

# **Opportunity Unraveled: Private Information and Missing Markets for Human Capital**

Daniel Herbst and Nathaniel Hendren

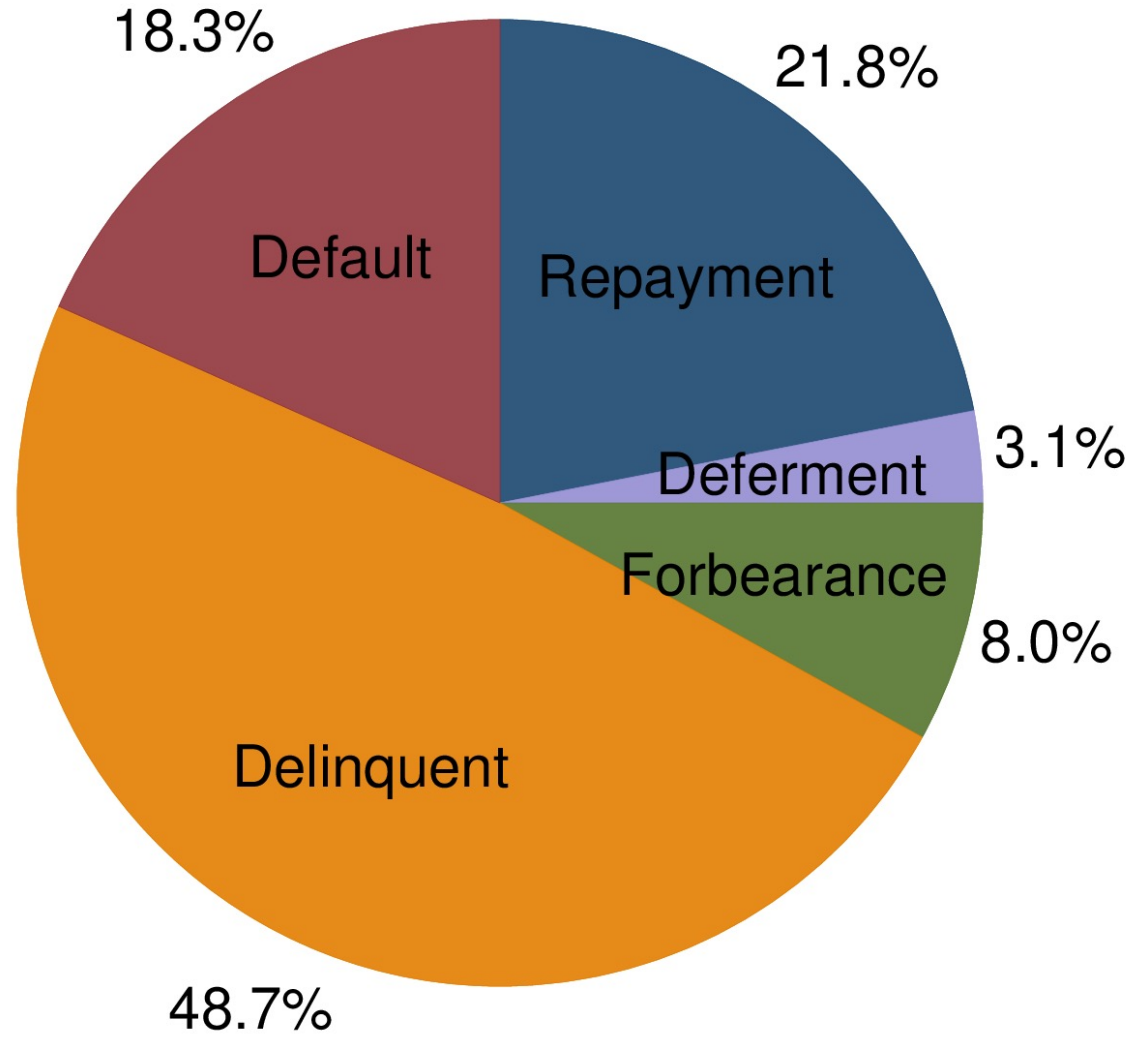
September, 2021

# Going to College is Risky

- Investing in college in the US carries high returns but also high risks
  - Almost half of all college students fail to complete their degrees within six years
  - Among 2012 graduates, only 85% find jobs by 2017
  - By age 40, over 15% of college graduates have household incomes below \$40,000 per year
- Despite this risk, non-dischargeable debt is the primary method of college finance
  - Typically federally-backed student loans that cannot be discharged in bankruptcy
  - \$1.7 trillion in outstanding student debt
  - 45 million borrowers
  - $\approx$ 1 million defaults each year

# 2/3 of Student Borrowers were Delinquent or in Default within Six Years

Most severe non-repayment event since leaving college



# Economists' Solution: Risk-Mitigating Financing for Human Capital

- Economists often promote financial contracts that mitigate college-investment risk:

## 1. **Earnings-equity contracts:** borrower pays $X\%$ of earnings

*"[Human capital] investment necessarily involves much risk. The device adopted to meet the corresponding problem for other risky investments is equity investment...The counterpart for education would be to 'buy' a share in an individual's earnings prospects; to advance him the funds needed to finance his training on condition that he agree to pay the lender a specified fraction of his future earnings."*

- Milton Friedman (1955)

- Rationale behind public income-contingent loan programs

## 2. **State-contingent debt contracts:** Borrower pays \$ $X$ only if event occurs

- **Completion-contingent loan:** Debt forgiveness for college dropouts
- **Employment-contingent loan:** Debt that's forgiven in unemployment
- **Dischargeable loan:** Debt that's dischargeable in delinquency/default

- Equity and state-contingent debt are common in markets for *physical* capital investment

Research Question: Why don't we see similar financial markets for *human* capital investments?

# **This Paper: Adverse Selection has Unraveled These Markets**

## **This Paper: Adverse Selection has Unraveled These Markets**

1. Develop model of financial markets for human capital to characterize when risk-mitigating financial markets can exist
  - Clarify role of adverse selection vs. other forces such as moral hazard in market existence
  - Two curves determine market (non)existence
    - “Willingness to Accept” (WTA) in exchange for a future share of an outcome
    - “Average value” (AV) of worse risks of future outcomes

## **This Paper: Adverse Selection has Unraveled These Markets**

1. Develop model of financial markets for human capital to characterize when risk-mitigating financial markets can exist
2. Use subjective expectations about future outcomes to provide reduced-form evidence of private information about future outcomes
  - Use subjective expectations about future outcomes as noisy/biased measures of true beliefs
  - Elicitations predict future income, college completion, employment, and loan repayment
  - Predictive power remains after conditioning on a rich set of publicly observable characteristics

## This Paper: Adverse Selection has Unraveled These Markets

1. Develop model of financial markets for human capital to characterize when risk-mitigating financial markets can exist
2. Use subjective expectations about future outcomes to provide reduced-form evidence of private information about future outcomes
3. Empirically test unraveling condition ( $WTA > AV$ ) using subjective elicitation
  - Estimate non-parametric lower bounds on average AV “markdown”
  - Semi-parametric point-estimates of AV and WTA using MLE and deconvolution methods
  - In all four market settings, find  $WTA > AV$  so that the market unravels
  - Example: Earnings-equity market
    - $WTA = \$16K \Rightarrow$  median college-goer is willing to repay \$1.28 for every \$1 of equity financing
    - $AV = \$12K \Rightarrow$  same student would have to repay \$1.64 in expectation to prevent unraveling



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1. Develop model of financial markets for human capital to characterize when risk-mitigating financial markets can exist
2. Use subjective expectations about future outcomes to provide reduced-form evidence of private information about future outcomes
3. Empirically test unraveling condition ( $WTA > AV$ ) using subjective elicitations
4. Measure welfare impact of government subsidies to open up these markets
  - Estimate the  $MVPF = \frac{Benefits}{Net\ Govt\ Cost}$  of subsidies for these contracts
  - Baseline specifications suggest MVPFs  $> 1$  for  $\frac{3}{4}$  markets: earnings-equity, employment-contingent loans, and completion-contingent loans
    - ⇒ Insurance value  $>$  distortionary costs

## Related Work

- Subjective probability elicitation to test for market unraveling
  - Hendren (2013, 2017)
  - Our approach allows for continuous outcome (e.g. income) and indirect elicitation-belief relationship
- Information asymmetries in household finance:
  - Stroebe (2016); Gupta and Hansman (2019); Adams, Einav and Levin (2009); Einav, Jenkins and Levin (2012); Dobbie and Skiba (2013); DeFusco, Tang and Yannelis (2020); Karlan and Zinman (2009); Einav et al. (2010)
- Income-contingent college financing:
  - Friedman (1955); Nerlove (1975); Palacios (2004); Chapman (2006); Field (2009); Barr et al. (2017); Abraham et al. (2018); Mumford (2020); Britton and Gruber (2020); Mueller and Yannelis (2020); Herbst (2020)
- Optimal taxes/subsidies for human capital
  - Mirrlees (1978); Bovenberg and Jacobs (2006); Jacobs and van Wijnbergen (2007); Stantcheva (2017)

# Outline

- ① **Model of Market Unraveling**
- ② **Data and Reduced Form Evidence of Private Information**
- ③ **Lower-Bound on Magnitude of Private Information**
- ④ **Estimation of Average Value and Willingness to Accept Curves**
- ⑤ **Welfare Impacts of Government Subsidies**

# Outline

- 1 Model of Market Unraveling**
- 2 Data and Reduced Form Evidence of Private Information**
- 3 Lower-Bound on Magnitude of Private Information**
- 4 Estimation of Average Value and Willingness to Accept Curves**
- 5 Welfare Impacts of Government Subsidies**

## Model of Market Unraveling

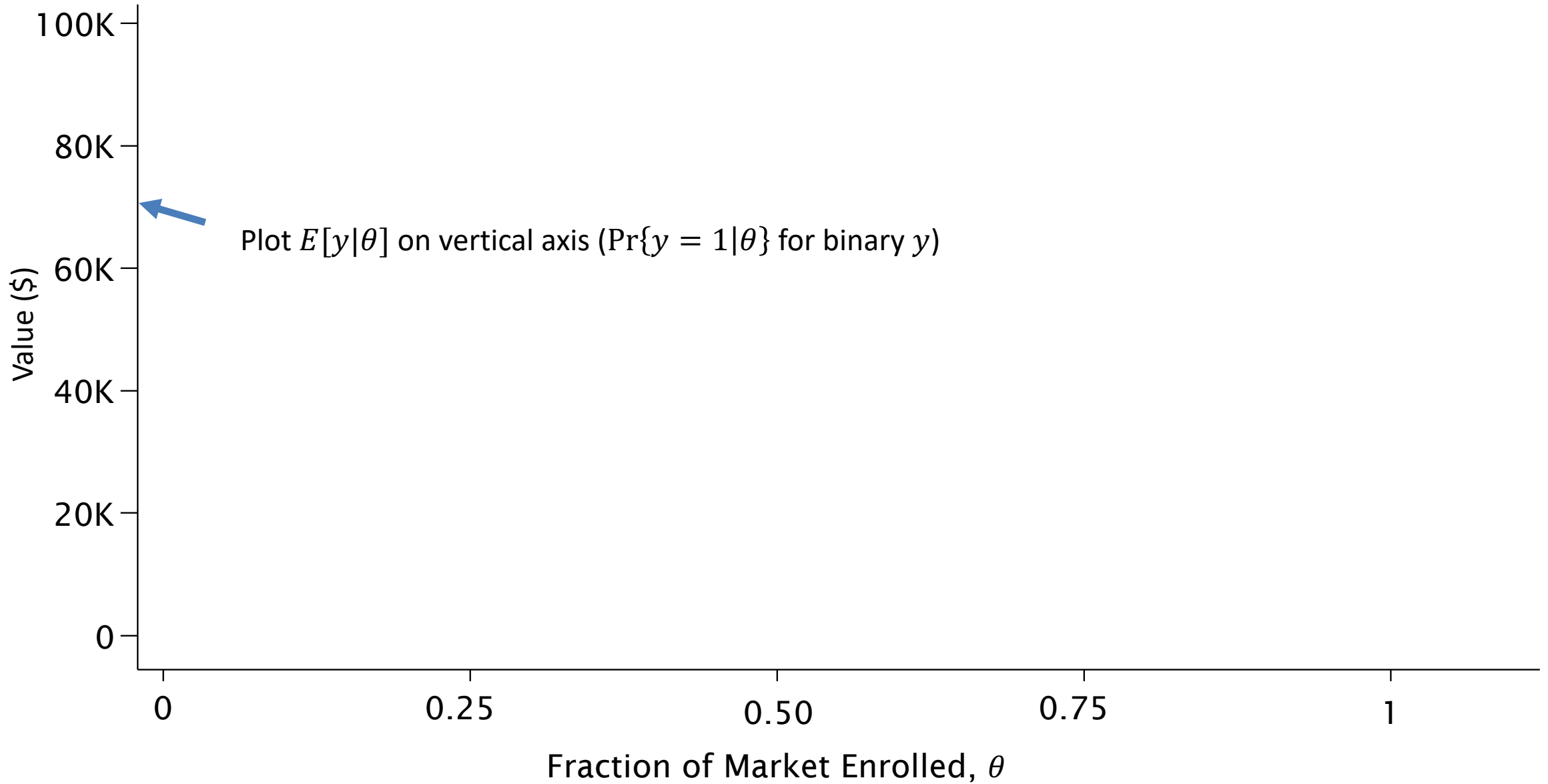
- Consider a financial contracts that pays  $\eta\lambda$  to college enrollees today in exchange for  $\eta y$ , where  $y$  is a later-realized outcome (binary or continuous)
  - $\eta$  is the “size” of the contract
  - $\lambda$  is the “price” of the contract (amount the financier would pay for the entire  $y$ )
- We consider four hypothetical contracts on four outcomes,
  1. *Earnings-Equity Contract*:  $y = \text{earnings}$
  2. *Completion-Contingent Loan*:  $y = \text{complete degree}$
  3. *Employment-Contingent Loan*:  $y = \text{employed}$
  4. *Dischargeable Loan*:  $y = \text{no delinquency}$

} (continuous  $y$ )  
} (binary  $y$ )
- When does there exist a pair  $(\eta, \lambda)$  such that this market can be profitable?

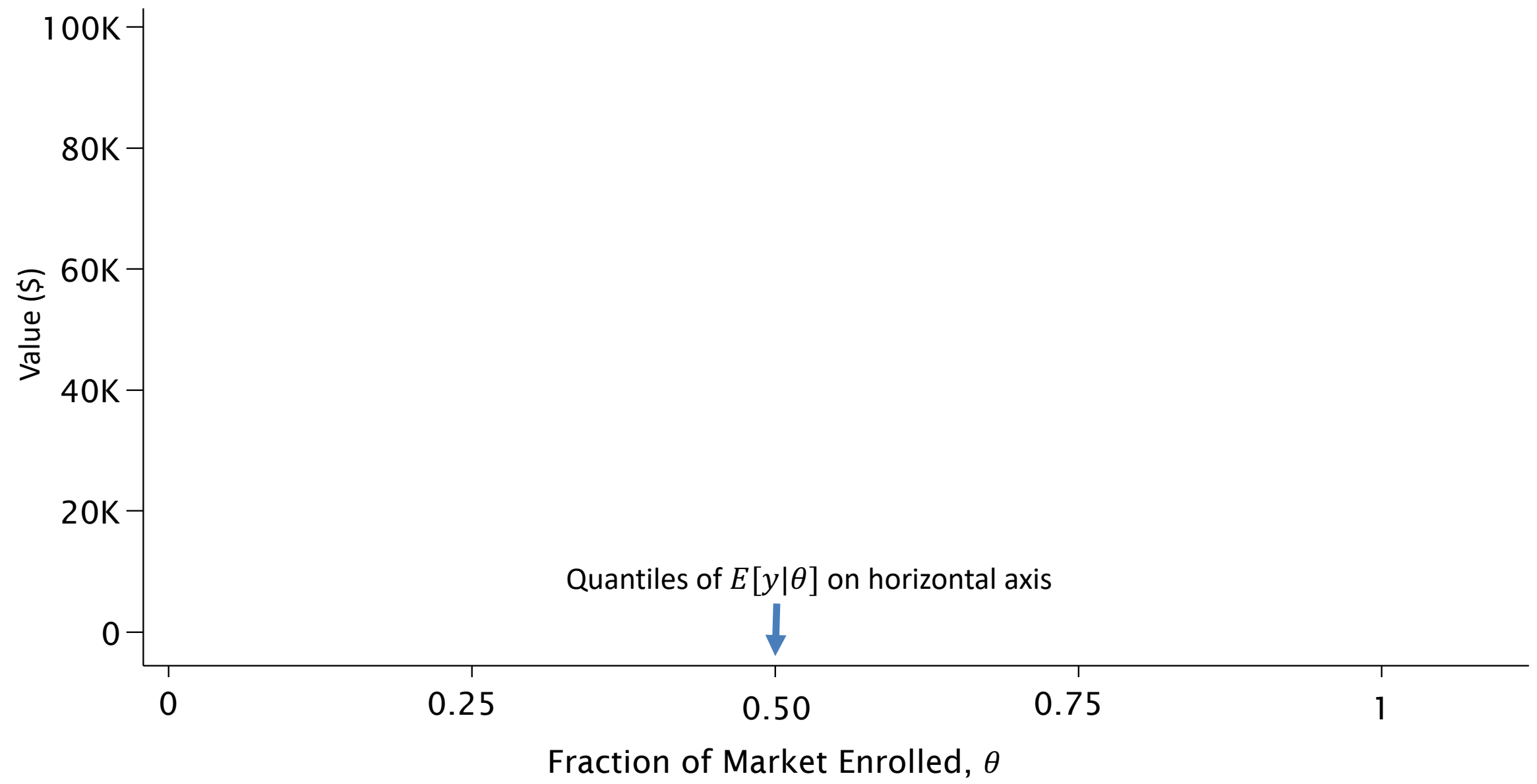
## Model of Market Unraveling

- Individuals have a utility function  $u(c_1, c_2, a)$ 
  - Consumption while in college,  $c_1$
  - Consumption at the point when  $y$  occurs,  $c_2$
  - A vector of other actions,  $a$  (includes “moral hazard”)
  - Let “type”  $\theta \in \mathbb{R}$  denote individuals’ beliefs about  $y$ 
    - assume “single index” ordered by each  $\theta$ ’s believed mean outcome  $\mu_\theta \equiv E[y|\theta]$
- First dollar of the contract has the highest potential market surplus (Hendren 2017)
  - ⇒ Sufficient to consider existence of small contracts,  $\eta \approx 0$
  - ⇒ Moral hazard does not affect market existence (Shavell 1979, Hendren 2017)
- Financiers observe  $X$  and can price on observables
  - We condition on  $X = x$  in empirical exercise, but suppress  $X$  notation for now (imagine a market of observationally equivalent individuals)

## Example Model Setup: $E[y|\theta]$

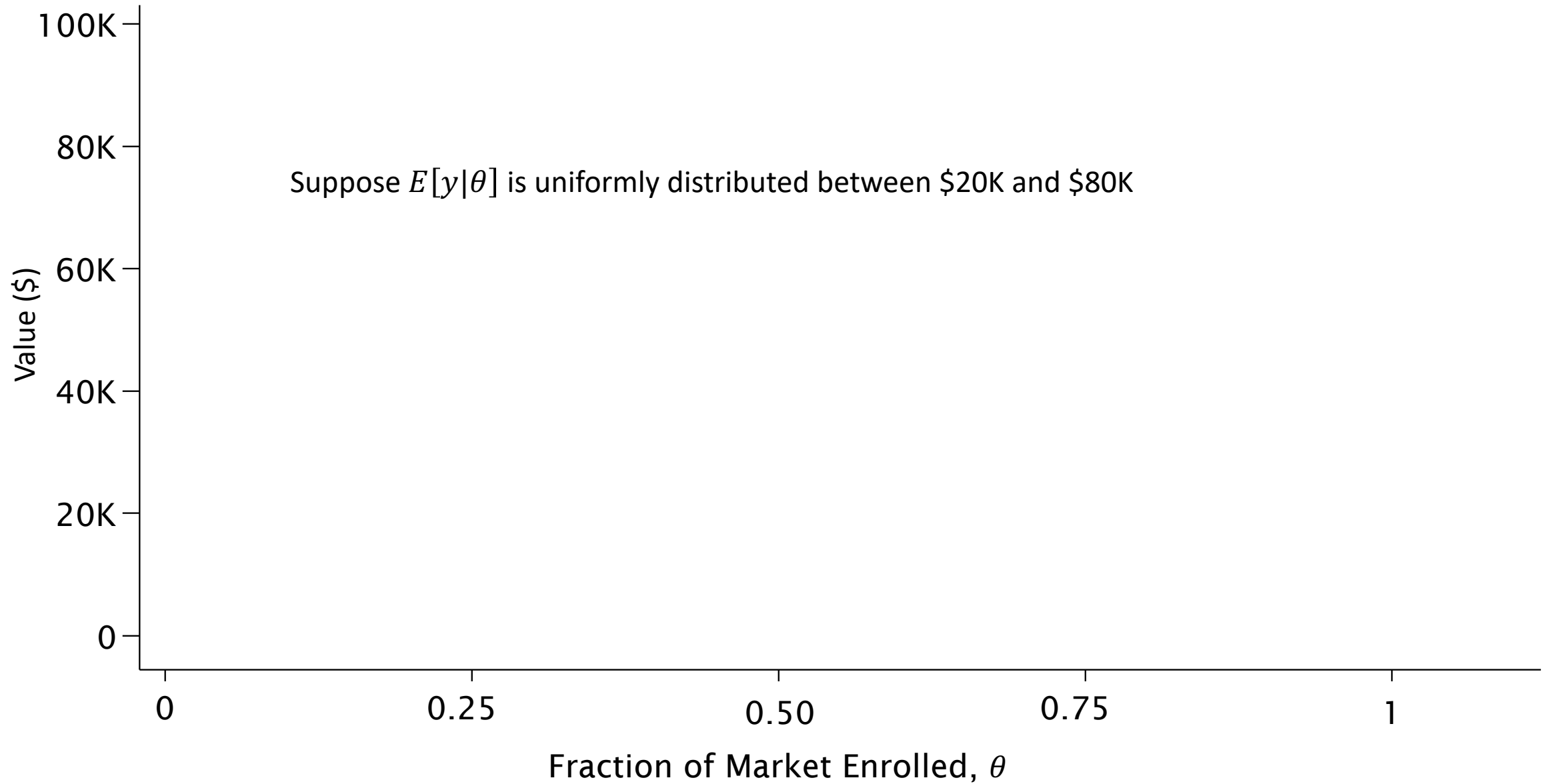


# Example Model Setup: $E[y|\theta]$

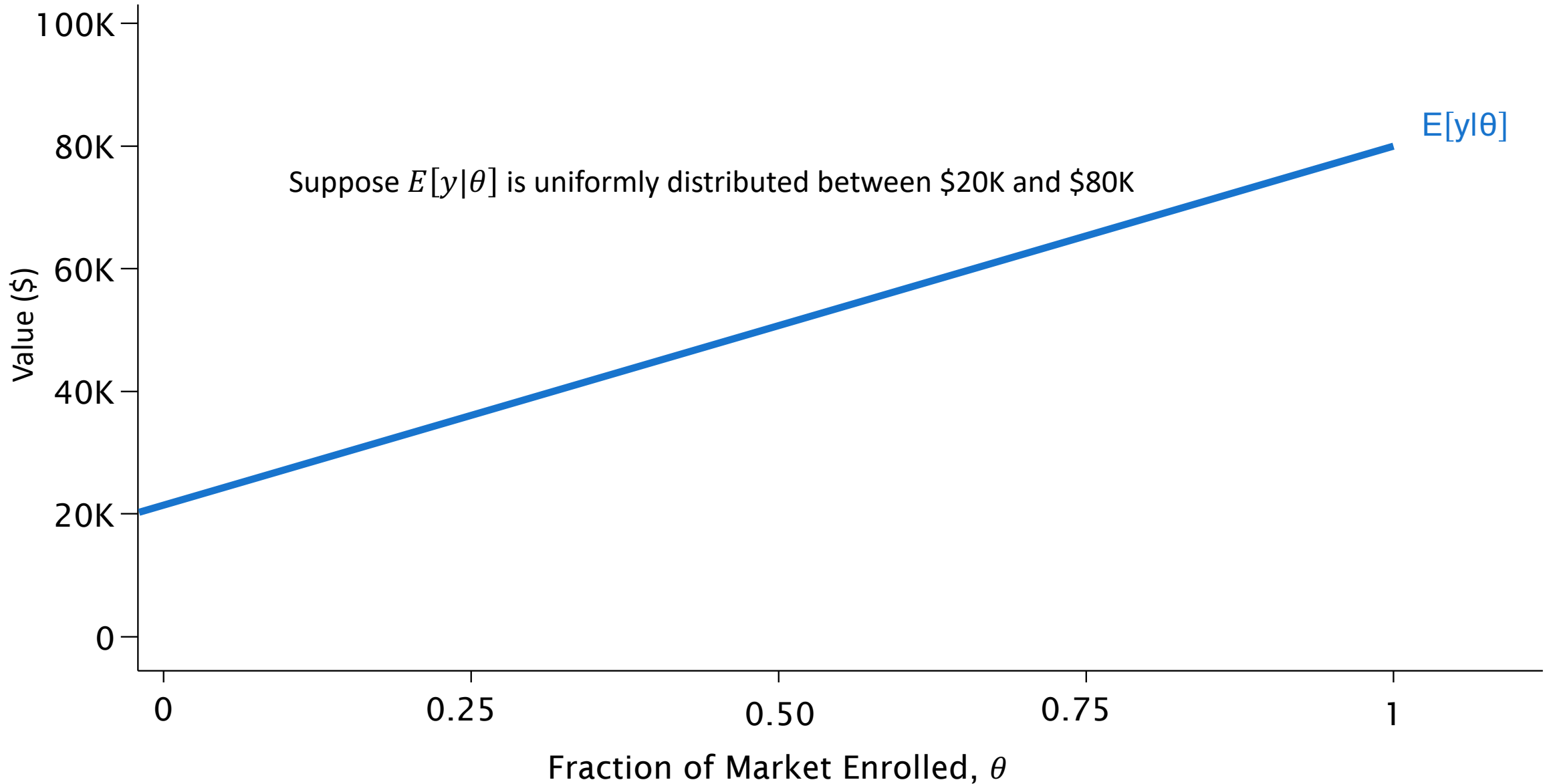




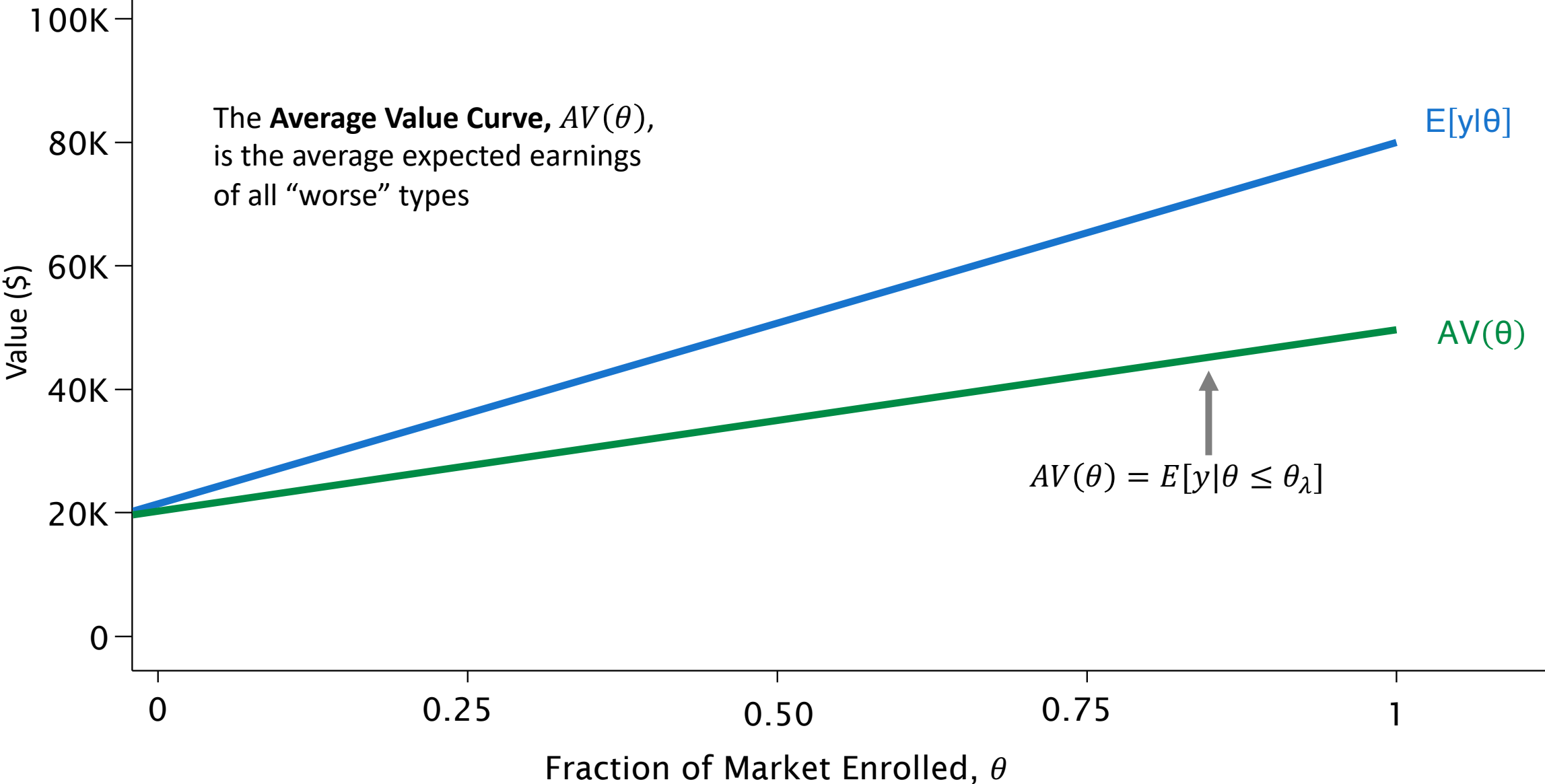
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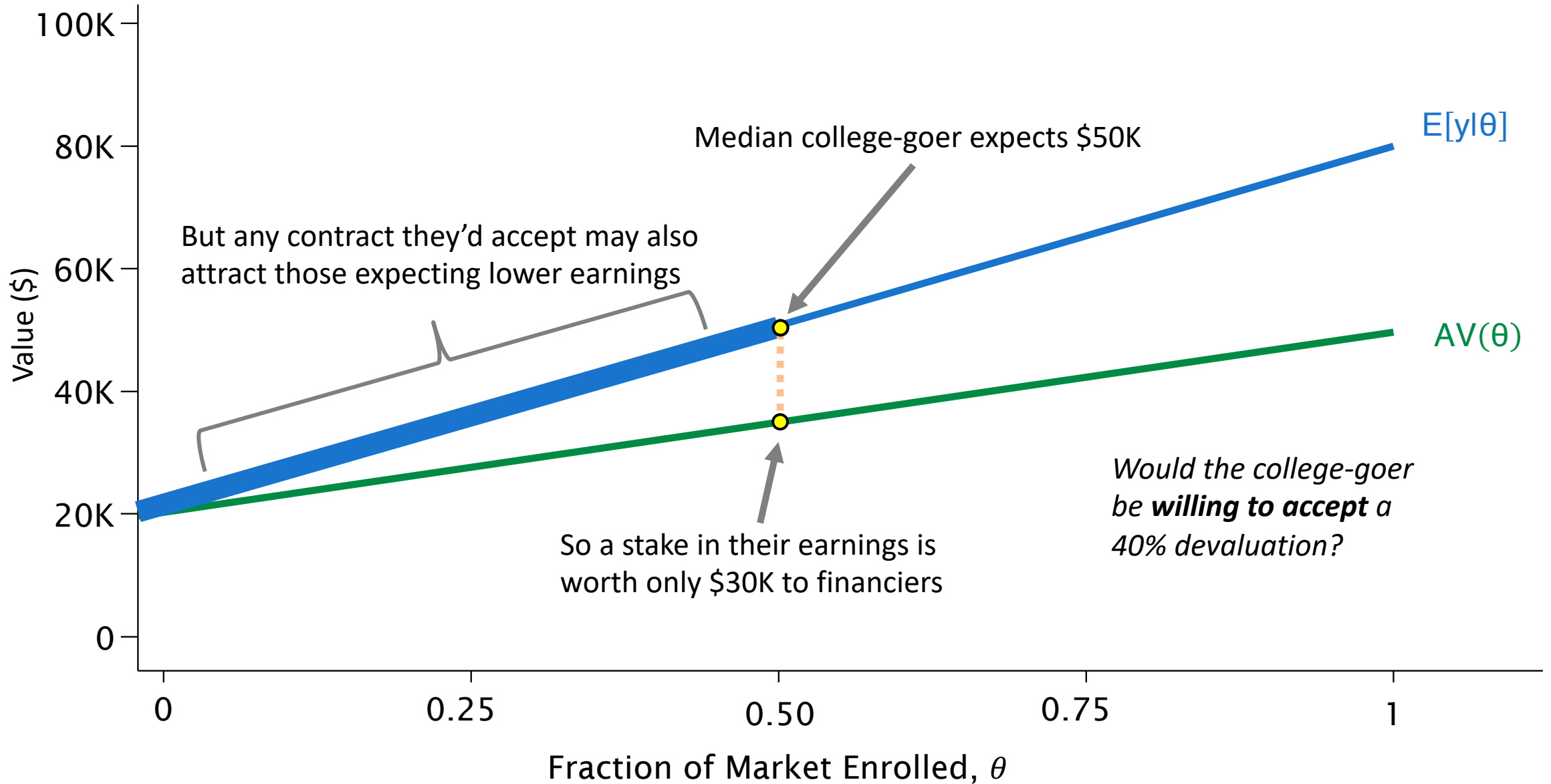
## Example Model Setup: $E[y|\theta]$



# Average Value Curve, $AV(\theta)$



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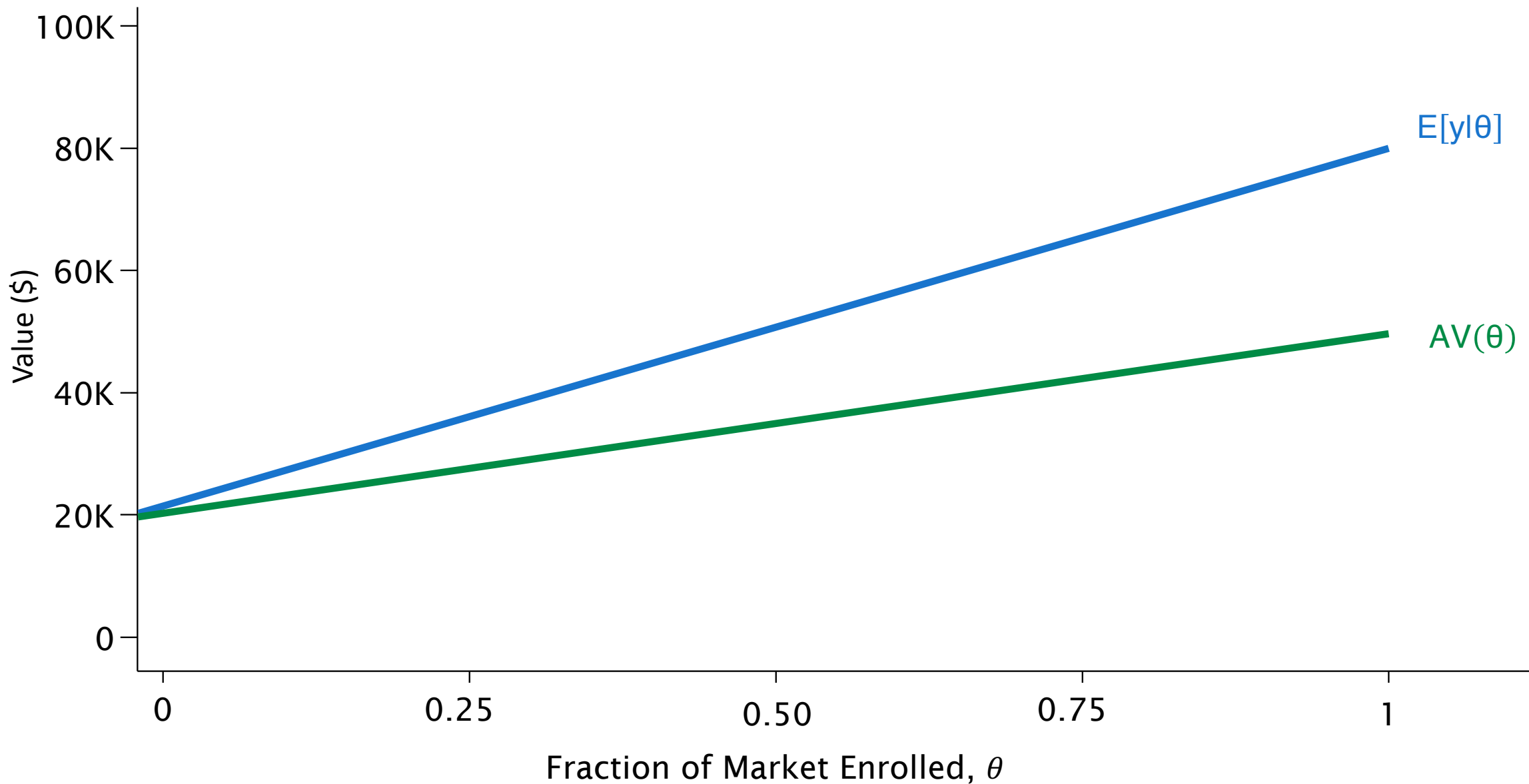
## What are Borrowers Willingness to Accept in Exchange for a Share of $y$ ?

- How much are borrowers willing to accept for a small amount of  $\eta$ ,  $d\eta$ ?
- Type  $\theta$  will accept a small amount  $\eta$  iff  $\lambda u_1(\theta) \geq E[yu_2|\theta]$ 
  - For small  $\eta$ , choice of  $a$  does not affect decision to accept because of envelope theorem
- Let  $WTA(\theta)$  denote the value of  $\lambda$  at which individuals are willing to accept:

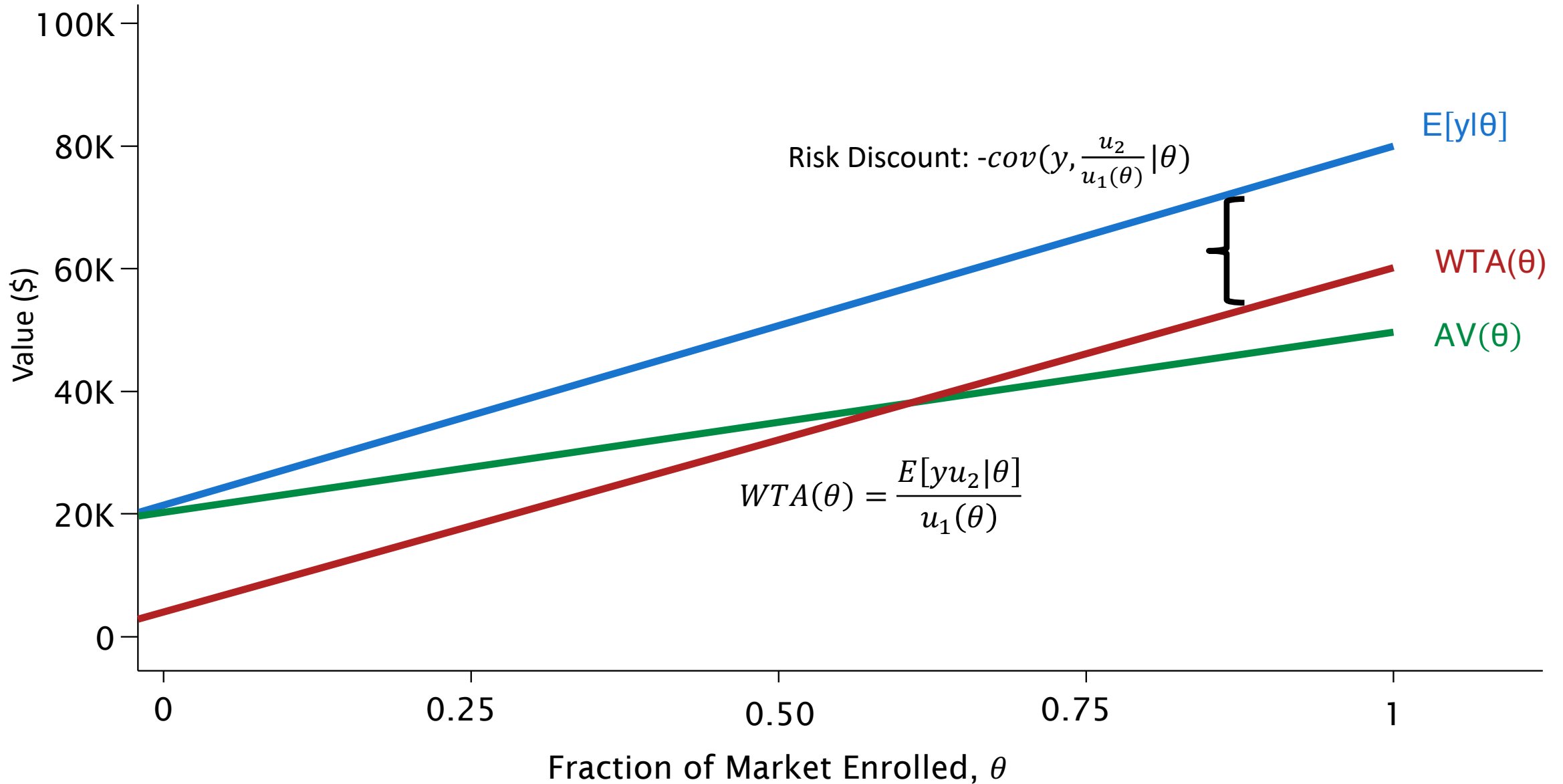
$$WTA(\theta) = \frac{E[yu_2|\theta]}{u_1(\theta)}$$

- Individuals “sell” a small share of outcome  $y$  for college financing if  $WTA(\theta) \leq \lambda$

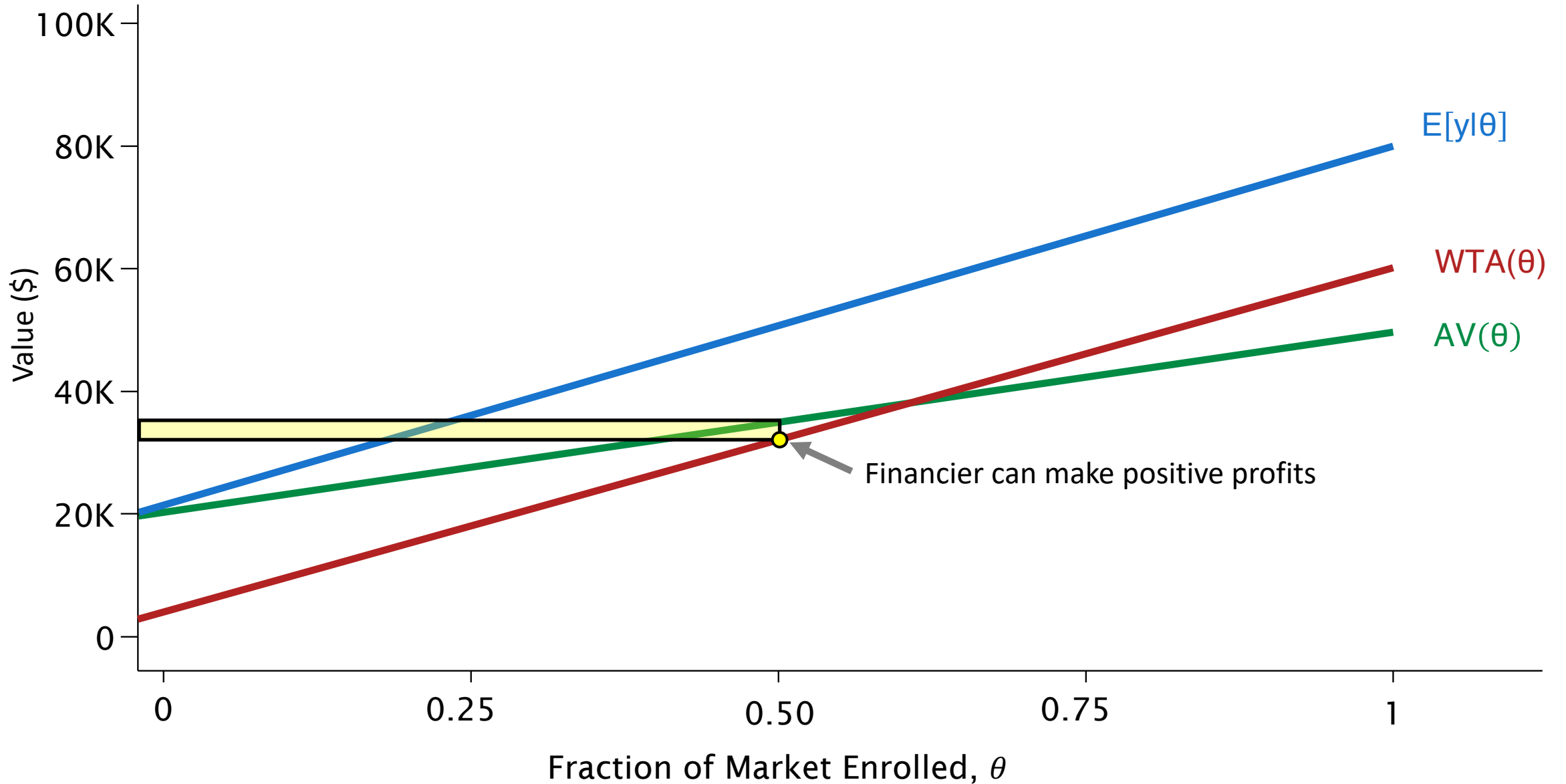
# Willingness to Accept: Scenario #1



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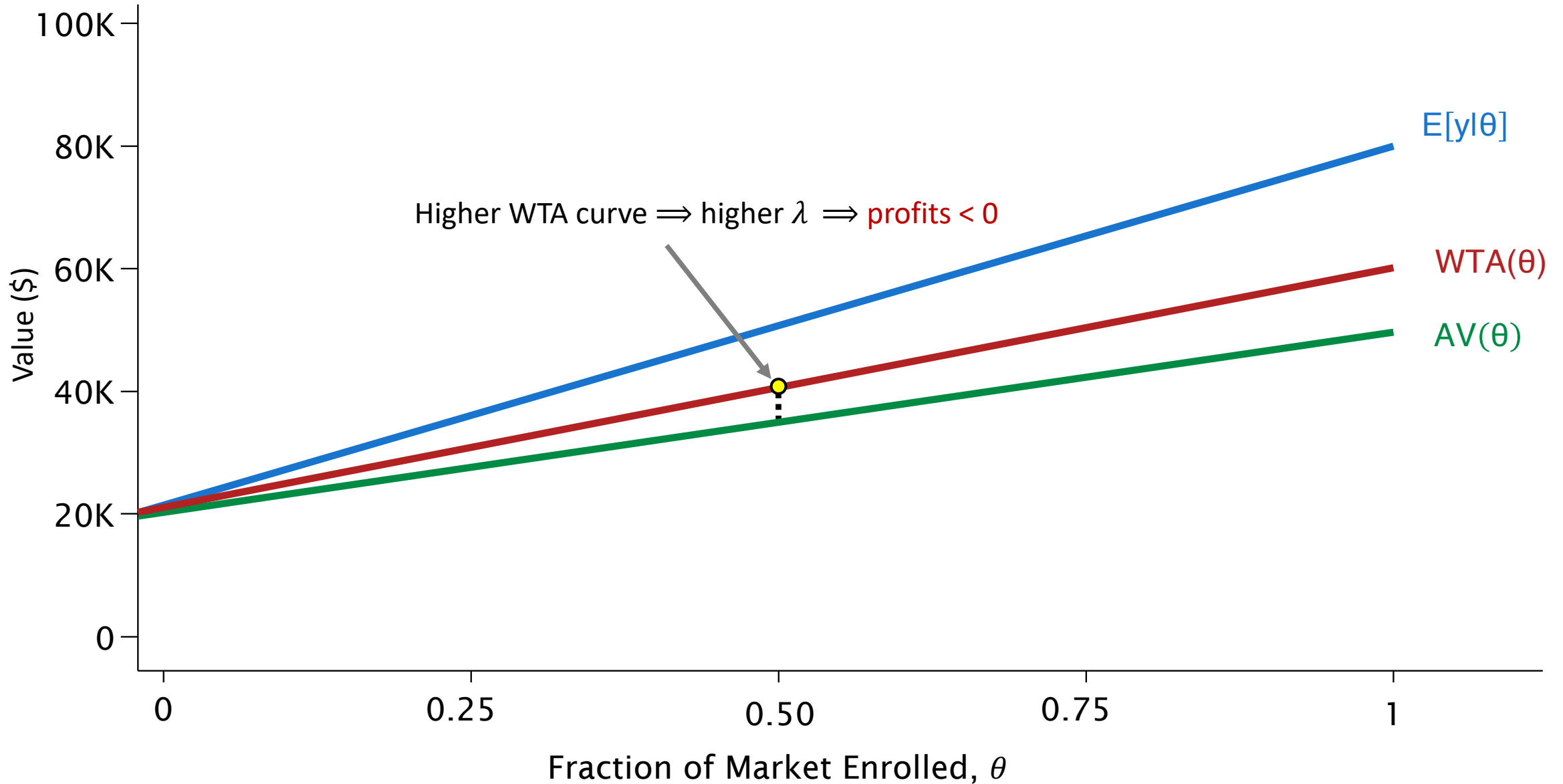


# Willingness to Accept: Scenario #1

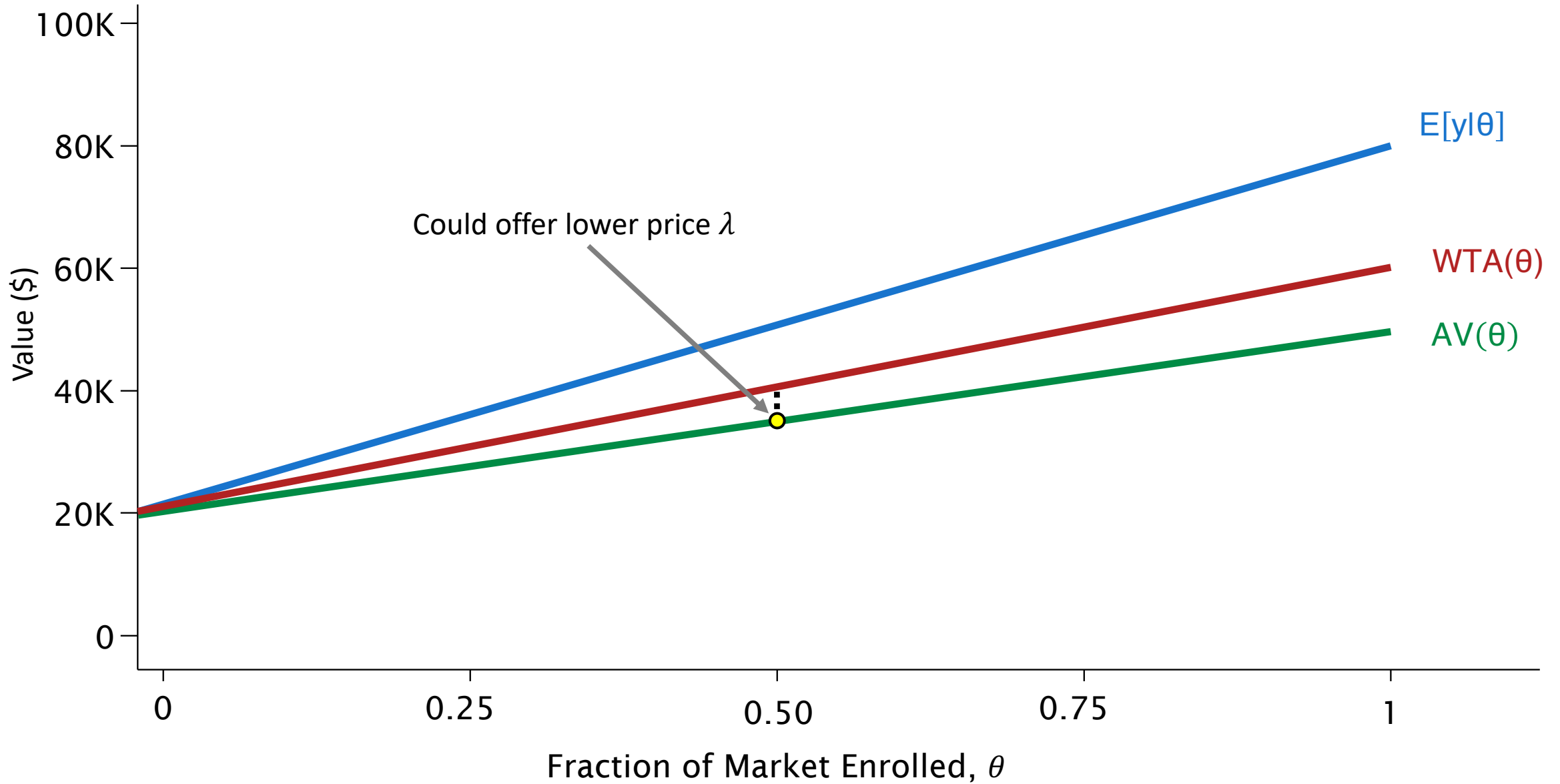




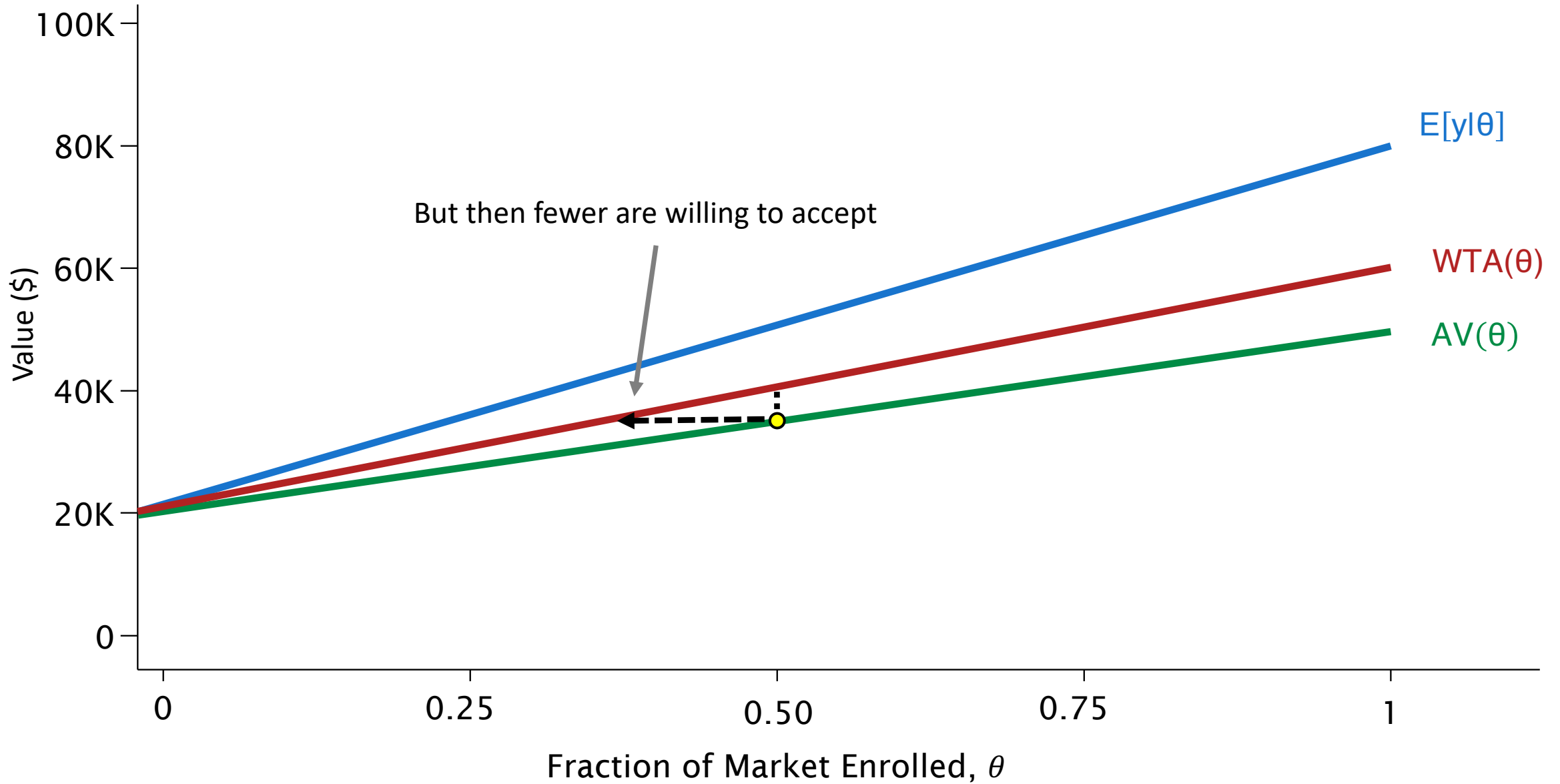
## Willingness to Accept: Scenario #2



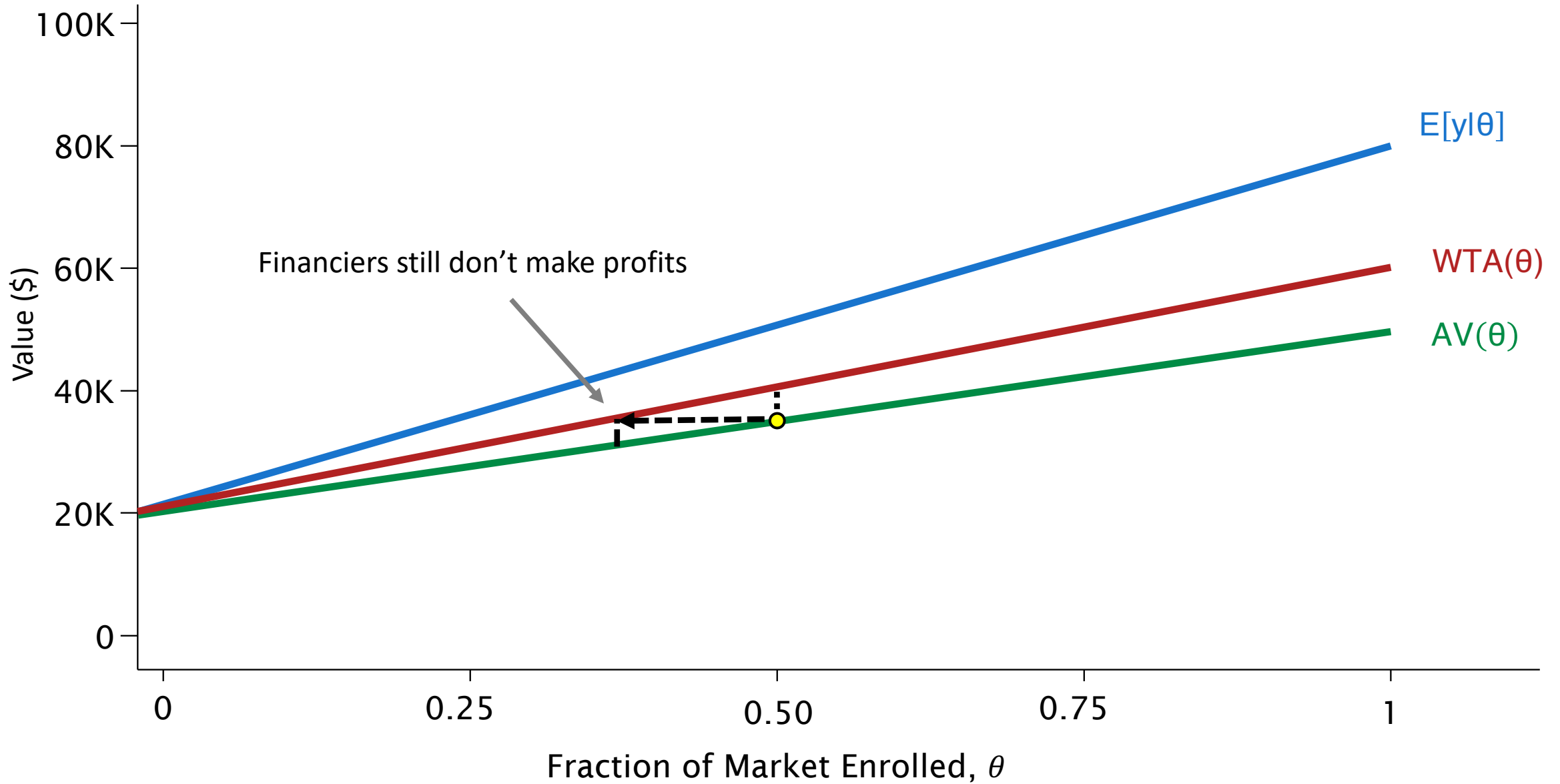
# Potential for Market Unraveling



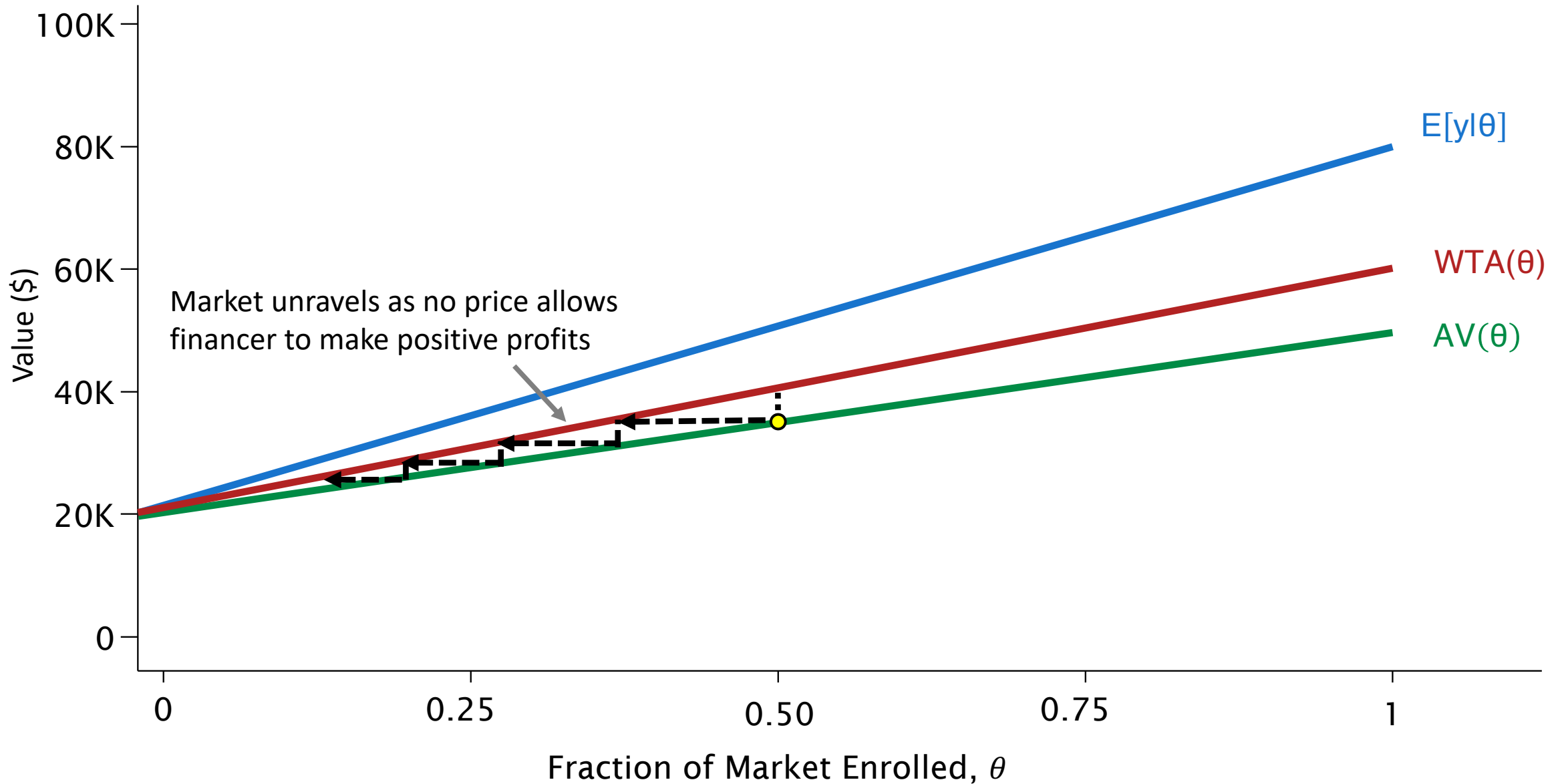
# Potential for Market Unraveling



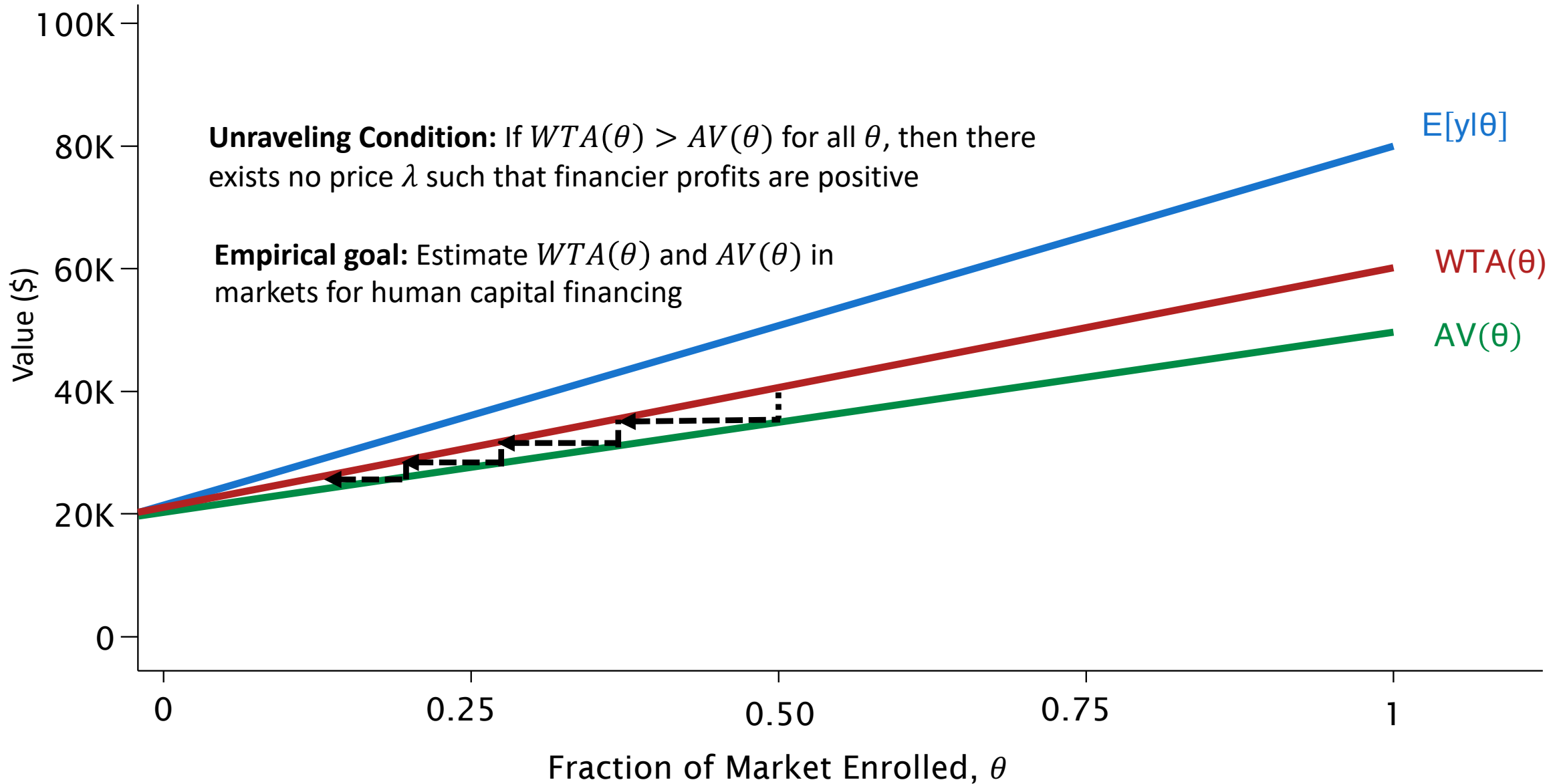
# Potential for Market Unraveling



# Market Unravels when $WTA(\theta) > AV(\theta) \forall \theta$



# Market Unravels when $WTA(\theta) > AV(\theta) \forall \theta$



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# Data: Beginning Postsecondary Students Survey (BPS)

- 2012/2017 Beginning Postsecondary Students (BPS)
  - First-year college students in Spring 2012
  - Follow up in 2017
  
- Links data across several sources
  1. FAFSA records (parental income, sex, age, etc.)
  2. Administrative loan data (National Student Loan Database System)
  3. Administrative academic information (major, GPA, SAT scores)
  4. Survey data (beliefs, employment outcomes, salary)



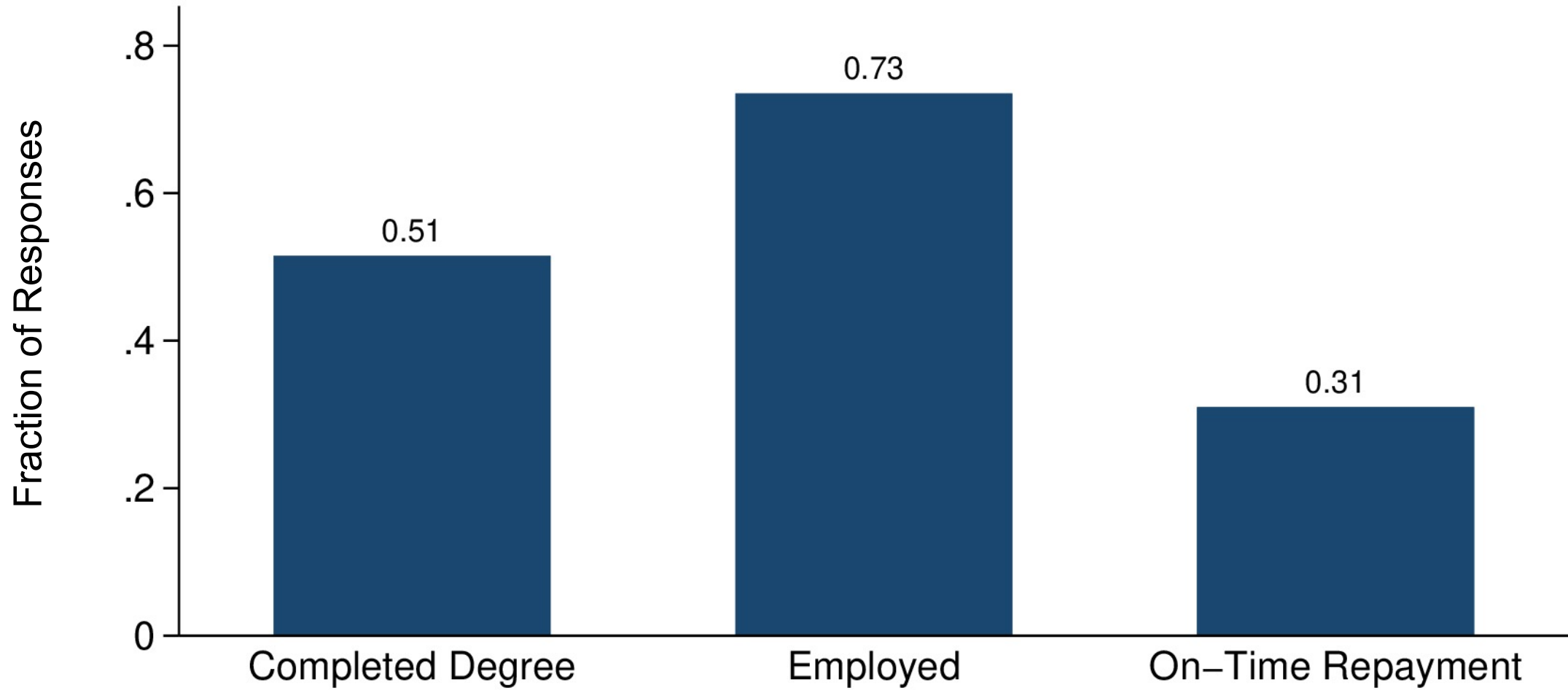
## Empirical Approach Relies on Three Types of Variables

- Y: Outcomes corresponding 4 hypothetical markets we consider
  - Equity Contract (continuous  $y$ ):
    - $y$  is annual salary from last job held in January and June 2017
  - Three state-contingent debt contracts (binary  $y$ ):
    - Dropout forgiveness: Degree completion as of 2017 (6 years post-enrollment)
    - Unemployment forgiveness: No unemployment for  $\geq 1$  months since leaving college, as of June 2017
    - Dischargeable debt: No delinquency/default-triggering events since leaving college as of June 2017
- Note: A limitation of our approach is we must observe the outcome ( $y$ ) corresponding to the contract

# Histogram of Realized Earnings in 2017



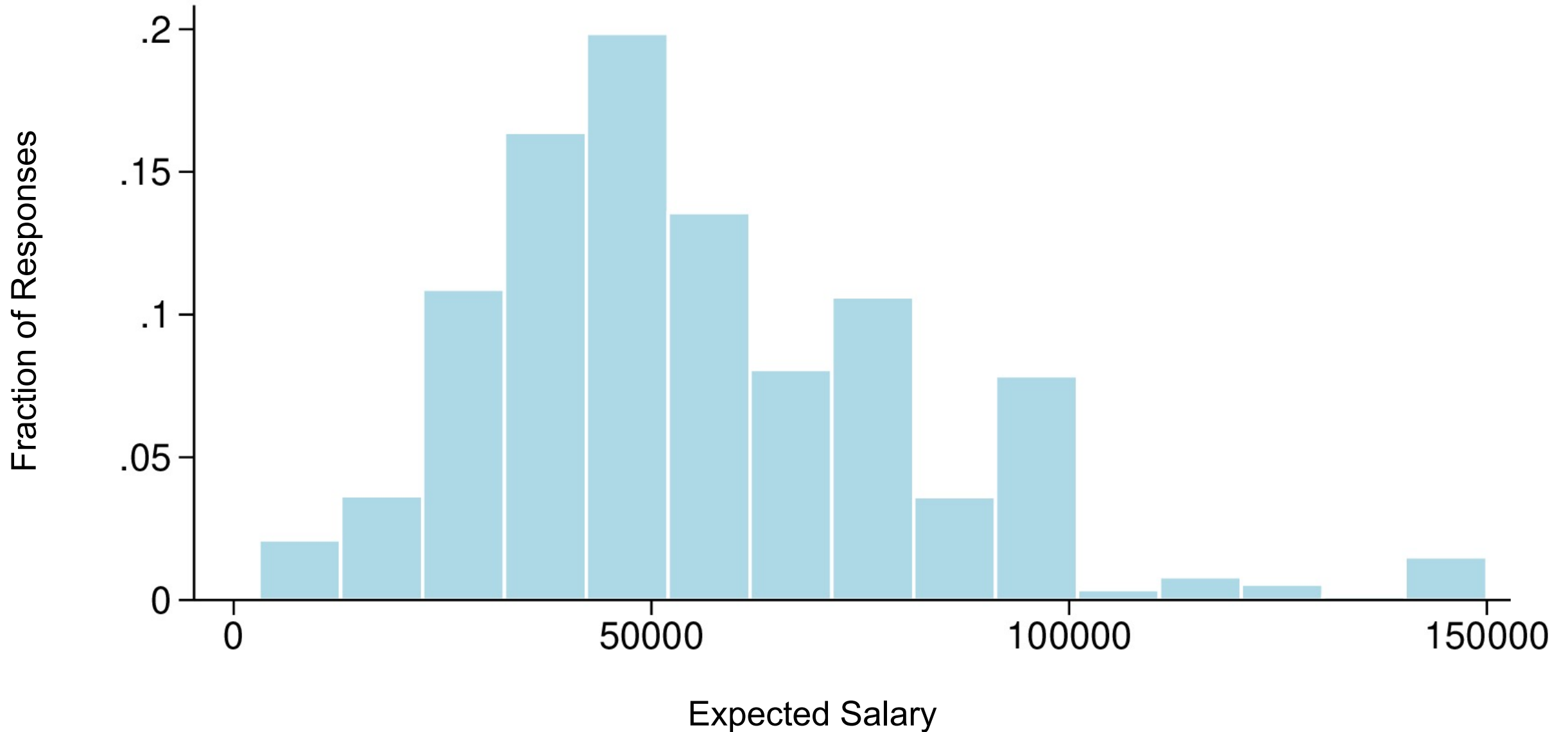
## Summary Statistics for 2017 Outcomes



# Empirical Approach Relies on Three Types of Variables

- Y: Outcomes corresponding to each of the 4 hypothetical markets we consider
  
- Z: Subjective elicitations of future outcomes
  - On-time Degree Completion: *“On a scale from 0-10, how likely is it you will finish your degree by [expected date]”*
  - Occupation: *“What do you think the job title and duties of the occupation you intend to hold will be after having completed your education?”*
  - Employment in Occupation: *“On a scale from 0-10, how likely do you think it is that you will hold a(n) [EXPECTED OCC] job?”*
  - Salary: *“Once you begin working [in EXPECTED OCC], what is your expected yearly salary?”*
  - Expected Salary without College: *How much do you think you would have earned from working if you had not attended college at all in the 2011- 2012 school year?*
  - Parental Support: *“On a scale of 1-5, how much do agree with the following statement: “My parents encourage me to stay in college”*
  - Parental Financial Support: *“Through the end of the 2011-2012 school year (July 1, 2011-June 30, 2012), will your parents (or guardians) have helped you pay for any of your education and living expenses while you are enrolled in school?...How much?”*

# Histogram of Expected Salary in Expected Occupation



## Empirical Approach Relies on Three Types of Variables

- Y: Outcomes corresponding to each of the 4 hypothetical markets we consider
- Z: Subjective elicitations of future outcomes
- X: Observable information about borrowers that financiers could use to price contracts
  - **Institutional Characteristics:** enrollment size, admit rate, tuition charged, degree offerings, region, urban/rural, avg. demographics and test scores
  - **Academic Program Characteristics:** degree type (BA, AA), field of study, years since HS
  - **High School Performance Measures:** HS GPA, SAT/ACT (verbal, math, combined)
  - **Demographics:** age, citizenship status, marital status, no. of children, prior state of residence
  - **Parental Characteristics:** marital status, no. of children, annual income, EFC
  - **Protected Classes:** race, gender (*illegal to use in pricing*)

## Test for Potential for Adverse Selection

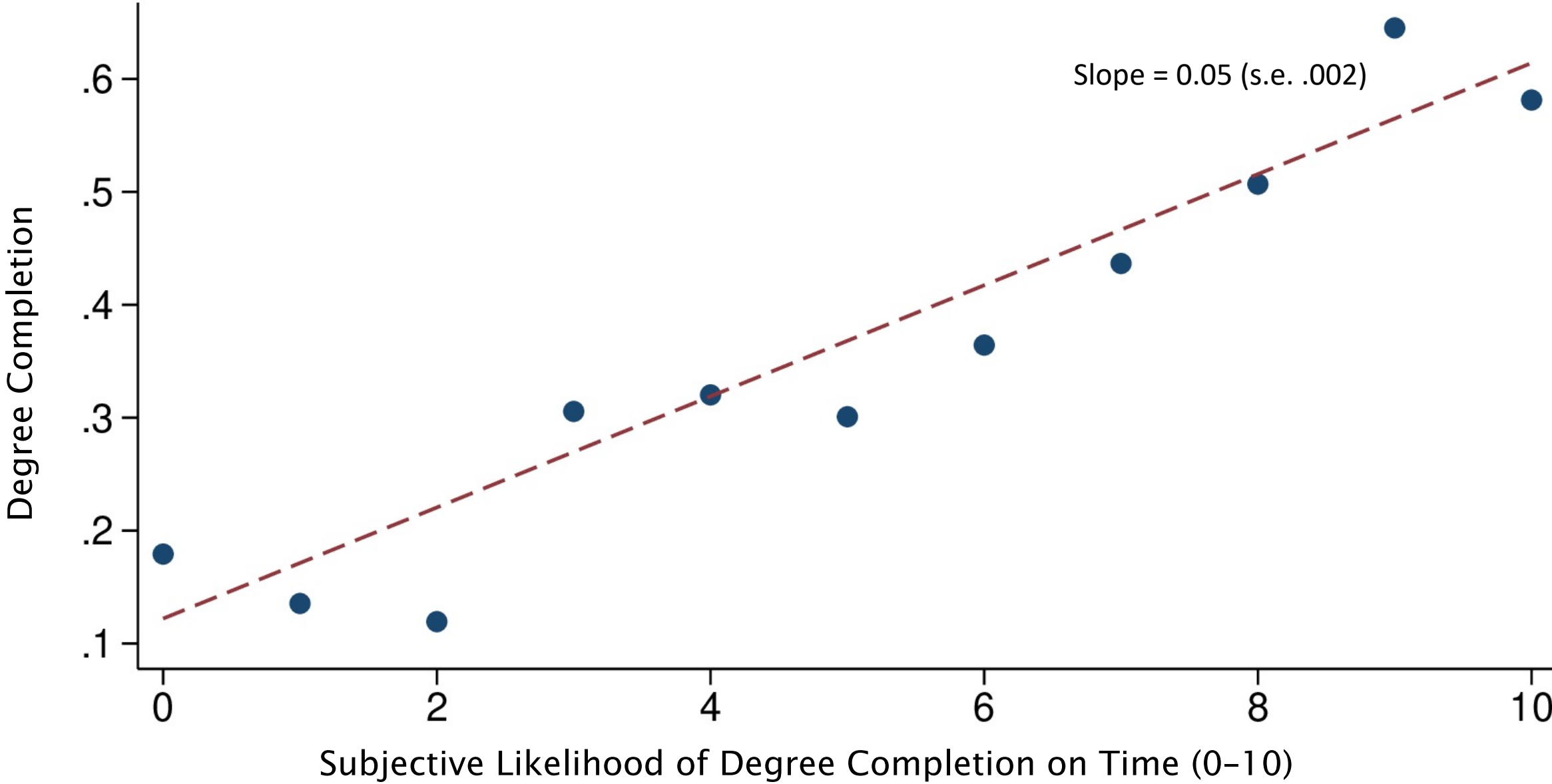
- Begin with simple test for the potential for adverse selection: Are individuals able to predict the outcomes?
  - How about conditional on observables,  $X$ , that financiers might use to price the contracts?
- Begin with simple binned scatter plots of  $Y$  on  $Z$  with no controls

# Expected Future Salary

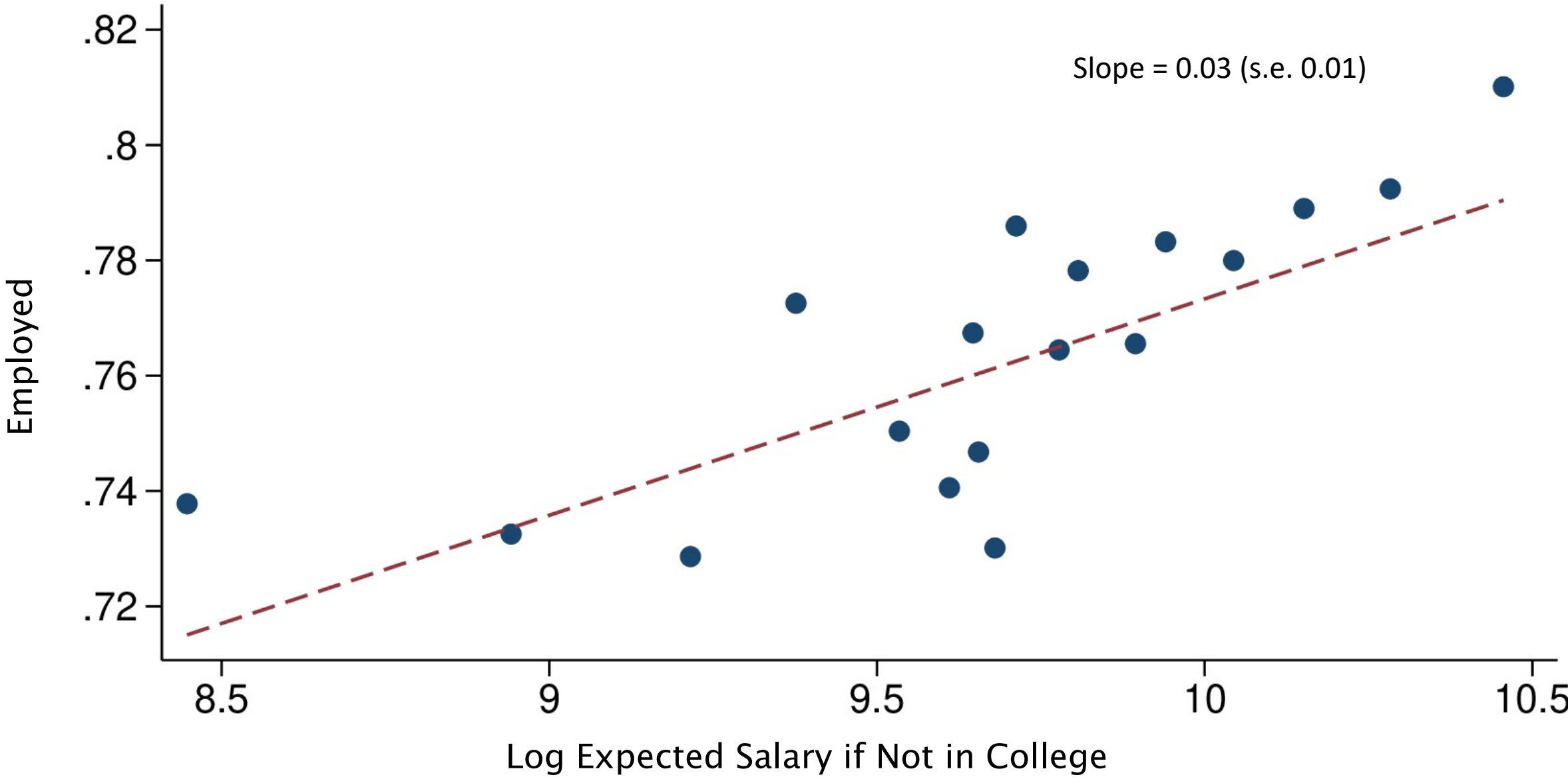




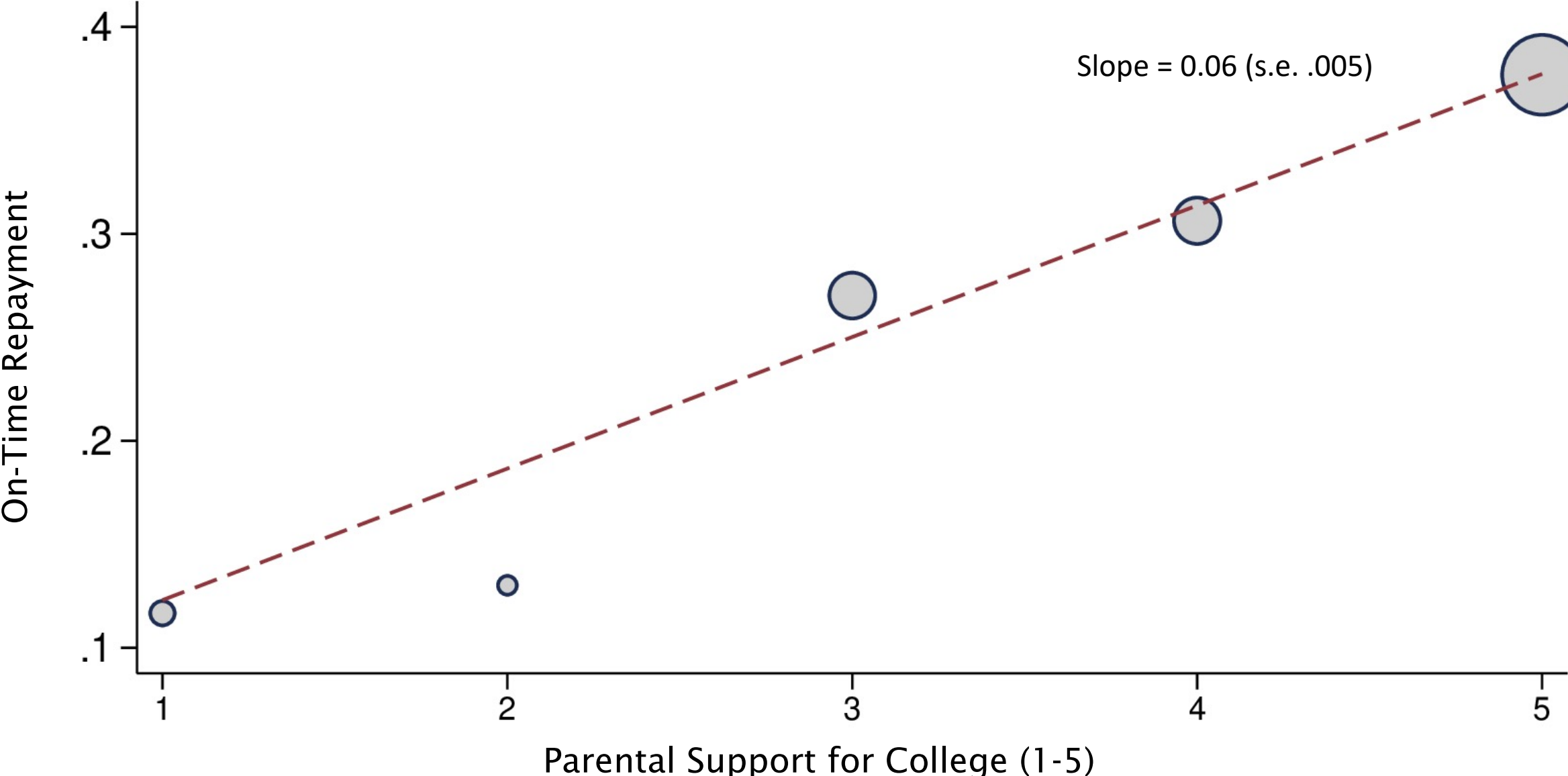
# Likelihood of Completing Degree



# Likelihood of Unemployment



# Likelihood of On-Time Student Loan Repayment



## Test for Potential for Adverse Selection

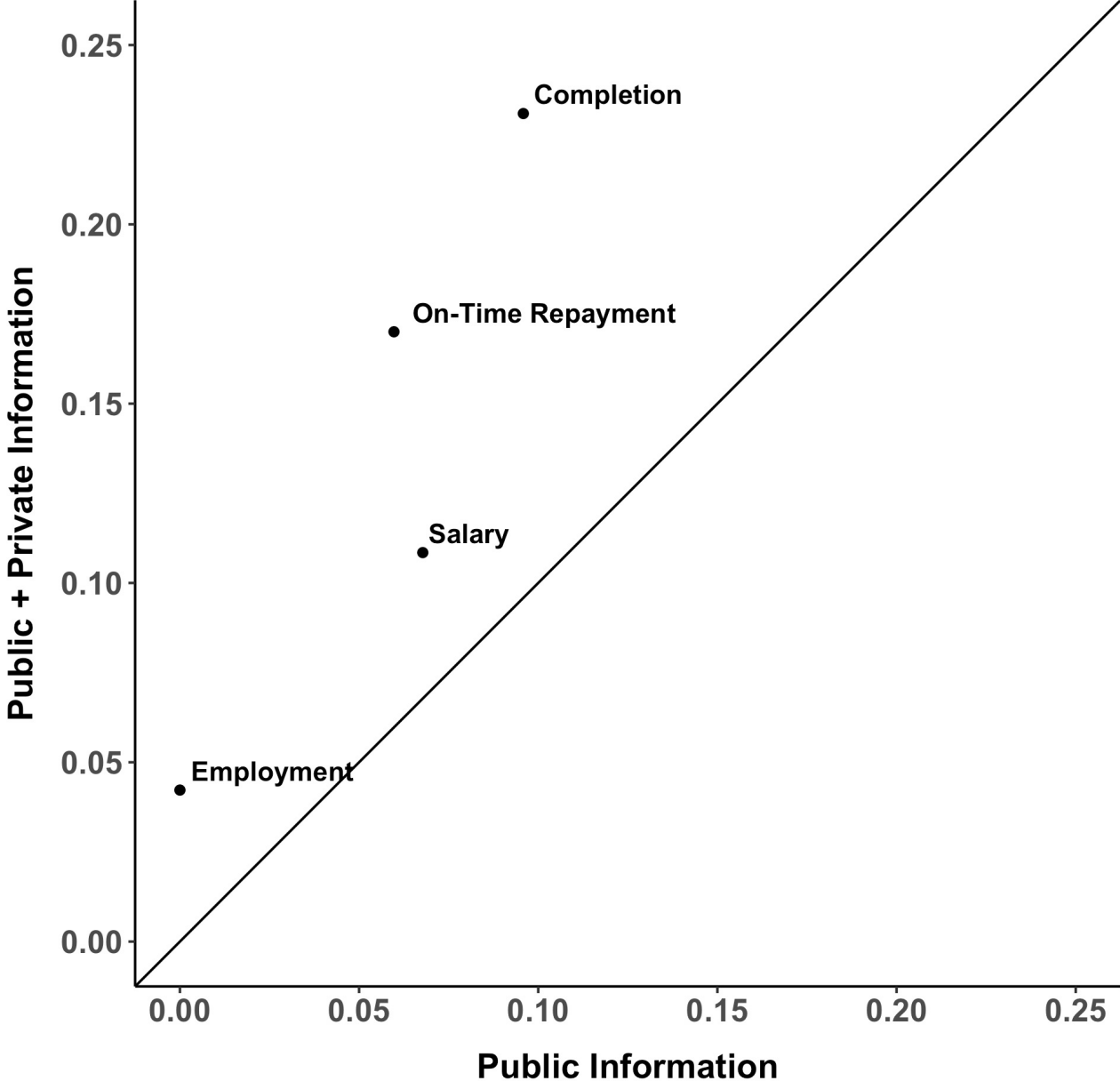
- Assuming borrowers are aware of their own observables ( $X$ ) and elicitation ( $Z$ ), we can test for private information by comparing predictions of  $Y$ :

$$\begin{aligned} E[Y|X, Z] &\neq E[Y|X] \\ \Rightarrow E[Y|\theta] &\neq E[Y|X] \end{aligned}$$

(predictive power improves by adding  $Z \Rightarrow$  existence of private information)

- $X$ : Observable to individual and financier (e.g. Citibank)
  - Institutional characteristics? Degree type? Field of study?
  - Academic Performance? Demographic Information?
  - Parental Characteristics?
- $Z$ : Observable only to individual
  - Elicitations
  - Other information not contained in  $X$

# Predictive Power of Public v. Private Information: (Pseudo) R<sup>2</sup>



[Predictions Table]

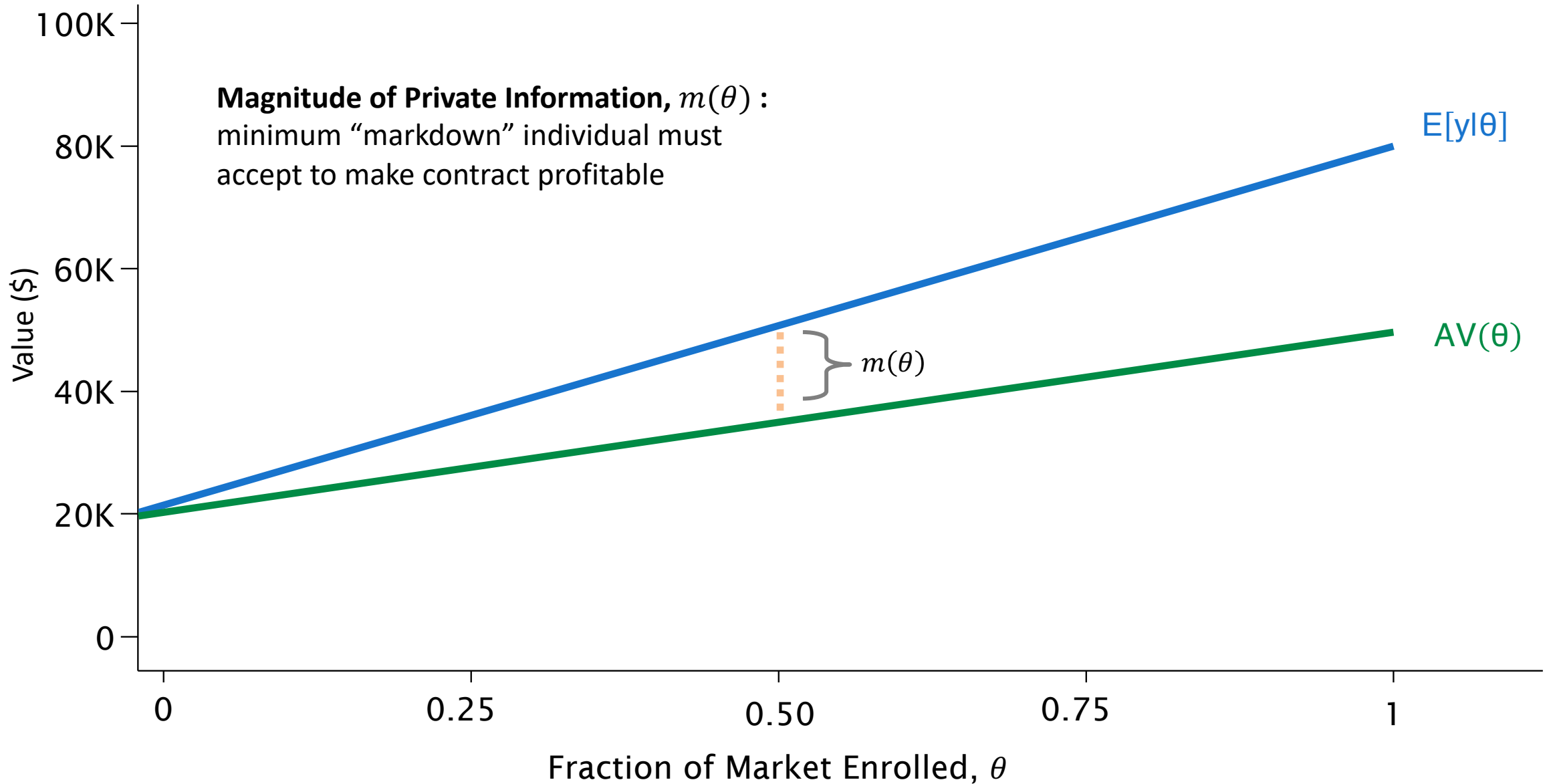
## Open Questions: Quantifying Private Information

- Individuals have private knowledge about future outcomes
- But is this “enough” private information to cause the market to unravel?
- Need to estimate willingness to accept (WTA) and Average Value (AV) curves

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# Magnitude of Private Information





## Lower-Bound on Magnitude of Private Information

Use predictions to non-parametrically estimate lower-bound on average  $m(\theta)$ :

$$E[m(\theta)] \geq E[r|r < r_i],$$

$$\text{where } r_i \equiv E[Y|X_i, Z_i] - E[Y|X_i]$$

- $E[m(\theta)]$ : “How much lower are expected outcomes among those worse than you?”  
⇒ minimum “markdown” individual must accept to make contract profitable
- $E[Y|X_i, Z_i]$  and  $E[Y|X_i]$  are estimated from out-of-sample RF predictions
- Several specifications for  $X$ : What info would financier use to price contracts?

## Lower-Bound on Magnitude of Private Information

	Category				
	(1) <i>No Public Info</i>	(2) <i>Institution + Academic</i>	(3) <i>Institution + Academic + Performance + Demographics</i>	(4) <i>Institution + Academic + Performance + Demographics + Parental</i>	(5) <i>Institution + Academic + Performance + Demographics + Parental + Protected</i>
Earnings Equity	5765	5314	3797	2907	2381
Completion-Contingent Loan	0.20	0.16	0.13	0.11	0.11
Employment-Contingent Loan	0.09	0.11	0.07	0.05	0.04
Dischargeable Loan	0.13	0.13	0.07	0.05	0.04

- Average markdown is large, even if financier could screen on *a lot* of observables
- Baseline results suggest that the average borrower would need to accept at least...
  - ≈ \$0.20 loss for \$1 of earnings-equity financing
  - ≈ \$0.30 loss for \$1 completion-contingent loan
  - ≈ \$0.15 loss for \$1 employment-contingent loan
  - ≈ \$0.40 loss for \$1 dischargeable loan

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## Empirical Approach to Estimate $WTA(\theta_\lambda)$ and $AV(\theta_\lambda)$ curves

- Start with  $AV(\theta_\lambda)$  curves,  $AV(\theta_\lambda) \equiv E[y|\theta \leq \theta_\lambda]$
- Requires estimation of distribution of  $E[y|\theta]$
- Approach: use information contained in elicitation,  $Z$ , about outcome,  $Y$ , conditional on observables,  $X$
- Build on approach in Hendren (2013, 2017), with two key advances:
  - Allow for outcome  $y$  to be continuous (e.g. income-share/equity contract)
  - Allow elicitation to not correspond directly to outcomes
- Use results from non-parametric measurement error / identification of factor models (Bonhomme and Robin (2010), Hu and Schennach (2008))

# Beliefs' Relationship with Outcomes and Elicitations

Goal: Identify distribution of latent beliefs  $g(\mu_\theta)$  from observed outcomes,  $y$ , and elicitions,  $z$

- Realized outcome,  $y$ :

$$y = \mu_\theta + \epsilon$$

Belief

Uncertainty

- Elicitation,  $z$ :

$$z = \alpha + \gamma\mu_\theta + v$$

Bias

Measurement Error

# Beliefs' Relationship with Outcomes and Elicitations

Goal: Identify distribution of latent beliefs  $g(\mu_\theta)$  from observed outcomes,  $y$ , and elicitation,  $z$

- Realized outcome,  $y$ :

$$y = \mu_\theta + \epsilon$$

- Assumes beliefs are unbiased:  $\mu_\theta = E[y|\theta]$
- Assumes “expectational error” ( $\epsilon$ ) is homoscedastic

- Elicitation,  $z$ :

$$z = \alpha + \gamma\mu_\theta + v$$

- $z$  can be biased ( $\alpha \neq 0$ ), imperfect ( $\lambda \neq 1$ ), and noisy ( $\sigma_v > 1$ ) in beliefs
- $\gamma$  is estimated using IV and second elicitation,  $z'$  ([Details/Results](#))
  - **Identification assumption:** measurement error is orthogonal:  $cov(z', v|\theta) = 0$

# Estimating Belief Distribution, $g(\mu_\theta)$ : Two Cases

## 1. Continuous $y$ : log salary

- We estimate  $g(\mu_\theta)$  non-parametrically using a linear **deconvolution**  
(Bonhomme & Robin 2010)

## 2. Binary $y$ : degree completion, loan repayment, and employment

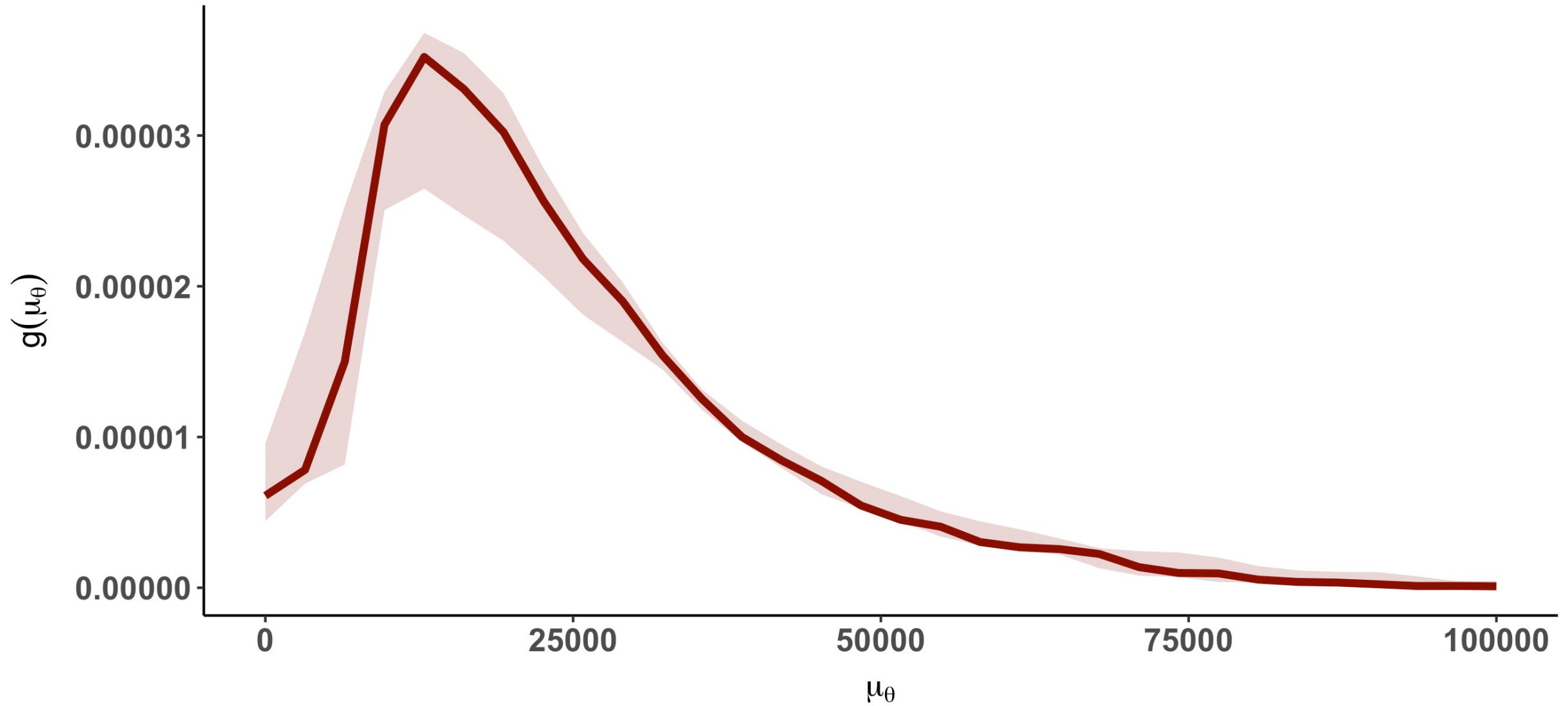
- Semi-parametric specification for  $g(\mu_\theta)$ :

$$G(\mu_\theta) = \sum_j \xi_j \mathbf{1}\{\mu_\theta \leq a_j\}$$

where  $\{a_j\}$  is a set of twenty-five evenly-spaced point masses in  $[0,1]$ .

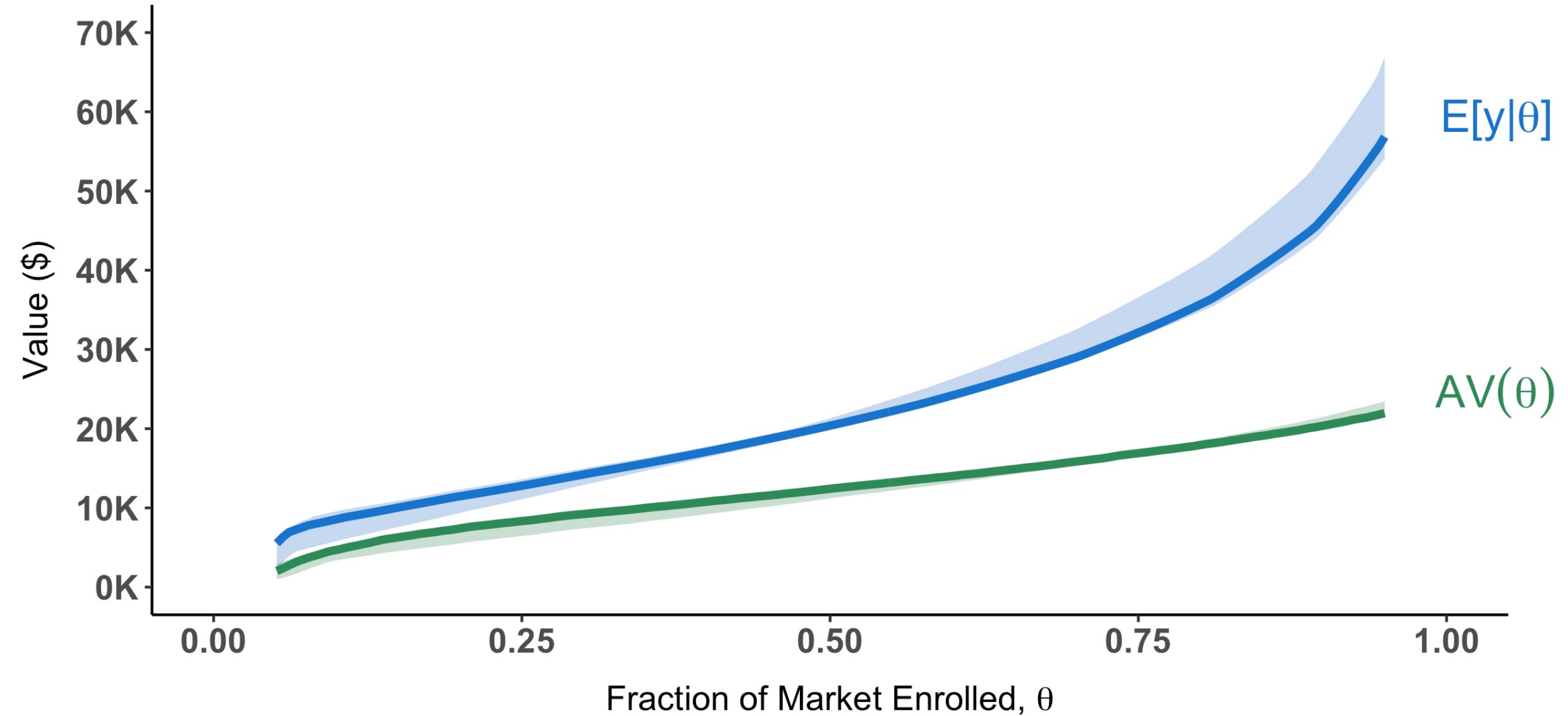
(Note: In both cases, we allow for [conditioning on observables](#))

# Distribution of Beliefs about Earnings

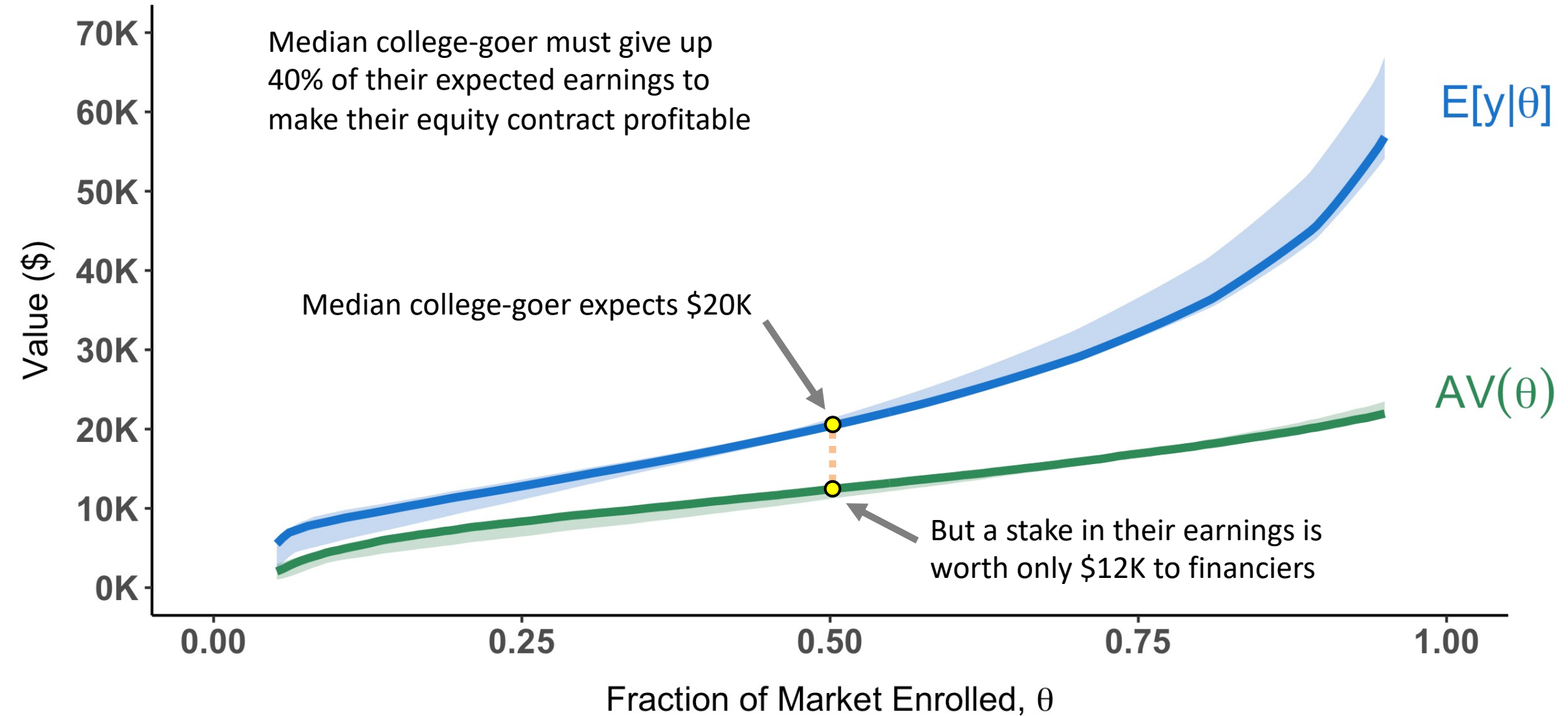




# Average Value for Earnings-Equity Market



# Average Value for Earnings-Equity Market



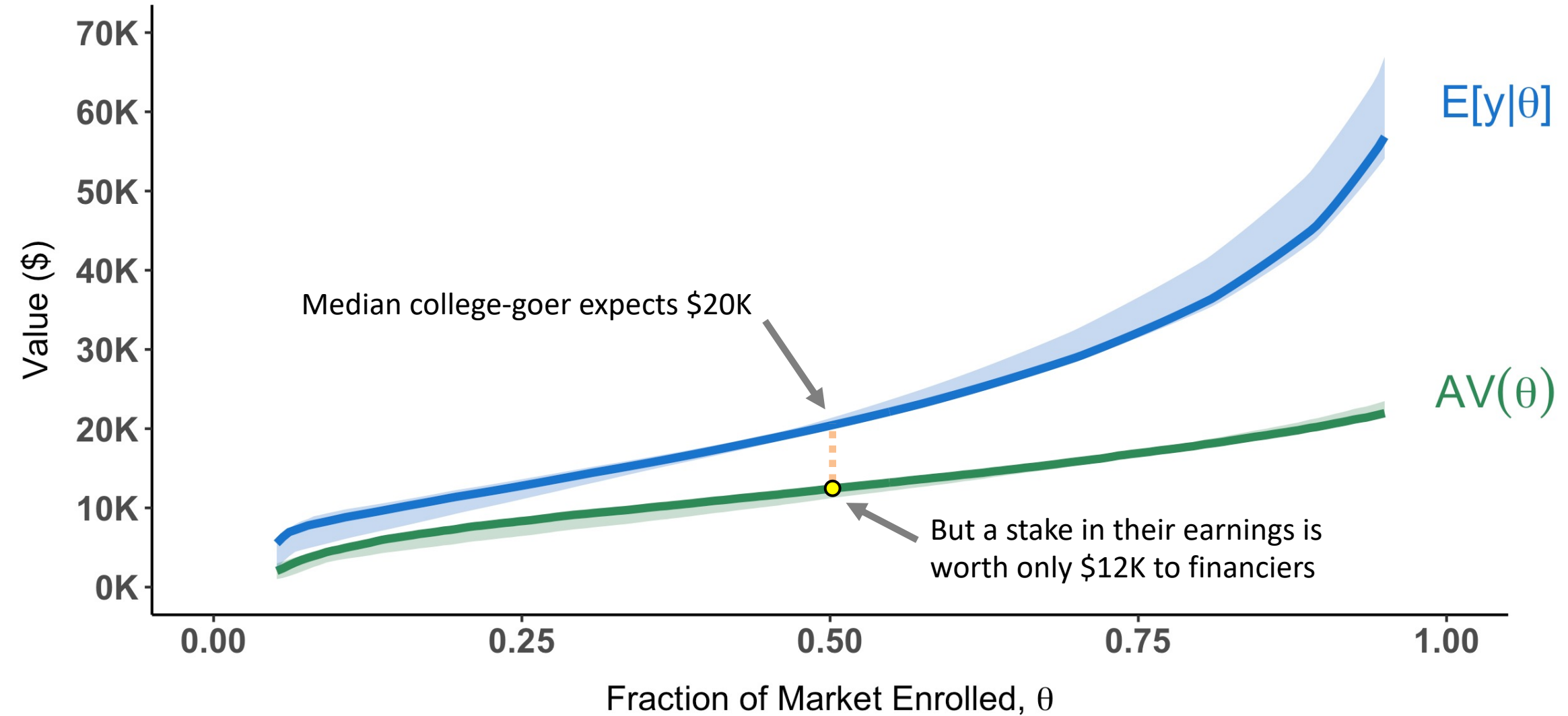
## Construction of $WTA(\theta)$

- Recall

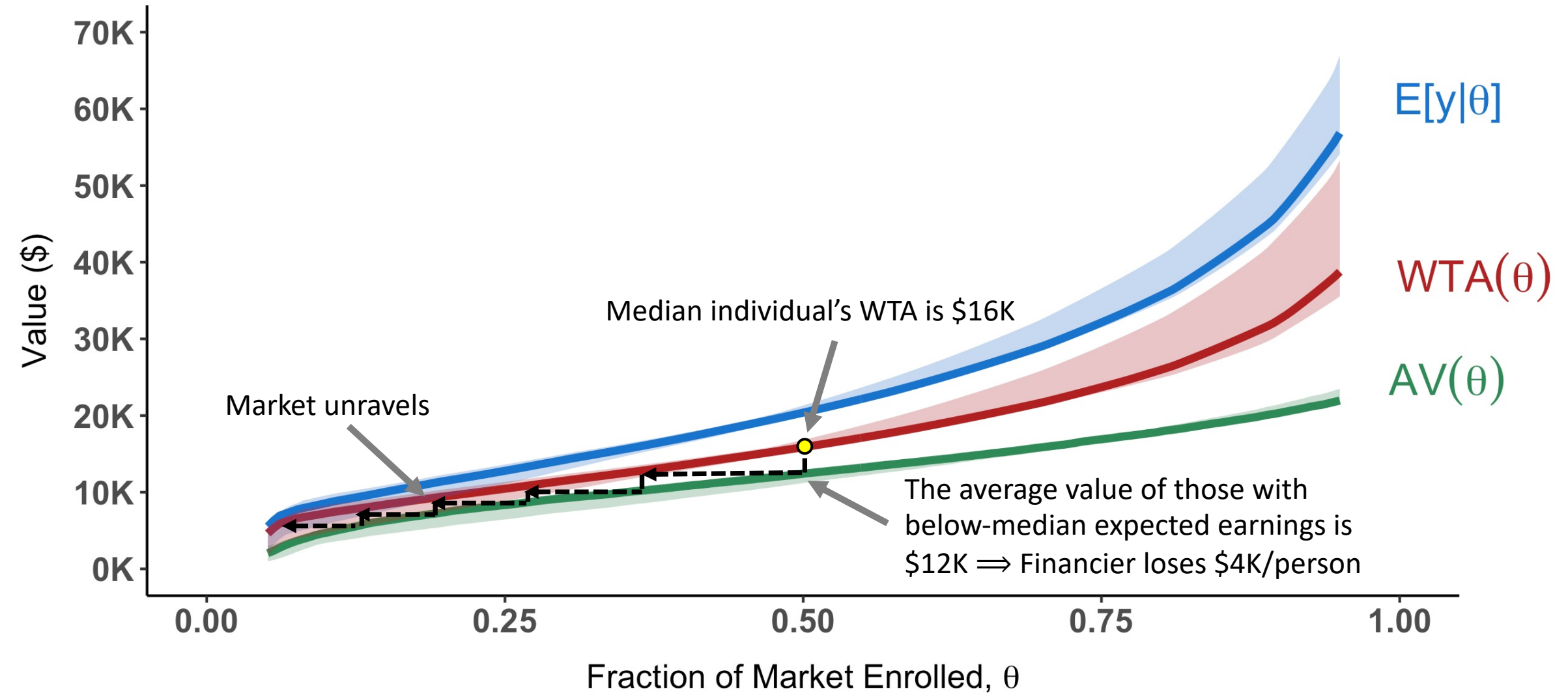
$$WTA(\theta) = \frac{E[yu_2|\theta]}{u_1(\theta)}$$

- Three calibration assumptions building on optimal social insurance literature:
  - CRRA preferences:  $u_2(c) = c^{-\sigma}$  where baseline  $\sigma = 2$
  - Euler equation:  $u_1(\theta) = E[u_2|\theta]$  (consistent with presence of low-interest student loans)
  - $\frac{dc}{dy}$  for each  $y$  taken from literature:
    - Earnings: 0.23 (Ganong et al., 2020)
    - Degree completion: 16% (Zimmerman 2014)
    - Employment: 9% (Hendren 2017)
    - Loan Repayment: 5% (Our estimates of consumption response)

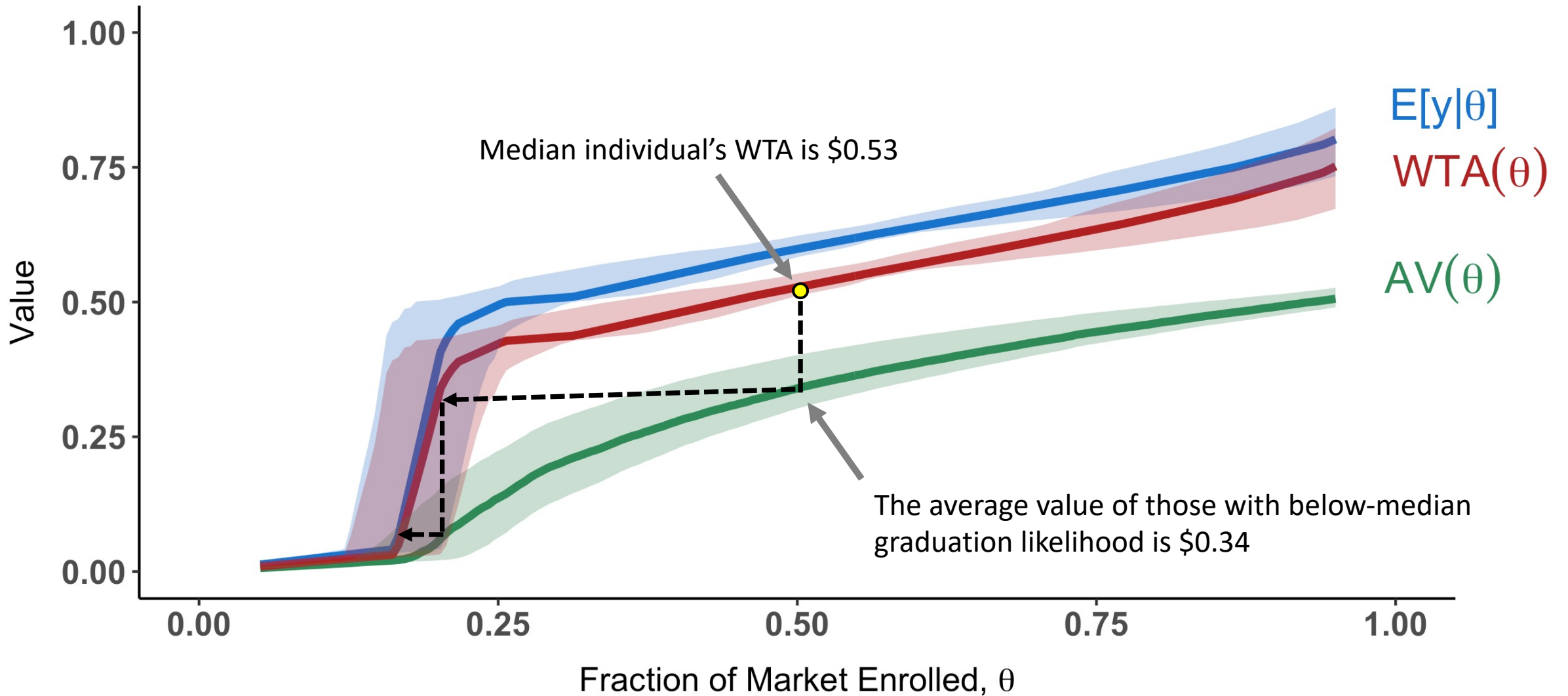
# Willingness to Accept for Earnings-Equity Market



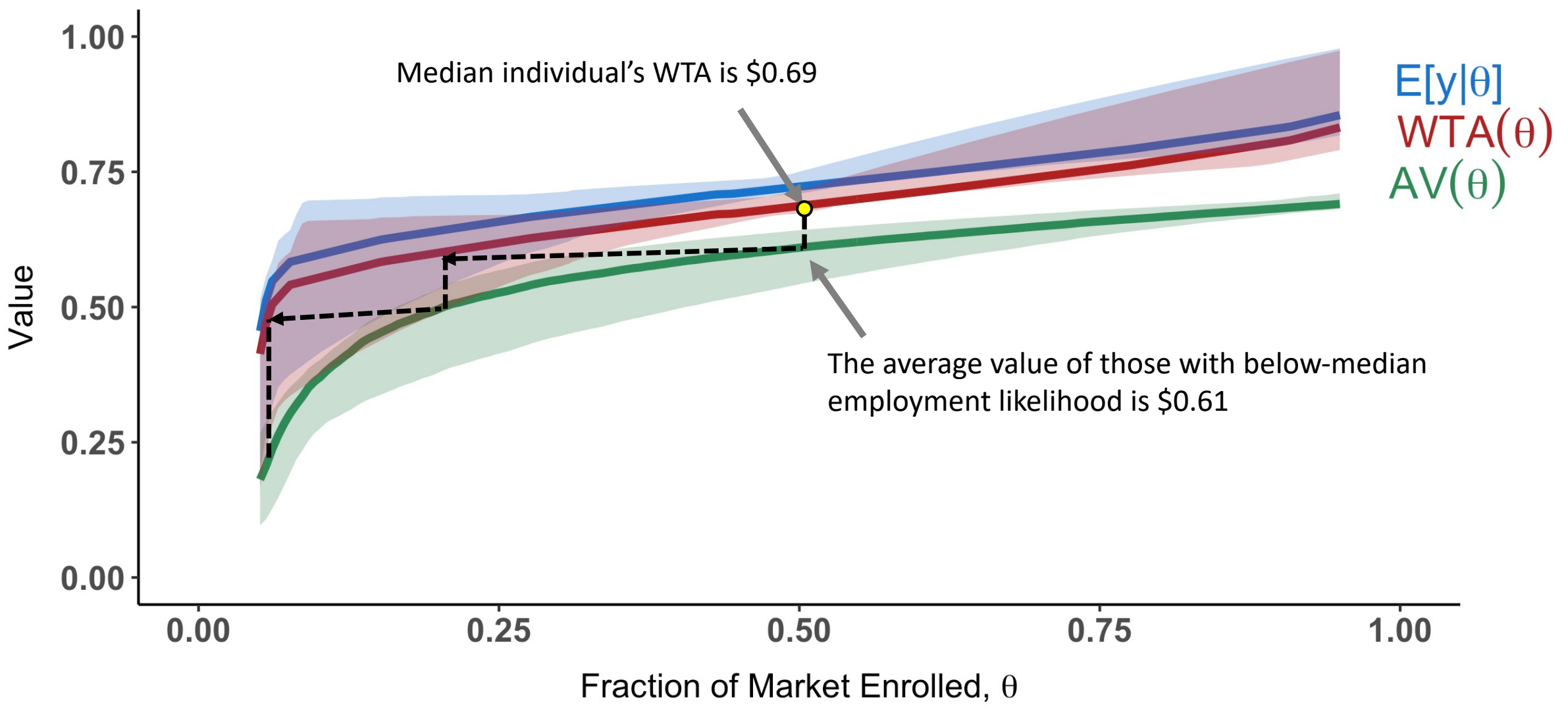
# Unraveling of Earnings-Equity Market



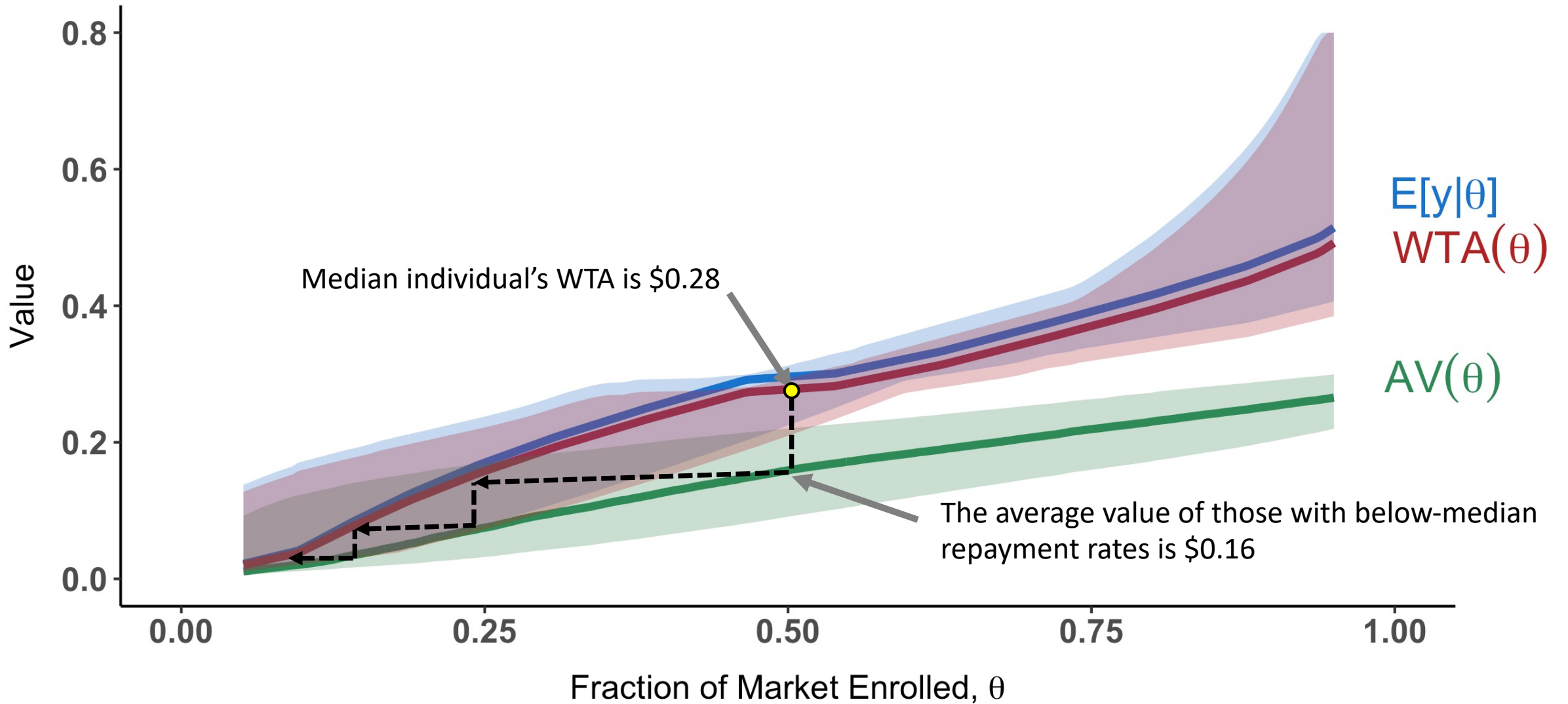
# Unraveling of Completion-Contingent Loan Market



# Unraveling of Employment-Contingent Loan Market



# Unraveling of Dischargeable Debt Market





# Outline

- ① **Model of Market Unraveling**
- ② **Data and Reduced Form Evidence of Private Information**
- ③ **Lower-Bound on Magnitude of Private Information**
- ④ **Estimation of Average Value and Willingness to Accept Curves**
- ⑤ **Welfare Impacts of Government Subsidies**

## Comparing Welfare Impact of Alternative Policies

- Results suggest markets for risk-mitigating financial contracts have unraveled
- But these contracts may carry large welfare gains
  - $\approx \frac{1}{2}$  of earnings variation reflects ex-ante uncertainty
- Should the government subsidize these losses and open up these markets?
  - Expand income-contingent debt forgiveness?
  - Partial forgiveness for unemployed borrowers?
  - “Front-load” tuition assistance to ease burden among dropouts?
  - Dischargeable student debt in times of financial distress?
- Or should we just eliminate student debt all together?

FEBRUARY 04, 2021

## **Warren, Schumer, Pressley, Colleagues: President Biden Can and Should Use Executive Action to Cancel up to \$50,000 in Federal Student Loan Debt Immediately**

*At 11 am today. Senator Warren, Leader Schumer and Representatives Pressley, Alma Adams (D-NC), Ilhan Omar (D-MI), and Mondaire Jones (D-N.Y) will hold a press conference reintroducing their resolution. The event will stream live [here](#).*

*Canceling student debt is the single most effective executive action available to provide massive consumer-driven stimulus*

## Measuring the Welfare Impact Using the MVPF

- Calculate the Marginal Value of Public Funds (MVPF) of government subsidies for each of our four markets of interest

$$MVPF = \frac{Benefits}{Net\ Cost\ to\ Govt}$$

- *Benefits*: The amount borrowers would be willing to pay the right to contract  $\lambda$ .
- *Net Cost to Govt*: Lost profits and fiscal externalities from changes in earnings
  - Pre-existing tax distortions make behavioral responses first order

## Measuring the MVPF: Borrowers' Benefits

- Borrower  $\theta$ 's benefit,  $V(\theta)$ , from contract  $\lambda$  depends on two components:

$$\begin{aligned} V(\theta) &= \lambda - \frac{E[yu_2|\theta]}{u_1(\theta)} \\ &= \underbrace{\lambda - E[y|\theta]}_{\text{Transfer}} + \underbrace{\lambda E[y|\theta] \text{cov}\left(-y, \frac{u_2}{u_1} \mid \theta\right)}_{\text{Consumption Smoothing}} \end{aligned}$$

- *Transfer*: Net transfer from financier  $\rightarrow$  individual with type  $\theta$  (negative financier's profits)
  - *Consumption smoothing*: risk-premium individuals are WTP for insuring  $y$
- $V(\theta)$  is identified from estimation of distribution of  $y$  given  $\theta$  and calibration of  $WTA(\theta)$

## Measuring the MVPF: Net Cost to Government

- Net cost to government for equity contract:

$$\begin{aligned}
 \text{Net Cost to Govt} &= \lambda - E[y|\theta] + \text{Fiscal Externality} \\
 &= \underbrace{\lambda - E[y|\theta]}_{\text{Transfer}} - \underbrace{\lambda \frac{\tau}{\Pr\{\theta \leq \theta_\lambda\}} \frac{dE[y^L]}{dg}}_{\text{Impact of } \$\lambda \text{ in College on Lifetime Earnings}} + \underbrace{\frac{\tau}{1-\tau} \lambda E[y|\theta \leq \theta_\lambda] \epsilon_{y,1-\tau}}_{\text{Impact of Repayment Disincentive on Earnings}}
 \end{aligned}$$

- Net cost to govt depends on two parameters studied in previous literature:
  - Impact of \$1 of college financing on lifetime earnings – additional \$1000 in loan eligibility → 2.8% increase in ten-year earnings among existing enrollees (Gervais and Ziebarth 2019)
  - Impact of higher tax rate on earnings – elasticity of taxable income w.r.t. after-tax income of 0.3 (Saez Slemrod and Giertz 2012)

# MVPF Components

*MVPF for  $\lambda = E[y]$*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Take-up	Transfer	Smoothing	WTP	FE Grant	FE Tax Distortion	Cost	MVPF
Salary	0.77	0.26	0.18	0.44	0.09	-0.04	0.21	2.06
Dropout	0.30	0.47	0.08	0.55	0.07	-0.07	0.46	1.18
Unemployment	0.59	0.08	0.03	0.11	0.10	-0.07	0.05	2.13
Non-Repayment	0.73	0.31	0.14	0.45	0.11	-0.07	0.27	1.67
Grant	1.00	1.00	0.00	1.00	0.14	-0.00	0.85	1.18

# Conclusion

- Evidence of unraveling in several markets for risk-mitigating financial contracts
  1. *Earnings-Equity Contract*
  2. *Completion-Contingent Loan*
  3. *Employment-Contingent Loan*
  4. *Dischargeable Loan*
  
- Motivates a high value to government intervention to offer student loan alternatives for college financing
  
- Empirical approach can be applied to other settings with asymmetric information:
  - Small-business investments
  - Income insurance / compensation schemes
  - Union formation
  
- Provide step towards finding “optimal” form of public investment in human capital



## Elicitation Summary Statistics

Category	Variable	Mean	SD
<i>Elicitations</i>	Ever Completion Likelihood	9.314	1.838
	On-Time Completion Likelihood	8.413	2.103
	Expected Completion Year	2014.3	1.091
	Employment Likelihood	8.159	1.734
	Exp. Occ. Unemployed	0.400	0.0961
	Expected Salary	64124.2	45017.2
	Highest Expected Salary	117308.7	142964.6
	Lowest Expected Salary	43928.3	27018.8
	Expected Salary if No College	17336.0	7825.0
	Exp. Occ. Salary	30080.8	8519.6
	Elicited Discount Factor	0.369	0.321
	Supportive Friends	4.375	0.969
	Supportive Classmates	4.230	1.071
	Supportive Parents	4.228	1.073
	Parent Financial Support	6468.2	9502.7

## Observable Variables Summary Statistics (1/2)

Category	Variable	Mean	SD
<i>Academic</i>	BA Program	0.478	0.500
	STEM Major	0.182	0.386
<i>Performance</i>	High School GPA	3.059	0.612
	SAT Score	1009.4	203.8
<i>Demographics</i>	Age	20.52	5.879
	Female	0.565	0.496
	Black	0.177	0.381
	US Citizen	0.946	0.227
	Children	0.120	0.325
	Married	0.0572	0.232
<i>Parental</i>	Parent Education	4.472	2.214
	Parents Married	0.660	0.474
	Parental Income	77702.3	73843.4
	Dependent	0.785	0.411
	EFC	10198.2	16843.8
<i>Financial</i>	Financial Aid	10533.1	12231.6
	Student Debt	3013.1	4166.6

## Observable Variables Summary Statistics (2/2)

Category	Variable	Mean	SD
<i>Institution</i>	Four-Year	0.545	0.498
	Private	0.302	0.459
	For-Profit	0.129	0.335
	Enrollment	18262.0	35178.7
	Tuition	9724.1	10967.4
	Share Female	0.573	0.124
	Share Black	0.138	0.163
	Admissions Rate	0.633	0.199
	Completion Rate	0.413	0.245
	Avg. SAT Score	1102.1	137.5
	Md. Parent Income	32289.7	20623.8
	Md. 6-Yr Earnings	29581.9	8131.3

# Predictive Performance

Outcome	Statistic	Category				
		(1) <i>Institution + Academic</i>	(2) <i>Institution + Academic + Performance + Demographics</i>	(3) <i>Institution + Academic + Performance + Demographics + Parental</i>	(4) <i>Institution + Academic + Performance + Demographics + Parental + Protected</i>	(5) <i>All Public + Elicitations</i>
<i>Panel A: Log Salary</i>	$R^2$	0.068 (0.009)	0.073 (0.010)	0.078 (0.010)	0.092 (0.010)	0.108 (0.011)
	RMSE	0.641 (0.012)	0.638 (0.013)	0.636 (0.012)	0.631 (0.012)	0.626 (0.012)
	MAE	0.464 (0.007)	0.461 (0.007)	0.460 (0.007)	0.455 (0.007)	0.453 (0.007)
<i>Panel B: Dropout</i>	Pseudo $R^2$	0.096 (0.013)	0.157 (0.008)	0.166 (0.007)	0.170 (0.007)	0.231 (0.007)
	ROC	0.742 (0.006)	0.761 (0.006)	0.768 (0.006)	0.770 (0.006)	0.813 (0.005)
	Accuracy	0.684 (0.006)	0.697 (0.006)	0.701 (0.006)	0.704 (0.006)	0.741 (0.005)
<i>Panel C: On-Time Repayment</i>	Pseudo $R^2$	0.060 (0.014)	0.133 (0.011)	0.155 (0.010)	0.158 (0.010)	0.170 (0.009)
	ROC	0.723 (0.008)	0.758 (0.008)	0.773 (0.008)	0.775 (0.008)	0.785 (0.007)
	Accuracy	0.755 (0.006)	0.763 (0.006)	0.761 (0.006)	0.763 (0.006)	0.766 (0.006)
<i>Panel D: Employment</i>	Pseudo $R^2$	-0.110 (0.022)	0.002 (0.007)	0.021 (0.006)	0.027 (0.006)	0.042 (0.005)
	ROC	0.565 (0.009)	0.596 (0.009)	0.610 (0.009)	0.621 (0.009)	0.640 (0.009)
	Accuracy	0.700 (0.006)	0.719 (0.006)	0.719 (0.006)	0.721 (0.006)	0.723 (0.006)

## $\gamma$ Estimation

(1) Outcome	(2) Elicitation	(3) Instrument	(4) $\gamma$ -Estimate
Salary	<i>Log Expected Salary</i>	<i>Log Avg. Salary Expected Occ.</i>	0.69 (0.16)
Completion	<i>On-Time Completion Likelihood</i>	<i>Supportive Parents</i>	3.20 (0.23)
Employment	<i>Log Expected Salary if No College</i>	<i>Avg. Employment Expected Occ.</i>	0.59 (0.29)
On-Time Repayment	<i>Supportive Parents</i>	<i>Parents' Financial Support</i>	1.47 (0.76)

## Estimating Belief Distribution, $g(\mu_\theta)$ : Two Cases

1. Continuous  $y$ : Residualize  $y$  and  $z$  by  $E[y|X]$  in deconvolution:

$$y^* = y - E[y|X]$$

$$z^* = z - \gamma E[y|X]$$

2. Binary  $y$ : allow point-mass in  $g(\mu_\theta)$  to depend on  $E[y|X]$ .

$$G(\mu_\theta) = w \sum_j \xi_j \mathbf{1}\{\mu_\theta \leq E[y|X] - a\} + (1 - w) \sum_j \xi_j \mathbf{1}\{\mu_\theta \leq aj\}$$

## Specification for Employment: $f_{Z|\theta}(Z|\theta)$

- Let  $Z = (z_1, z_2)$  denote a pair elicitation
- Model elicitation  $j$  of individual  $i$ ,  $z_{ij}$  of individual  $i$  as  $z_{ij} = h_j(z_{ij}^*)$  where

$$z_{ij}^* = a_j + \gamma_j \theta_i + v_{ij}$$

- $h_j(\cdot)$  depends on setting: e.g. if  $z$  on 1-5 scale  $\rightarrow h_j(\cdot)$  is an ordered probit
- Allowing  $\gamma \neq 1$  allows elicitation to not correspond to outcome  $y$
- Assume measurement error is independent:  $v_{i1} \perp v_{i2}$ 
  - $z_1$  is expected salary if not in college;  $z_2$  is average employment rate in expected occupation
- Estimate distribution of  $f_{Y|\theta}(y|\theta)$ ,  $f_{Z|\theta}(Z|\theta)$ ,  $g(\theta)$  using MLE
  - Exploit additional information in distribution of  $z_2$  to recover distributions

# Distribution of $y$

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