DO YOU KNOW THAT I KNOW YOU KNOW…?

HIGHER ORDER BELIEFS IN SURVEY DATA

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- How do agents form these higher order beliefs?
- Are models of infinite regress reasonable?
- Should we consider variants like limited reasoning (k-level thinking)?

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  - A unique feature of our experiment is that we use different treatments, including providing information about higher order expectations of others.

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- Estimates the treatment effect of information on first-order and higher-order expectations as well as firm actions.
- Characterizes how these empirical facts conform to the predictions of a simple noisy information model with infinite regress and how they can be used to pin down key parameters.
  - The moments over-identify certain parameters and these restrictions are largely consistent with the data.
  - The model is most at odds with the effects of information treatments.

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- Estimates the treatment effect of information on first-order and higher-order expectations as well as firm actions.
- Characterizes how these empirical facts conform to the predictions of a simple noisy information model with infinite regress and how they can be used to pin down key parameters.
- We consider one departure from the model with infinite regress: *k*-level thinking.
  - We show that we can measure *k*-level thinking in our survey following experimental literature and measure beliefs of agents about distribution of *k*-levels of other agents.
  - But *k*-level thinking does not appear to account for the differences between the model and data.

SURVEY

- Random representative sample with broad coverage of firms in New Zealand
  - Exclude very small firms (less than 6 employees)
- How the survey was conducted:
  - Send questionnaire in advance
  - Phone interview with general manager
  - Response rate ≈ 20 percent
- Multiple waves

Panel	Wave	# firms
#1	09/2013 – 12/2013	3,150
	03/2014 – 04/2014	716
	06/2014 – 09/2014	1,608
	12/2014 – 01/2015	1,257
#2	04/2016 – 05/2016	2,040
	10/2016 – 12/2016	1,404
#3	11/2017 – 12/2017	≈1,032
	03/2018 – 04/2018	515

SURVEY QUESTIONS

- We ask for point estimates of inflation expectations

During the *next twelve* months, by how much do you think prices will change overall in the economy? Please provide an answer in percentage terms. **……%**

SURVEY QUESTIONS

- We ask for point estimates of inflation expectations
- As well as questions that capture beliefs about distribution of outcomes

Please assign probabilities (from 0-100) **to the following ranges of overall price changes in the economy over the next 12 months for New Zealand:** (Note that the probabilities in the column should sum to 100)

Percentage Price Changes in 12 Months	**Probabilities**	
More than 25%:	**……**	**%**
From 15 to 25%:	**……**	**%**
From 10 to 15%:	**……**	**%**
From 8 to 10%:	**……**	**%**
From 6 to 8%:	**……**	**%**
From 4 to 6%:	**……**	**%**
….. etc…		
From -10 to -15%:	**……**	**%**
From -15 to -25%:	**……**	**%**
Less than -25%:	**……**	**%**
Total (the column should sum to 100%):	**100 %**	

SURVEY QUESTIONS

- We ask for point estimates of inflation expectations
- As well as questions that capture beliefs about distribution of outcomes
- Then ask managers the distribution question about *beliefs of others*

We would like to know what your opinion is about what *other* managers (drawn from all sectors of the New Zealand economy in a representative way) think will happen to overall prices in the acconomy. Please assign probabilities (from 0-100) **to the following ranges beliefs that other managers might hold about overall price changes in the economy over the next 12 months for New Zealand:** (Note that the probabilities in the column should sum to 100)

Percentage Price Changes in 12 Months	**Probabilities**	
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MOMENTS IMPLIED BY DISTRIBUTIONS

Type of expectations	Mean
Own expectations	3.41
Expectations of other managers	3.50
p-value of equality	0.18

Moment 1: the means of first order and higher order inflation expectations are almost identical.

MOMENTS IMPLIED BY DISTRIBUTIONS

Type of expectations	Mean	St.Dev
Own expectations	3.41	3.06
Expectations of other managers	3.50	2.43
p-value of equality	0.18	0.00

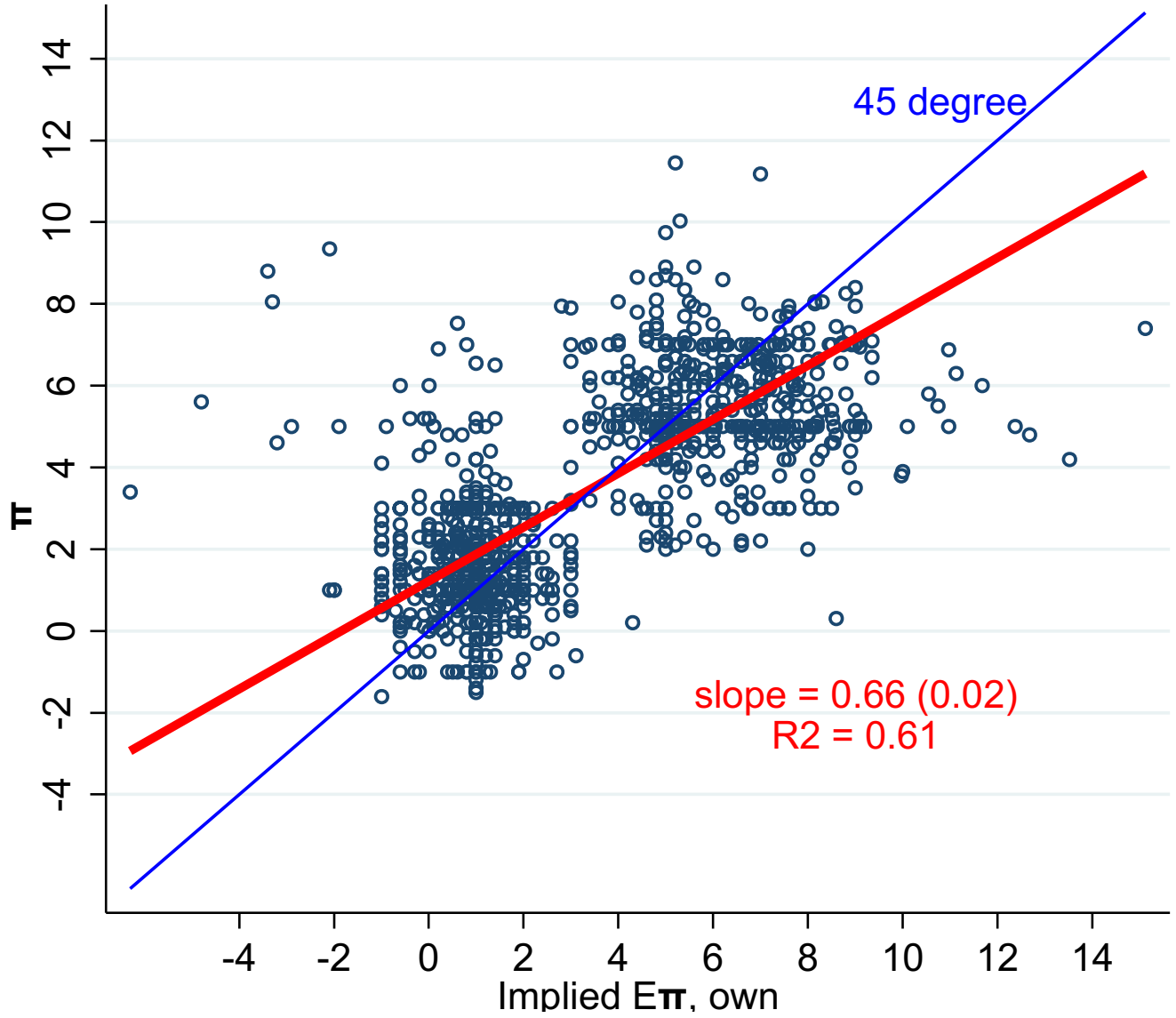
Moment 2: the cross-sectional dispersion of higher order inflation expectations is statistically significantly lower than the dispersion of first order expectations.

MOMENTS IMPLIED BY DISTRIBUTIONS

Type of expectations	Mean	St.Dev	Uncertainty
Own expectations	3.41	3.06	1.10
Expectations of other managers	3.50	2.43	0.89
p-value of equality	0.18	0.00	0.00

Moment 3: the average uncertainty in higher order inflation expectations is statistically significantly lower than the uncertainty in first order expectations.

MOMENTS IMPLIED BY DISTRIBUTIONS



Moment 4: There is a strong positive correlation between HO and FO expectations with slope coefficient less than one.

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Follow-up:

- Shortly after info is presented, we ask firms to report their expectations.

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Follow-up:

- Shortly after info is presented, we ask firms to report their expectations.
- Three months later, we ask firms for their expectations as well as their actions over the past three months. (We asked for planned actions in the initial wave.)

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- $\hat{\beta} \approx 0$ implies that the signal received is viewed as fully informative and prior beliefs are entirely disregarded in the face of new information.
- We use point predictions for posteriors and implied means of distribution questions for priors. This may result in some bias. We capture this effect by examining change in expectations for a control group.

REVISION OF EXPECTATIONS

$$Posterior_{i,group} = \alpha_{group} + \beta_{group} Prior_{i,group}$$

Group	Own expectations	HO expectations
A: *Control group*	0.727	0.699
	(0.020)	(0.021)
B: Treated with $\overline{E}[\pi]$		
C: Treated with $\overline{E}^2[\pi]$		
D: Treated with *B&C*		
E: Treated with $\overline{\pi}_{t-1}$		

For the control group, estimates highlight the differences between expectations as point predictions and expectations as probability distributions.

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Group	Own expectations	HO expectations
A: *Control group*	0.727	0.699
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B: Treated with $\overline{E}[\pi]$	0.502	0.430
	(0.041)	(0.039)
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When respondents receive information about other firms' inflation expectations, their beliefs respond only somewhat, as if this signal was not very informative.

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C: Treated with $\overline{E}^2[\pi]$	0.090	0.118
	(0.018)	(0.024)
D: Treated with *B&C*	0.096	0.071
	(0.022)	(0.020)
E: Treated with $\overline{\pi}_{t-1}$		

When respondents receive any information about other firms' higher-order expectations, their beliefs respond much more, as if this signal was very informative.

REVISION OF EXPECTATIONS

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Group	Own expectations	HO expectations
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	(0.018)	(0.024)
D: Treated with *B&C*	0.096	0.071
	(0.022)	(0.020)
E: Treated with $\overline{\pi}_{t-1}$	0.059	0.062
	(0.015)	(0.021)

Receiving information about the most recent values of inflation has approximately the same (large) effect on forecasts as receiving information about higher order beliefs.

REVISION OF EXPECTATIONS AFTER THREE MONTHS

$$Posterior_{i,group} = \alpha_{group} + \beta_{group} Prior_{i,group}$$

Group	Own expectations	HO expectations
A: *Control group*	0.744	0.708
	(0.038)	(0.038)
B: Treated with $\overline{E}[\pi]$	0.461	0.513
	(0.065)	(0.049)
C: Treated with $\overline{E}^2[\pi]$	0.116	0.146
	(0.043)	(0.047)
D: Treated with *B&C*	0.155	0.097
	(0.038)	(0.042)
E: Treated with $\overline{\pi}_{t-1}$	0.088	-0.006
	(0.043)	(0.040)

Information has a persistent effect after three months. The size of the treatment effect continues to depend on the type of information received.

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We instrument for the revision in expectations using the "surprise" agents receive:

$$Surprise_i = Prior_i - Treatment\ Value$$

EFFECT OF INFORMATION ON ACTIONS

We find that for each one percentage point increase in expectations, there is a corresponding change of:

- $\approx$ 0.4 percent increase in employment
- $\approx$ 0.2 percent increase in fixed assets
- no change in prices or wages
- conditional on moving expectations, treatment effects have same impact on actions

Information treatments impact firm actions primarily through input decisions.

In this way, changes in expectations have a real effect on the economy.

SUMMARY OF EMPIRICAL FACTS

1. Means of FO and HO forecasts are similar.
2. Cross-sectional dispersion of HO forecasts is lower than FO forecasts.
3. Uncertainty is lower for HO forecasts than FO forecasts.
4. Strong positive correlation between individual FO and HO forecasts, with slope coefficient between 0 and 1.
5. Information treatments using HO beliefs have larger effects on expectations than treatments using FO beliefs.
6. Effects on actions of treatments operate primarily on real variables and little on nominal variables.

THEORY OF HIGHER ORDER EXPECTATIONS

Firm $i \in [0,1]$ sets its price according to:

$$p_i = (1-\alpha)m + \alpha E_i[\overline{p}]$$

where $\alpha \in (0,1)$ indicates degree of strategic complementarity.

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Iterating the problem forward:

$$p_i = (1-\alpha)m + \alpha E_i\left[\int_0^1 p_j dj\right]$$

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Aggregate price is then:

$$\overline{p} = (1-\alpha)\overline{E}[m] + \alpha(1-\alpha)\overline{E}^2[m] + \alpha^2(1-\alpha)\overline{E}^3[m] + \cdots$$

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Individual price:

$$p_i = (1-\alpha)E_i\left[\overline{E}[m]\right] + \alpha(1-\alpha)E_i\left[\overline{E}^2[m]\right] + \alpha^2(1-\alpha)E_i\left[\overline{E}^3[m]\right] + \cdots$$

INFORMATION STRUCTURE

Firms observe two signals:

Public signal: $y = m + \varepsilon$ where $\varepsilon \sim N\left(0, \kappa_y^{-1}\right)$

Private signal: $x_i = m + v_i$ with $v_i \sim N(0, \kappa_x^{-1})$
with uncorrelated noise.

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with uncorrelated noise.

In equilibrium:

$$p_i = \phi_y y + \phi_x x_i$$

where $\phi_y = \frac{1-\delta}{(1-\alpha)\delta+(1-\delta)}$ and $\phi_x = \frac{(1-\alpha)\delta}{(1-\alpha)\delta+(1-\delta)}$.

$\delta = \frac{\kappa_x}{\kappa_x+\kappa_y}$ is the relative precision of the private signal.

OUTCOME

First-order expectations:

$$E_i[\overline{p}] = (\phi_y + \phi_x(1-\delta))y + \phi_x \delta x_i$$

Higher-order expectations:

$$E_i^2[\overline{p}] = (\phi_y + \phi_x(1-\delta^2))y + \phi_x \delta^2 x_i$$

Higher order expectations load more on public signal and less on private signal.

MAPPING DATA TO MODEL

- Using the cross-sectional dispersion of expectations:

$$\frac{Disp^{HO}}{Disp^{LO}} = \frac{Var\left(E_i\left[\overline{E}[\overline{p}]\right]|y\right)}{Var(E_i[\overline{p}]|y)} = \frac{(\phi_x\delta^2)^2\kappa_x^{-1}}{(\phi_x\delta)^2\kappa_x^{-1}} = \delta^2 < 1$$

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$$\delta = \frac{2.43}{3.06} \approx 0.8$$

  - More generally, the model implies that we should see less dispersion in HO beliefs than FO beliefs, as found in the data.

MAPPING DATA TO MODEL

- Using the cross-sectional dispersion of expectations: $\delta = \frac{2.43}{3.06} \approx 0.8$
- Using the level of uncertainty:

$$\frac{\Omega^{HO}}{\Omega^{LO}} = \frac{(\phi_x \delta^2)^2 \kappa_x^{-1}}{(\phi_x \delta)^2 \kappa_x^{-1}} = \delta^2 < 1$$

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$$\delta = \frac{0.89}{1.11} \approx 0.8$$

  - This yields the same value of delta despite coming from a different set of moments. The model provides an overidentifying restriction which is consistent with the data.
  - More generally, the model implies that we should see less uncertainty in HO beliefs than FO beliefs, as found in the data.

MAPPING DATA TO MODEL

- α – degree of strategic complementarity: $\alpha \approx 0.70$

For the next three questions, suppose that neither you nor your competitors face any costs in changing your prices. Also suppose that you get news that the general level of prices went up by 10% in the economy:

a. By what percentage do you think your competitors would raise their prices on average?

b. By what percentage would your firm raise its price on average?

c. By what percentage would your firm raise its price if your competitors did not change their price at all in response to this news?

Afrouzi (2018) shows that α is the slope in the regression of {the answer in "b" minus the answer in "c"} on {the answer in "a"}.

MAPPING DATA TO MODEL

- α – degree of strategic complementarity: $\alpha \approx 0.70$
- ϕ_x and ϕ_y – equilibrium pricing strategies: $\phi_x \approx 0.55$
  - These follow from model structure and values of α and δ

$$\phi_x = \frac{(1-\alpha)\delta}{(1-\alpha)\delta + (1-\delta)}$$

MAPPING DATA TO MODEL

- α – degree of strategic complementarity: $\alpha \approx 0.70$
- ϕ_x and ϕ_y – equilibrium pricing strategies: $\phi_x \approx 0.55$
- $m - y$ – realization of the public signal: $m - y \approx -1$
  - The difference between the means of HO and FO expectations in the data pins down the sign of $m - y$, and the other parameters determine its level:

$$\left(\overline{E}[\overline{p}] - \overline{E}^2[\overline{p}]\right)|y = \phi_x(1-\delta)\delta[m-y].$$

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- ϕ_x and ϕ_y – equilibrium pricing strategies: $\phi_x \approx 0.55$
- $m - y$ – realization of the public signal: $m - y \approx -1$
- κ_x and κ_y – govern the precision of private and public signals
  - Using the level of dispersion of expectations:

$$Var(E_i[\overline{p}]|y) = (\phi_x \delta)^2 \kappa_x^{-1} \Rightarrow \quad \kappa_x = 0.02$$

  - Using the uncertainty of expectations:

$$\Omega^{FO} = (\phi_x \delta)^2 \kappa_x^{-1} \quad \Rightarrow \quad \kappa_x = 0.15$$

  - Problem is that model imposes restriction that dispersion and uncertainty are equal, which data strongly rejects.

INFORMATION TREATMENTS IN THE MODEL

- In the model, providing information about the average forecast of other firms' or their average higher order beliefs is fully revealing, at odds with data.
- We assume treatments are a noisy signal these underlying moments.
- In this case, regressions of posteriors on the priors reveal the precision of the signal.

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- *Summary*: To explain why HO treatment has a larger effect than FO treatment, we need signal about HO expectation to be almost 10 times more precise than signal about FO expectations.

SUMMARY

- The model is consistent with a number of facts from the data:
  - Lower dispersion of HO forecasts than FO forecasts
  - Lower uncertainty in HO forecasts than FO forecasts
  - Positive slope coef. between FO and HO forecasts.

SUMMARY

- The model is consistent with a number of facts from the data.
- The data can be used to discipline the model in new ways:
  - We can recover the underlying parameters given our data.
  - We can test overidentifying restrictions implied by the model.

SUMMARY

- The model is consistent with a number of facts from the data.
- The data can be used to discipline the model in new ways.
- The model is at odds with the data along several dimensions:
  - Levels of uncertainty and dispersion are different in the data.
  - It is difficult to make sense of very strong response to HO information treatment relative to FO information treatment.

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- The data can be used to discipline the model in new ways.
- The model is at odds with the data along several dimensions.
- Possible fixes/extensions to the model:
  - Semi-public signals.
  - Dynamics to generate heterogeneous priors.
  - Limits to infinite regress/*k*-level thinking.

ARE HIGHER ORDER BELIEFS DRIVEN BY K-LEVEL THINKING?

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Introduce level-*k* thinking

ARE HIGHER ORDER BELIEFS DRIVEN BY K-LEVEL THINKING?

This question is being asked of all managers in the survey, drawn from all sectors of the New Zealand economy in a representative way.

Please choose a number from zero to 100. We will take your number as well as the numbers chosen by other managers to calculate the average pick. The winning number will be the number that is closest to two-thirds (2/3) of the average.

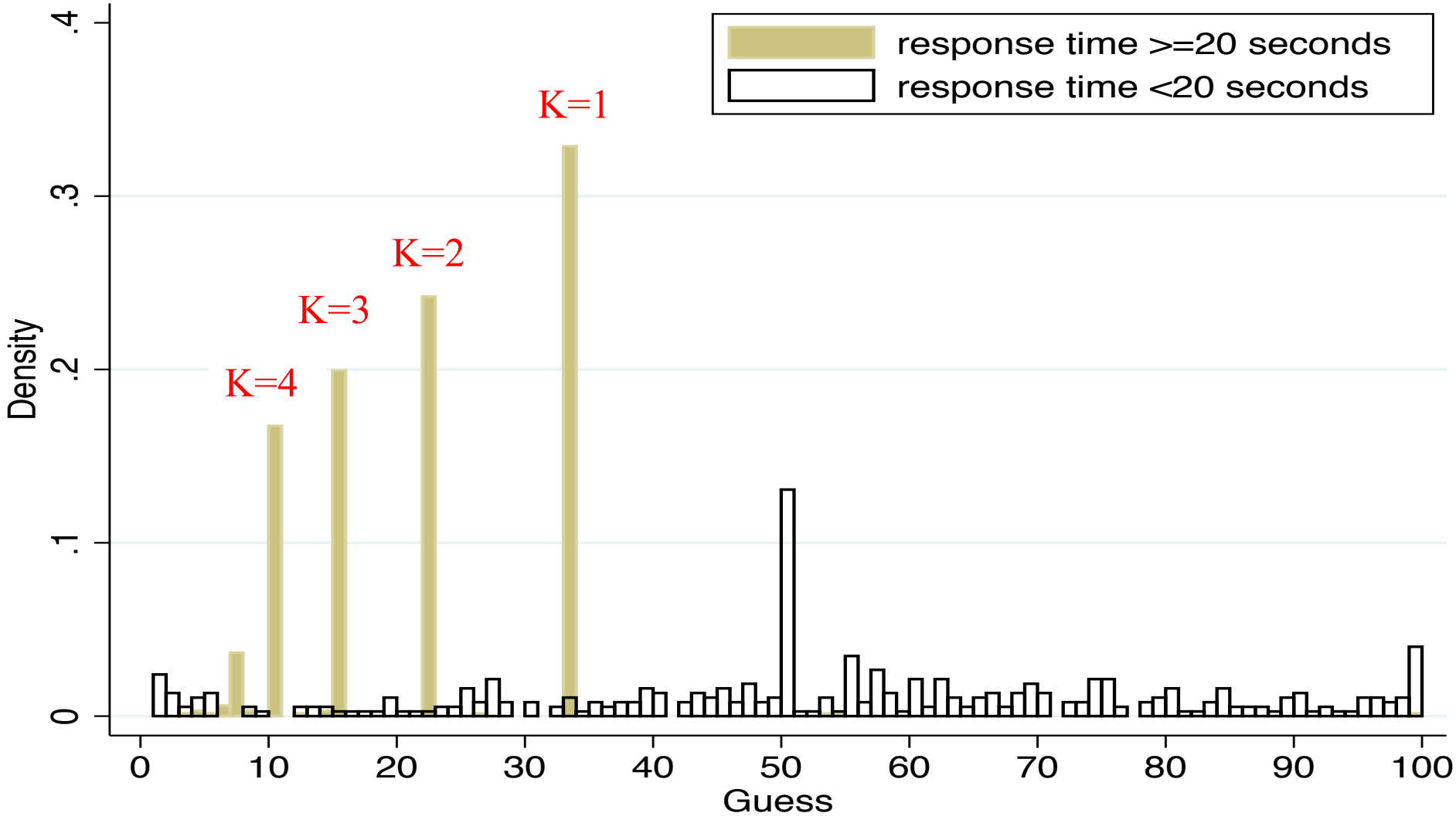
The individual(s) with the winning number will receive (or share with other winners in case of tie) $500.

Please take your time to answer this question.

Your chosen number is: ……

[We record their answer *and the time taken to answer*]

K-LEVEL THINKING



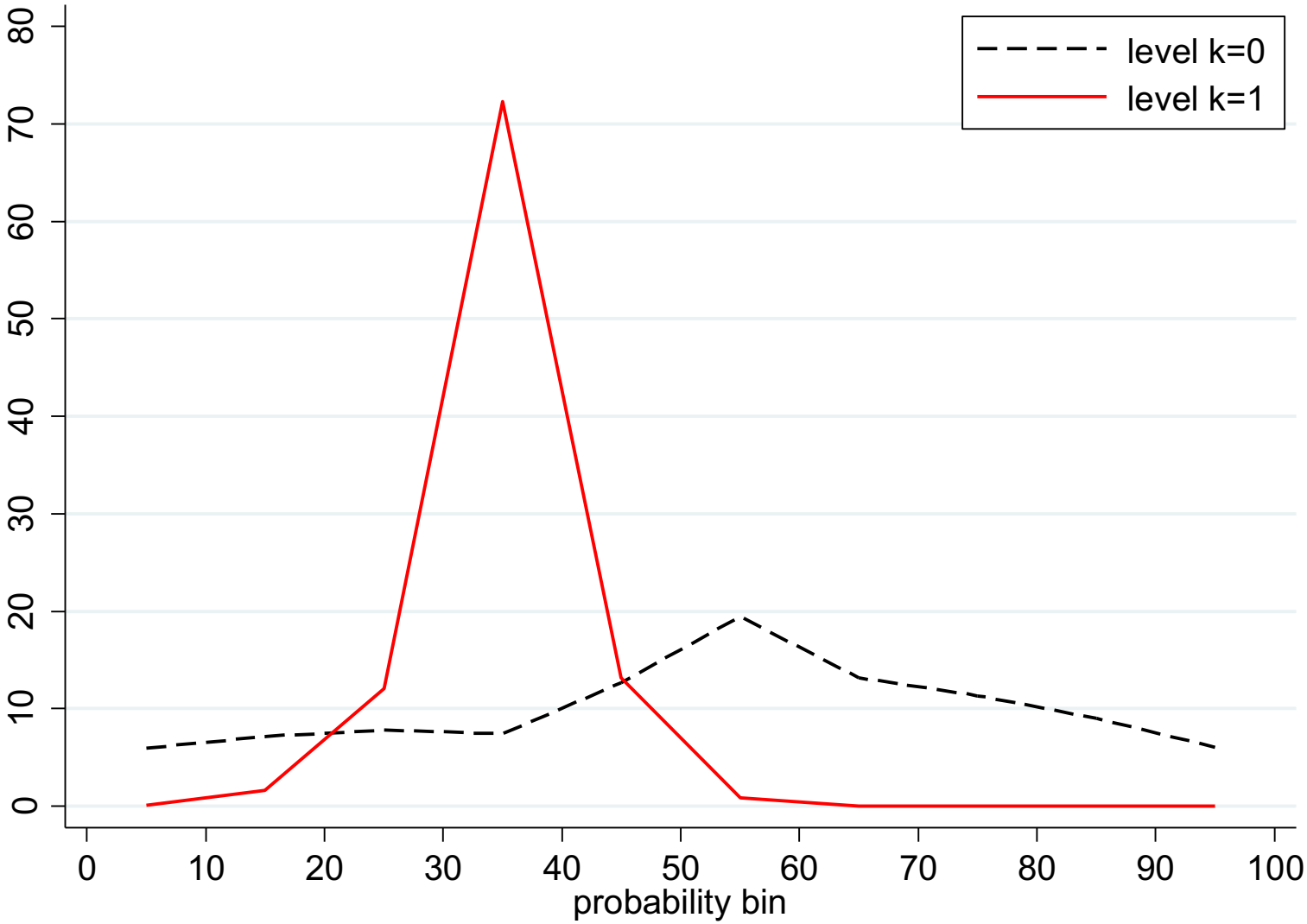
Those who take more than 20 seconds fall neatly into clear K-level categories of thinking.

NOVEL TWIST: WE ASK ABOUT THEIR EXPECTED DISTRIBUTION OF ANSWERS FROM OTHER MANAGERS

Other managers are asked to guess a number from zero to 100, with the goal of making their guess as close as possible to two-thirds of the average guess of all those participating in the contest. *What percentage of other managers' guesses do you think will fall in each of the following ranges?*

Range of Guesses	Percentage of Other Managers
From 0 to 9.99	..... %
From 10 to 19.99	..... %
From 20 to 29.99	..... %
From 30 to 39.99	..... %
From 40 to 49.99	..... %
From 50 to 59.99	..... %
From 60 to 69.99	..... %
From 70 to 79.99	..... %
From 80 to 89.99	..... %
From 90 to 100	..... %

K-LEVEL THINKING



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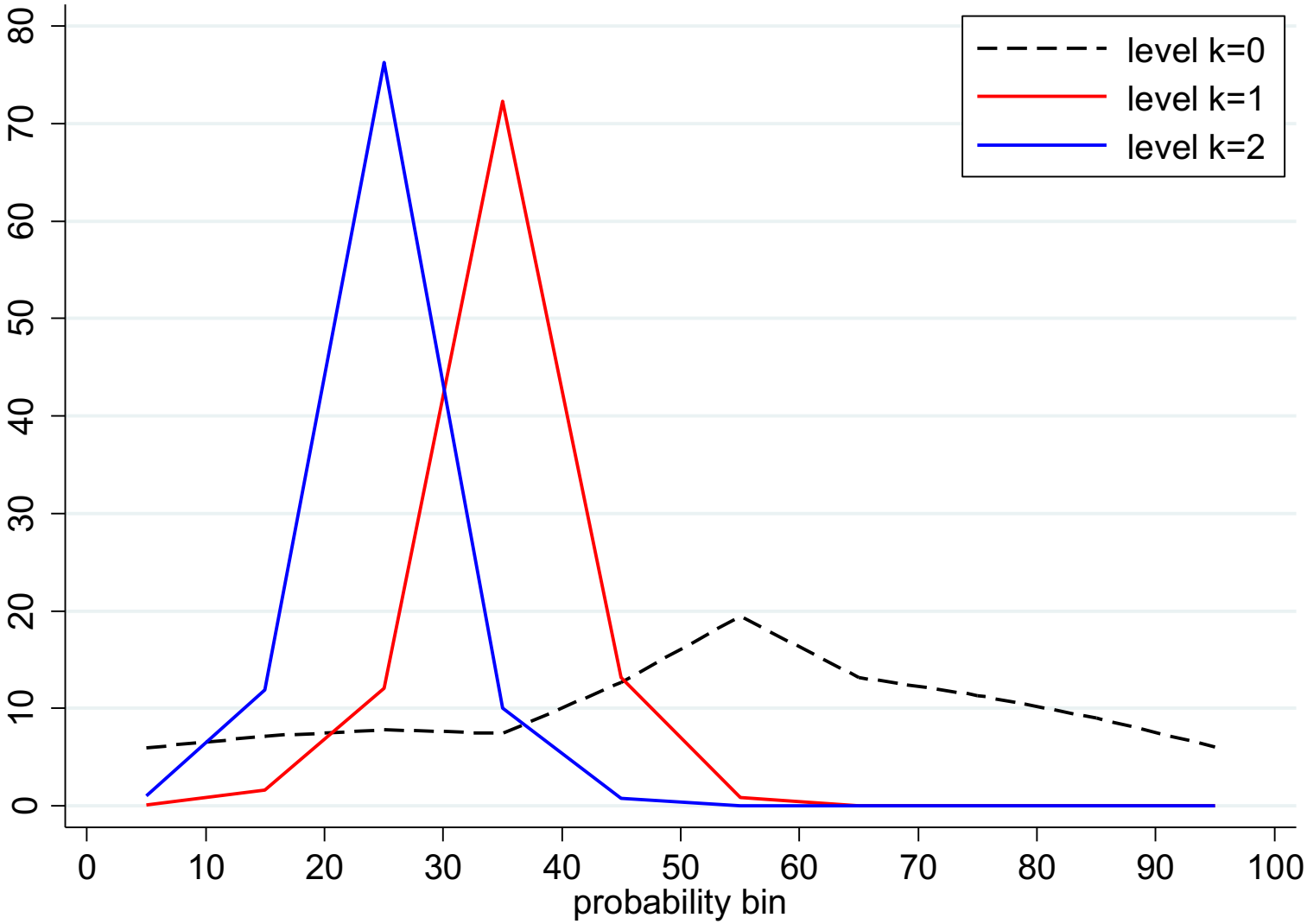

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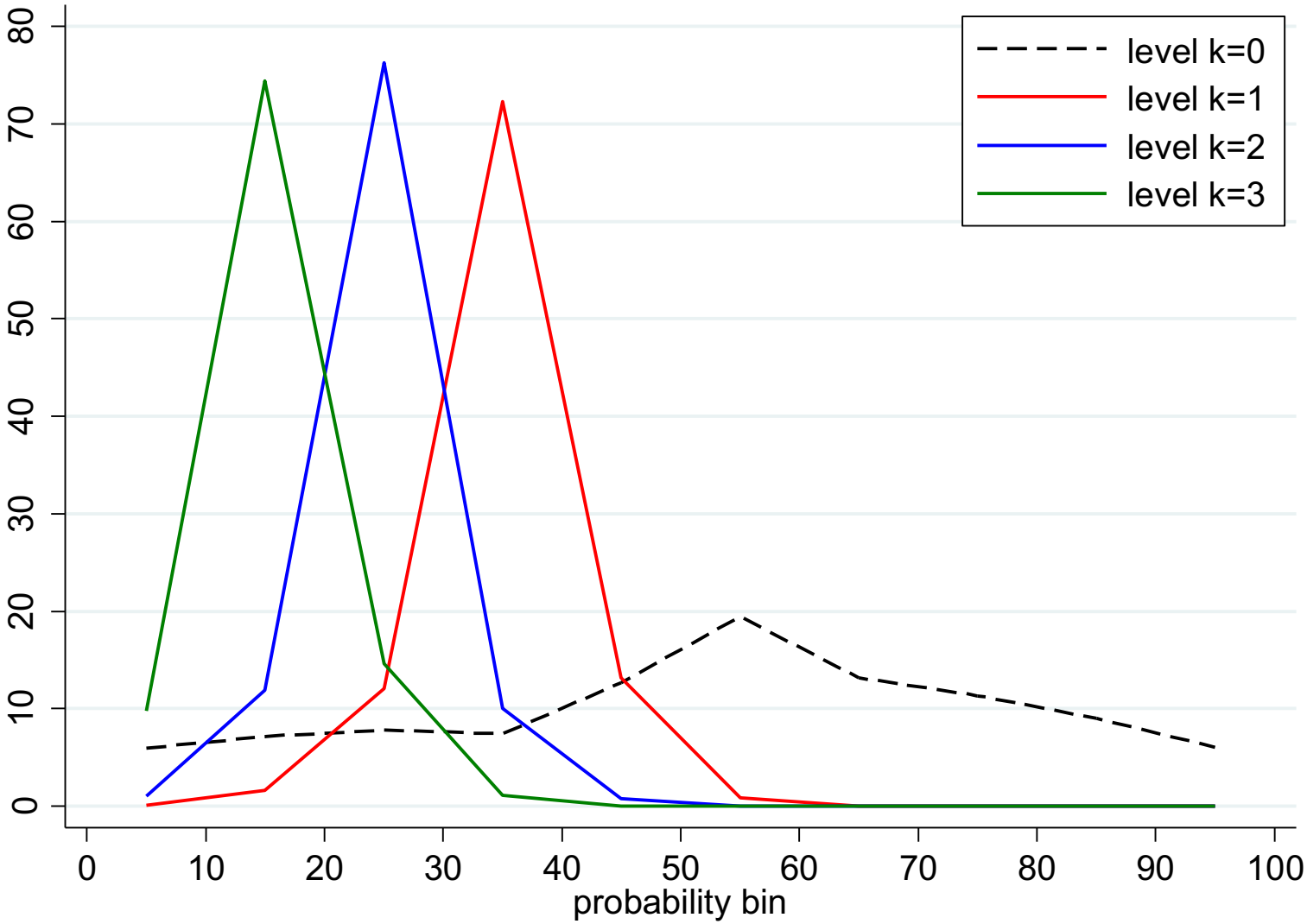

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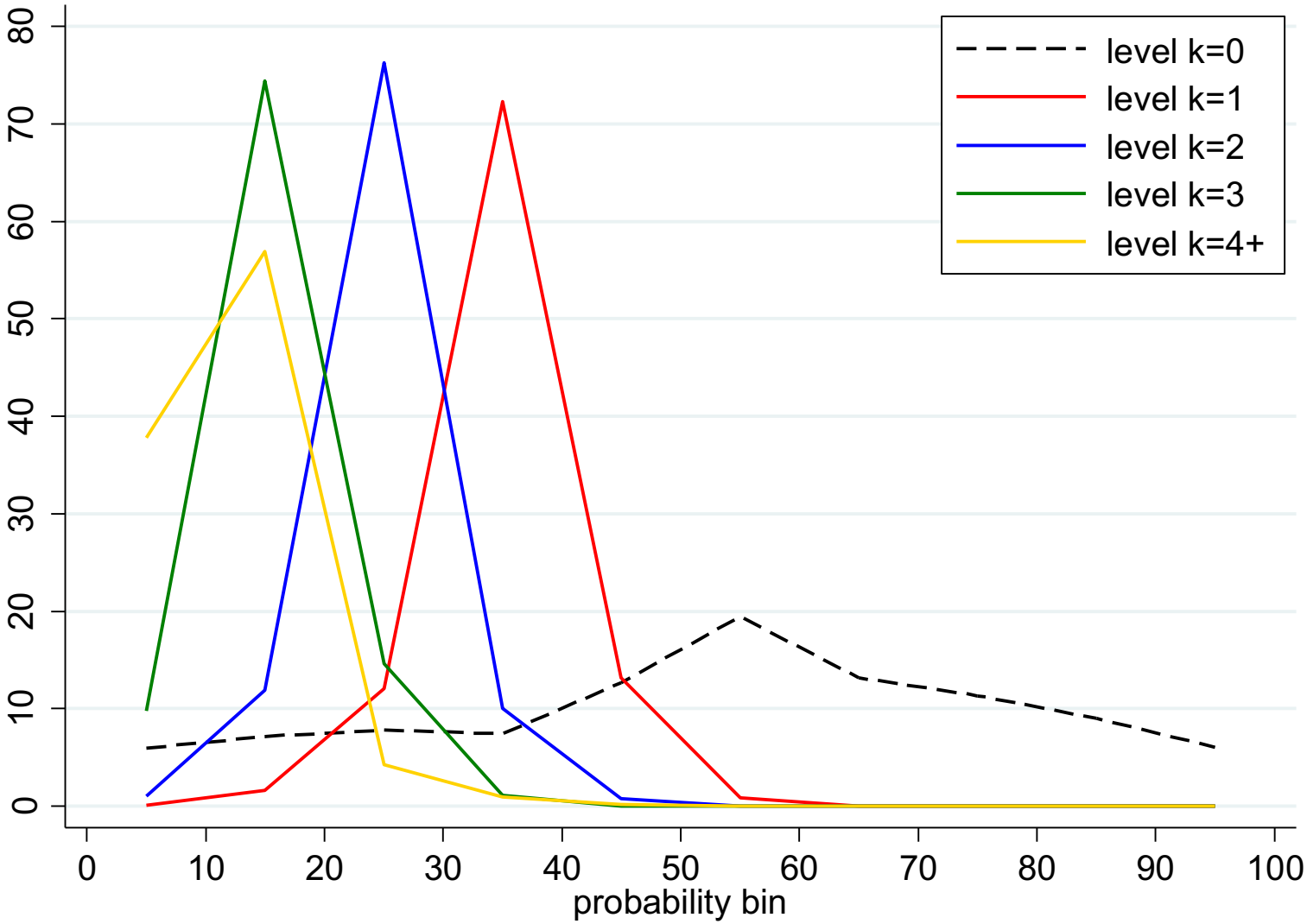

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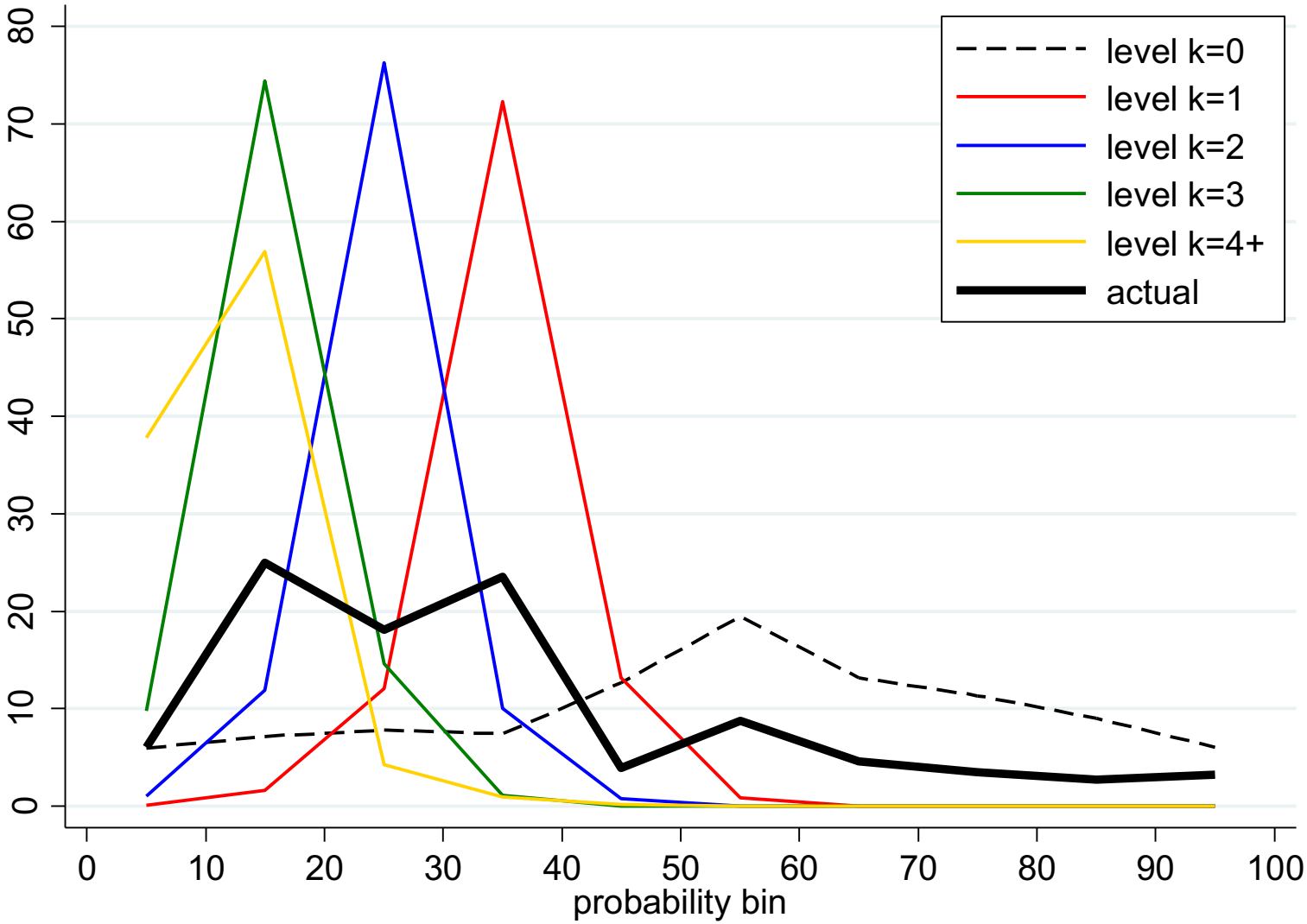

Managers systematically underestimate the dispersion of answers observed.

PREDICTIONS ABOUT BELIEFS OF OTHERS

- Nagel (1995) model of level-k thinking:
  - Place positive probability on exactly one bin.

- Camerer et al (2004) model of cognitive hierarchy:
  - Level-k thinkers may place positive probability on multiple bins

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K-LEVEL THINKING

Level of thinking, k	Fraction reporting			
	Positive probability on more than one bin			
0	0.87			
1	0.82			
2	0.78			
3	0.82			
4	0.83			

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K-LEVEL THINKING

Level of thinking, k	Fraction reporting			
	Positive probability on more than one bin	Average probability on the same bin as the guess		
0	0.87	-		
1	0.82	0.72		
2	0.78	0.77		
3	0.82	0.74		
4	0.83	0.38		

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Level of thinking, k	Fraction reporting			
	Positive probability on more than one bin	Average probability on the same bin as the guess	Average probability on bins associated with lower *k* than the guess	
0	0.87	-	-	
1	0.82	0.72	0.14	
2	0.78	0.77	0.11	
3	0.82	0.74	0.16	
4	0.83	0.38	0.62	

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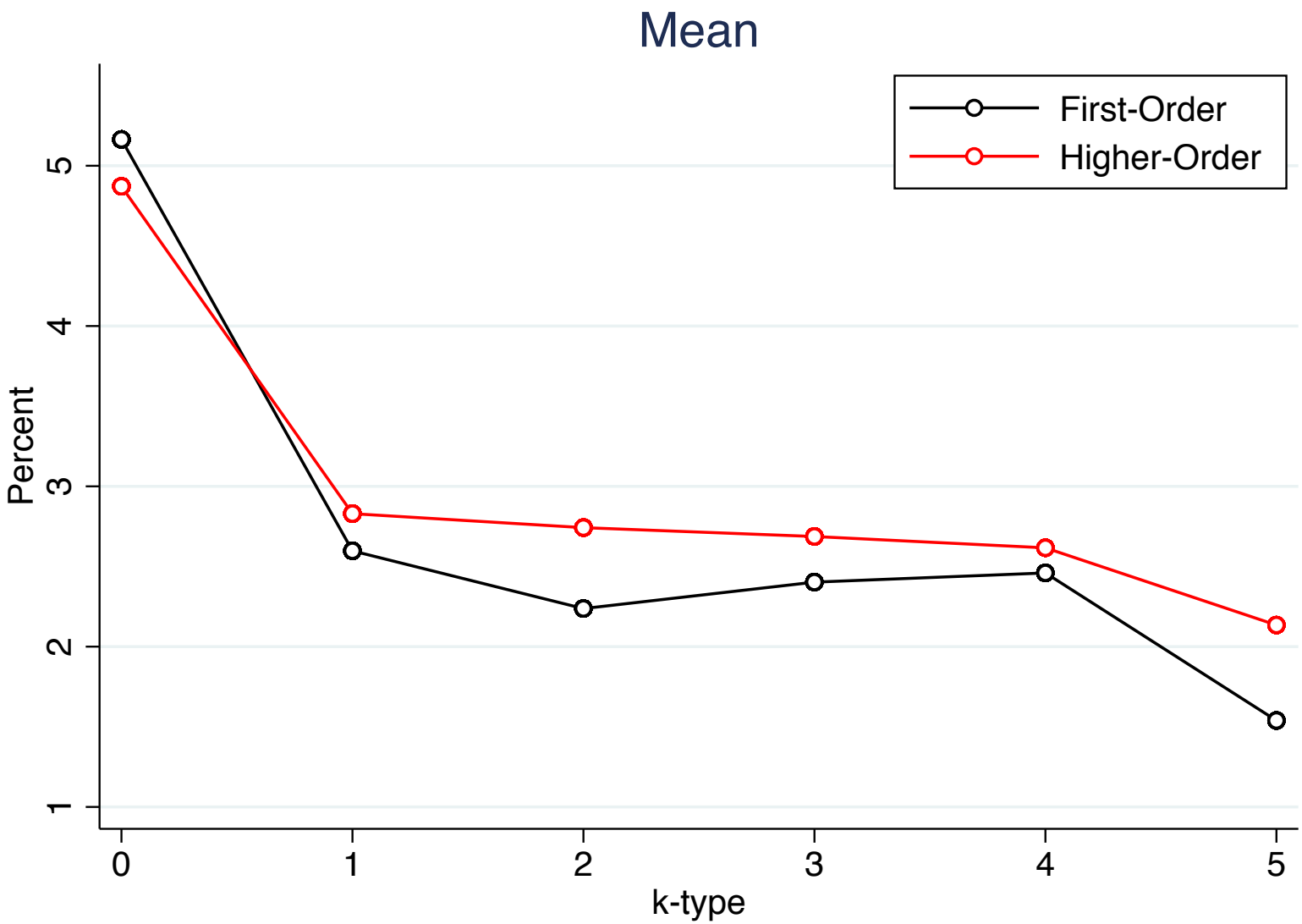
AVERAGE EXPECTATIONS BY *K*-TYPE



K-Level thinking Predictions About Moments

- Average expectations should be similar across thinking types.
  - True for $k \geq 0$
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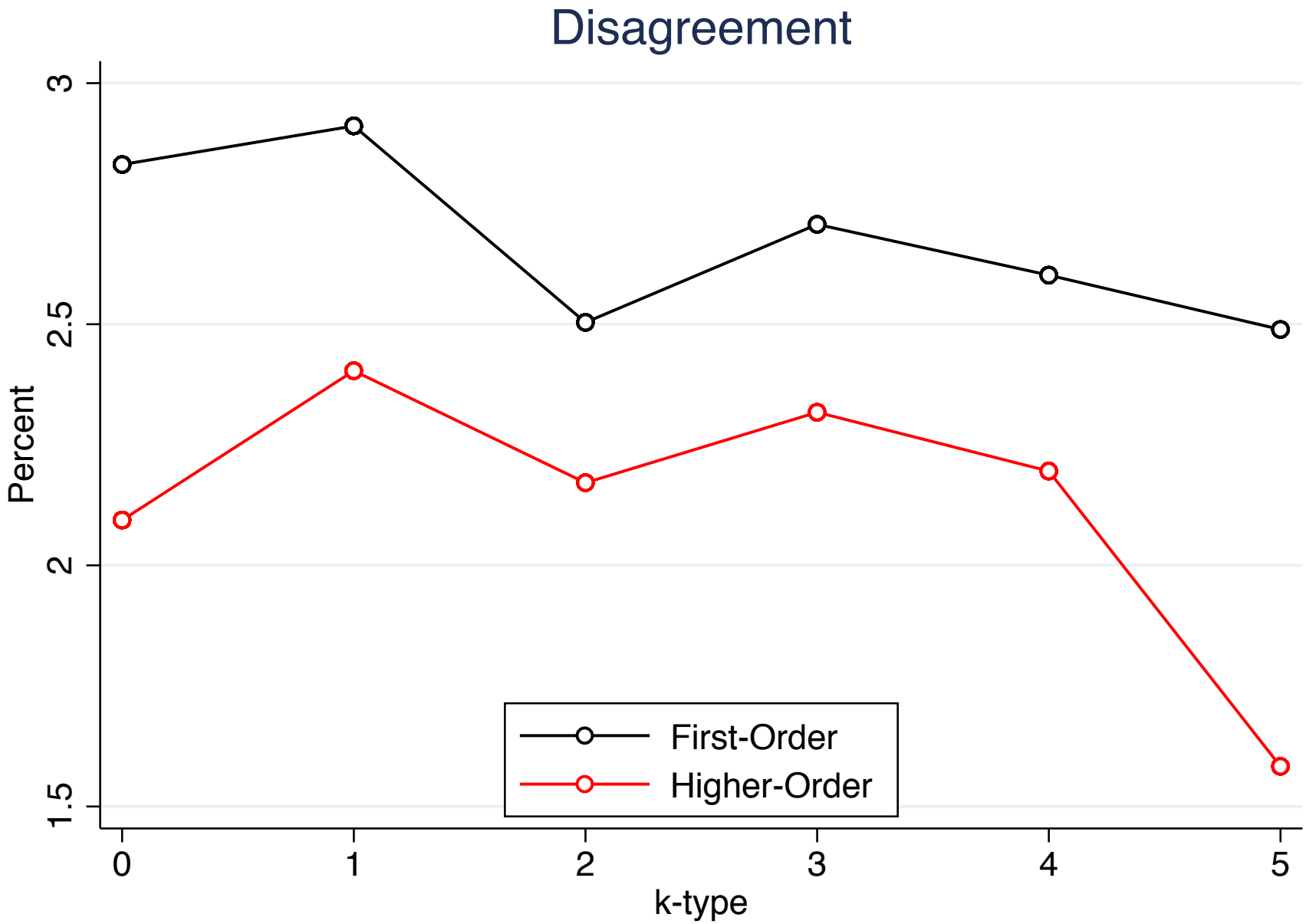
DISAGREEMENT BY *K*-TYPE



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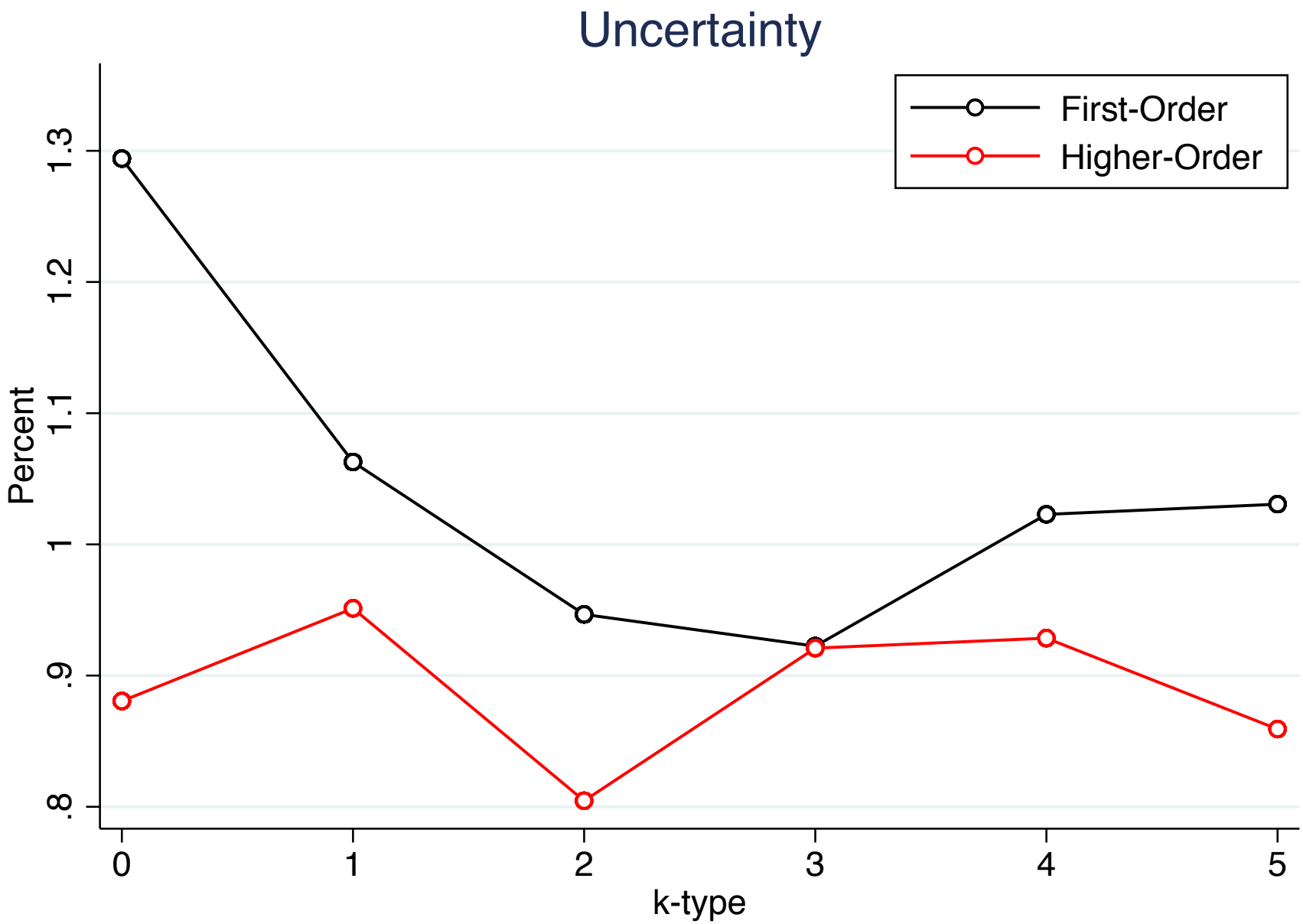
UNCERTAINTY BY *K*-TYPE



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- Lower-level thinkers will update their expectations by more than higher-level thinkers.

LEVEL-K THINKING RESPONSE TO INFORMATION

$$Posterior_{i,group} = \alpha_{group} + \beta_{group} Prior_{i,group}$$

Group	$k = 0$	$k = 1$	$k = 2$
A: *Control group*	0.704		
	(0.042)		
B: Treated with $\overline{E}[\pi]$	0.554		
	(0.109)		
C: Treated with $\overline{E}^2[\pi]$	0.100		
	(0.031)		
D: Treated with *B&C*	0.082		
	(0.035)		
E: Treated with $\overline{\pi}_{t-1}$	0.033		
	(0.019)		

K-Level thinking Predictions About Response to Information

- ~~Level-0 thinkers will not be able to differentiate between different signal types and updates expectations by the same amount in response to different signals~~
- Level-1 thinkers can differentiate between signals about past inflation and signals about the average first-order expectation, but cannot differentiate between signals about first-order and higher-order expectations
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	(0.031)	(0.021)	
D: Treated with *B&C*	0.082	0.107	
	(0.035)	(0.039)	
E: Treated with $\overline{\pi}_{t-1}$	0.033	0.103	
	(0.019)	(0.046)	

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	(0.031)	(0.021)	(0.038)
D: Treated with *B&C*	0.082	0.107	0.090
	(0.035)	(0.039)	(0.035)
E: Treated with $\overline{\pi}_{t-1}$	0.033	0.103	0.071
	(0.019)	(0.046)	(0.032)

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We may be concerned that, while expectations respond the same way to information across k, actions differ with thinking types.

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We may be concerned that, while expectations respond the same way to information across k, actions differ with thinking types.

We find that firms' plans for employment, fixed assets, prices, and wages respond by the same amount across thinking type.

CONCLUDING REMARKS

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- We provide new survey/RCT evidence on
  - Higher-order expectations
  - Level-*k* thinking
  - Treatment effects of information on inflation expectations and choices of managers