Behavioral bias in number processing: Evidence from analysts' expectations

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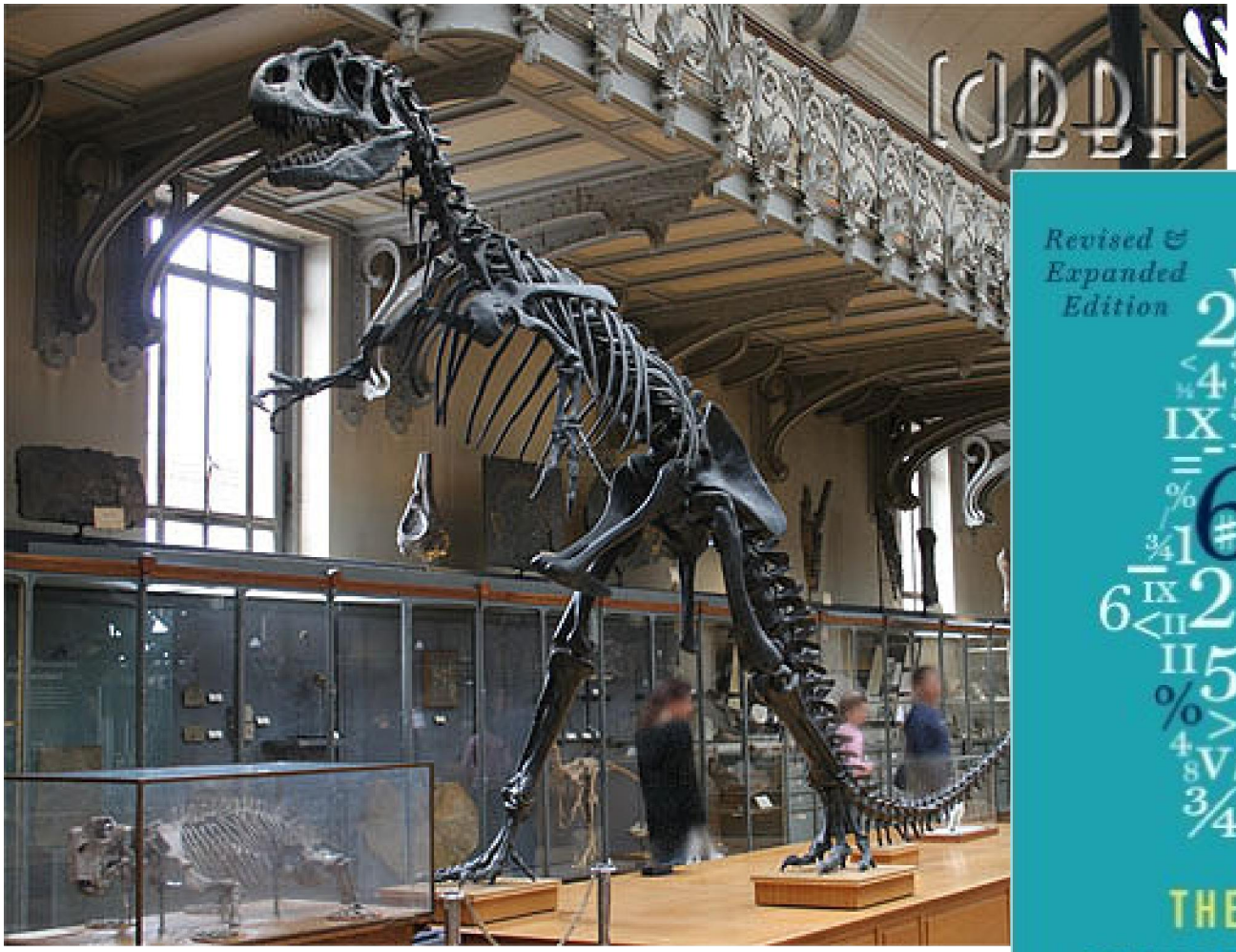

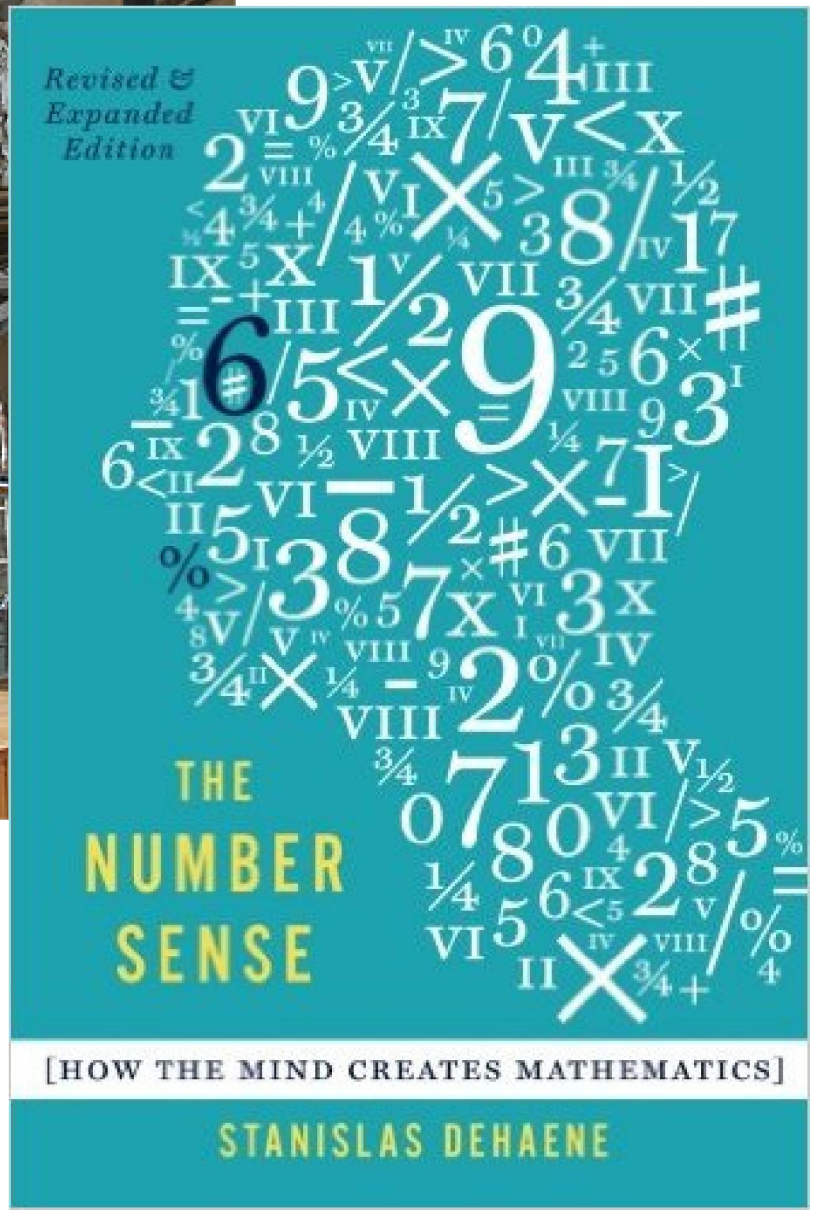
Revised & Expanded Edition
THE NUMBER SENSE
[HOW THE MIND CREATES MATHEMATICS]
STANISLAS DEHAENE

Introduction

Database and descriptive statistics

Univariate analysis

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Conclusion

Introduction

- The human brain processes numbers on a mental number line
  - Small numbers are represented on the left part of the line
  - Large numbers are represented on the right part of the line
    - The opposite is observed in cultures where people write from the right to the left

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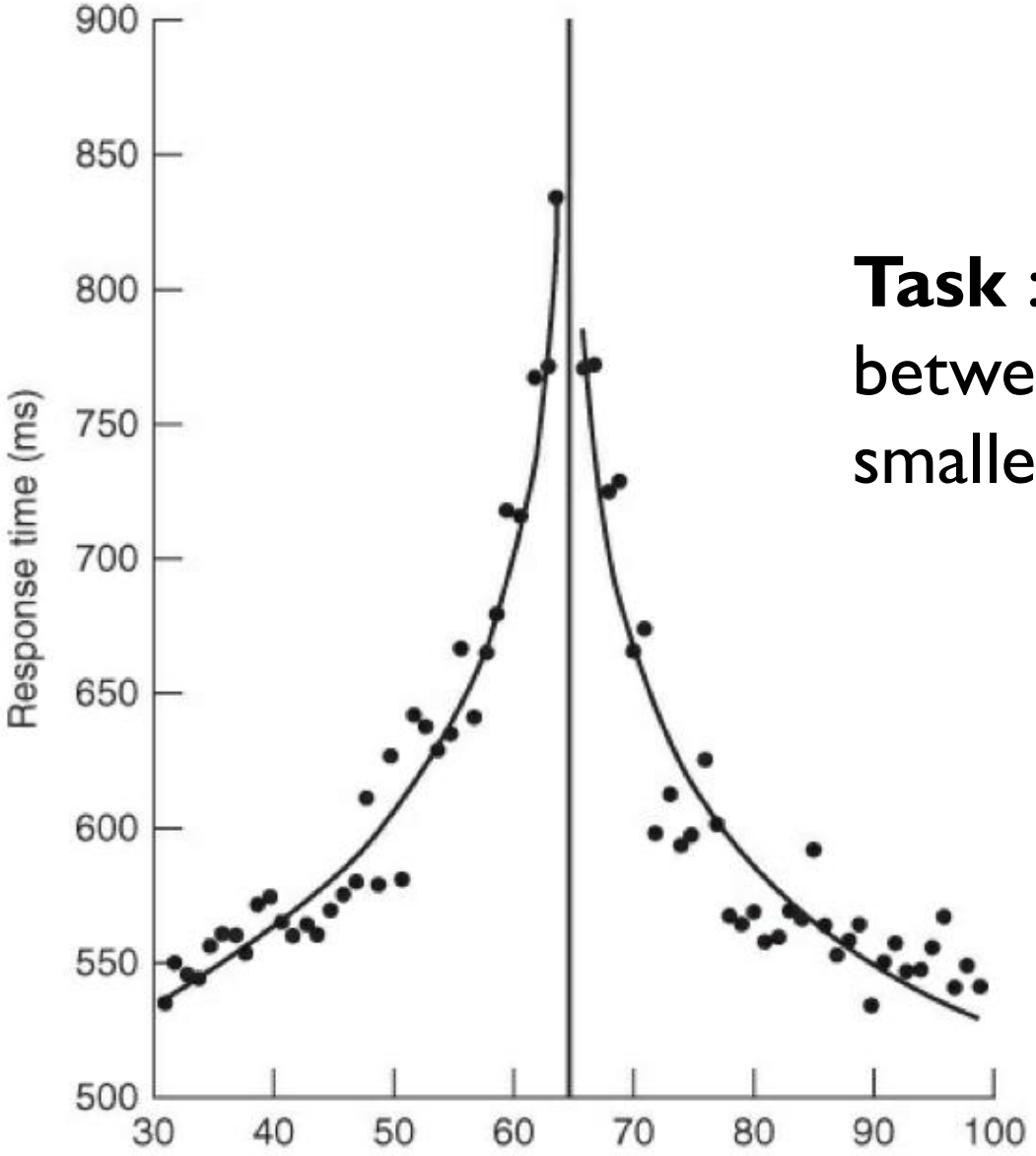
- Number processing (Weber's law)
  - Distance effect
    - Faster to recognize that 10 is greater than 1 than to perceive that 6 is greater than 5

Illustration of the distance effect



Task : classify numbers between 31 and 99 as being smaller or larger than 65

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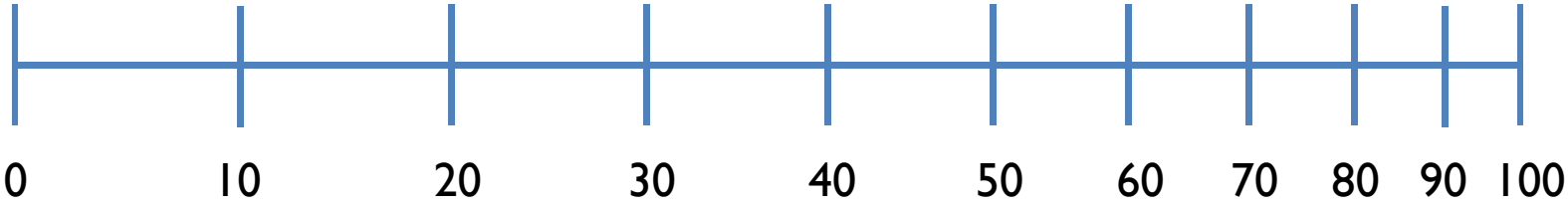
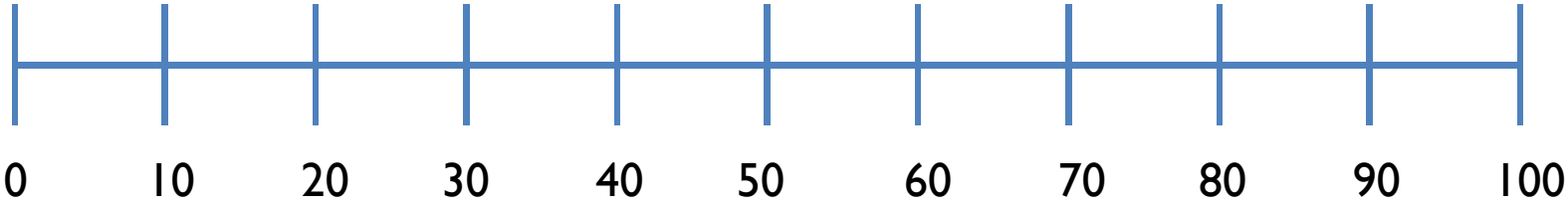
- Number processing (Weber's law)
  - Distance effect
    - Faster to recognize that 10 is greater than 1 than to perceive that 6 is greater than 5
  - Size effect
    - Faster to recognize that 6 is greater than 5 than to perceive that 35 is greater than 34
- Numbers are processed by the brain on a logarithmic scale
  - Nieder (2005)
- Deviations from the logarithmic scale are observed for small numbers
  - Dehaene *et al.* (2008); Hyde and Spelke (2009)

Introduction

- Number processing
  - Logarithmic scale



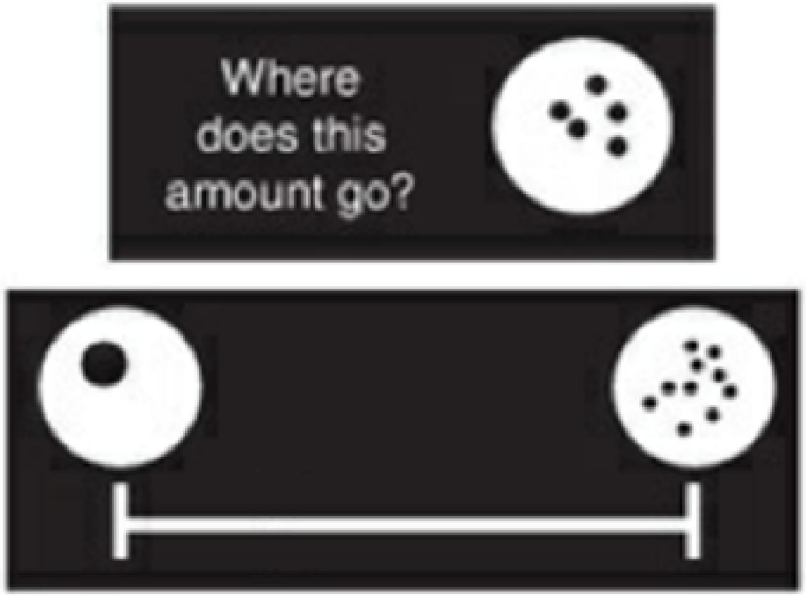
  - Linear scale

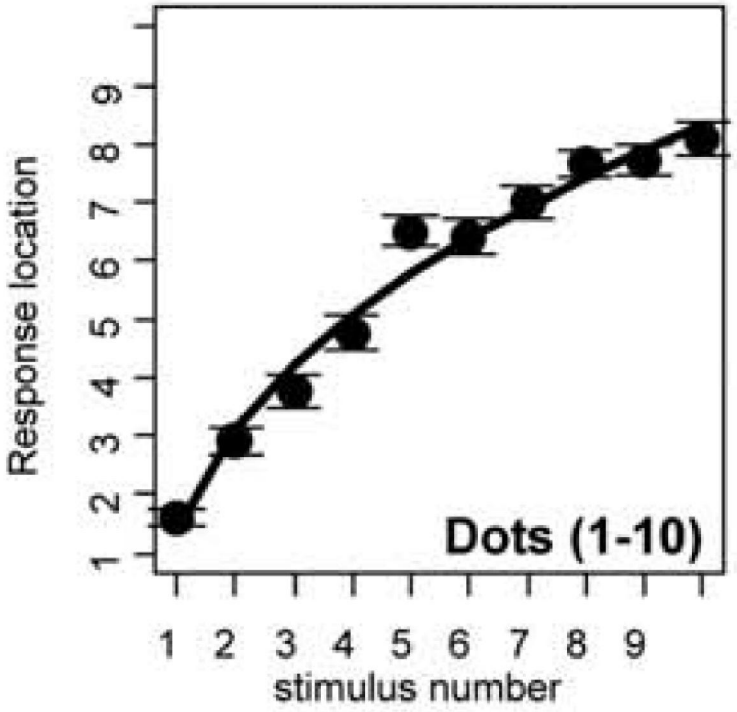


  - Education "linearizes" numerical distances (especially for small numbers)

Introduction

- Results of an experiment on Munduruku adults
  - Dehaene *et al.* (2008)
- Subjects are asked to locate numbers on a line





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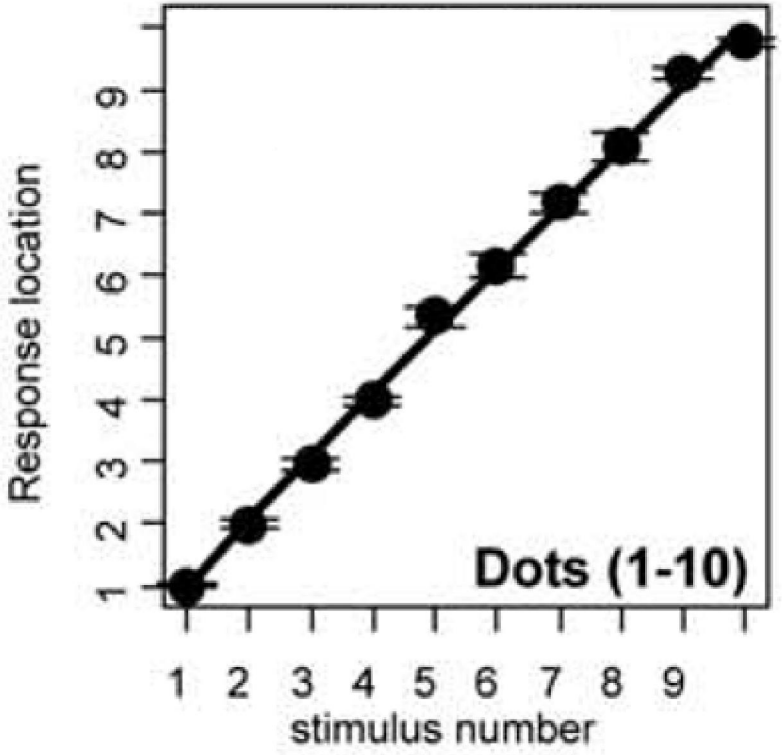
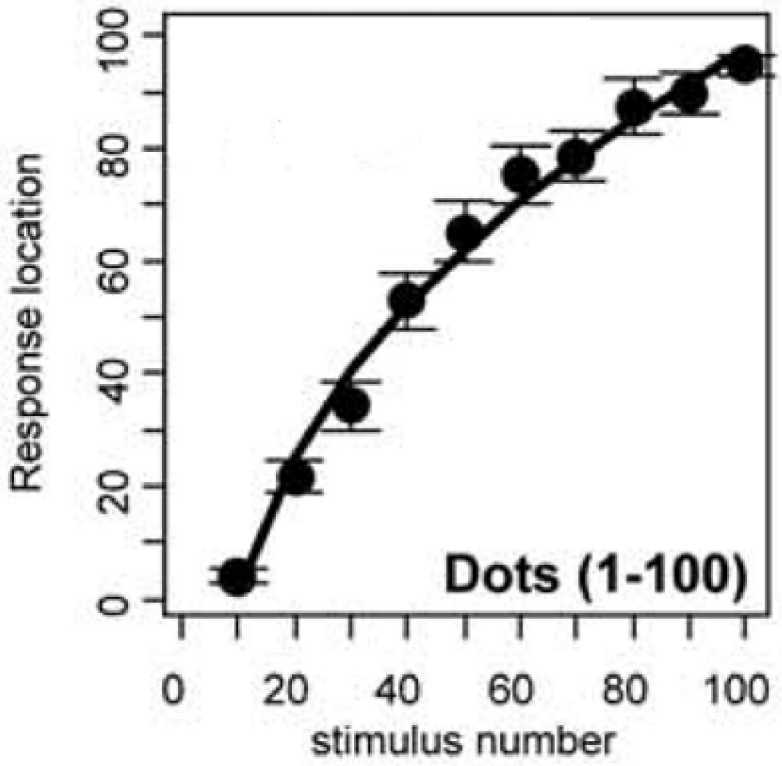
  - Subjects are asked to locate numbers on a line





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- Financial analysts
  - Earnings forecasts
  - Recommendations
  - Target prices
    - Significant abnormal returns following target price revisions (both unconditional and conditional on contemporaneously issued recommendations and earnings forecast revisions)
      - Brav and Lehavy (2003), *Journal of Finance*
      - Asquith, Mikhail and Au (2005), *Journal of Financial Economics*

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- Analysts' optimism bias
  - Conflicts of interest
    - Incentives to produce inaccurate figures
      - Lim (2001)
      - Mehran and Stulz (2007)
      - Bradshaw, Huang and Tan (2014)
      - Jackson (2005)
  - Behavioral biases
    - Some heuristics lead analysts to miscalculate
      - Cen, Hilary and Wei (2013)

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- What is our paper about?
  - We evidence a specific behavioral bias
    - The small price bias
  - Analysts process small stock prices differently than large stock prices
  - Our paper is grounded in recent research in neuropsychology on number processing

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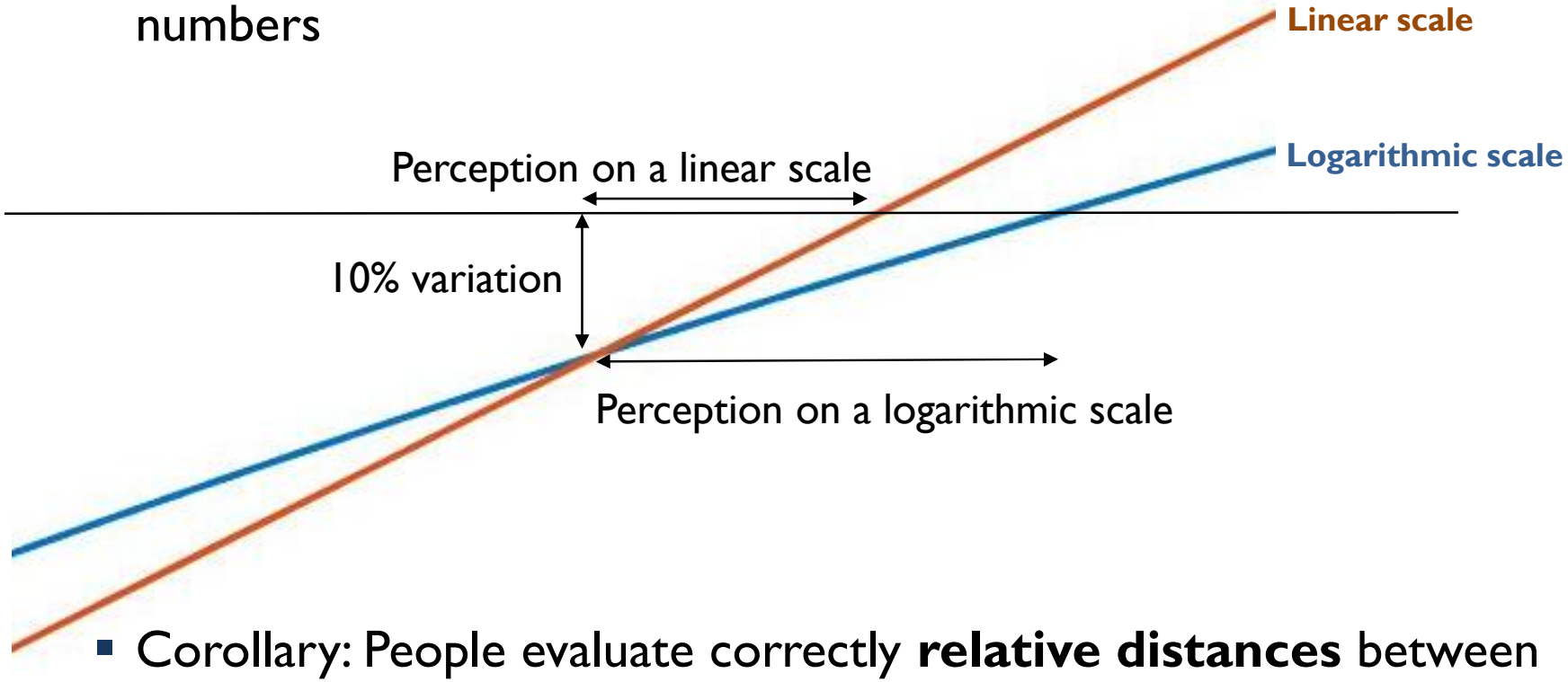
- Number processing - summing up
  - Individuals tend to use a linear scale for small numbers and a logarithmic scale for larger numbers
    - A price variation from $3 to $3.2 is seen as 20 cts increase
    - A price variation from $101 to $110 is seen (approximately) as a 10% increase (not a $9 variation)
- Our hypothesis
  - If analysts use a linear scale for small price stocks and a logarithmic scale for large price stocks, they will provide more optimistic target prices for small price stocks than for large price stocks

Linear vs. Logarithmic

- People evaluate correctly **absolute distances** between small numbers but underrepresent **absolute distances** between large numbers



- Corollary: People evaluate correctly **relative distances** between large numbers but exaggerate **relative distances** between small numbers

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Data

- 2000-2013 period
- Data on target prices (I/B/E/S)
  - 814,117 target prices issued by 9,141 analysts on 6,423 stocks
- Data on stock prices (CRSP)
  - NYSE, AMEX, NASDAQ
  - Stock prices
  - Stock splits
- Market, size, book-to-market and liquidity factors (WRDS, Kenneth French's website)
- Data on recommendations (I/B/E/S)
- Compustat

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Descriptive statistics

	Number of target prices	Number of analysts	No. of analysts per firm	Proportion of optimistic target prices	Average implied return
2000	34,027	3,111	9.62	96.04%	37.89%
2001	39,466	3,428	11.41	93.64%	31.95%
2002	46,441	3,258	12.21	92.40%	29.09%
2003	48,109	2,657	11.13	84.40%	17.46%
2004	51,505	2,728	11.20	85.55%	17.17%
2005	52,049	2,785	10.87	86.46%	16.73%
2006	53,442	2,743	11.07	85.69%	16.57%
2007	56,504	2,730	11.34	86.83%	16.77%
2008	67,619	2,679	11.59	88.44%	27.82%
2009	65,544	2,603	12.76	82.22%	18.82%
2010	69,254	2,989	14.78	87.62%	18.52%
2011	76,180	3,044	15.57	89.11%	20.48%
2012	72,677	2,913	15.49	87.53%	18.95%
2013	81,300	2,781	16.03	83.43%	13.46%

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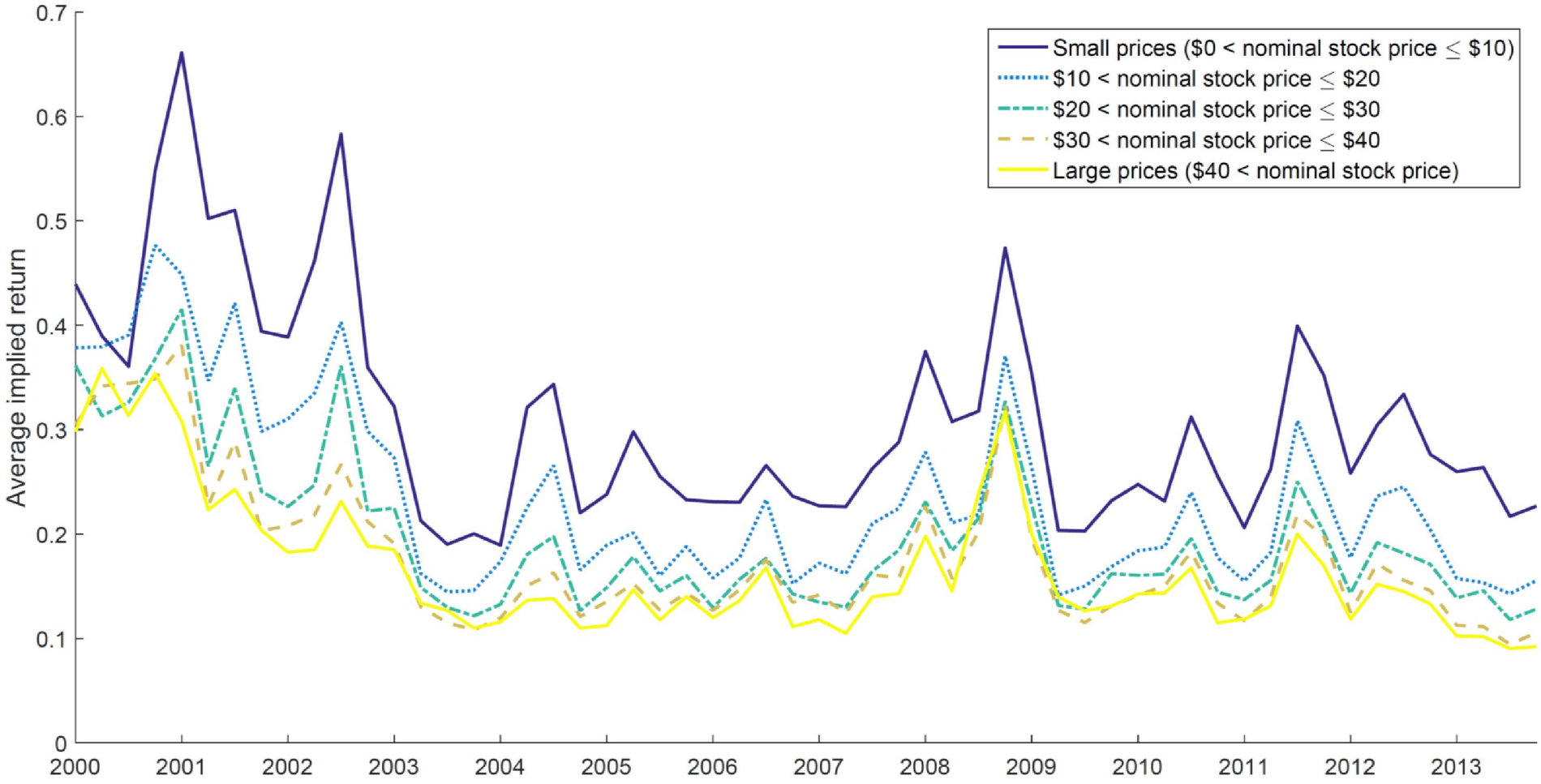
Univariate analysis

- Stock prices and implied returns
  - We build five price categories
    - **Category 1:** stock prices between $0 and $10
    - **Category 2:** stock prices between $10 and $20
    - **Category 3:** stock prices between $20 and $30
    - **Category 4:** stock prices between $30 and $40
    - **Category 5:** stock prices above $40
  - For each quarter between January 2000 and December 2013, we compute the average implied return for each price category

Univariate analysis



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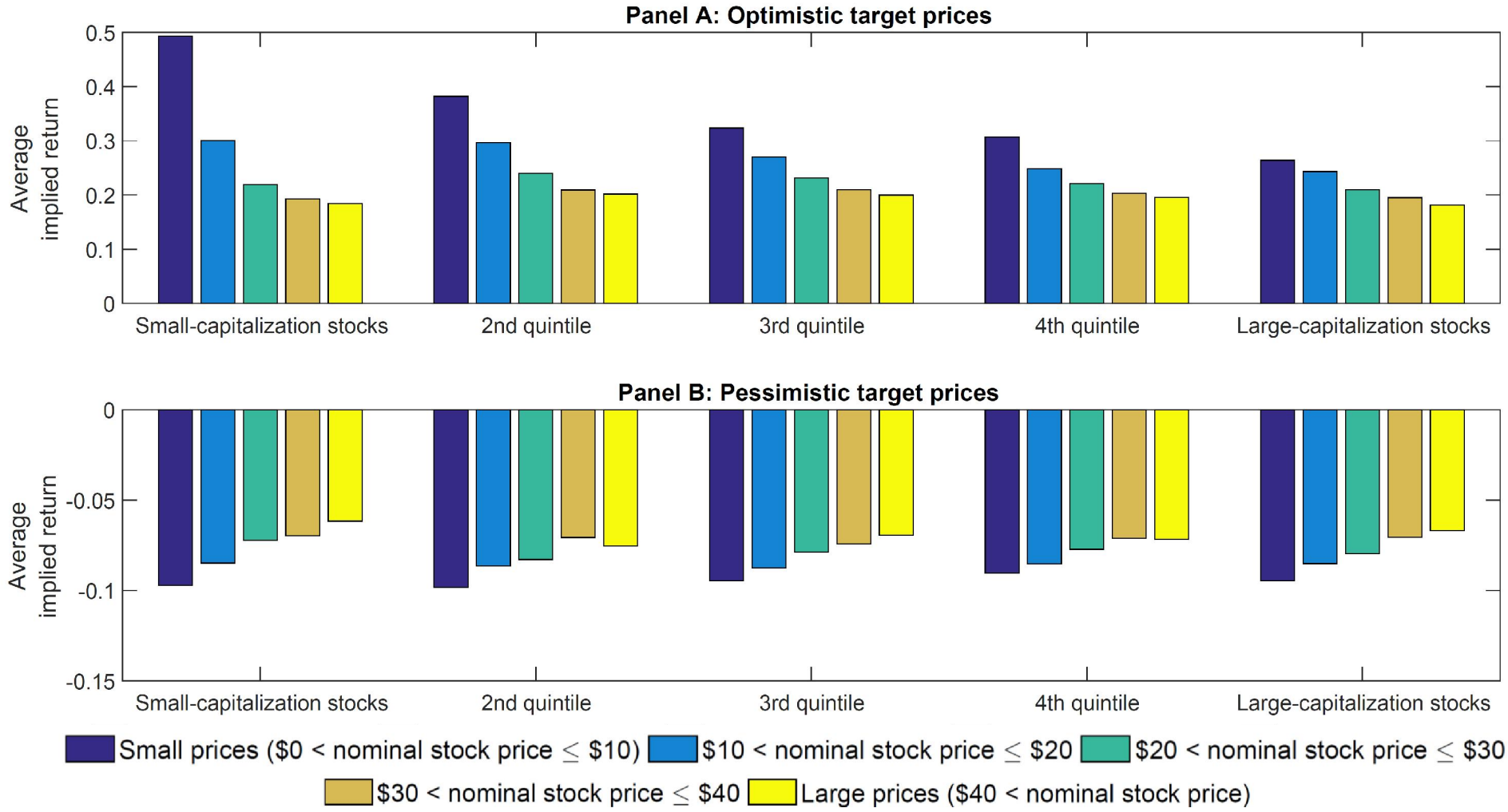
Univariate analysis

- Stock prices and market capitalization
  - There exists a strong correlation between nominal prices and firm size
  - However, this correlation is not perfect due to
    - Choice of IPO price
    - Stock splits
    - Stock dividends
  - We use a double sort on nominal prices and market capitalization to disentangle size and price effects

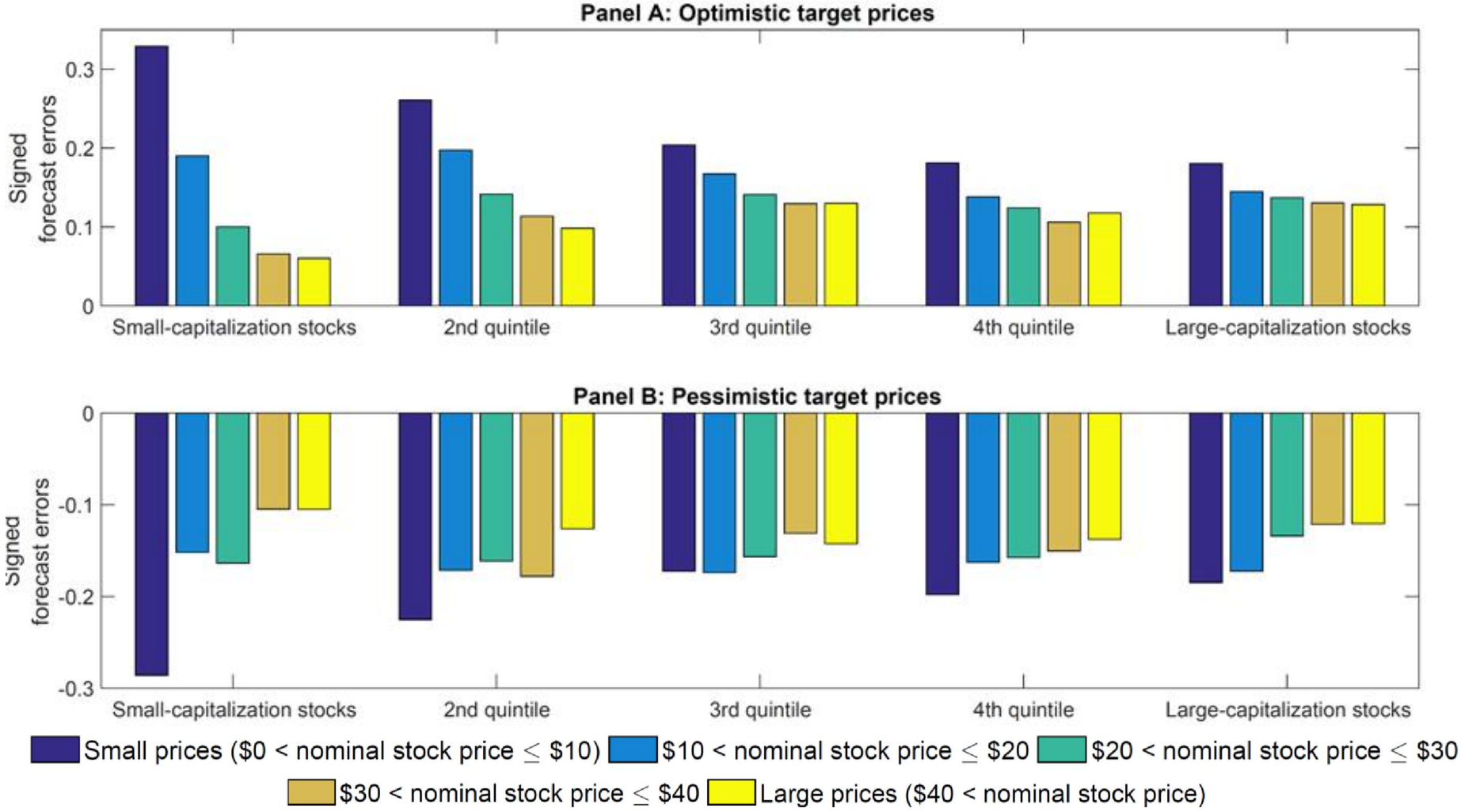
Univariate analysis

- Average implied returns



Univariate analysis

- Signed forecast errors



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Multivariate analysis

- The premium in implied returns observed for small price stocks may be explained by risk factors, firms' characteristics and analysts' characteristics
- Fama MacBeth (1973) approach
  - As in Brav *et al.* (2005), Barber *et al.* (2013)

$$IR_{i,j,t} = \alpha_t + \beta_{1,t} SIZE_{j,t} + \beta_{2,t} MOM_{j,t} + \beta_{3,t} BTM_{j,t} + NegativeIR_{i,j,t}$$
$$+ \sum_{k=1}^{4} \gamma_{k,t} PRICE\_CAT^{k}_{j,t} + NegativeIR_{i,j,t} \times \sum_{k=1}^{4} \theta_{k,t} PRICE\_CAT^{k}_{j,t}$$
$$+ \zeta_{i,t} AFE_{i,t} + \eta_{j,t} IFE_{j,t} + \delta_t Firm\text{-}Controls_{j,t} + \epsilon_{i,j,t}$$

Optimistic target prices

Pessimistic target prices

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Multivariate analysis

- Fama MacBeth (1973) approach
  - We therefore have 168 (14 years) cross-sectional regressions
  - We report the average of the estimated intercept and slope coefficients
  - Standard errors are adjusted using the Newey-West procedure

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Multivariate analysis

- Fama MacBeth (1973) approach
  - Controls
    - Operating profitability and investments
      - Fama and French (2015)
    - Dividend yield
    - Conflicts of interest
    - Distressed firms
    - 52-week high
    - Lottery-type stocks
      - LIDX index of Kumar, Page and Spalt (2016)
    - Skewness

Regression of target prices' implied returns on firm characteristics

	Model 1		Model 2		Model 3	
	Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Intercept	0.4199***	0.0271				
Negative IR	−0.2638***	0.0134	−0.2215***	0.0104	−0.2220***	0.0097
\$0 to \$10 dummy	0.1956***	0.0134	0.1560***	0.0109	0.0981***	0.0053
\$10 to \$20 dummy	0.0736***	0.0092	0.0637***	0.0065	0.0355***	0.0039
\$20 to \$30 dummy	0.0314***	0.0046	0.0301***	0.0035	0.0175***	0.0031
\$30 to \$40 dummy	0.0114***	0.0032	0.0141***	0.0025	0.0089***	0.0023
\$0 to \$10 dummy × Negative IR	−0.2429***	0.0129	−0.1963***	0.0082	−0.2008***	0.0086
\$10 to \$20 dummy × Negative IR	−0.1016***	0.0085	−0.0813***	0.0048	−0.0959***	0.0050
\$20 to \$30 dummy × Negative IR	−0.0481***	0.0035	−0.0379***	0.0023	−0.0512***	0.0044
\$30 to \$40 dummy × Negative IR	−0.0179***	0.0030	−0.0131***	0.0029	−0.0192***	0.0039
Size	−0.0110***	0.0008	−0.0063***	0.0012	0.0010	0.0012
Book-to-market	−0.0216***	0.0037	−0.0078***	0.0018	−0.0048***	0.0017
Momentum	−0.0110*	0.0061	−0.0170***	0.0047	0.0163***	0.0027
Operating profitability					−0.0027**	0.0012
Investment					0.0038***	0.0012
Dividend Yield					−0.6962***	0.1143
External financing					0.0455***	0.0068
Earnings management					0.0011	0.0020
Negative earnings dummy					0.0262***	0.0000
52 week high ratio					−0.2435***	0.0200
LIDX					0.0513***	0.0100
Skewness					−0.0040***	0.0000
Industry fixed effects	NO		YES		YES	
Analyst fixed effects	NO		YES		YES	
Average adjusted R^2	32.81%		70.59%		75.05%	
Number of observations	761,271		761,271		490,733	

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Momentum	−0.0110*	0.0061

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	Model 2	
	Coefficient	Standard error
Intercept		
Negative IR	−0.2215***	0.0104
$0 to $10 dummy	0.1560***	0.0109
$10 to $20 dummy	0.0637***	0.0065
$20 to $30 dummy	0.0301***	0.0035
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$20 to $30 dummy × Negative IR	−0.0379***	0.0023
$30 to $40 dummy × Negative IR	−0.0131***	0.0029
Size	−0.0063***	0.0012
Book-to-market	−0.0078***	0.0018
Momentum	−0.0170***	0.0047

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	Model 3	
	Coefficient	Standard error
Intercept		
Negative IR	−0.2220***	0.0097
$0 to $10 dummy	0.0981***	0.0053
$10 to $20 dummy	0.0355***	0.0039
$20 to $30 dummy	0.0175***	0.0031
$30 to $40 dummy	0.0089***	0.0023
$0 to $10 dummy × Negative IR	−0.2008***	0.0086
$10 to $20 dummy × Negative IR	−0.0959***	0.0050
$20 to $30 dummy × Negative IR	−0.0512***	0.0044
$30 to $40 dummy × Negative IR	−0.0192***	0.0039
Size	0.0010	0.0012
Book-to-market	−0.0048***	0.0017
Momentum	0.0163***	0.0027

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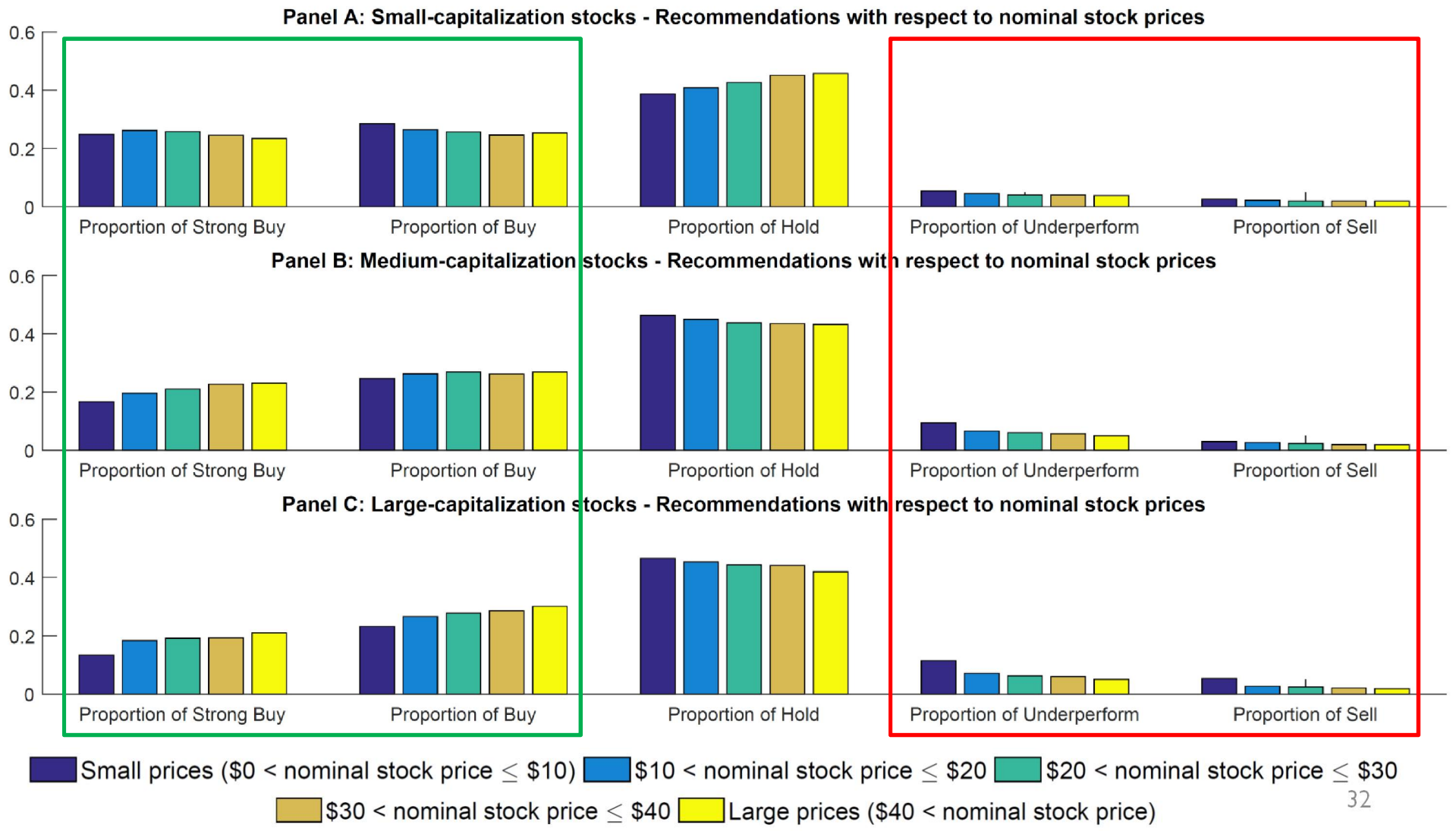
Recommendations

- Risk adjusted returns and stock prices
  - Analysts' forecast higher risk-adjusted returns for small price stocks
  - Thus, analysts should make more favorable recommendations for small price stocks
  - Except if the differences in implied returns are the result of a behavioral bias
  - What happens when we look at recommendations?
    - Double sort on market capitalization and nominal prices

Recommendations



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Stock splits

- We look at implied returns pre-split and post-split (with a 3-month window around the split date)
- Using stock splits allows us to make sure that the relationship between nominal prices and implied returns is not driven by other factors
- We have
  - 532 splits with a ratio between 1.25 and 2
  - 869 splits with a ratio larger or equal to 2

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- For splits with ratio between 1.25 and 2:
  - Pre-split implied return of 15.78%
  - Post-split implied return of 20.30%
- For splits with ratio larger or equal to 2:
  - Pre-split implied return of 16.83%
  - Post-split implied return of 22.81%
- The differences are highly significant

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- Propensity score matching approach (Rosenbaum and Rubin, 1983)
  - We build a sample of controls firms with the same propensity to split as our splitting firms
  - We match on the following characteristics
    - Log price
    - Market capitalization
    - Previous return
    - Previous volatility
    - Book-to-market
    - Average previous implied return

Stock splits

- Difference-in-differences analysis

	Average implied return		
	Splitting firms	Control firms	Difference
Split ratio between 1.25 and 2			
Before splits	0.1447	0.1845	−0.0398
After splits	0.1853	0.1927	−0.0074
Difference	0.0406	0.0082	0.0324***
Split ratio greater or equal to 2			
Before splits	0.1565	0.1879	−0.0314
After splits	0.2031	0.2019	0.0013
Difference	0.0466	0.0140	0.0326***

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- Nominal prices and implied returns
  - We provide strong evidence of a behavioral bias which
    - Leads analysts to be more optimistic on small price stocks
- Consequences for the research on analysts
  - Target prices issued on small price stocks are not accurate and are overoptimistic.

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- Other implications
  - If educated professionals such as financial analysts suffer from this small price bias, other market participants may suffer from it as well.
  - This small price bias may be the explanation for puzzles such as
    - Abnormal returns of small price stocks
      - Bandi, Russell and Sabbagui (2009), Birru-Wang(JFE 2016)
    - Higher volatility of small price stocks
    - Stock return comovements driven by price level
      - Green and Hwang (JFE 2009)
    - Abnormal returns following splits

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- Additional evidence
  - *Another law of small numbers: Patterns of trading prices in experimental markets*
    - Roger T., Bousselmi W., Roger P. and M. Willinger
  - Experimental markets
    - Small price markets and large price markets
    - Greater deviation from fundamental value in small price markets than in large price markets
    - Results are found between-participants and within-participants