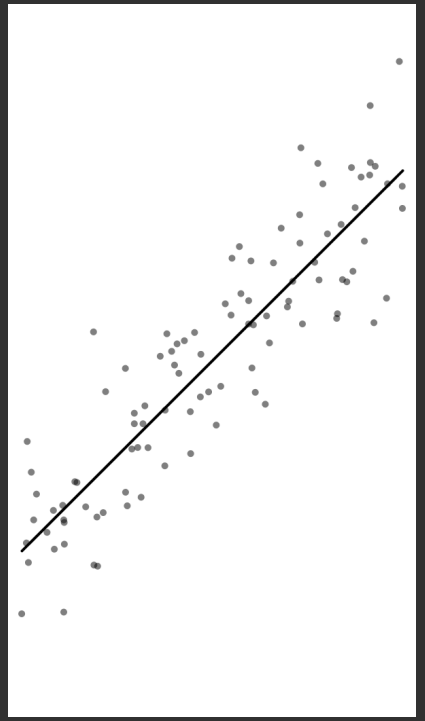


Experimental Task



Stimuli Generation

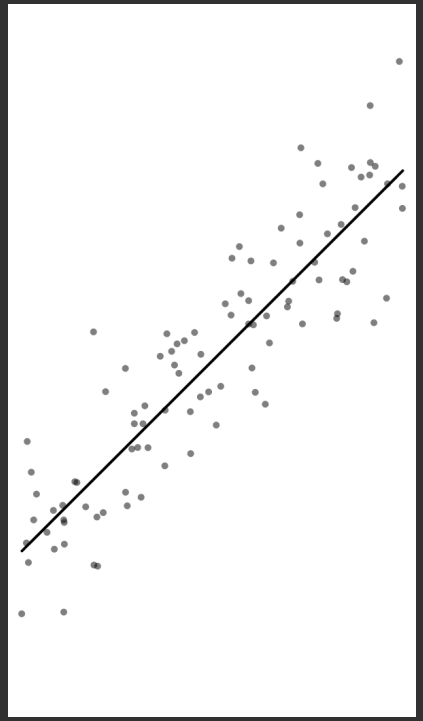
$y = \beta x + \varepsilon$



Stimuli Generation

$y = \beta x + \varepsilon$

Gaussian residuals



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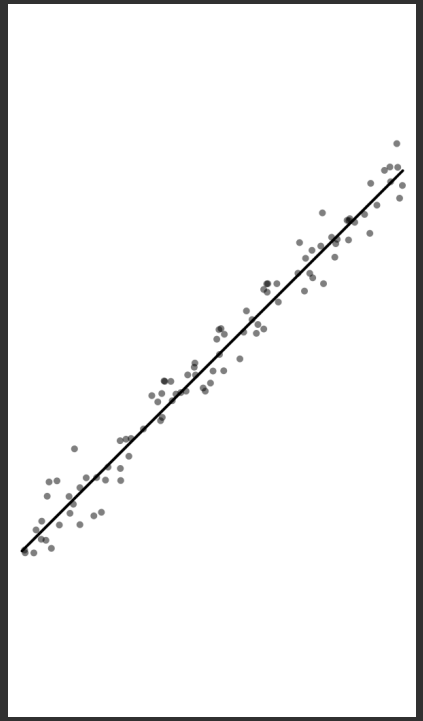
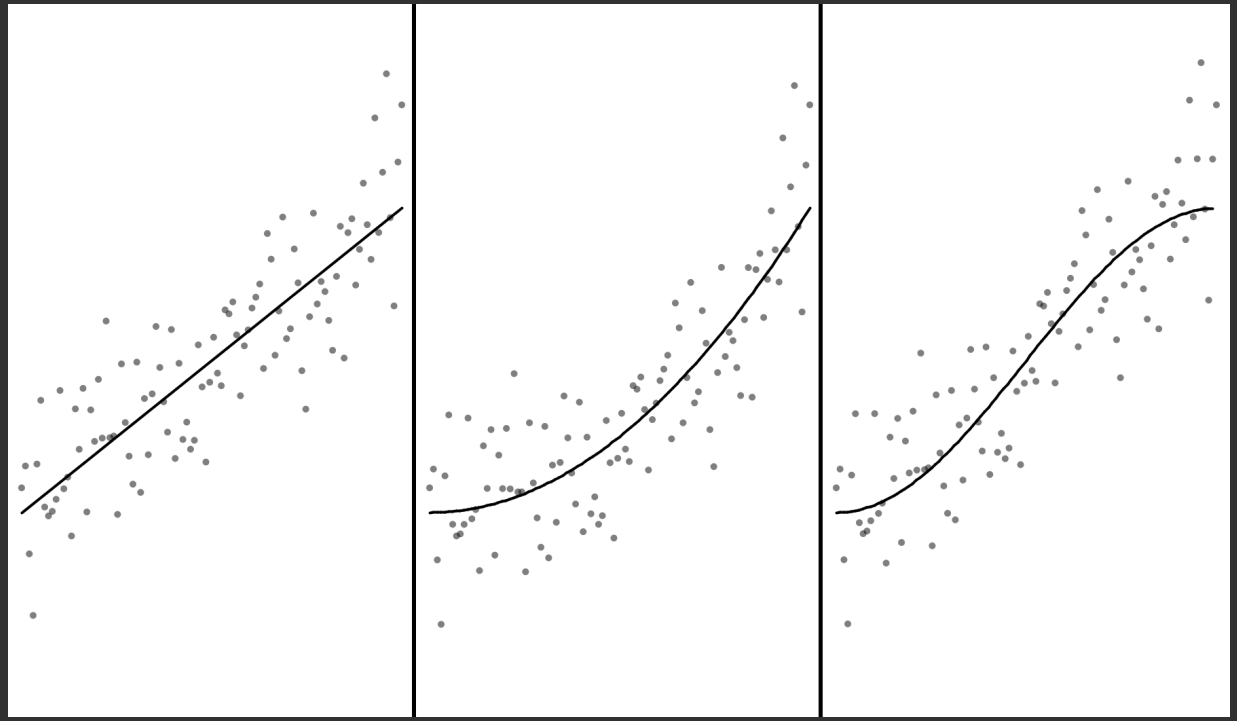


Fit Types



Methods

3 MTurk Experiments

144 Participants

4608 Trials

Regression by Eye

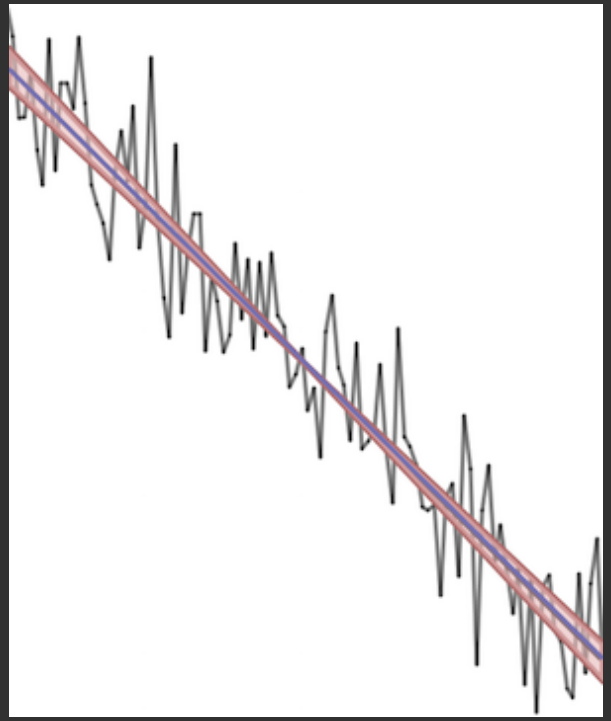
Are we good at it?

Does it line up with the stats?

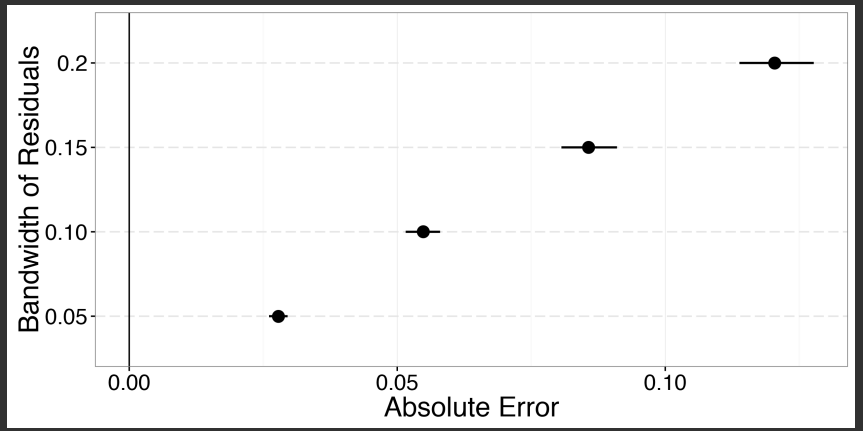
Should designers intervene?

Results

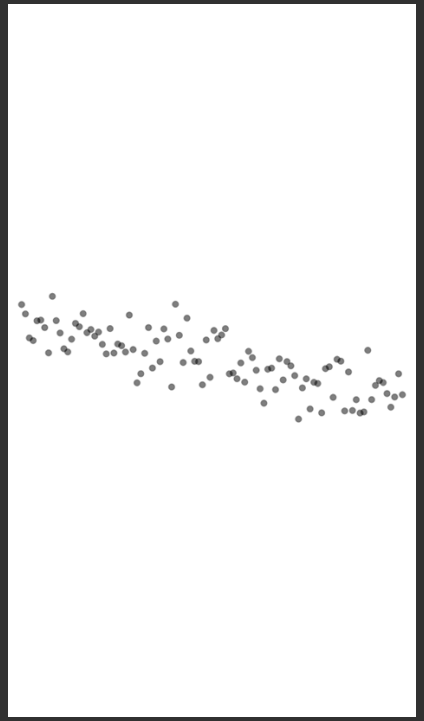
Results

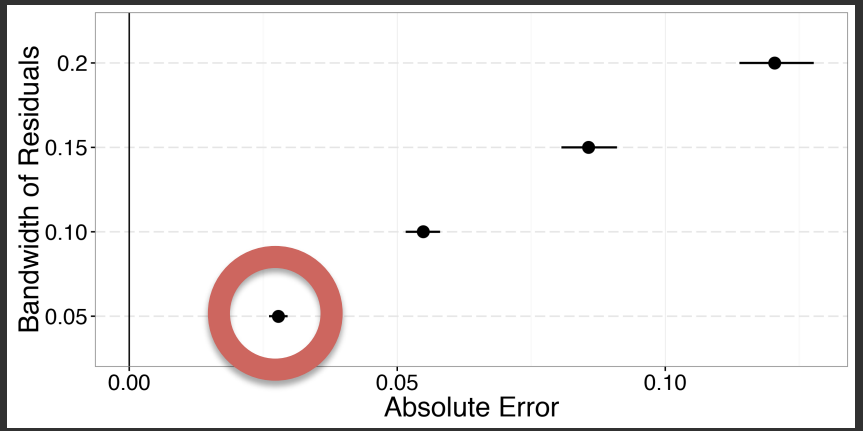


Results

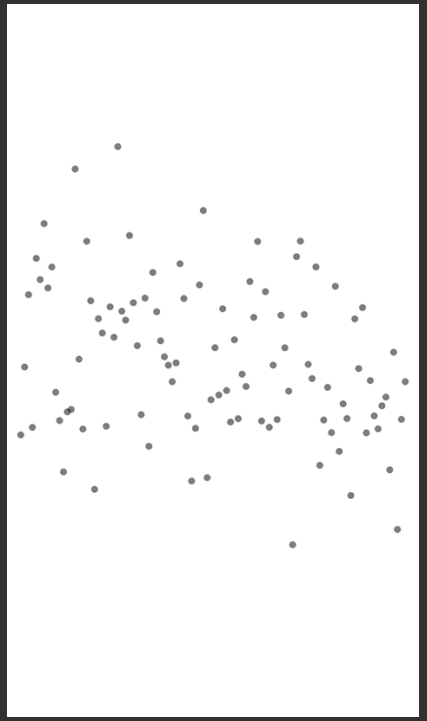

Bandwidth of Residuals
0.2
0.15
0.10
0.05
0.00
0.05
0.10
Absolute Error

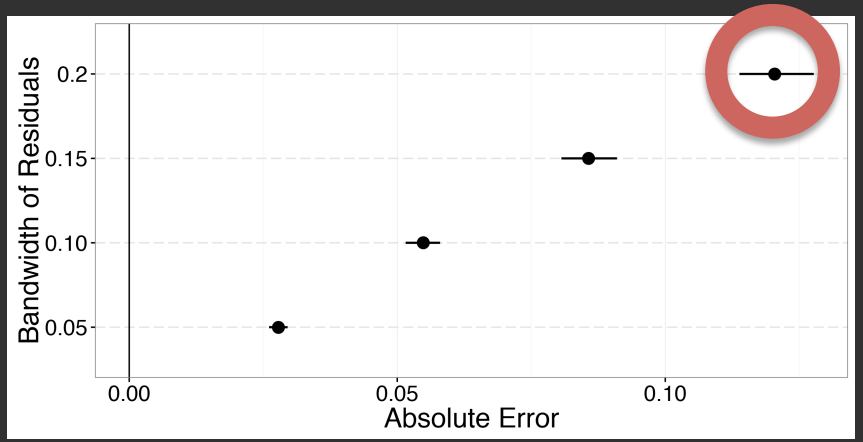
Results



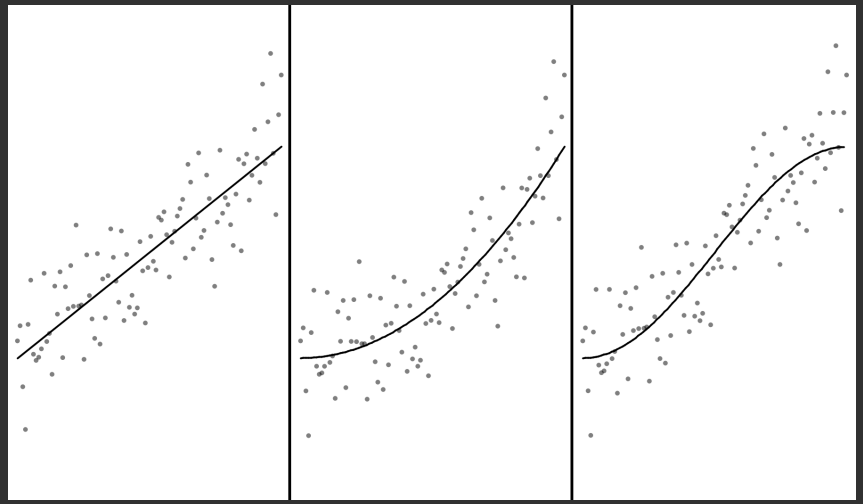

Bandwidth of Residuals
0.2
0.15
0.10
0.05
0.00
0.05
0.10
Absolute Error

Results

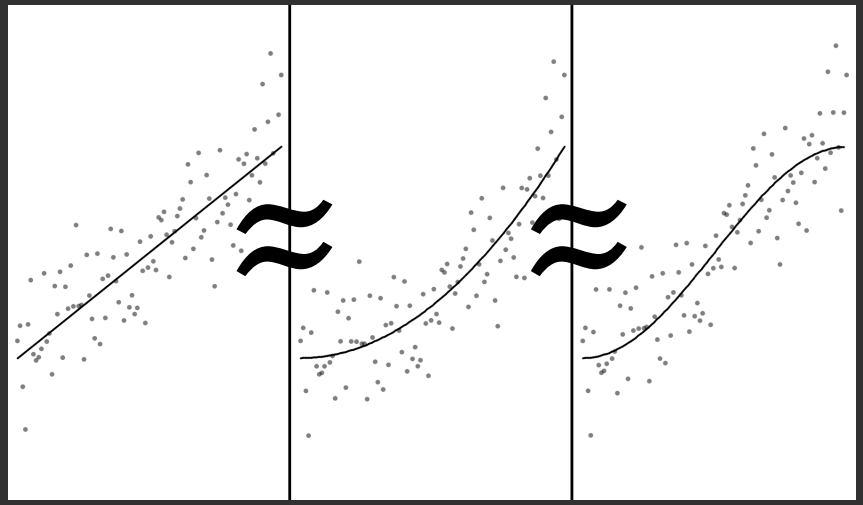


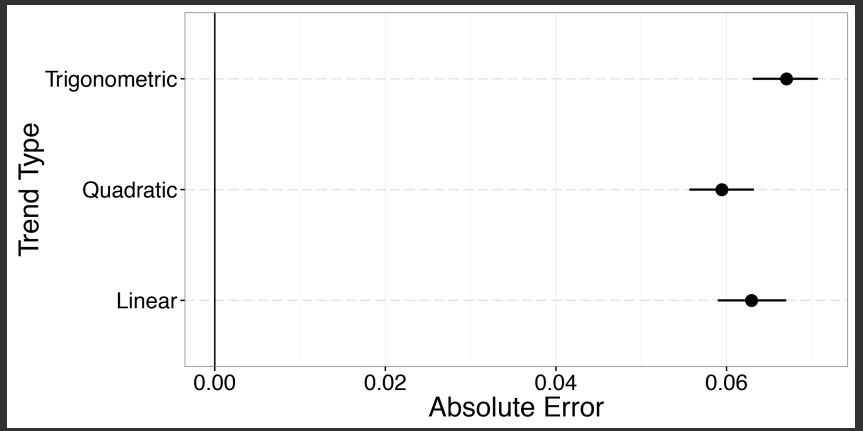

Bandwidth of Residuals
0.2
0.15
0.10
0.05
0.00
0.05
0.10
Absolute Error

Results



Results




Trigonometric
Quadratic
Linear
Trend Type
0.00
0.02
0.04
0.06
Absolute Error

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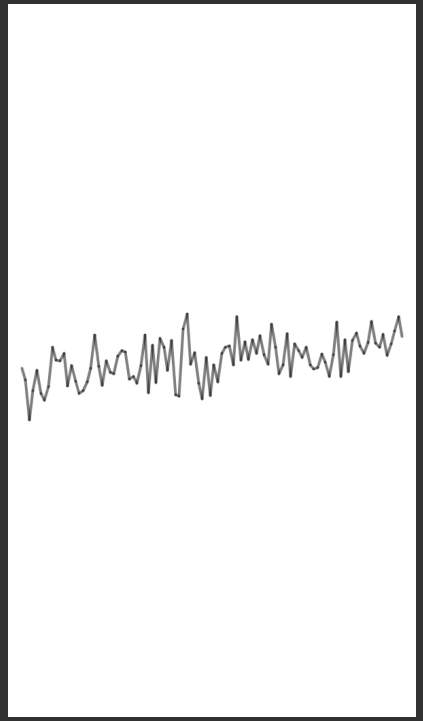
Outliers

Outliers

$y = \beta x + \varepsilon$

Gaussian residuals



Outliers

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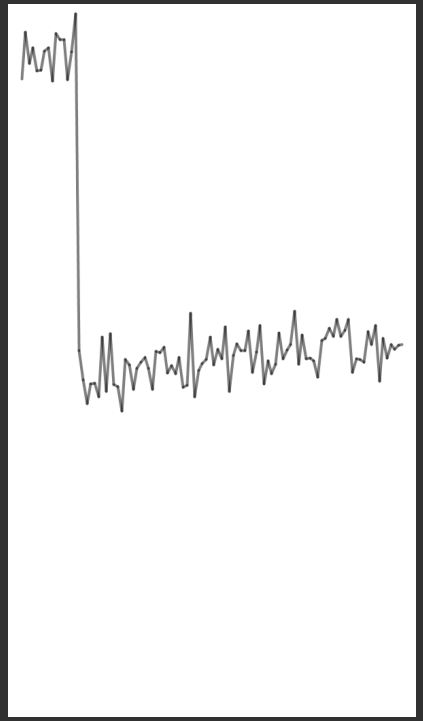
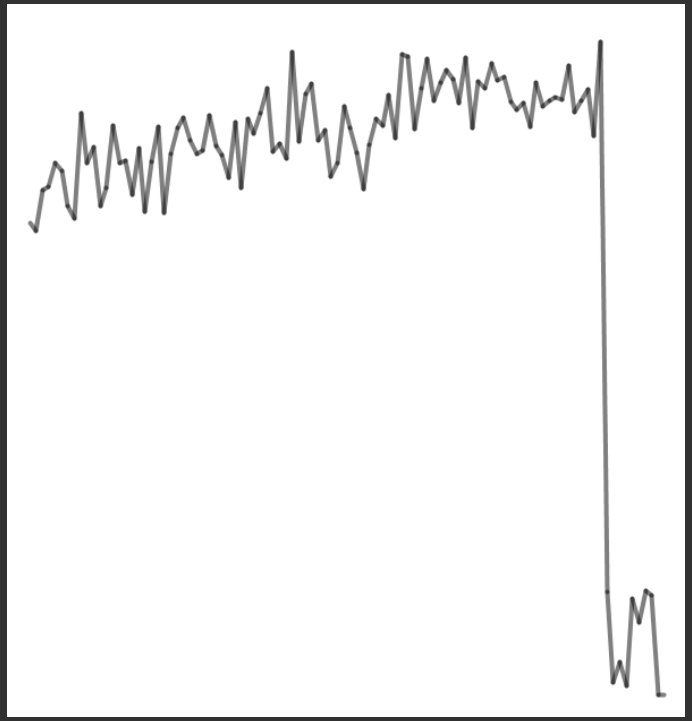
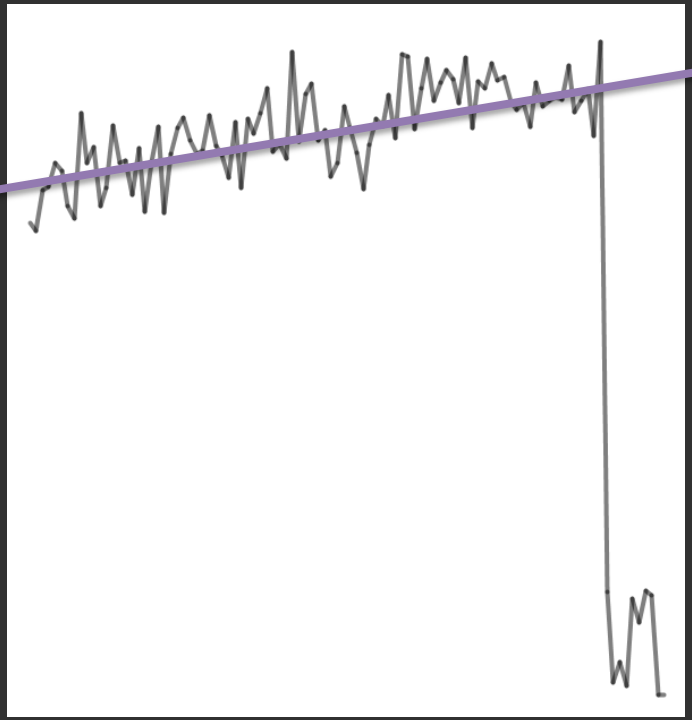
~~Gaussian residuals~~



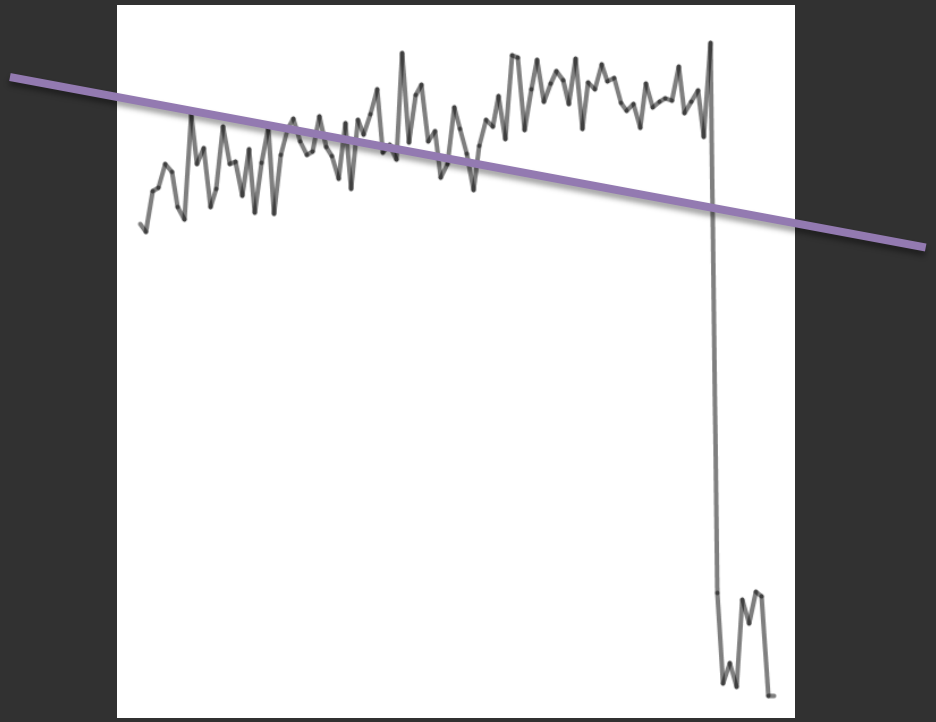
What Should We Do?



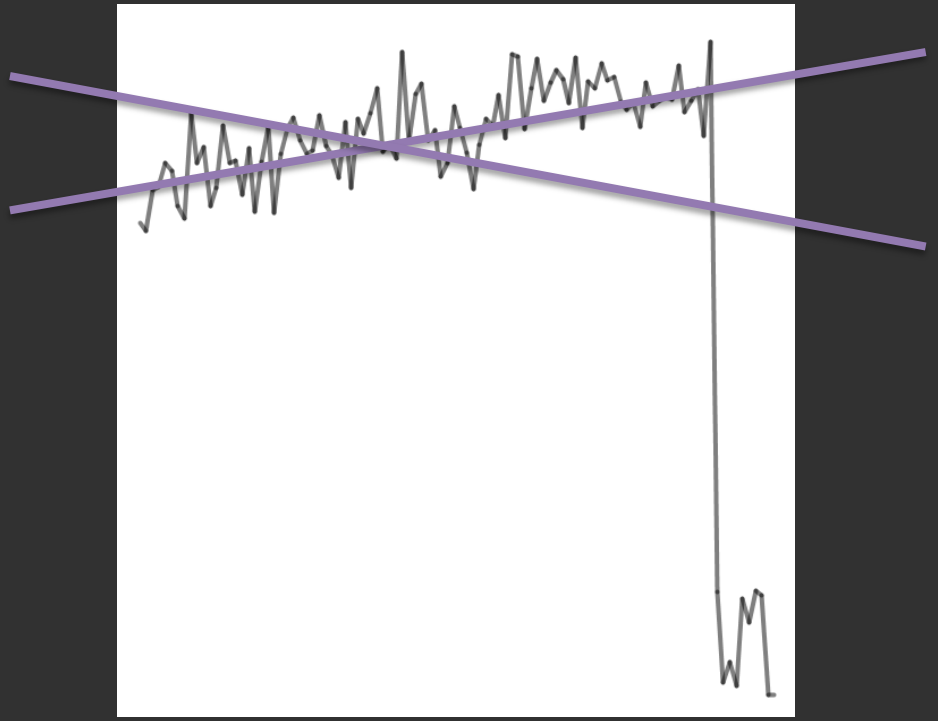
Ignore the outliers?



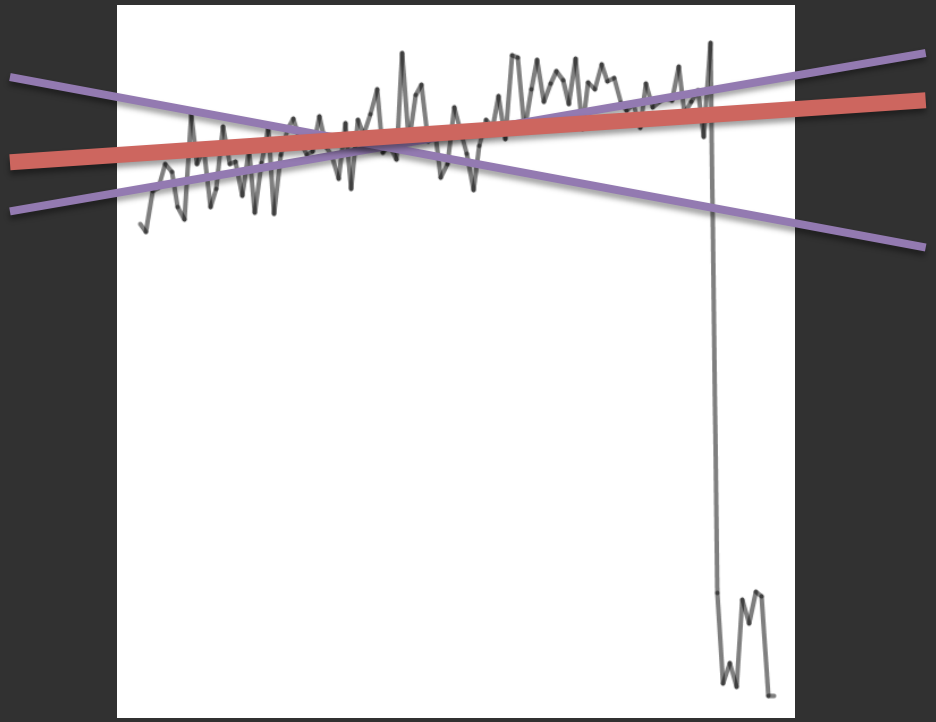
Consider the outliers?



Results



A little of both?



Regression by Eye

Are we good at it?

Does it line up with the stats?

Should designers intervene?

Regression by Eye

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Chart Types

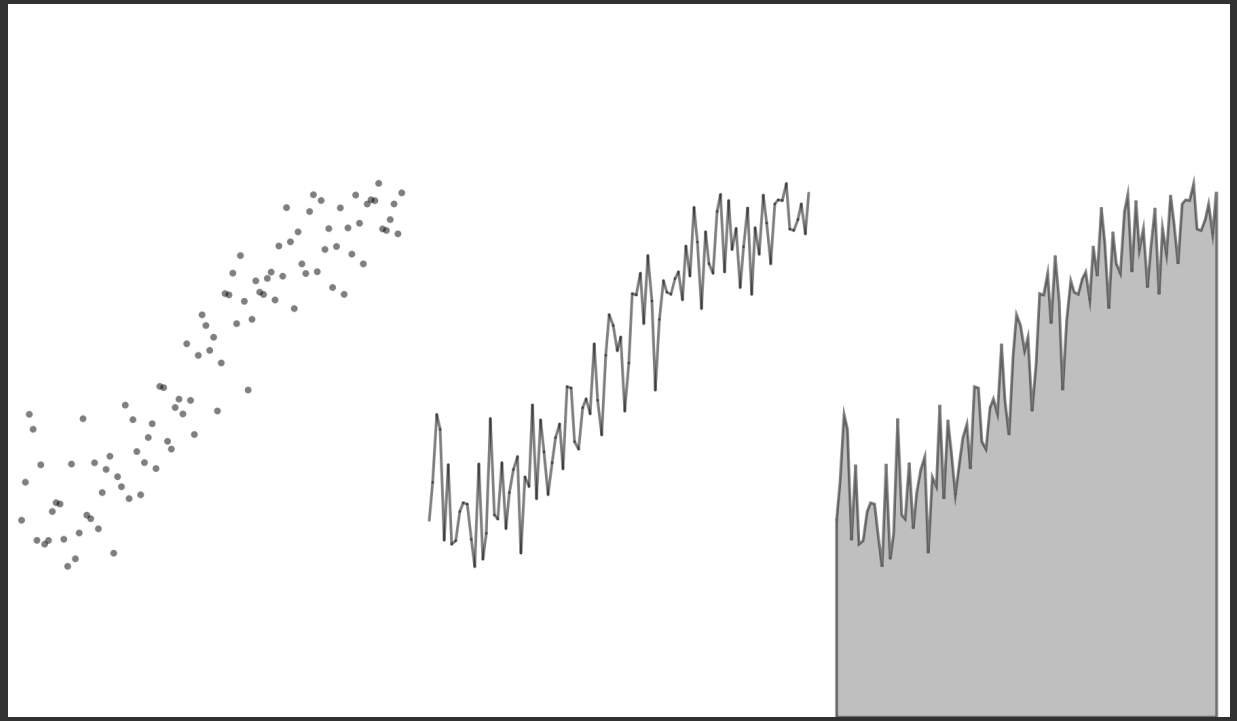


Chart Types

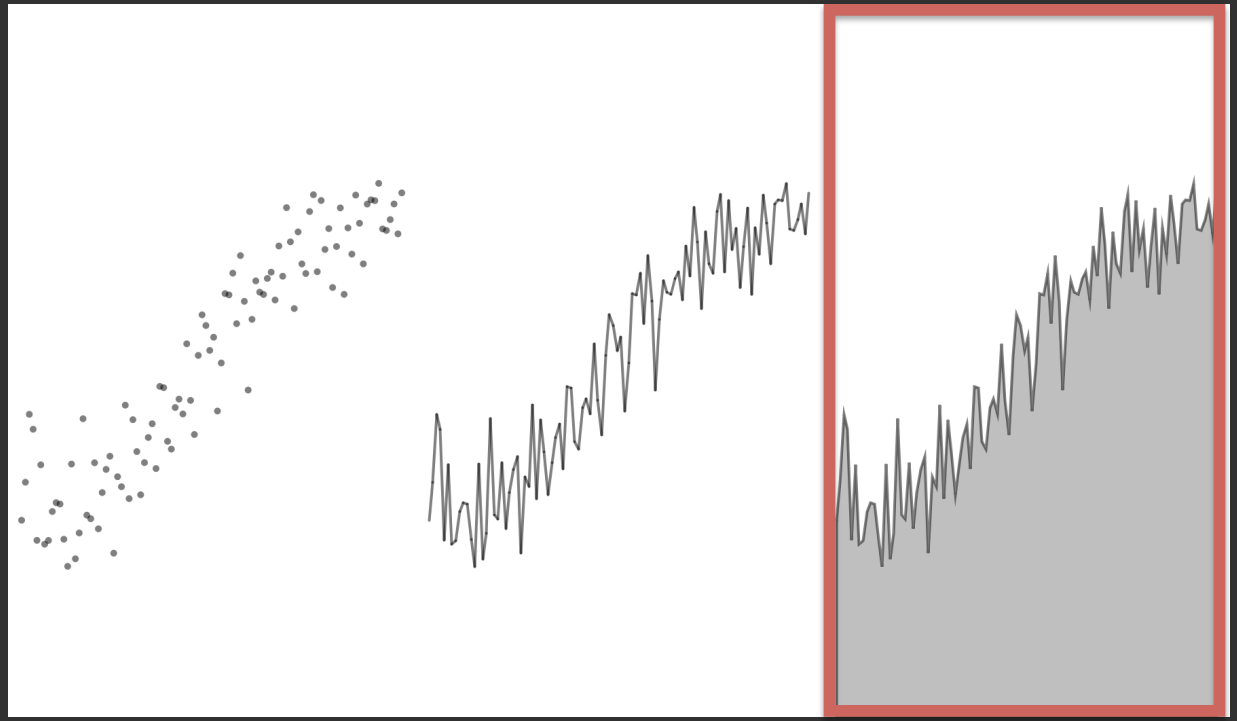


Chart Types

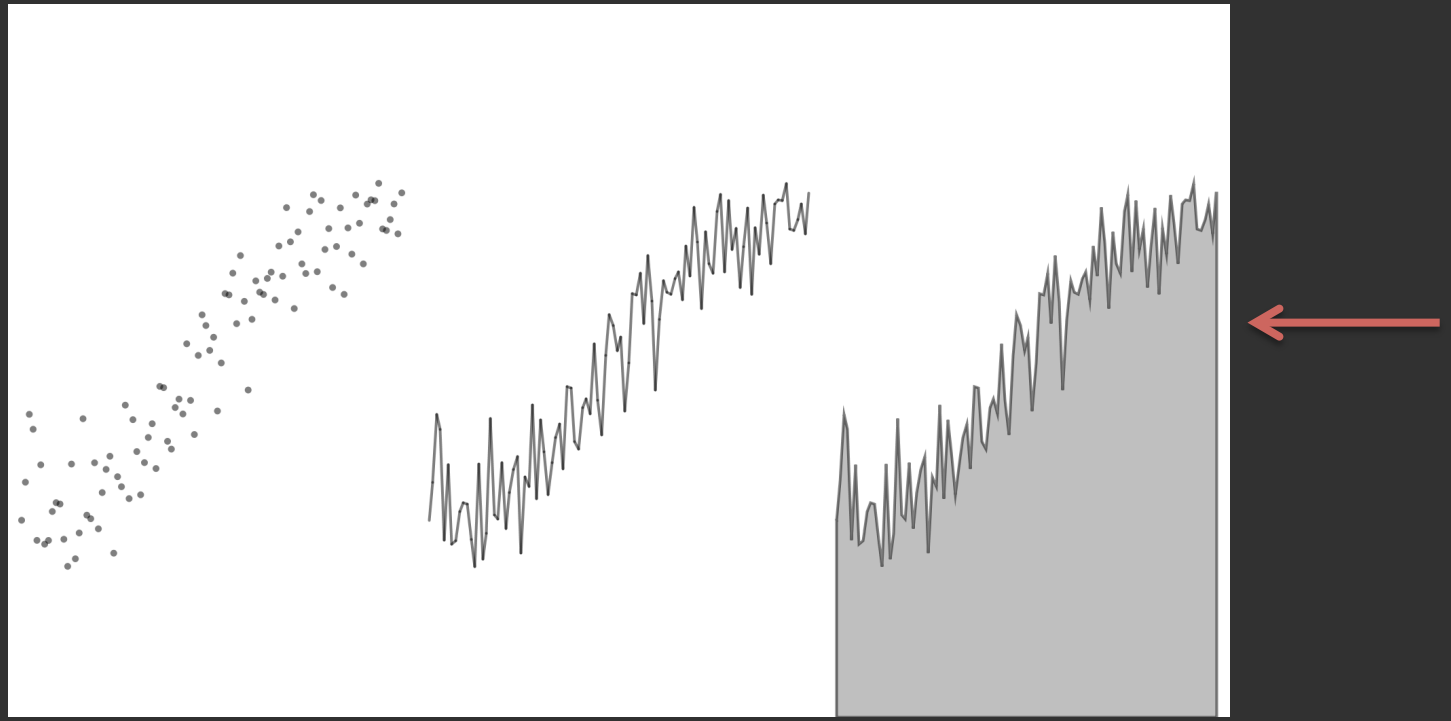
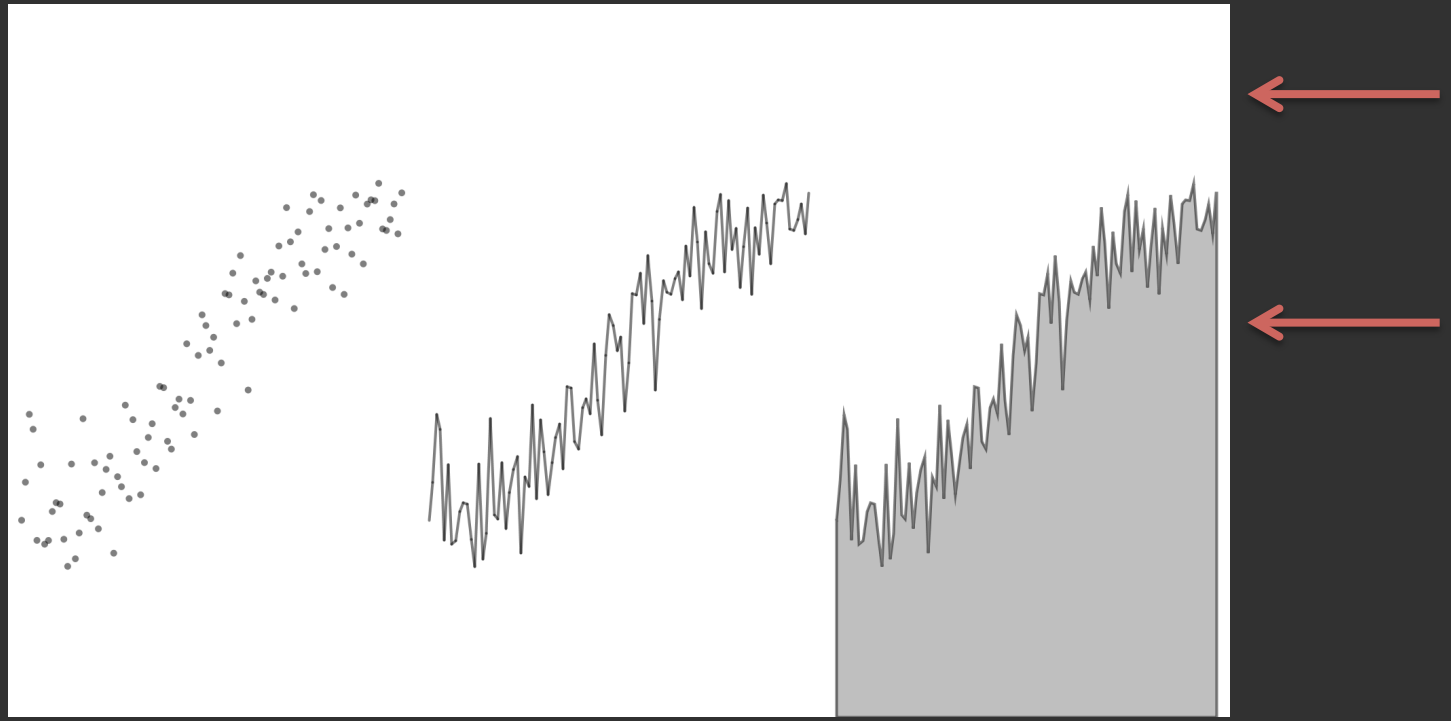
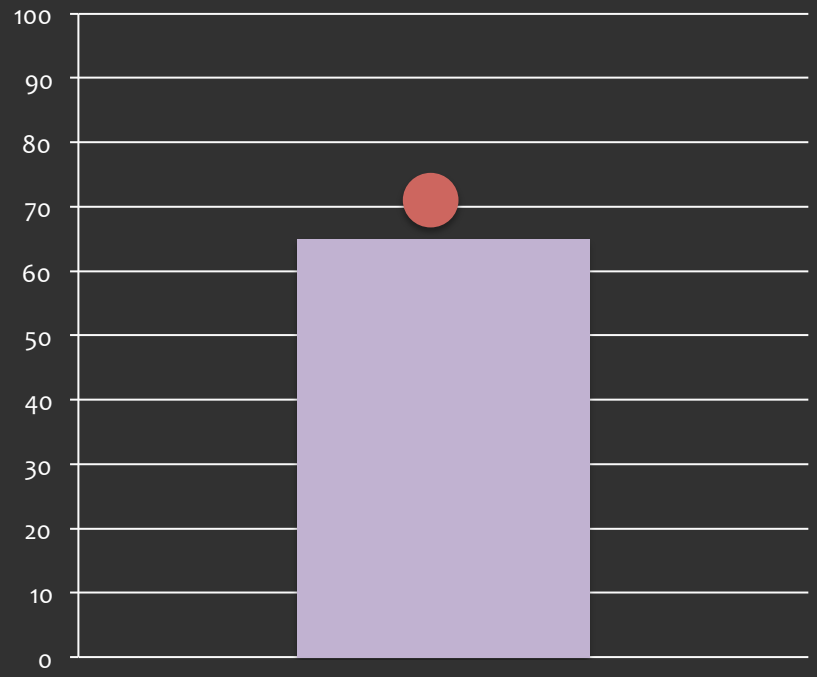
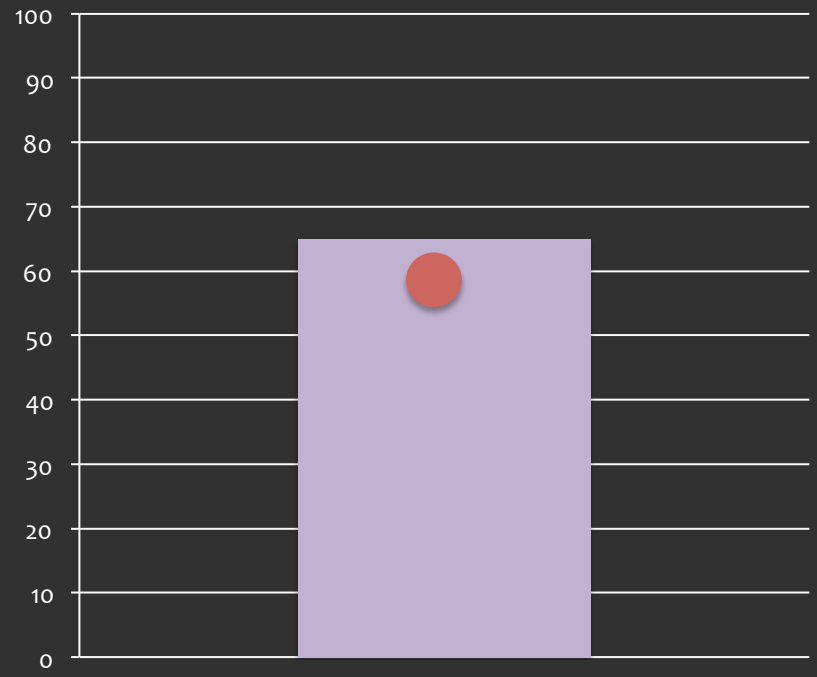


Chart Types



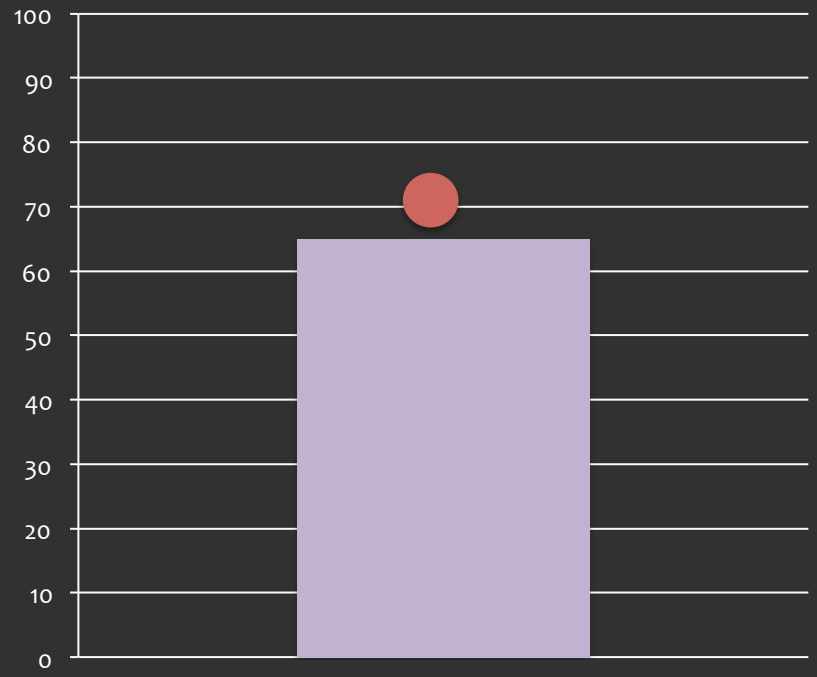
Within-the-bar bias

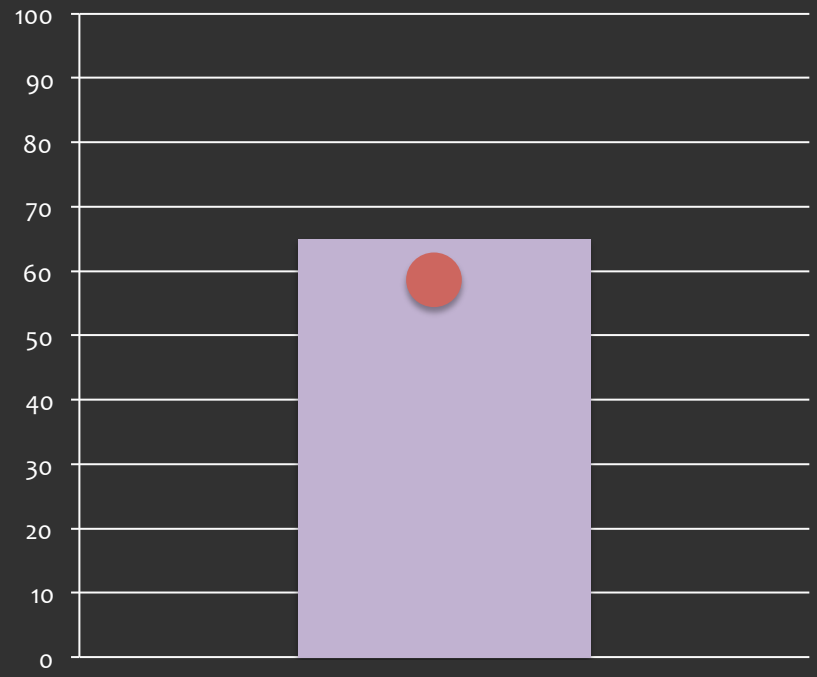




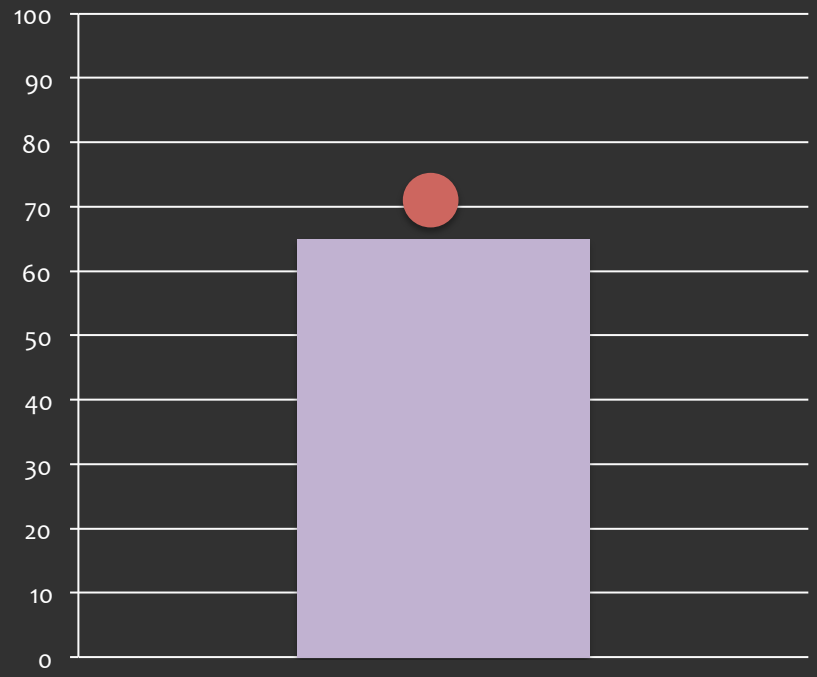
Newman, George E, and Brian J Scholl. "Bar graphs depicting averages are perceptually misinterpreted: the within-the-bar bias." Psychonomic bulletin & review 19.4 (2012): 601–7.

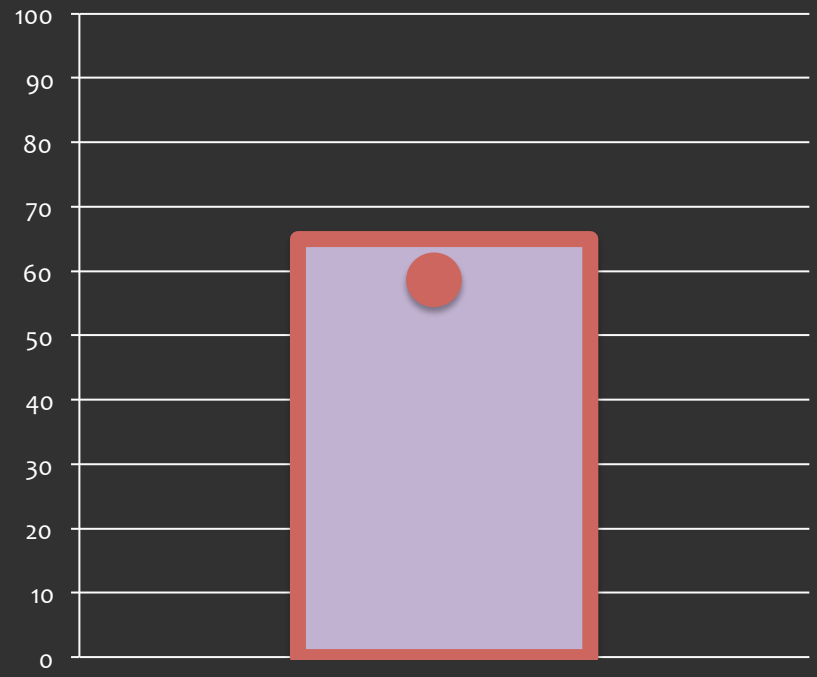
Within-the-bar bias



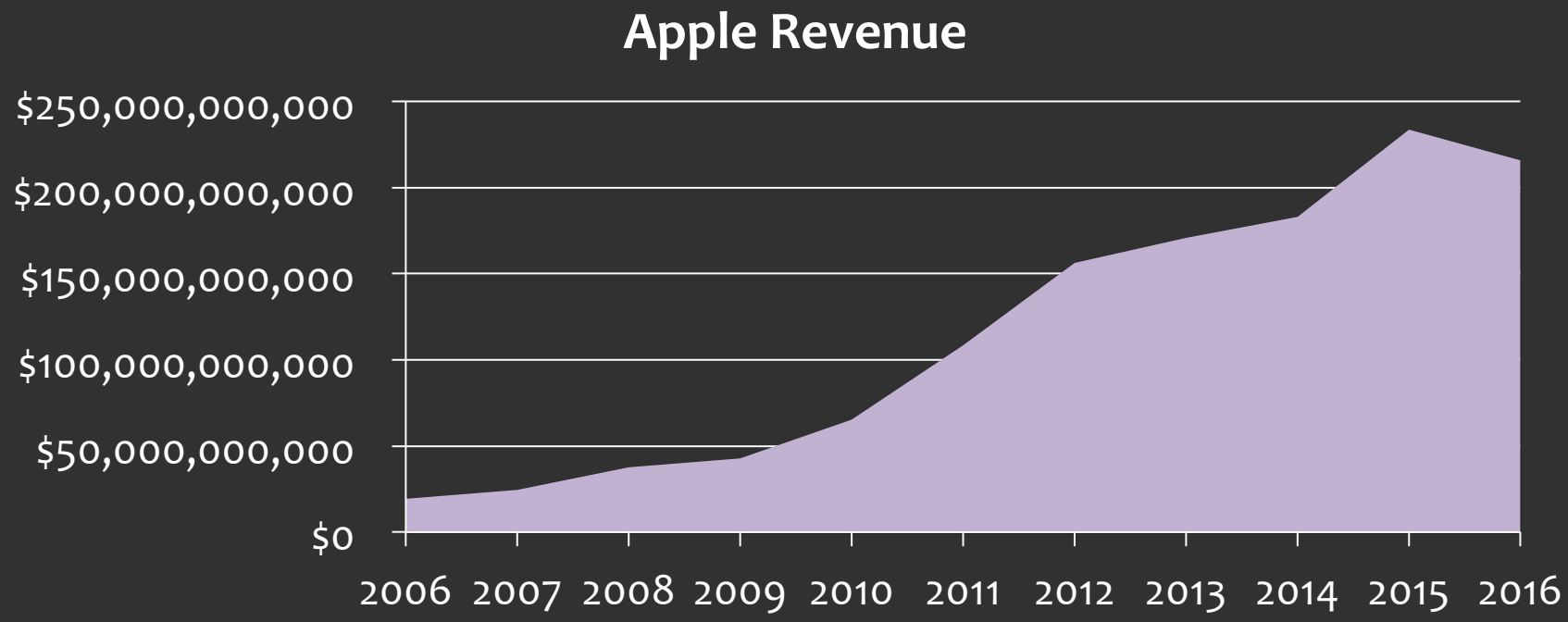


Within-the-bar bias

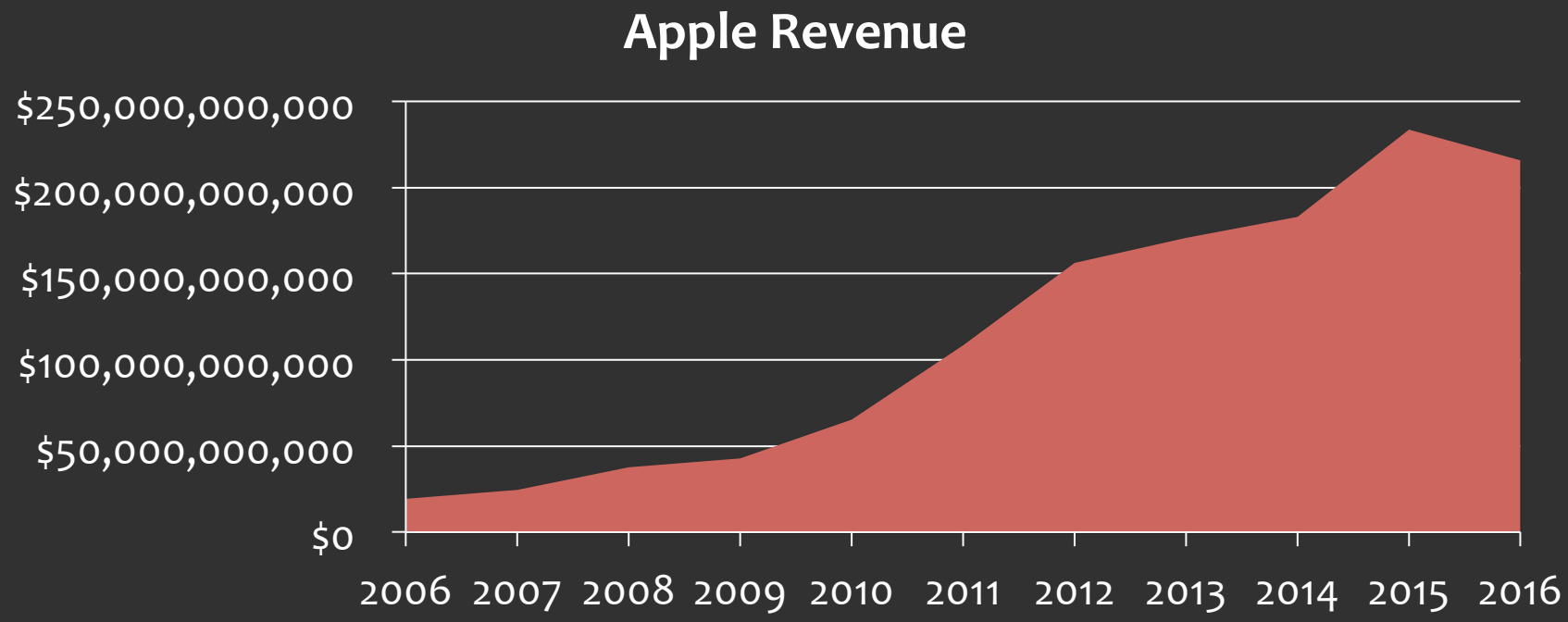




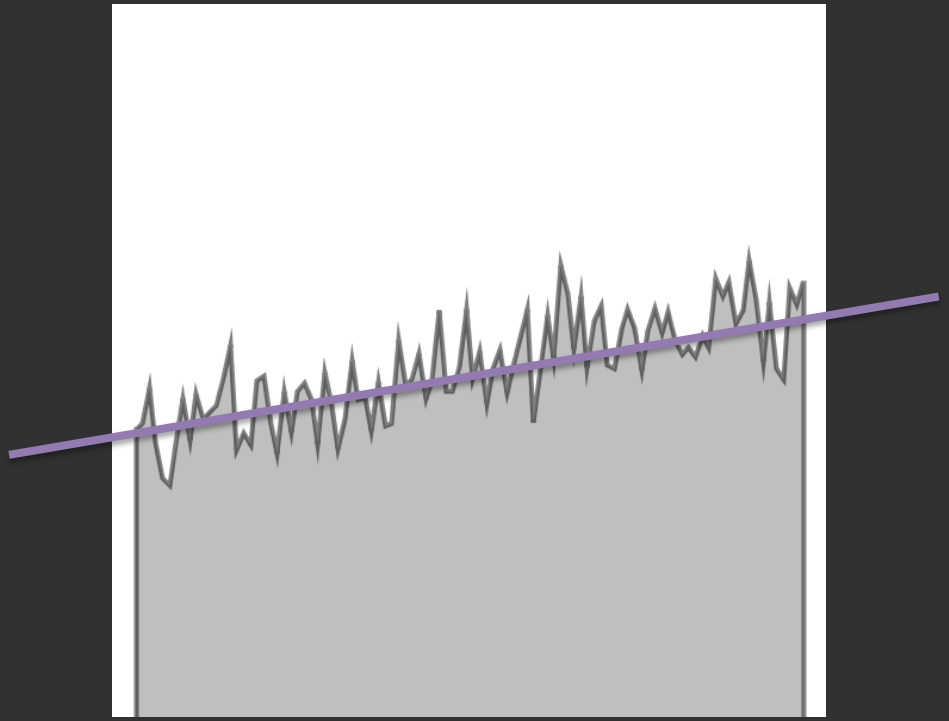
Visual Asymmetry



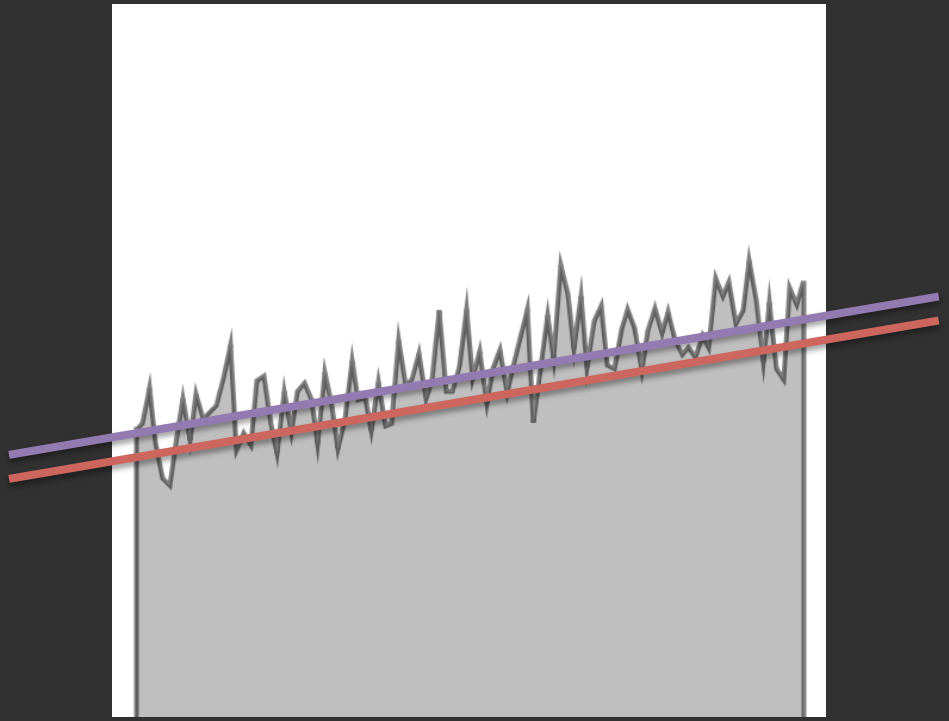
Visual Asymmetry



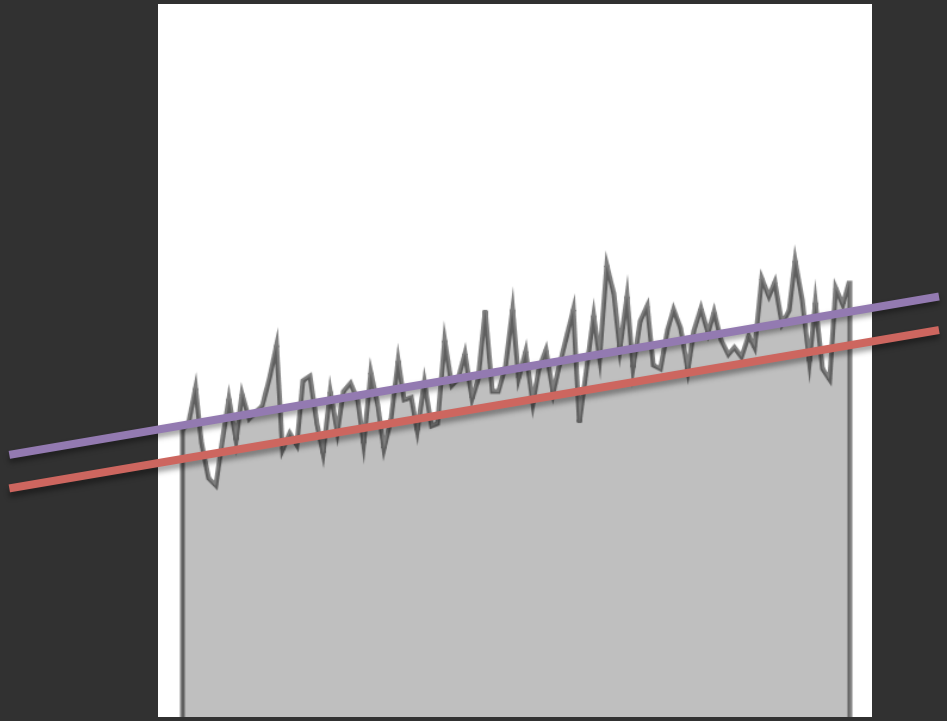
Within-the-area bias

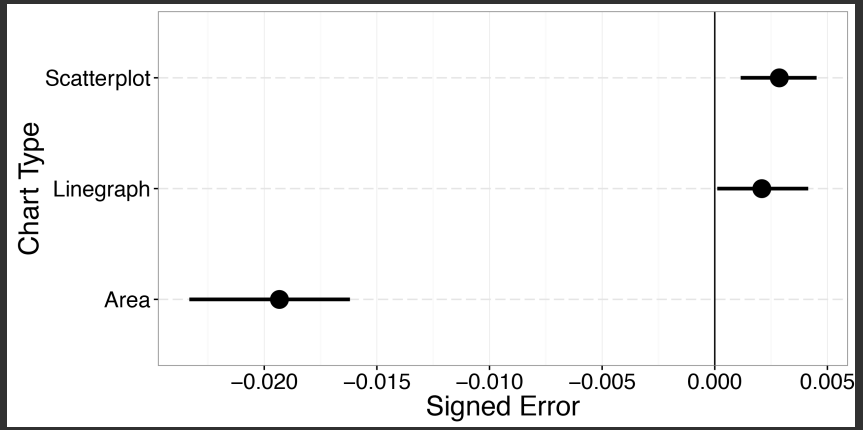


Within-the-area bias

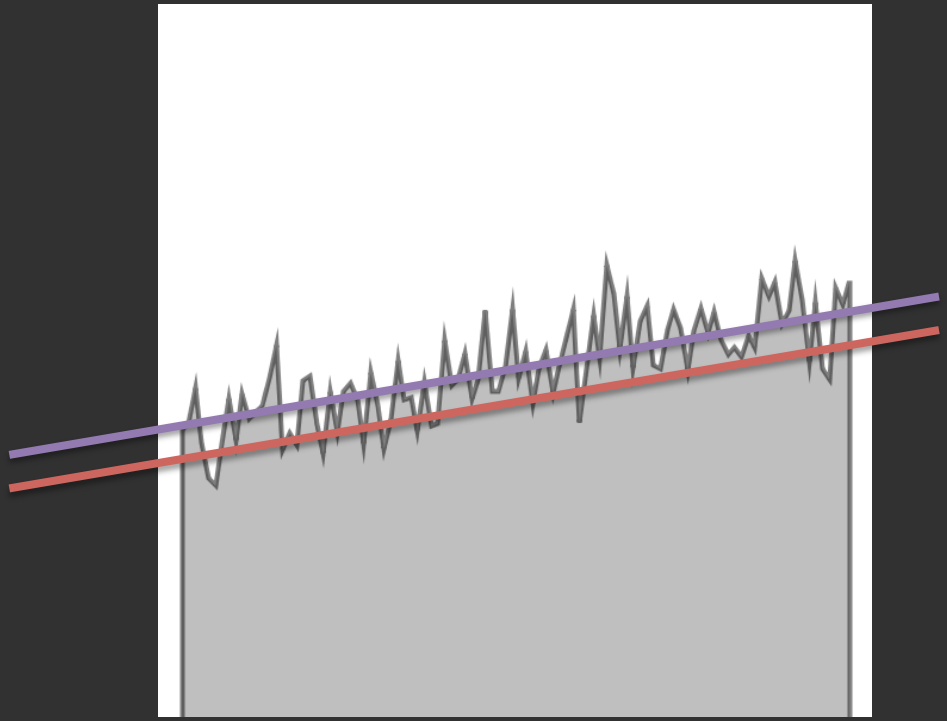


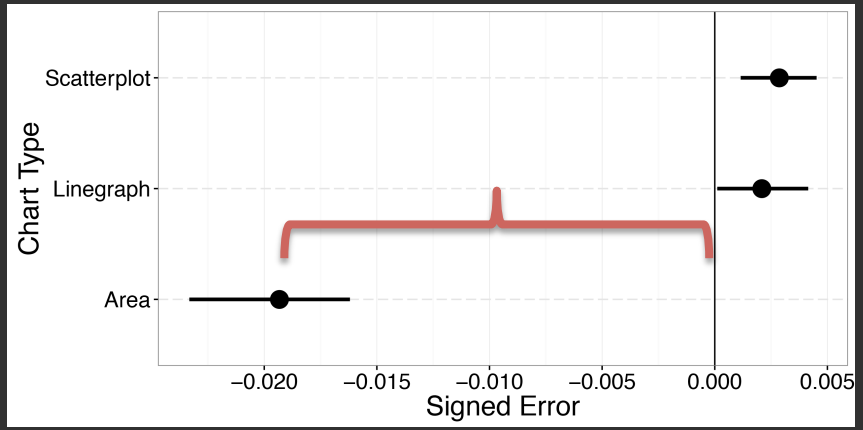
Within-the-area bias



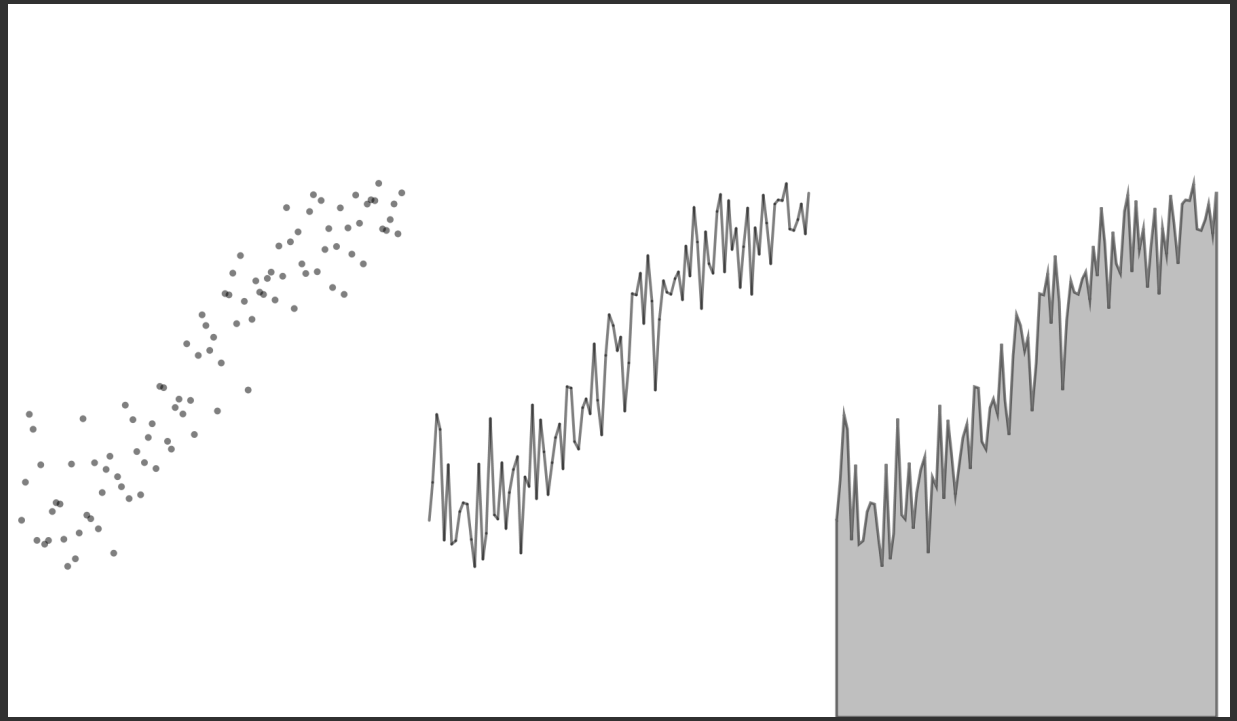


Within-the-area bias

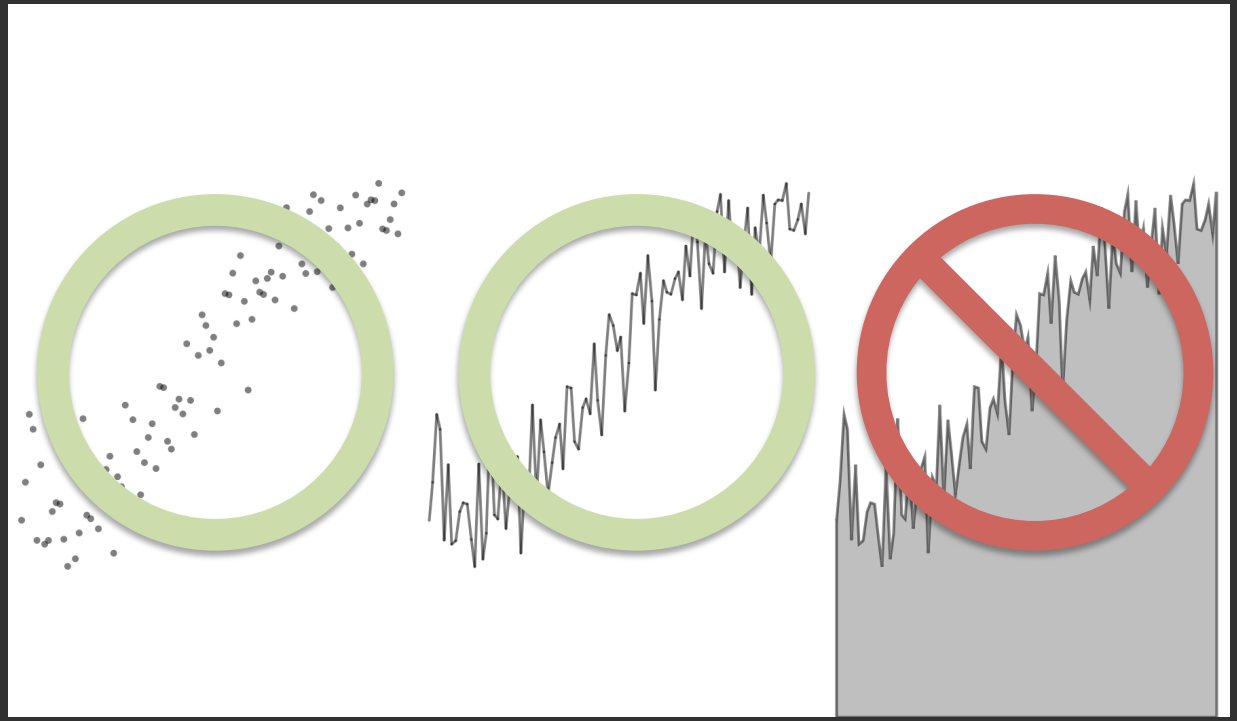




Avoid Asymmetry!



Avoid Asymmetry!



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SOMETIMES

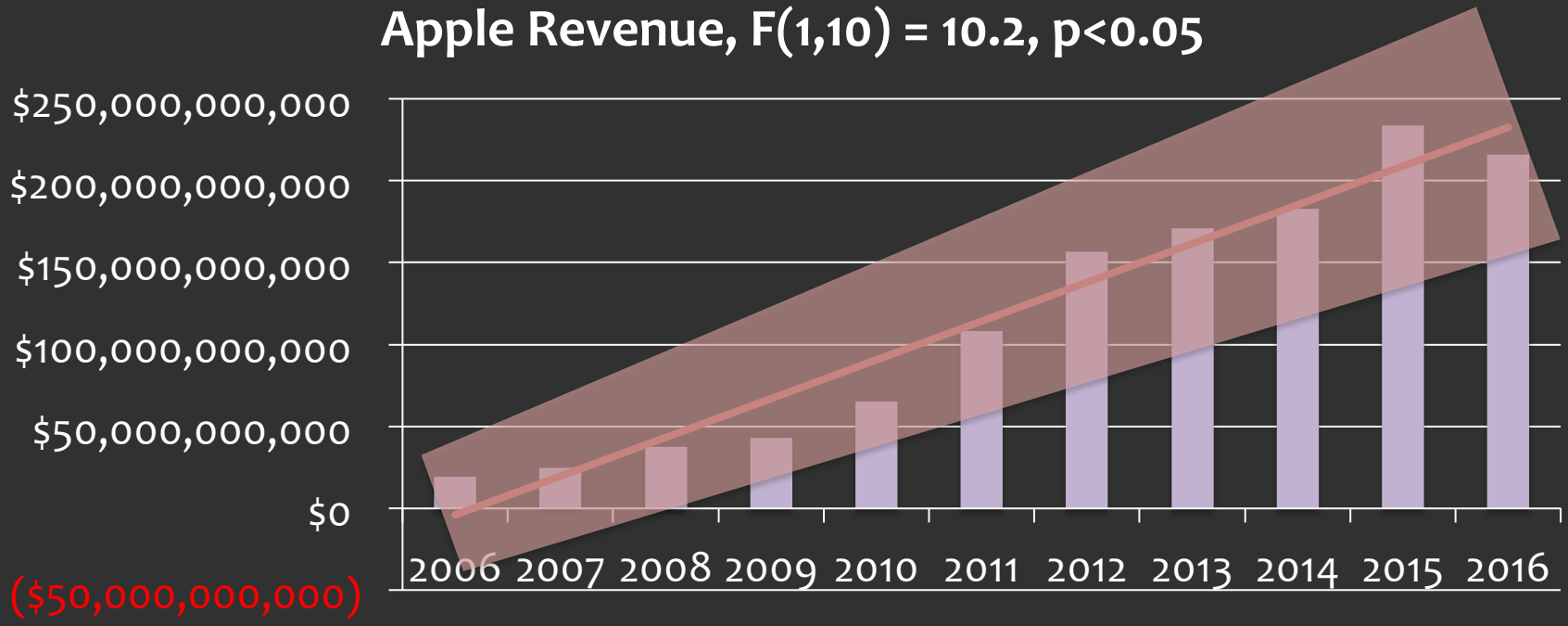
Future Work

Conveying Uncertainty

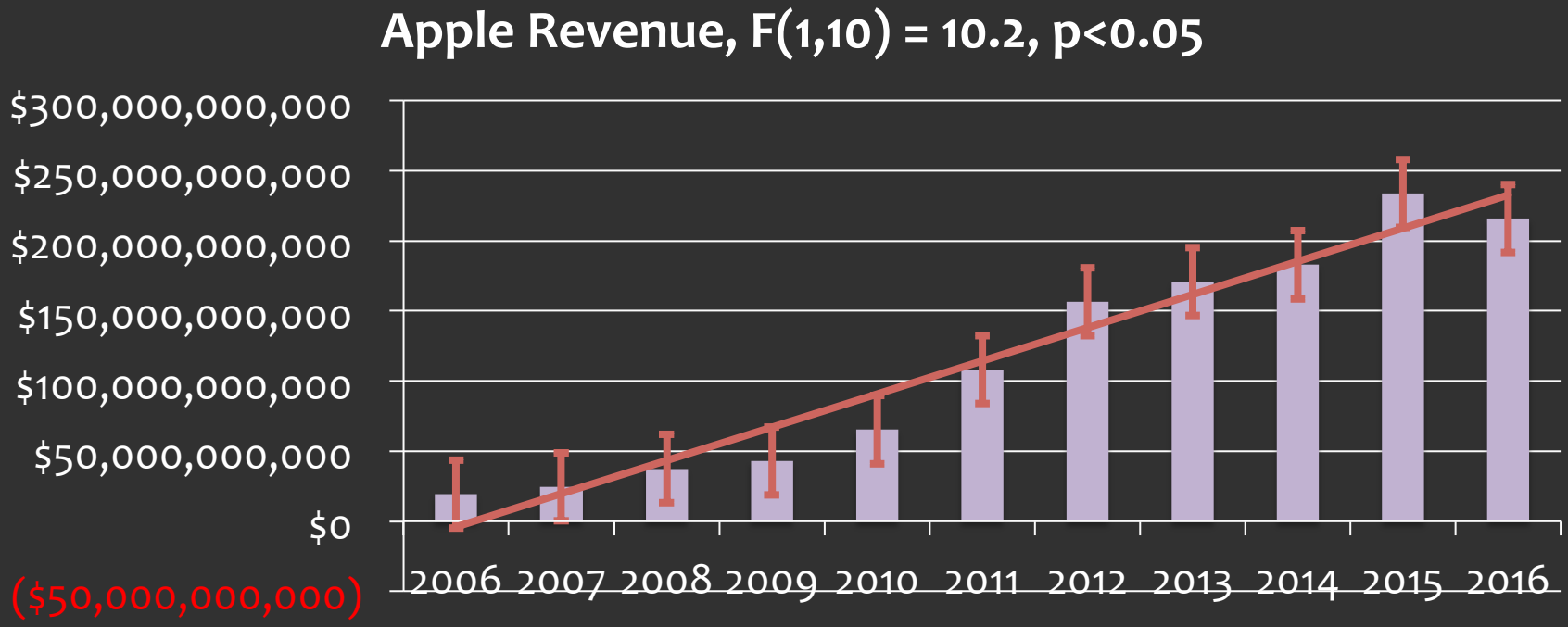
Nudges

Conveying Uncertainty

Conveying Uncertainty

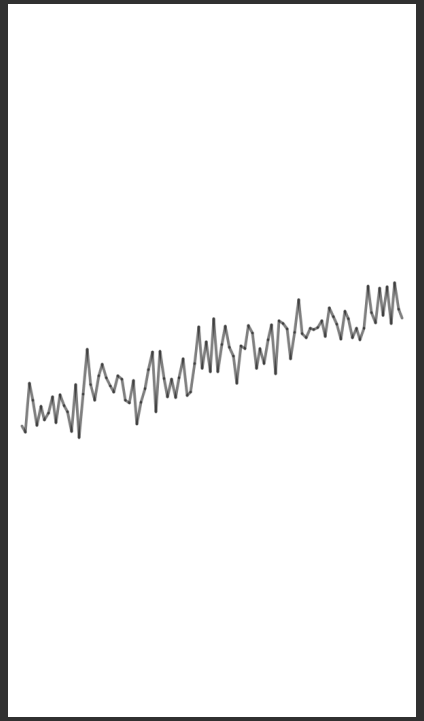


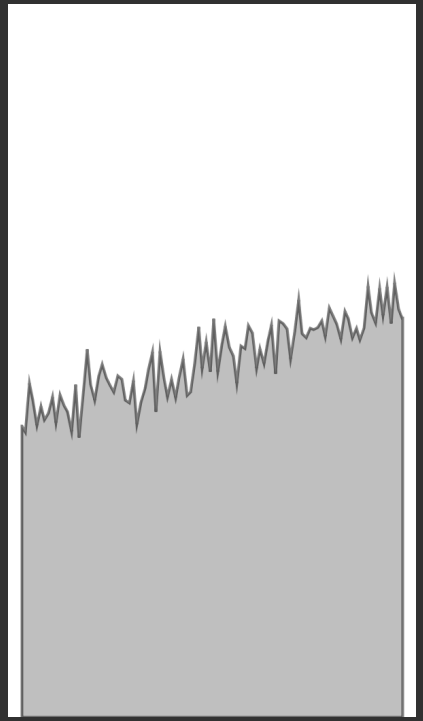
Conveying Uncertainty



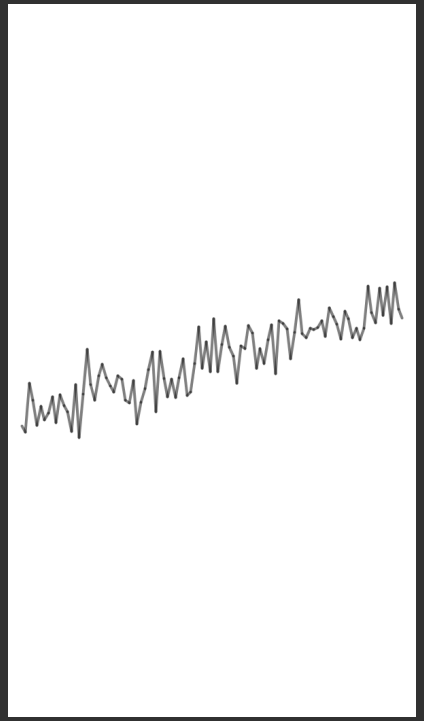
Nudges

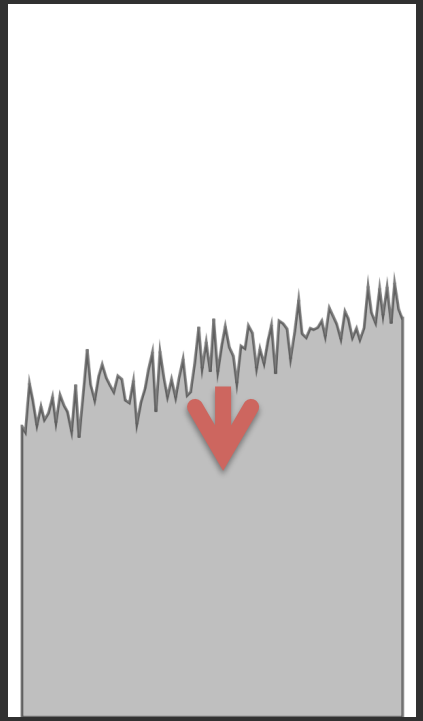
Nudges



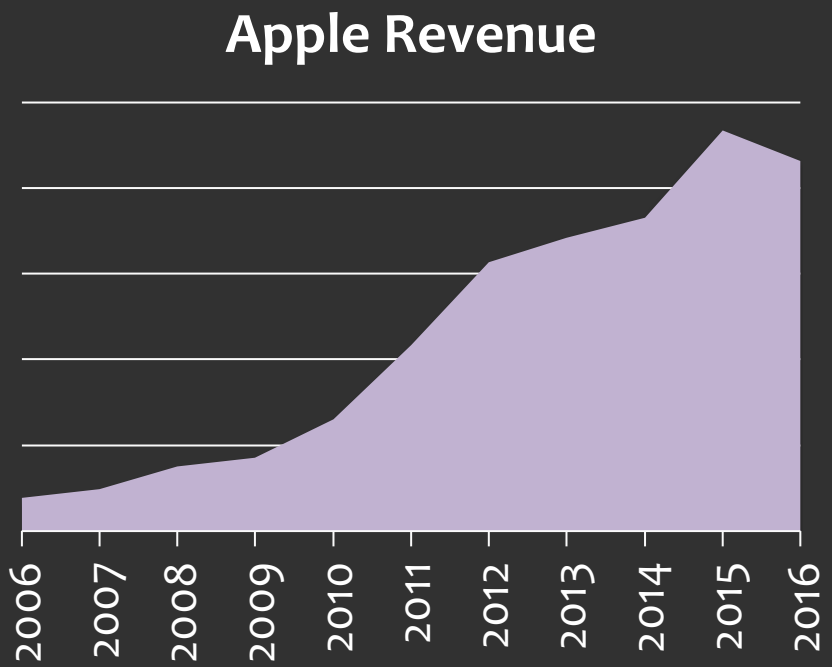


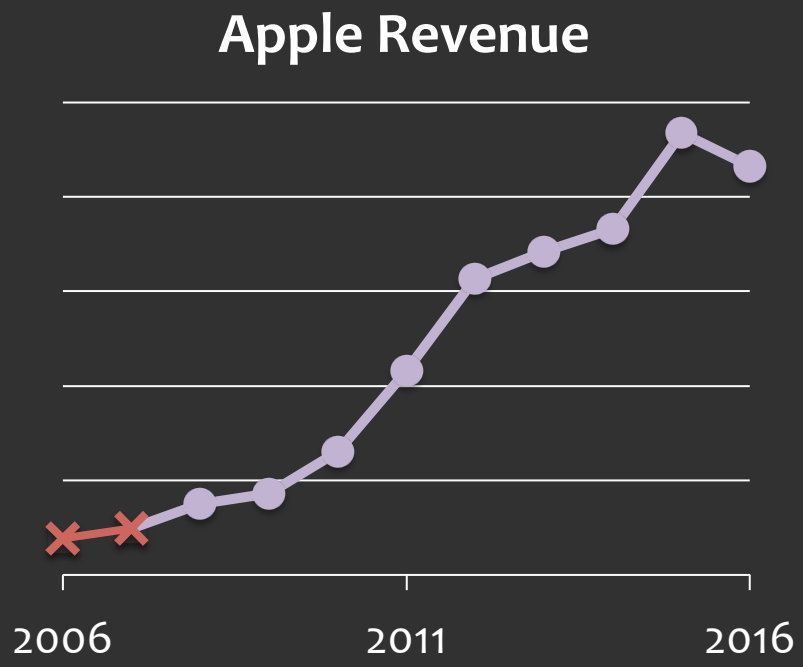
Nudges



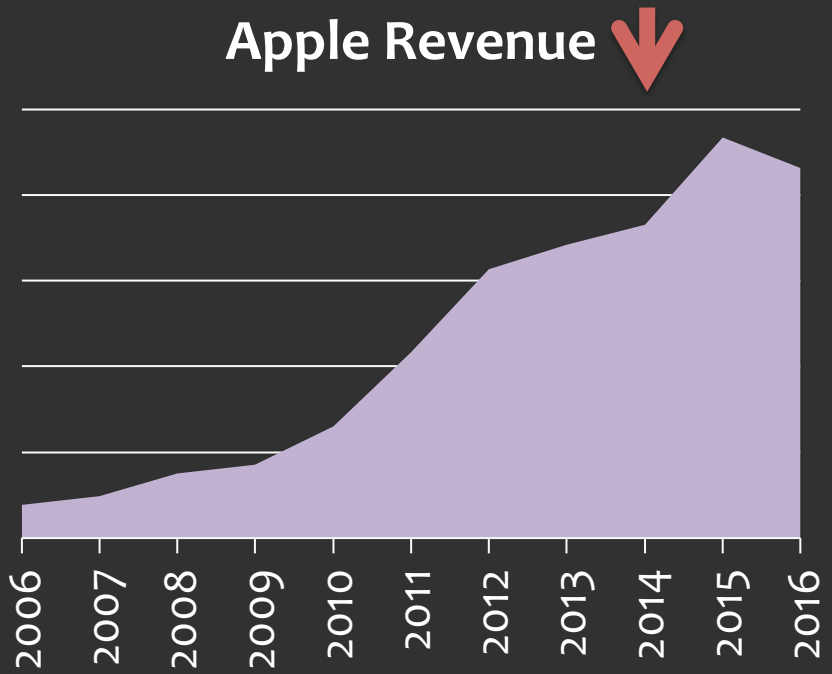


Nudges


Apple Revenue
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016


Apple Revenue
2006
2011
2016

Nudges


Apple Revenue
2006
2007
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2012
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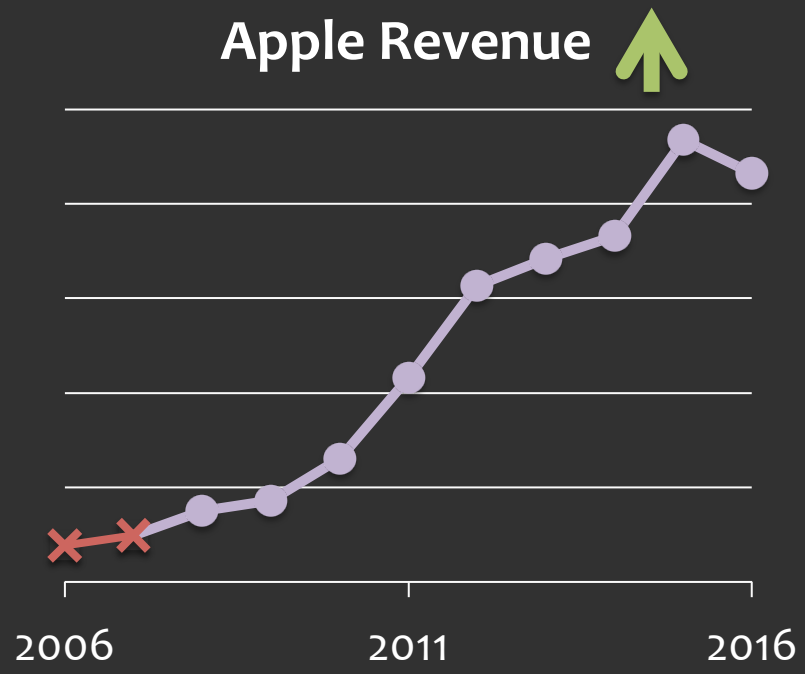
2014
2015
2016


Apple Revenue
2006
2011
2016

Conclusion

We can rely on regression by eye!

Conclusion

We can rely on regression by eye…

in that our visual estimates of trends in data with unimodal residuals are unbiased, and generally similar to statistical methods of regression, with a few key exceptions in the case of asymmetry and outliers.

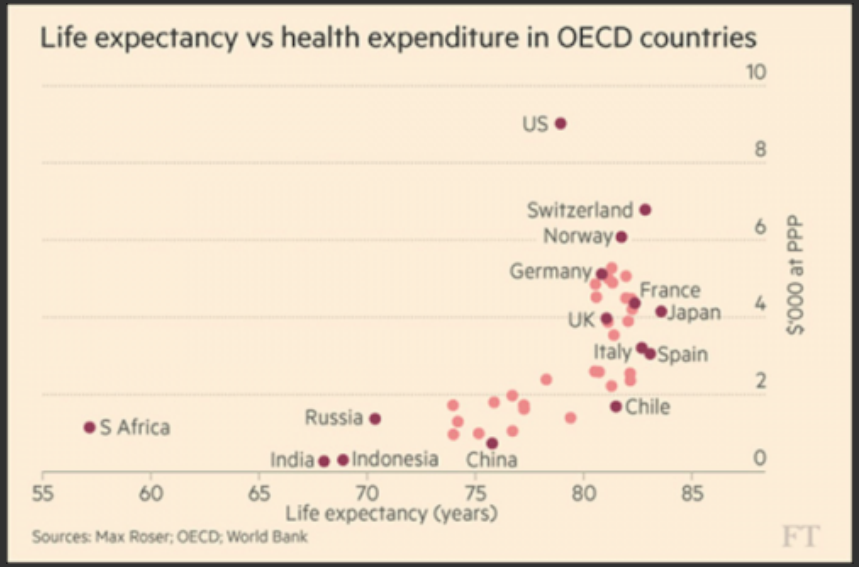
Thanks!

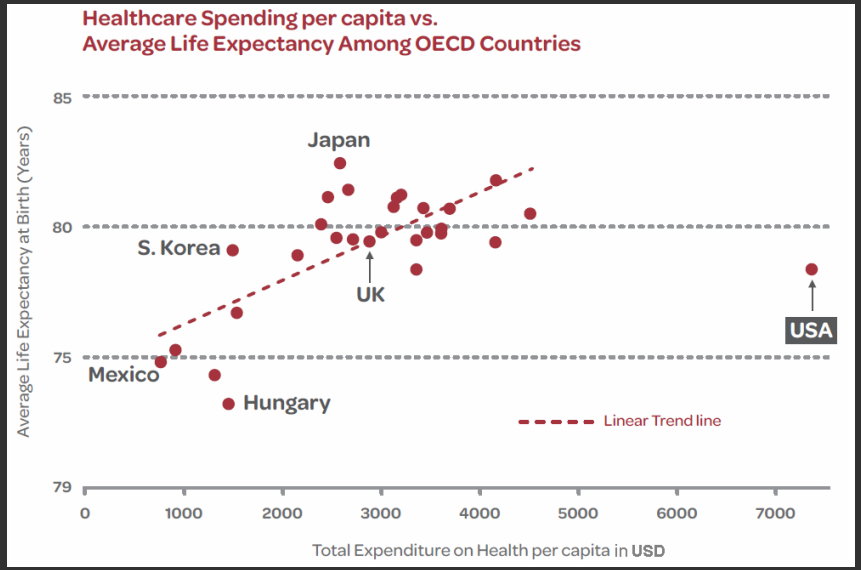
This work was supported by a Moore Foundation Data-Driven Discovery Investigator award.

Materials available at:
https://github.com/uwdata/trend-bias


Extra Slides

Detour

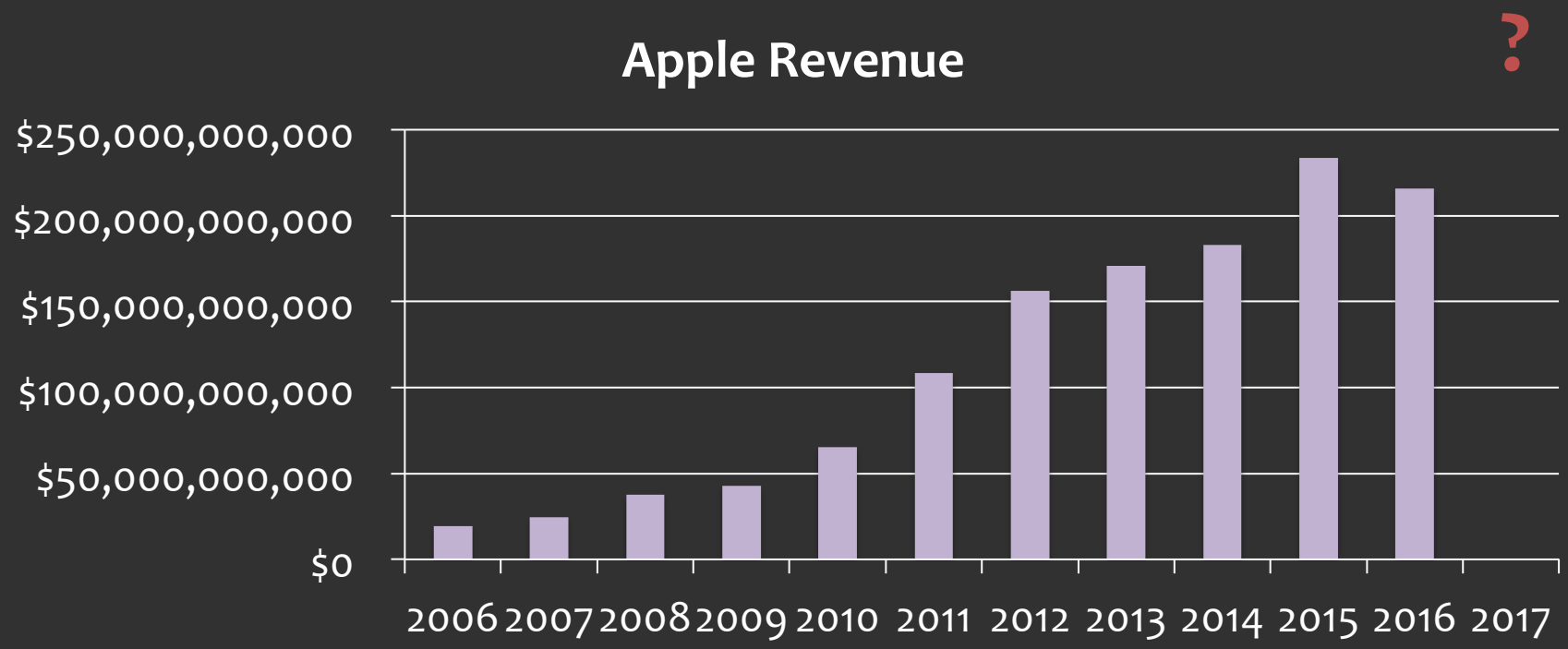

Life expectancy vs health expenditure in OECD countries
US
Switzerland
Norway
Germany
France
UK
Japan
Italy
Spain
Chile
S Africa
Russia
India
Indonesia
China
10
8
6
4
2
0
$'000 at PPP
55
60
65
70
75
80
85
Life expectancy (years)
Sources: Max Roser; OECD; World Bank
FT


Healthcare Spending per capita vs.
Average Life Expectancy Among OECD Countries
Average Life Expectancy at Birth (Years)
85
80
75
79
Japan
S. Korea
UK
USA
Mexico
Hungary
Linear Trend line
0
1000
2000
3000
4000
5000
6000
7000
Total Expenditure on Health per capita in USD

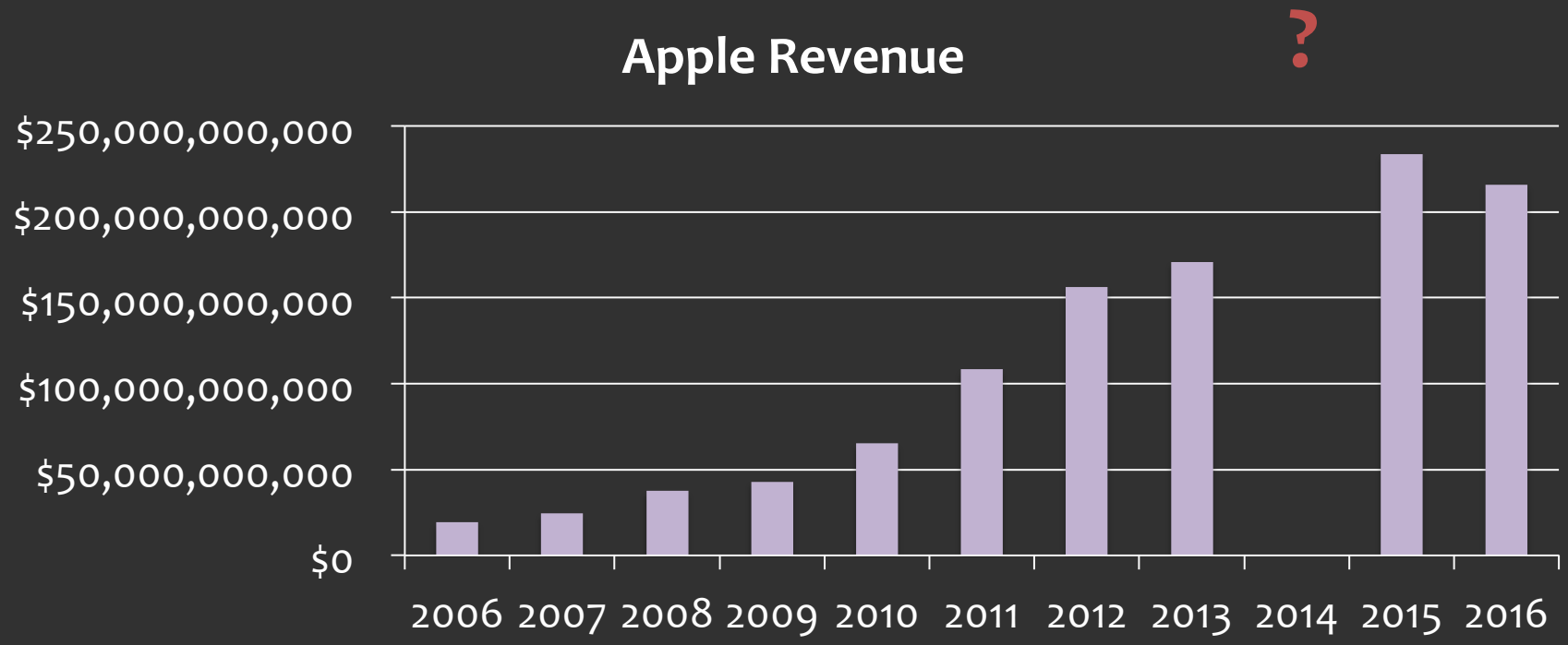
Measuring Regression by Eye

Model Selection
Model Fitting
Outlier Detection
Prediction
Correlation
…

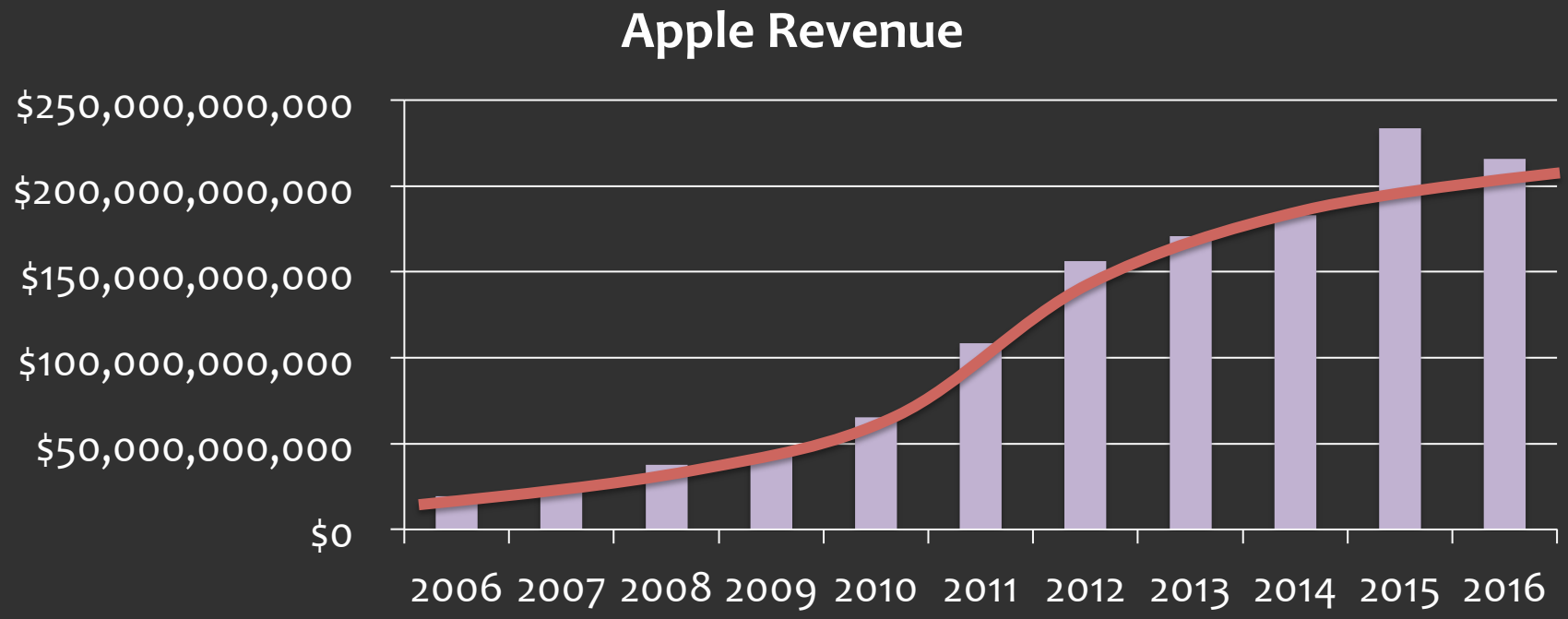
Prediction


Apple Revenue
?
$250,000,000,000
$200,000,000,000
$150,000,000,000
$100,000,000,000
$50,000,000,000
$0
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

Imputation


Apple Revenue
?
$250,000,000,000
$200,000,000,000
$150,000,000,000
$100,000,000,000
$50,000,000,000
$0
2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016

Free Drawing



Measuring Regression by Eye

Model Selection
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…

Experimental Task