Taking Productivity in Education Seriously I:
Insights from Higher Education

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SOME FIGURES IN THIS PRESENTATION ARE BASED ON "THE VALUE-ADDED OF U.S. POSTSECONDARY INSTITUTIONS" WHICH IS A COMPONENT OF A LARGER PROJECT EXAMINING THE EFFECTS OF FEDERAL TAX AND OTHER EXPENDITURES THAT AFFECT HIGHER EDUCATION THROUGH CONTRACT TIR-NO-12-P-00378 WITH THE STATISTICS OF INCOME (SOI) DIVISION AT THE U.S. INTERNAL REVENUE SERVICE. OPINIONS EXPRESSED IN THIS PRESENTATION ARE THOSE OF THE AUTHOR ALONE AND DO NOT REPRESENT THE VIEWS OF THE INTERNAL REVENUE SERVICE OR THE U.S. TREASURY DEPARTMENT.

Since Becker, the human capital production function has most often been written:

$$y_i = f(s_i, a_i)$$

where:

y = the outcome (human capital or some function of it like earnings)

s = schooling

a = cognitive skill or ability

The production function was assumed to obey **Single-Crossing** in schooling & cognitive skill

- Single-Crossing: That is, a student with higher cognitive skill is assumed always to derive more benefit from a marginal unit of educational resources than a student with lower cognitive skill:

$$\frac{\partial^2 f}{\partial s \partial a} > 0 \quad \forall\ s \geq 0$$

A Preview of the 2 Lectures

I: EMPIRICAL EVIDENCE SUGGESTS THAT, IN HIGHER EDUCATION, SINGLE-CROSSING IS IMPORTANT, NOT MERELY IN SIGN BUT IN *MAGNITUDE*.

People who begin higher education with much greater cognitive skill appear able to absorb many more dollars of educational resources and still be as/more productive with each dollar. This has potentially serious economic consequences.

II: EMPIRICAL EVIDENCE SUGGESTS THAT RECENT NEUROSCIENCE IS CORRECT TO DIRECT OUR ATTENTION TO EARLY ADOLESCENCE, WHEN THE BRAIN IS ESPECIALLY PLASTIC WITH REGARD TO COGNITIVE SKILL (ABILITY) .

Educational interventions applied in early adolescence have disproportionate and unusually path-determinative effects.

Cognitive Skill –What's in a Word?

Economists have traditionally been fairly free and loose with their terminology:

- Cognitive skill
- Aptitude
- Ability
- Mental readiness
- College readiness
- Productivity, etc.

when what they meant was "the expected treatment effect of margin-pushing education, in terms of skills."

Slippery word choices: good or bad?

- Becker's model of human capital was not based on neuroscience.
- Rather, it was based on the observation that people who were regarded as more able tend to acquire more education.

- Good: Economists' use of various words for the same concept turns out to be somewhat justified by neuroscience.
- Bad: The use of the word "ability" (and the letter "*a*") in seminal models of human capital encouraged economists to think of the parameter as fixed.

- In *this* lecture, how cognitive skill arises will not matter much. In the next lecture, it will.

"Cognitive Skill," "Ability," …

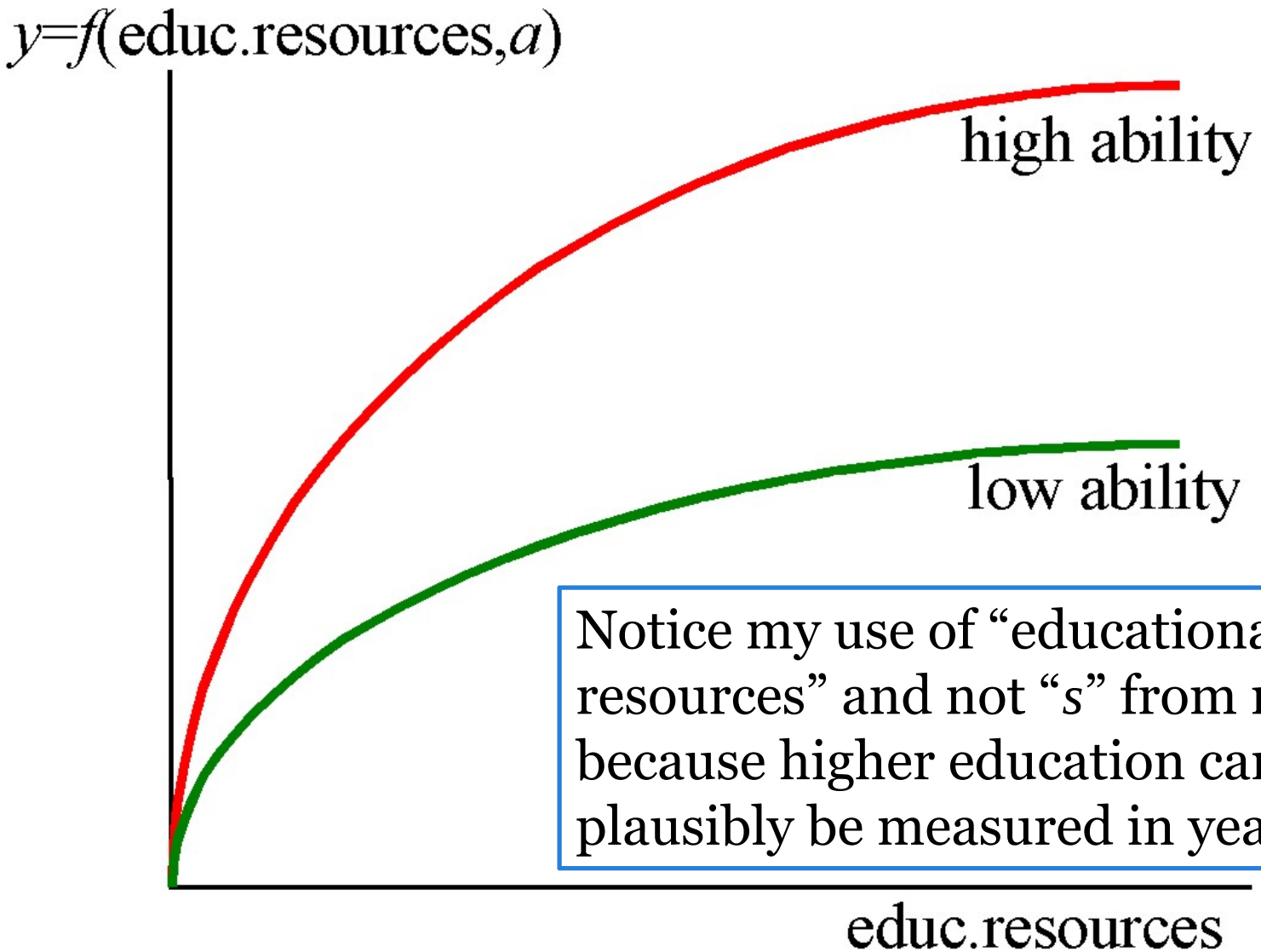
- In these lectures, I am forced to use "cognitive skill" and "ability" somewhat interchangeably owing to existing research.
- What is ruled in: the capacity for succeeding in cognitive tasks in which the brain's frontal lobe plays a disproportionate role:
  - Reasoning
  - Planning
  - Integration
  - Self-regulation
- These capacities are <u>not</u> independent of knowledge or training, and they are intertwined with emotional and social skills. Nevertheless, they are also somewhat distinct and especially valuable in formal education.

This lecture's argument proceeds in 4 steps

1. In the workhorse model, if people invest optimally in education, we should observe that the marginal productivity of educational resources is the same across cognitive skill types. However, resources per person should differ—driven by the single-crossing condition.
2. Both historical and current evidence suggest that, when markets drive human capital investments, much greater educational resources are allocated to those with much greater cognitive skill.
3. Measuring productivity is difficult in this setting: a plausible empirical method must tackle selection.
4. The evidence suggests that markets are not crazy but that single-crossing is powerful in higher education.

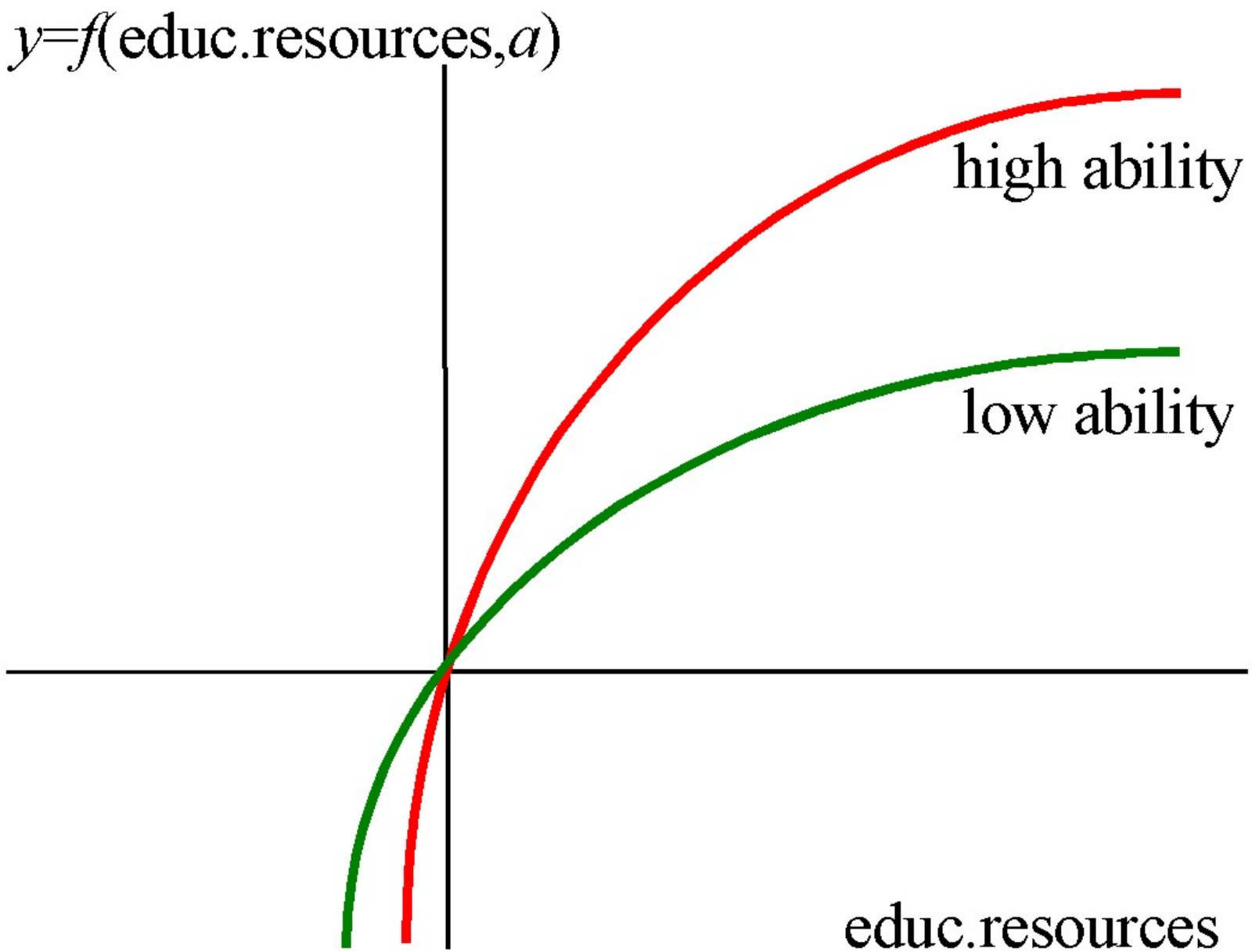
A Quick Graphical Review of the Becker Model & Single-Crossing

Human capital production functions that exhibit Single-Crossing

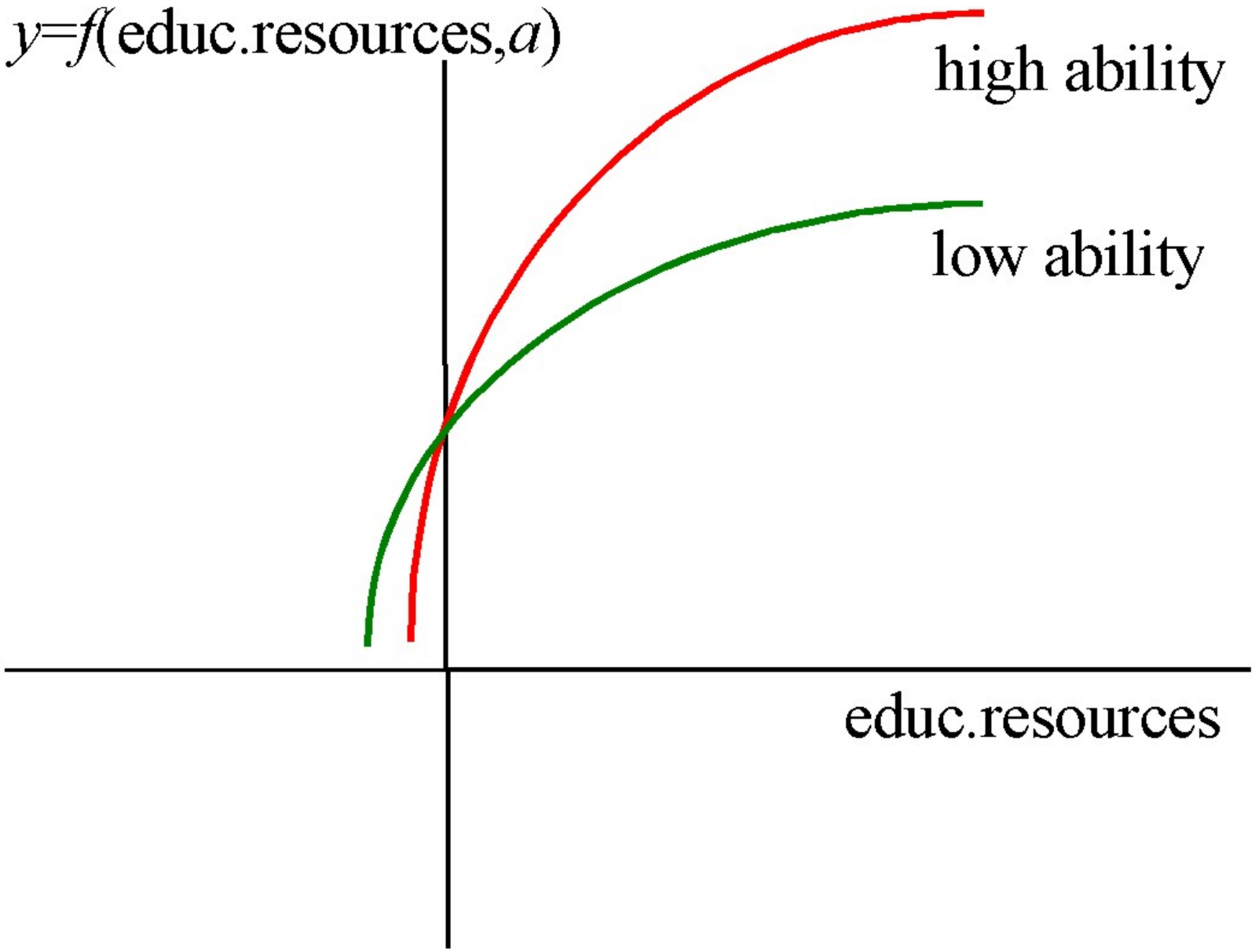


Notice my use of "educational resources" and not "*s*" from now because higher education cannot plausibly be measured in years.

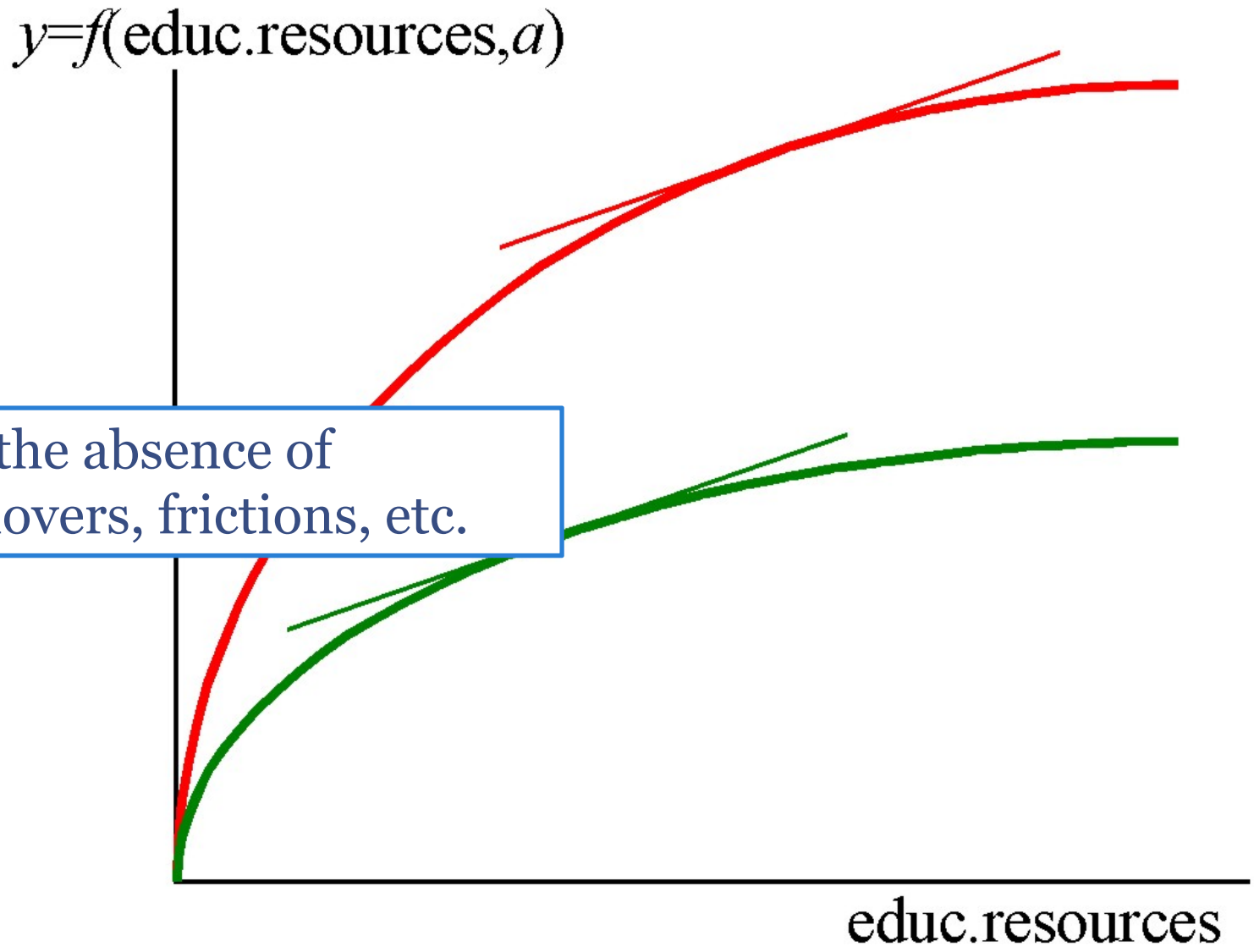
For these pdtn functions, the cross is at the origin



Here, the cross is higher because uneducated workers are nevertheless productive

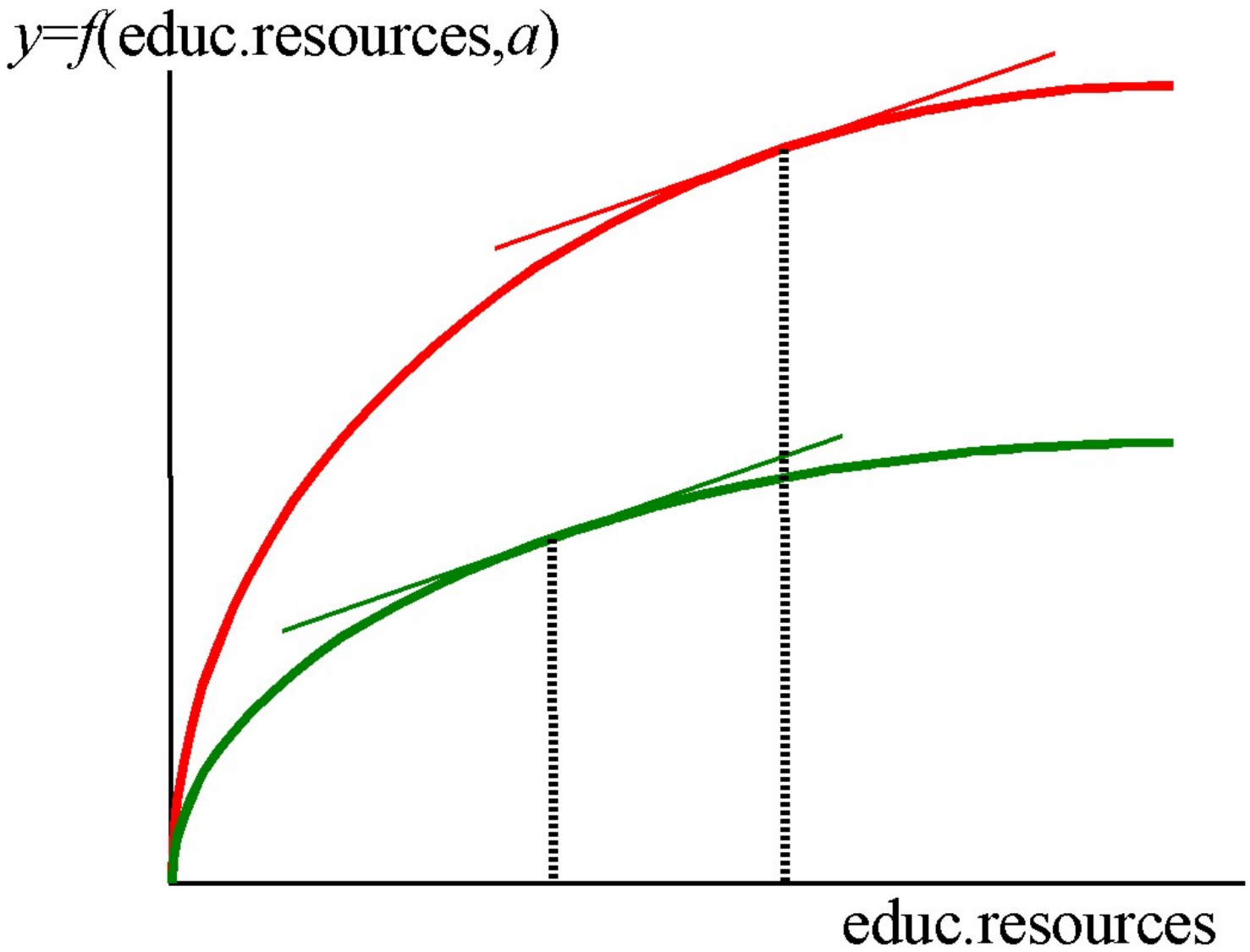


An efficient capital market would set the marginal return to educational resources equal across ability types*

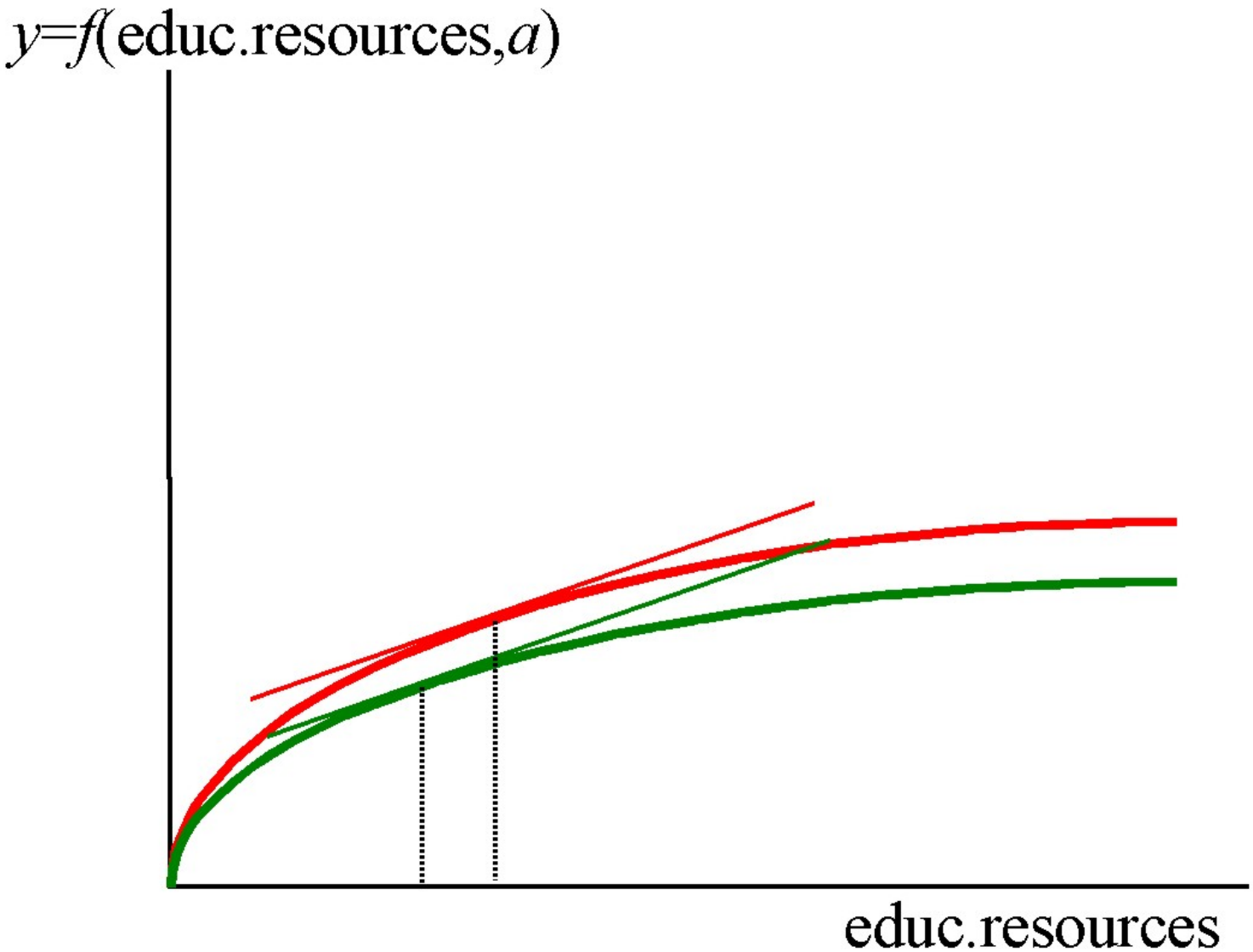


*In the absence of spillovers, frictions, etc.

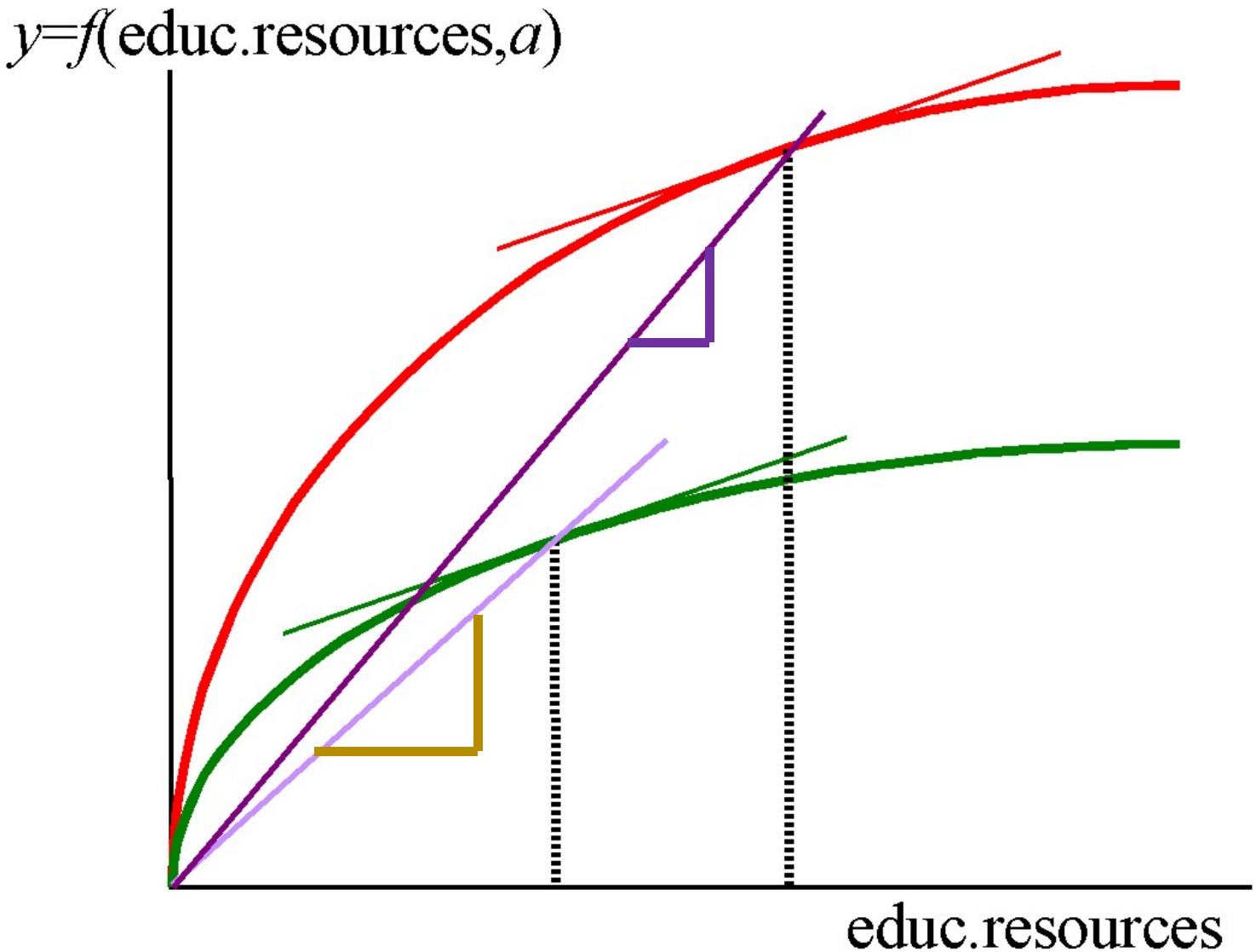
Which would result in educational resources being greater for the more able.



But how much greater depends on the <u>magnitude</u> of $\partial^2 f/\partial s \partial a$



We can read average productivity of educational resources off the figure:



U.S. higher education generates interesting evidence on productivity

The U.S. has arguably the only true market for higher education. It is certainly the most informative market for economic analysis.

There are numerous government interventions in U.S. higher education, but they interact with, rather than dominate, market forces.

The market exhibits strong variation, highly correlated with selectivity

- At the highly selective end of the spectrum, the market is
  - integrated/competitive
  - relatively informed (about schools, about students)
  - privately financed
  - populated by students whose choices are elastic with respect to institutions' academic and other resources
- At the other end of the selectivity spectrum, somewhat opposite conditions prevail.

Quick Review of the Market

- ~7,500 postsecondary institutions.
- 3 types of governance: public, non-profit, for-profit.
- Institutions choose tuition, application requirements, students, faculty, curriculum, salaries, financial aid, and how to raise money from donors (if non-profit) or investors (if for-profit).
  - Public institutions less autonomous but very autonomous by international standards.
- Selective schools admit holistically but college aptitude scores are statistically most powerful in admissions.
  - "more selective" = higher scores.

Quick Review, cont.

Financial Aid

State appropriations, Gifts

- Net tuition ≠ list tuition ≠ educational resources
  - Strikingly, the most selective schools have high resources and list tuition, but they are *free* for low-income students and subsidize tuition for *all* students.
  - Nevertheless, students at the most selective schools pay for their own education, in expectation.
- Federal intervention is mainly portable grants, loans, and tax credits/deductions.
- Think of U.S. postsecondary education as a market with price distortions, not a centrally controlled sector.

From Autarky to Integration

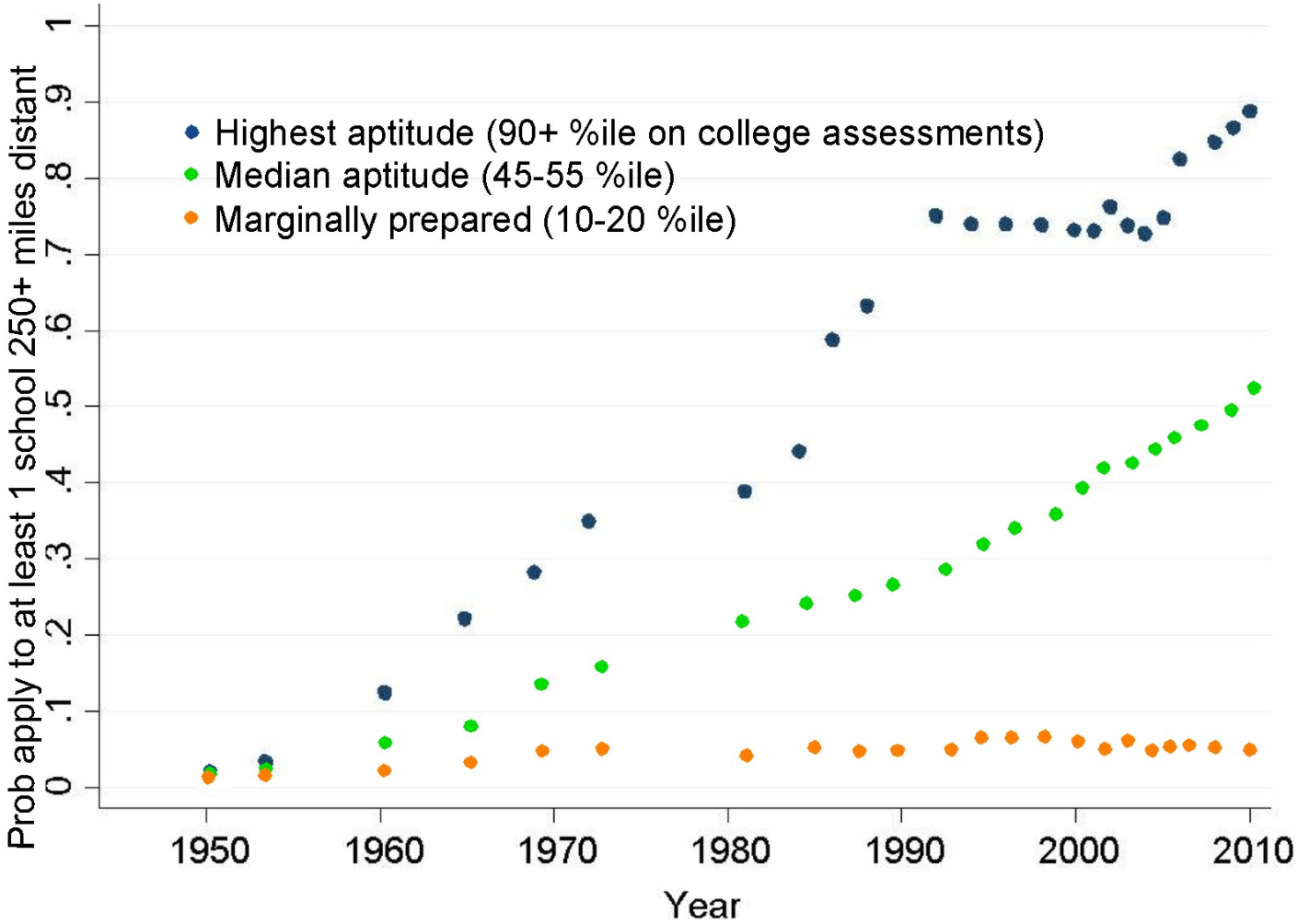
A QUICK RETROSPECTIVE OF THE U.S. POSTSECONDARY MARKET

History suggests that markets drove greater resources toward the more cognitively skilled

- Starting from near autarky in 1875, the postsecondary market became geographically integrated, especially for high ability students and after 1950 when information on students and institutions improved.
- As the market became more integrated, high cognitive skill students tended more and more to attend the institutions with the most resources per student.
- Since students could not necessarily pay for these resources up front, the allocation was achieved through increasingly large *at-time-of-enrollment* subsidies for students at selective institutions.
  - The "venture capital model" of universities.
  - The correlation between parents' income and educational resources fell dramatically and continues to fall.

More integrated markets for higher education

Percent of Students who Apply to a Postsecondary Institution at a Distance of at least 250 miles



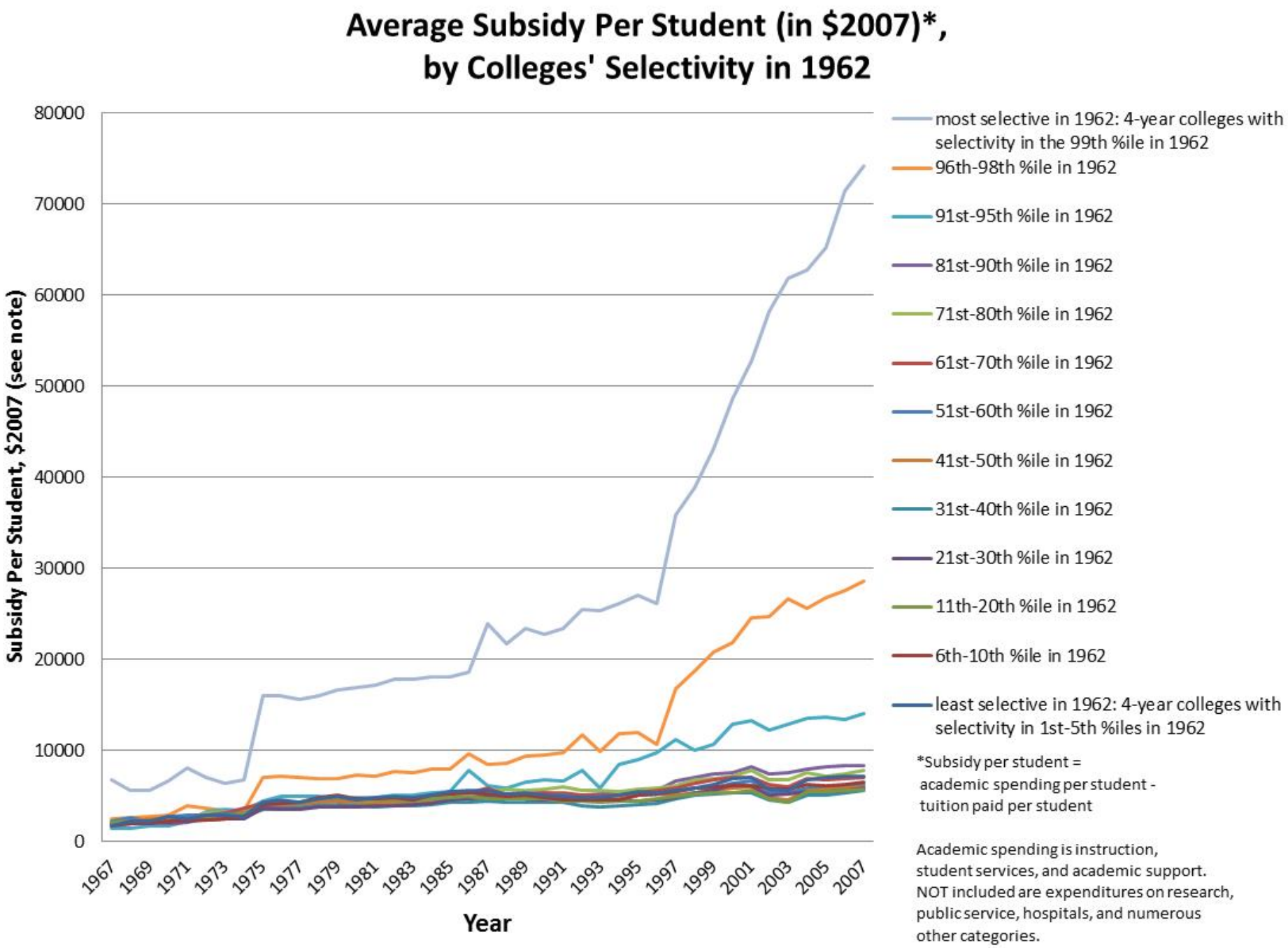
Statistical models of postsecondary choice…

- …based on comparable, longitudinal data from U.S. Dept. of Education* show that over time:
  - Distance *decreasing* in importance
  - Mat
    and ance
  - Parents' ability to pay for school's educational resources *decreasing* in importance

All of these changes over time much more dramatic for students with high ability.

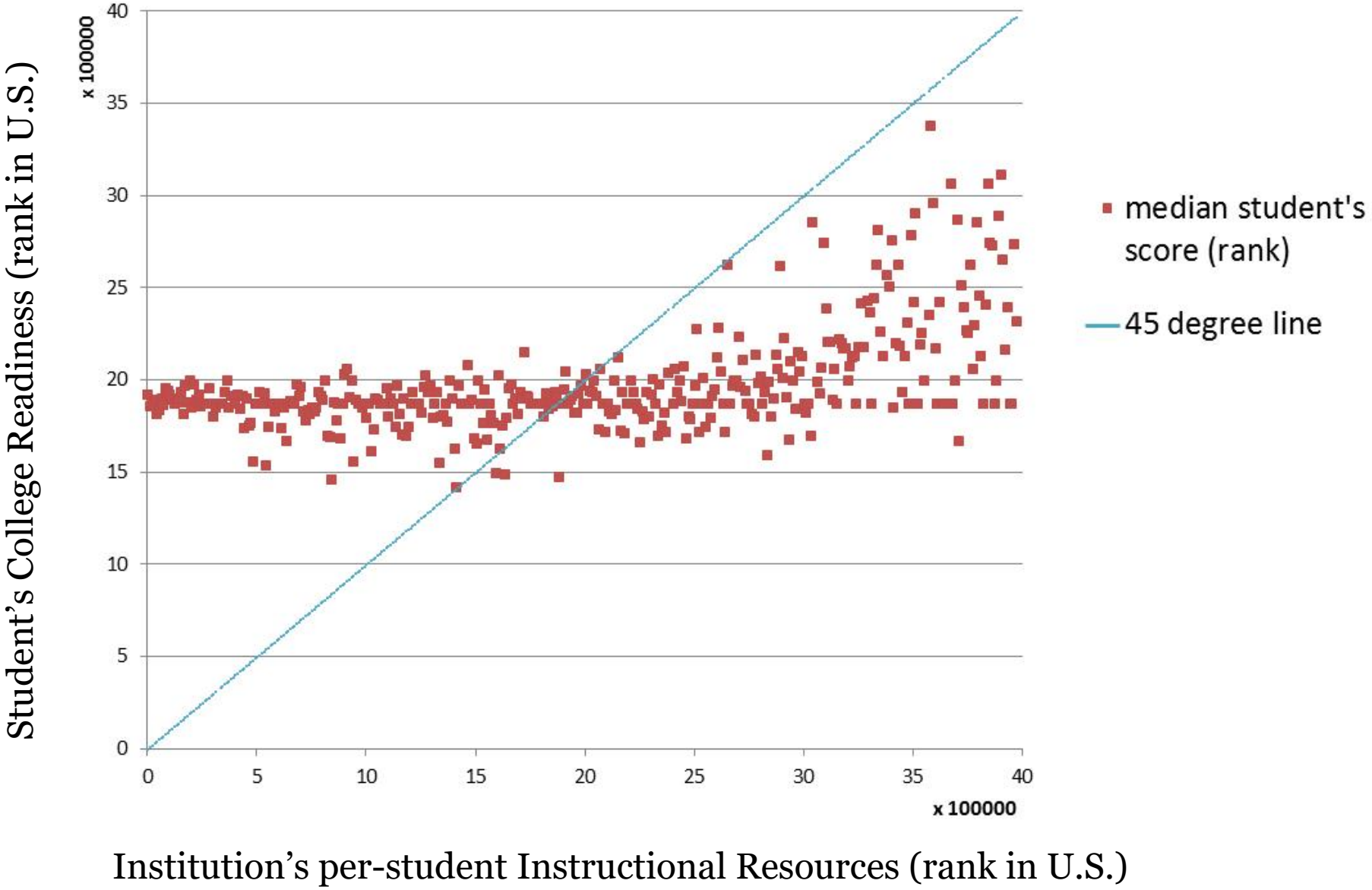
*SURVEY/GRADUATING CLASS: NLS (1972), HSB (1982), NELS (1992), ELS (2002), HSLS (2013).

Greater subsidies at the time-of-enrollment

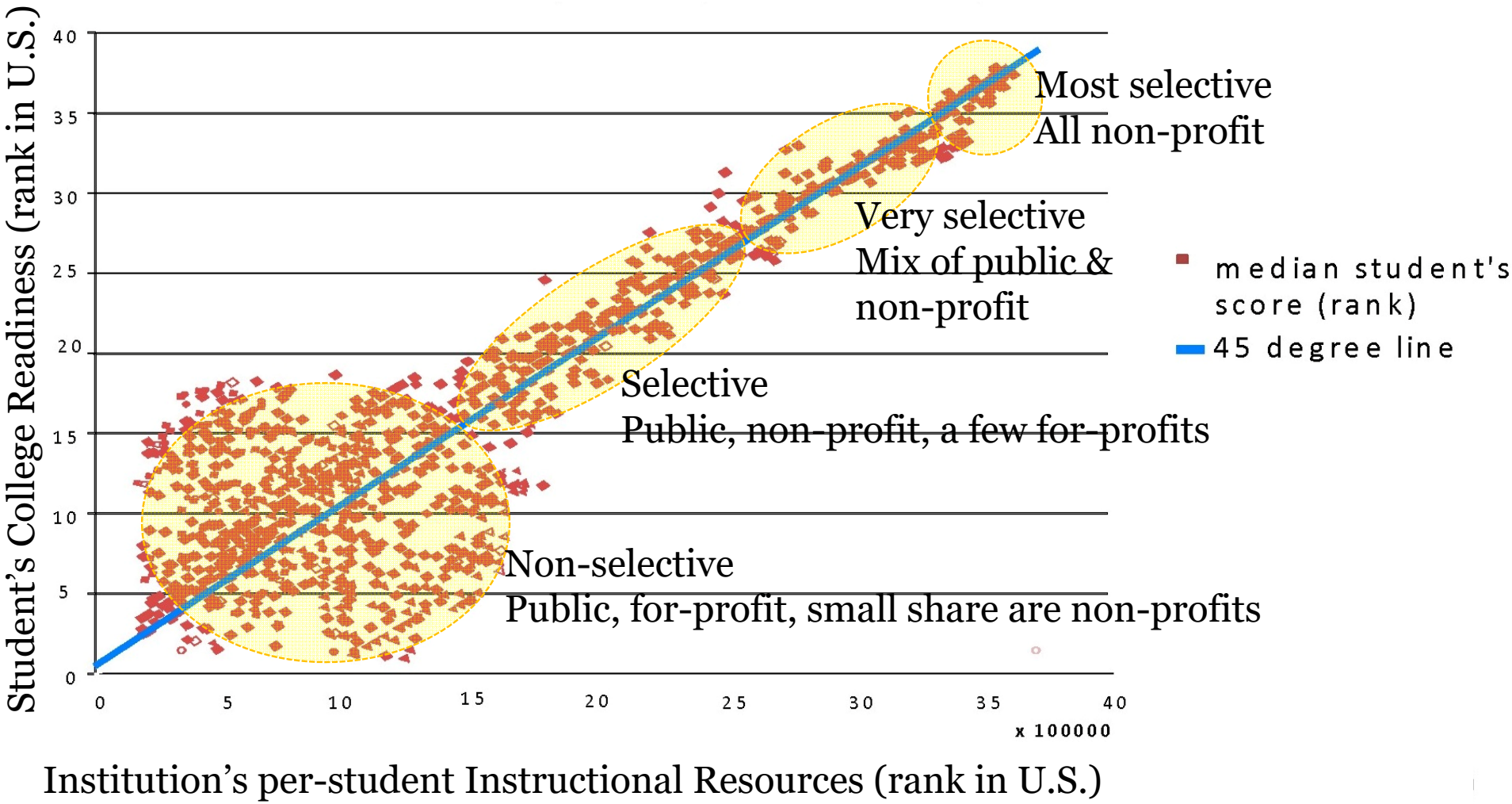

Average Subsidy Per Student (in $2007)*,
by Colleges' Selectivity in 1962
Subsidy Per Student, $2007 (see note)
80000
70000
60000
50000
40000
30000
20000
10000
0
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
Year
most selective in 1962: 4-year colleges with selectivity in the 99th %ile in 1962
96th-98th %ile in 1962
91st-95th %ile in 1962
81st-90th %ile in 1962
71st-80th %ile in 1962
61st-70th %ile in 1962
51st-60th %ile in 1962
41st-50th %ile in 1962
31st-40th %ile in 1962
21st-30th %ile in 1962
11th-20th %ile in 1962
6th-10th %ile in 1962
least selective in 1962: 4-year colleges with selectivity in 1st-5th %iles in 1962
*Subsidy per student = academic spending per student - tuition paid per student
Academic spending is instruction, student services, and academic support. NOT included are expenditures on research, public service, hospitals, and numerous other categories.

Greater sorting of students to educational resources: 1967 versus 2013

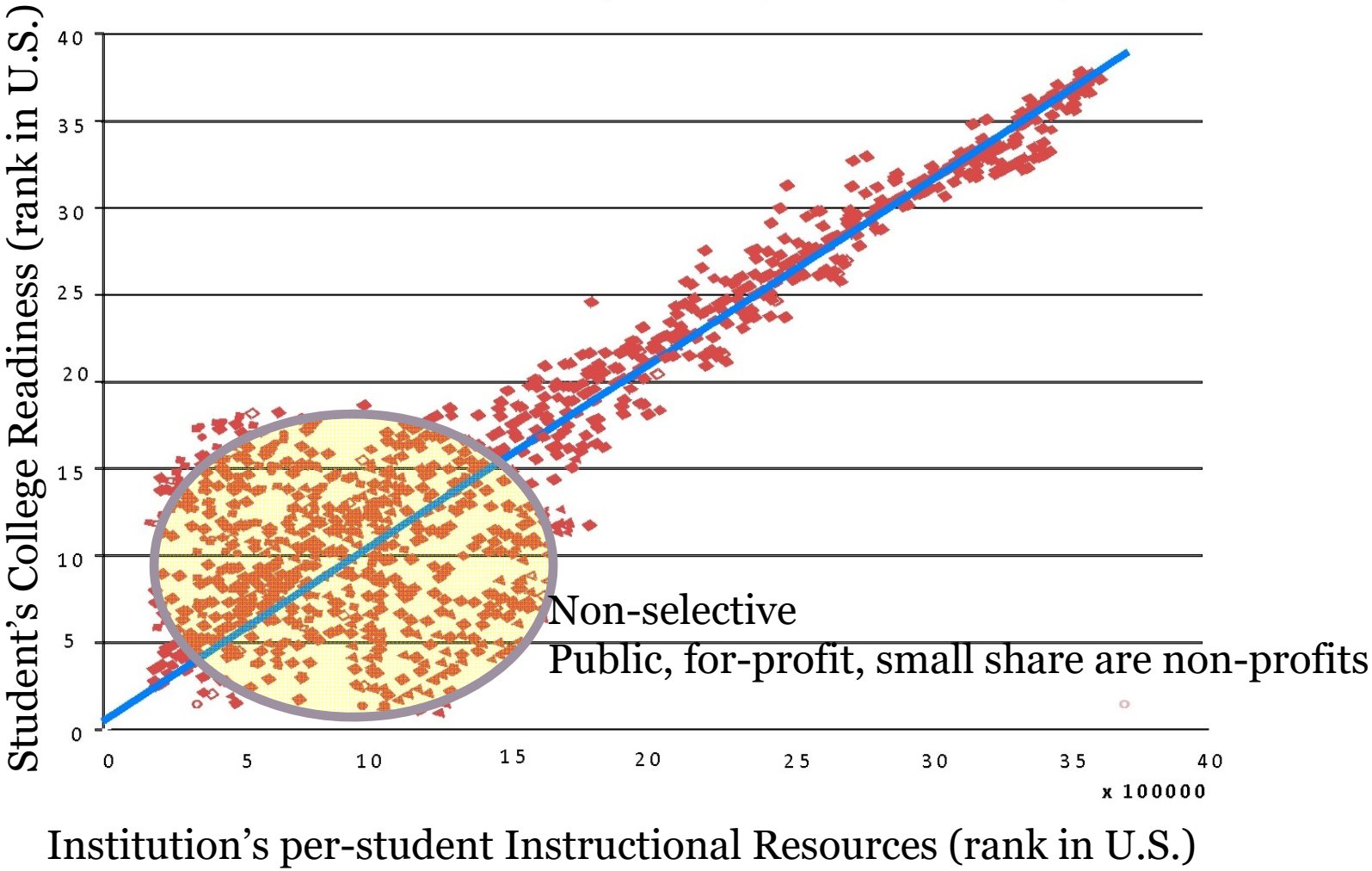
1967 Matching between Student's Rank on College Readiness and Institution's Rank on Educational Resources



2013 Matching between Student's Rank on College Readiness and Institution's Rank on Educational Resources



2013 Matching between Student's Rank on College Readiness and Institution's Rank on Educational Resources

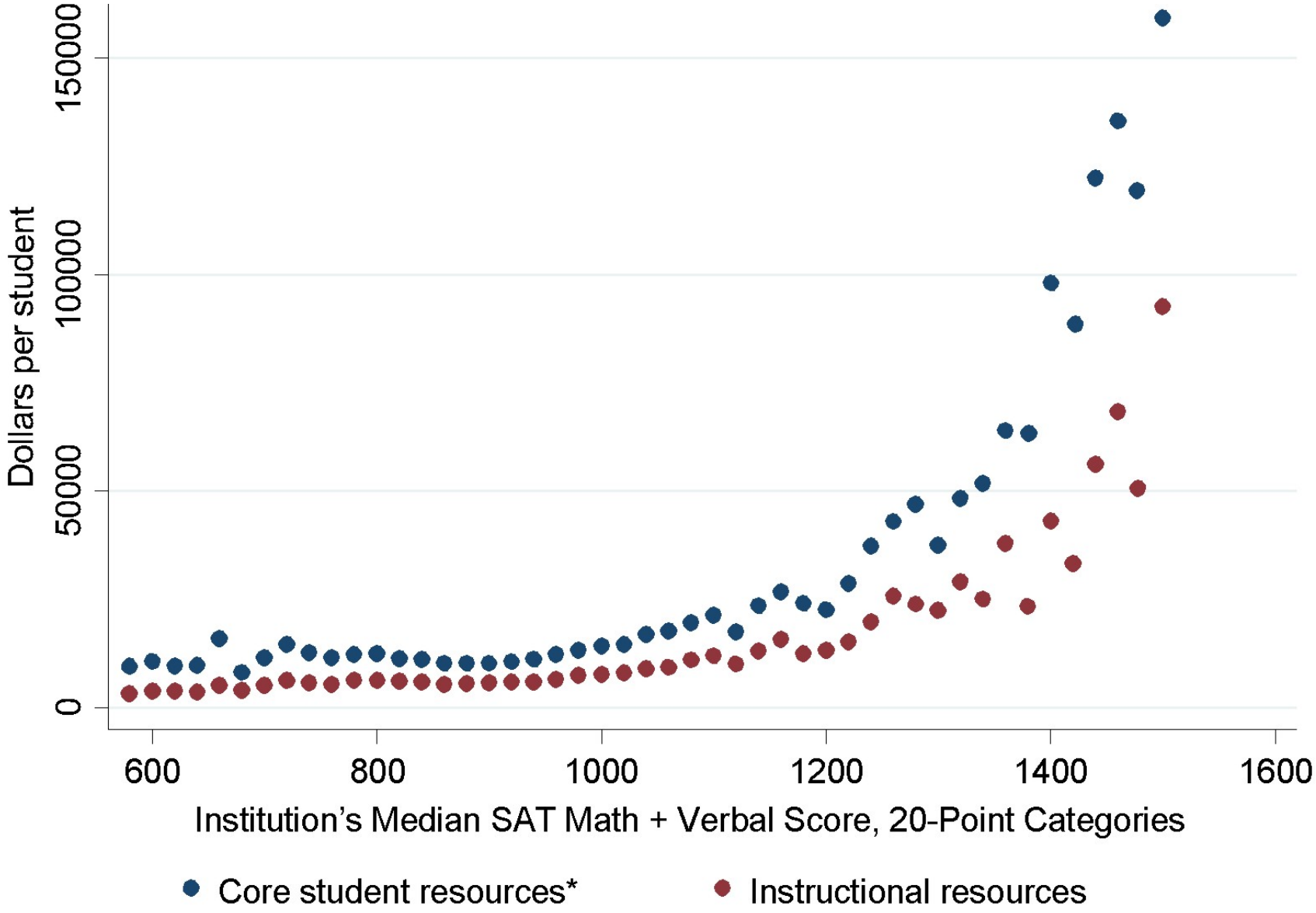


The U.S. Postsecondary Market Today

The highly selective & non-selective parts of the market differ in:

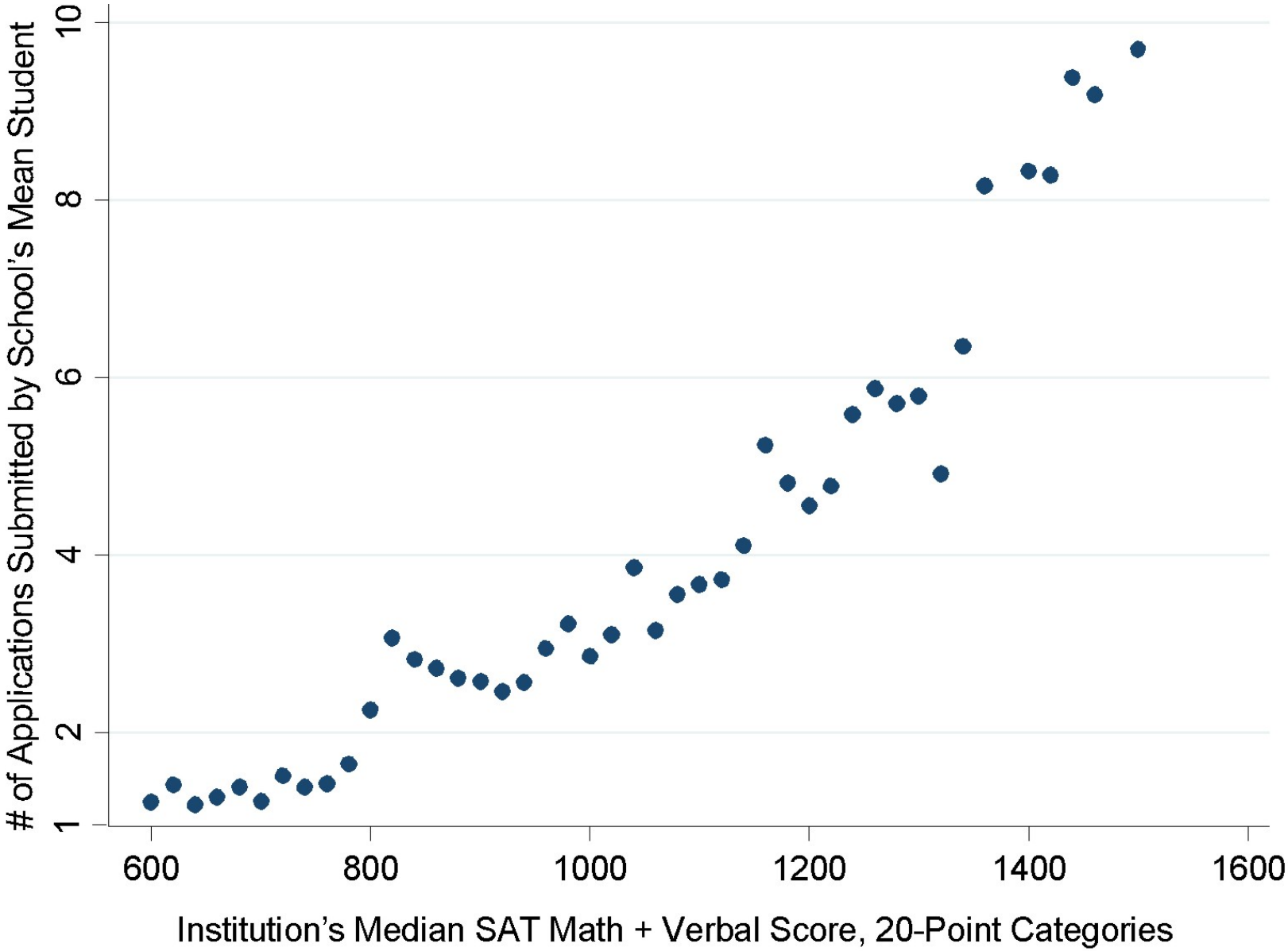
- educational resources
- integration/competition
- information (about schools, about students)
- degree to which undergraduate education is paid by students
- students' sensitivity to institutions' resources
- degree of assortative matching between students' ability and institutions' resources

Core Student & Instructional Resources per student, 2013-14 by Institution's Selectivity

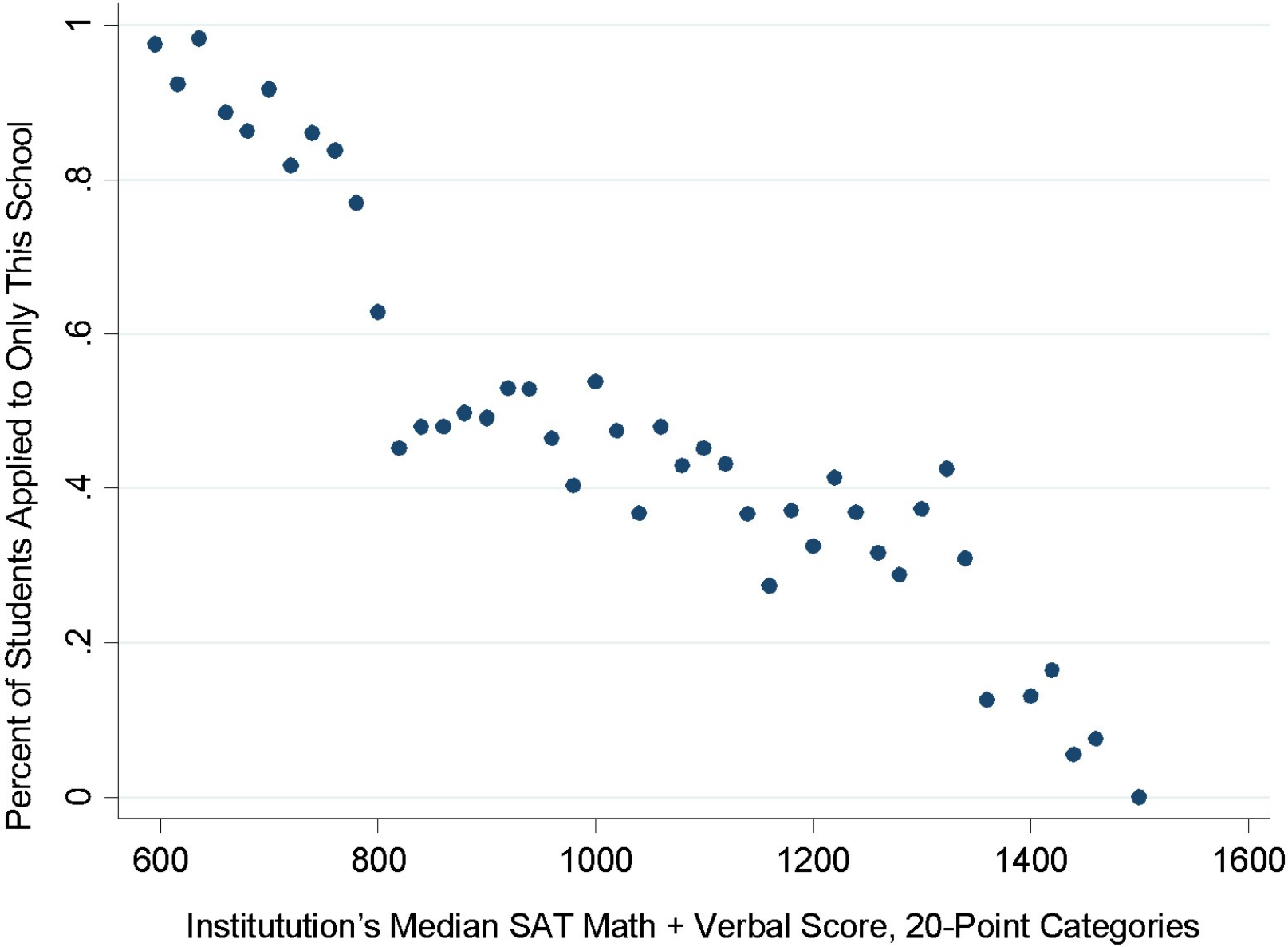


*CORE RESOURCES: INSTRUCTION, STUDENT SERVICES, ACADEMIC SUPPORT, INSTITUTIONAL SUPPORT

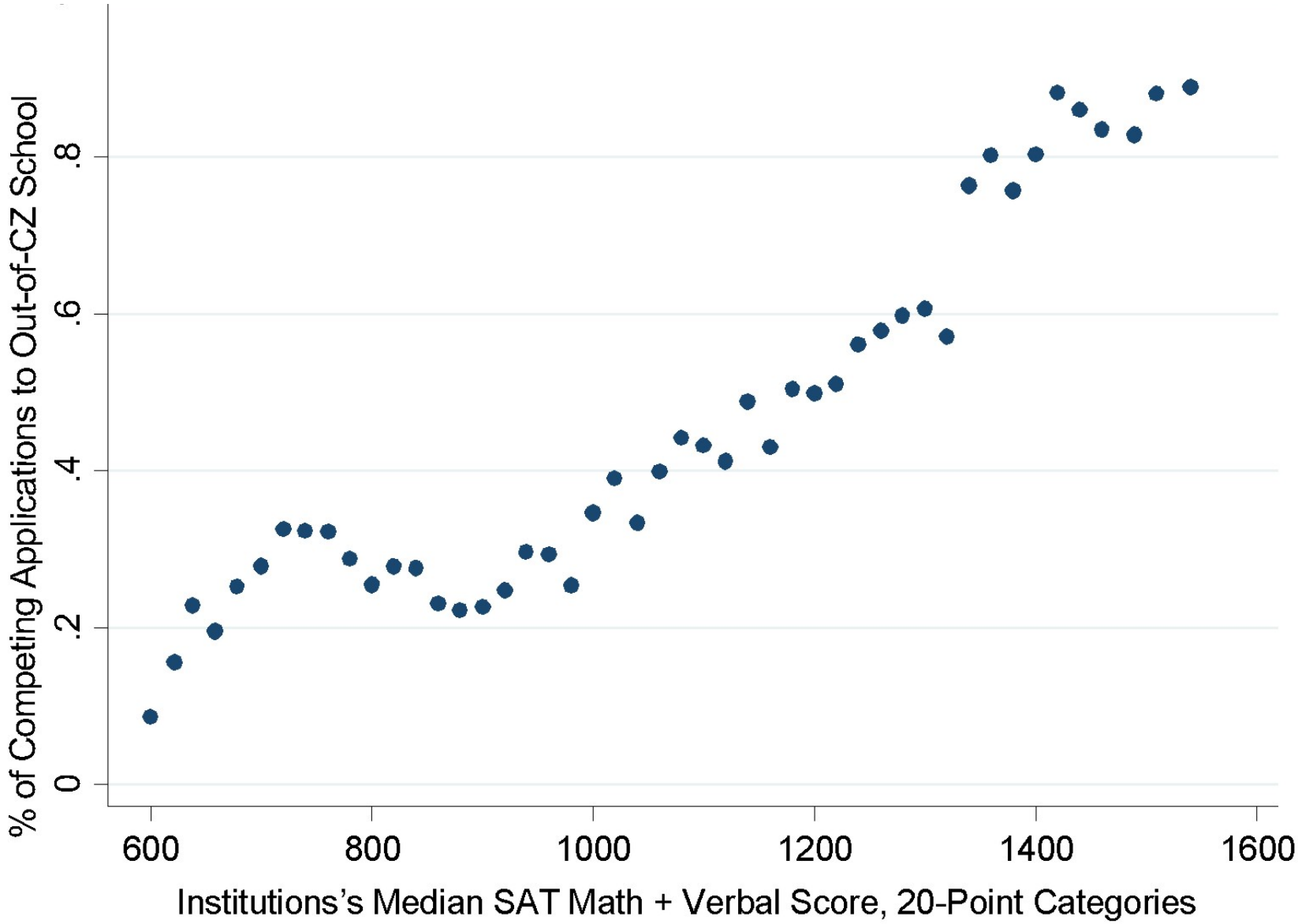
Competition/Integration 1: Average Number of Applications Submitted by Institution's Students



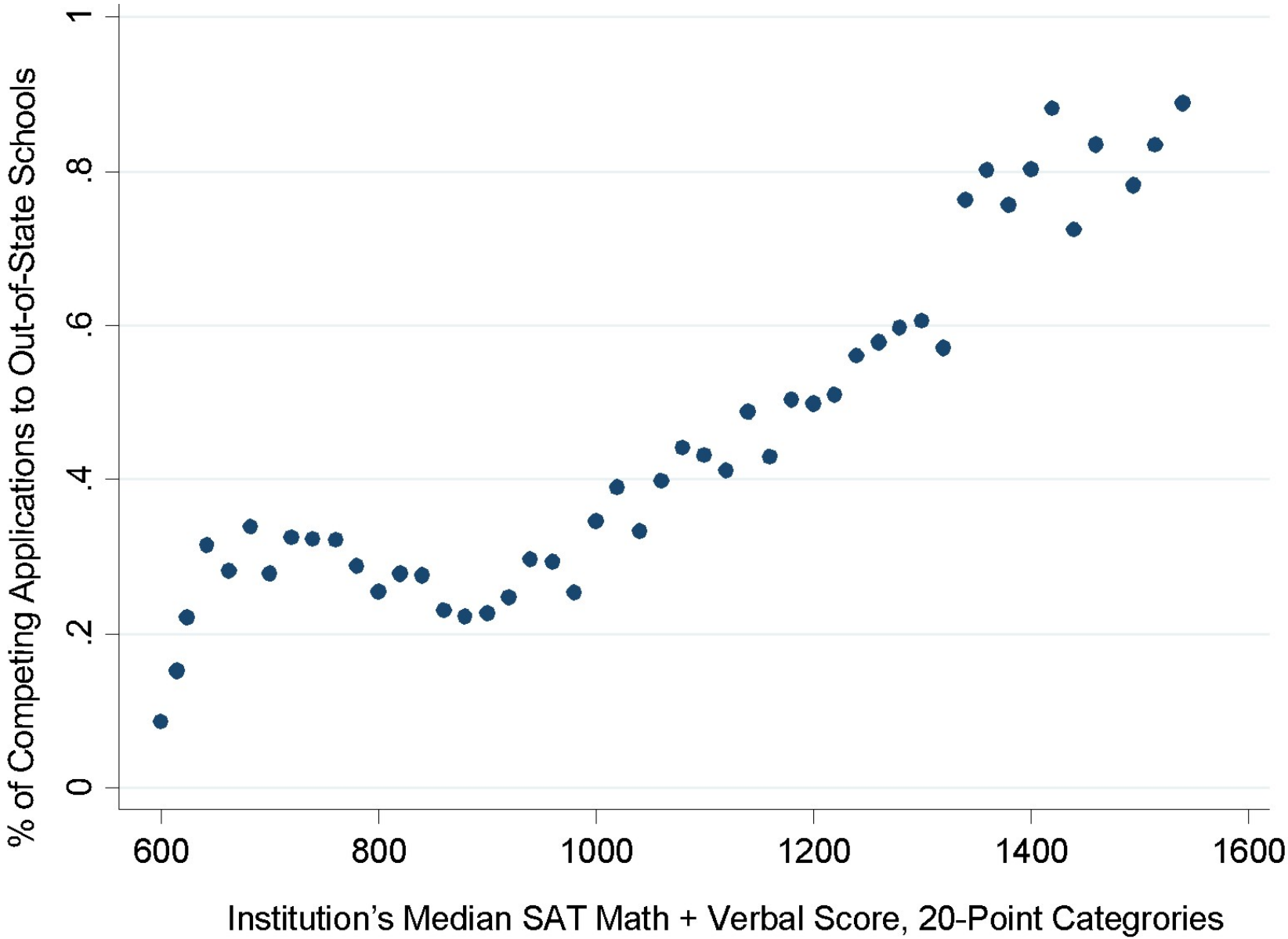
Competition/Integration 2: Share of Institution's Students who Applied *Only* to the School Itself



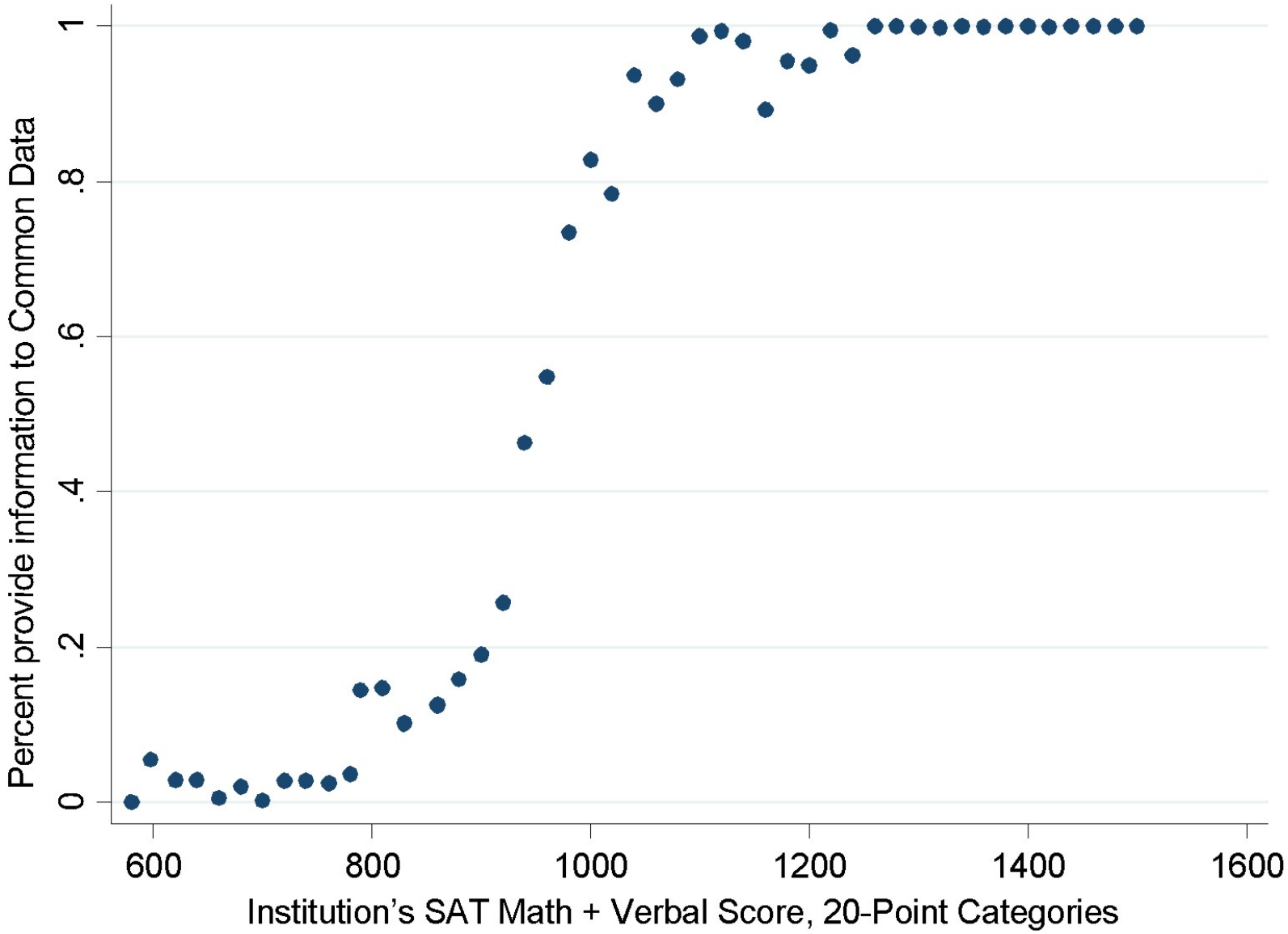
Competition/Integration 3: Share of "Competing Applications" Sent to Institutions in Another Commuting Zone



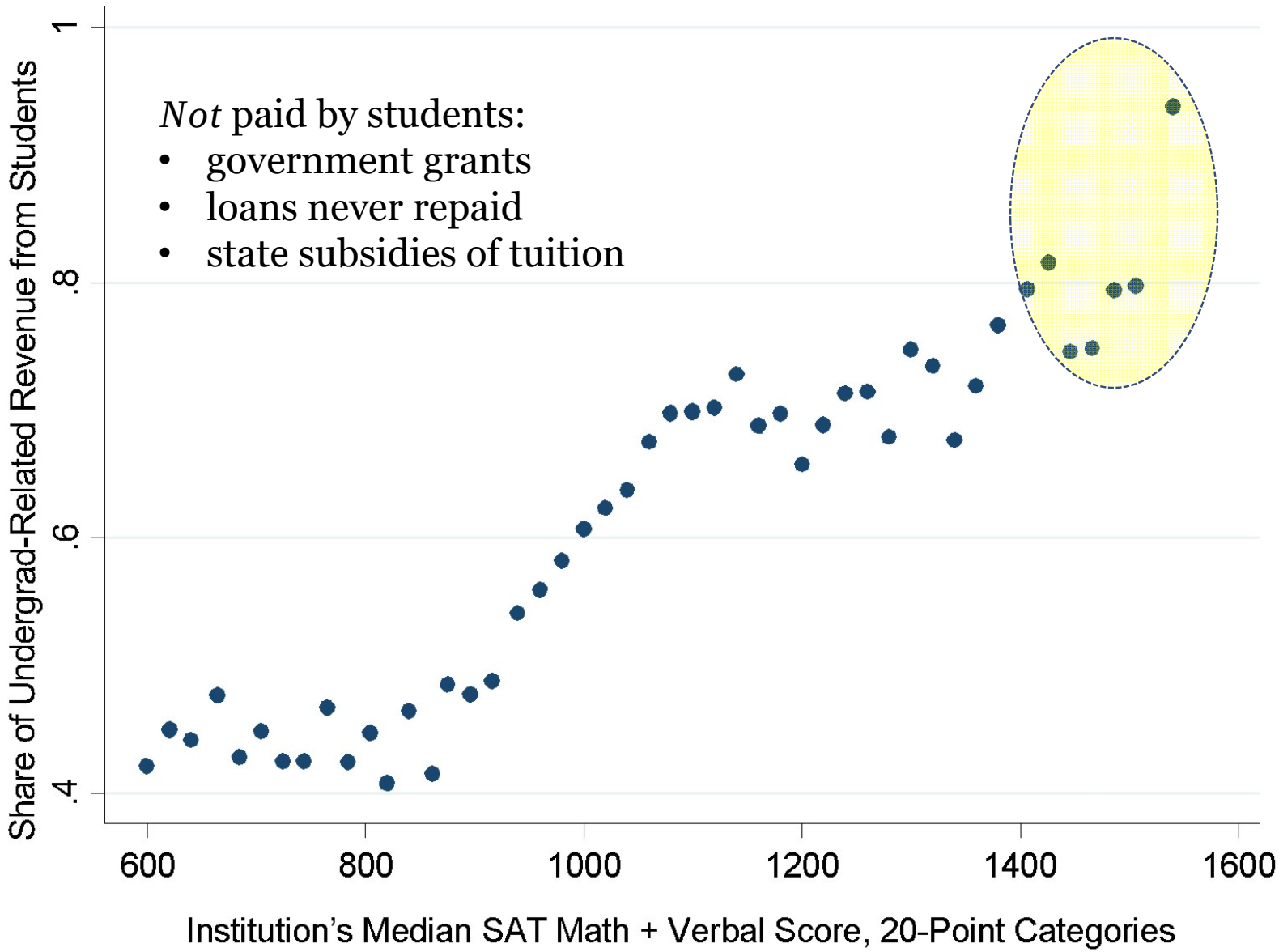
Competition/Integration 4: Share of "Competing Applications" Sent to Institutions in Another State



Information: Share of Institutions that Provide Comparable Information to the Common Data Set used in Guides



Share of Undergraduate Revenue Paid by Students*



Measuring the Productivity of Postsecondary Institutions

NUMERATOR: the *causal* increase in lifetime earnings triggered by enrolling in the institution. "Value-added"

DENOMINATOR: the *causal* increase in lifetime educational spending triggered by enrolling in the institution. "Social Investment"

PROBLEM: bias from vertical & horizontal selection

- Vertical: schools enroll students who differ in ability.
- Horizontal: schools that enroll students who are alike on ability may differ on geography etc.

The Method from 1000 Feet

- Deal with vertical selection by finding each school's "on the bubble" range in admission. Treat students on the bubble as randomized by *admissions staff*. Result: many A versus B experiments where college B is somewhat less selective.
- Deal with horizontal selection by finding *students* choosing among colleges that are in an indifference set (very similar selectivity on vertical grounds). Treat students as randomizing among them. Result: many A versus C experiments where A and C have very similar students.
- Using paired comparison methods, combine the results of all the pairwise experiments to obtain value-added and social investment that is as free of selection bias as possible.

More on the Vertical Experiments

- Staff do admissions in a fairly systematic way, heavily influenced by academic (and certain other) criteria until the class is mostly full.
- They then review a pool of students who would be fine but not special admits to "round out" the class.
- These "on the bubble" students are admitted based on some factor that matters to the shape of the class but is too minor to plausibly affect outcomes except through admissions.
  - Examples: Students who play musical instruments, interested in some field of study, live in some area,…
- I find the bubble range using structural break methods.

More on the Horizontal Experiments

- Student is considering two colleges that have admitted him and that are equally selective. He chooses one based on some factor too small to plausibly affect outcomes except through college choice.
  - E.g. One had better weather on the day he visited.
- I identify schools as horizontal equals if their test score distributions are extremely similar.

Why Combine the Results of the Head-to-Head Experiments?

1. To answer most economics questions, we need the full value-added scale.
2. Combining the head-to-head results connects schools that have infrequent head-to-head experiments because they are horizontally--for instance, geographically--differentiated.
3. We are discarding information if we do not combine the experiments. Each experiment cross-validates others.
   - E.g. Colleges A and B are equally selective and have very similar bubble ranges. Suppose that their head-to-head horizontal experiments suggest that they have equal value-added. If both have head-to-head vertical experiments versus college C, these vertical experiments should confirm that A and B have equal value-added. If we fail to use the information from the A-versus-C and B-versus-C experiments, we are throwing information away.

Crucial Notes on Implemention

- Administrative, population data used throughout: scores, applications, enrollment, educational resources, earnings.
  - Longitudinal data used up to age 32, projected thereafter.
  - In other work, I show productivity based on outcomes other than earnings: public service, innovation, etc.
- Students are only compared to others with the <u>same</u> scores who applied to the same institutions.
- This is a straightforward application paired comparison methods—although the implementation is computationally demanding because of the sheer scale.

Summary of the Method

1. Gather the differences in earnings and social investment from all vertical experiments involving students who are on-the-bubble at some selective school and exposed to randomization by admission staff.
   - Longitudinal data used up to age 32, projected thereafter.
2. Gather the differences in earnings and social investment from all horizontal experiments involving students who choose between equally selective schools.
3. Combine the experimental results using paired comparison techniques.

Strengths of the Method

Strength: Plausibly, most or all selection bias is eliminated.

Strength: Common support is always fulfilled.

Strength: No form imposed on relationship between value-added & ability.

Strength: The estimates are not very "local" owing to the paired comparison methods.

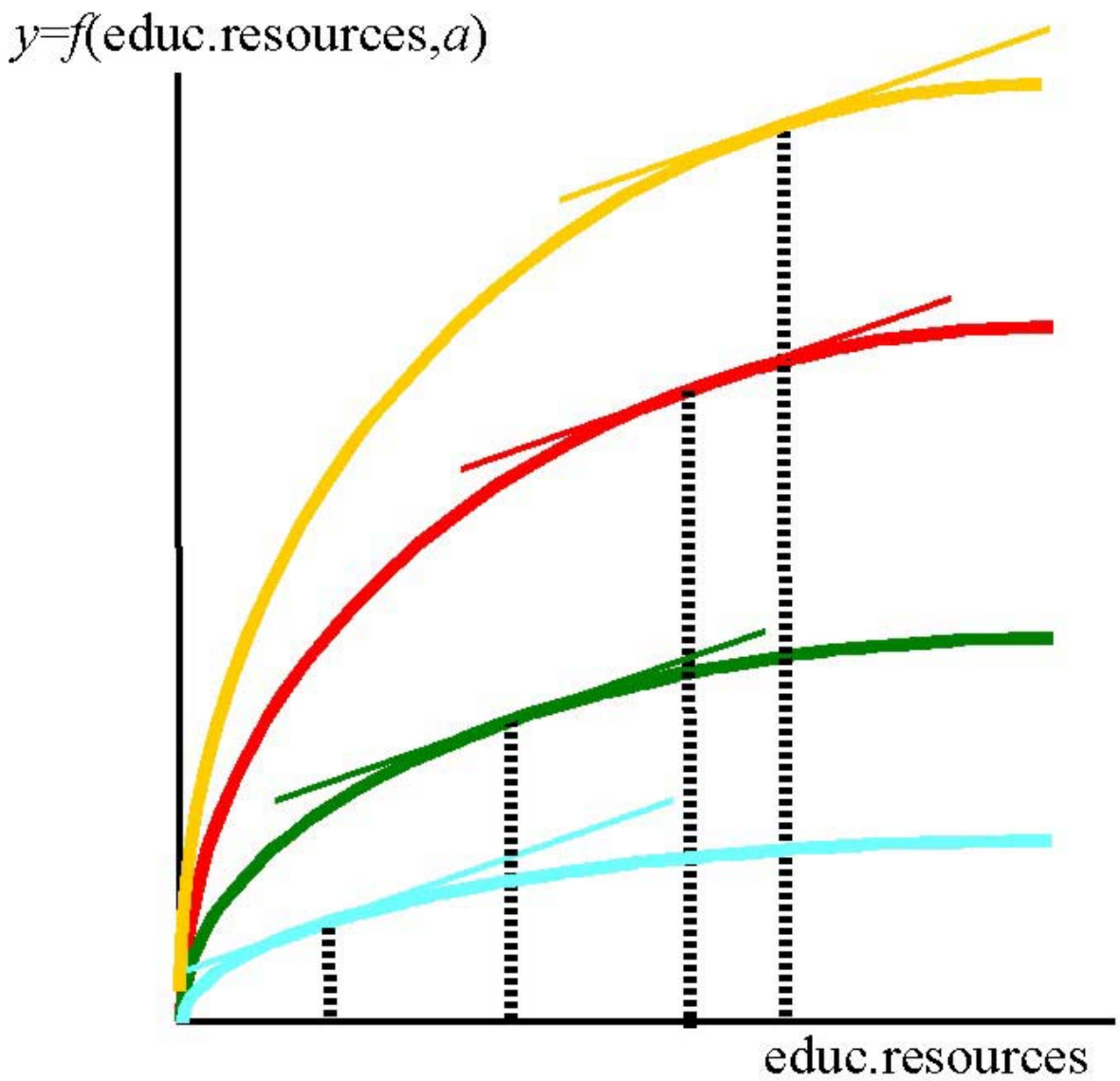
Strength: It is obvious which assumptions need robustness checks—e.g. discount rates, projecting earnings, structural breaks in admissions…

Limitations of the Method

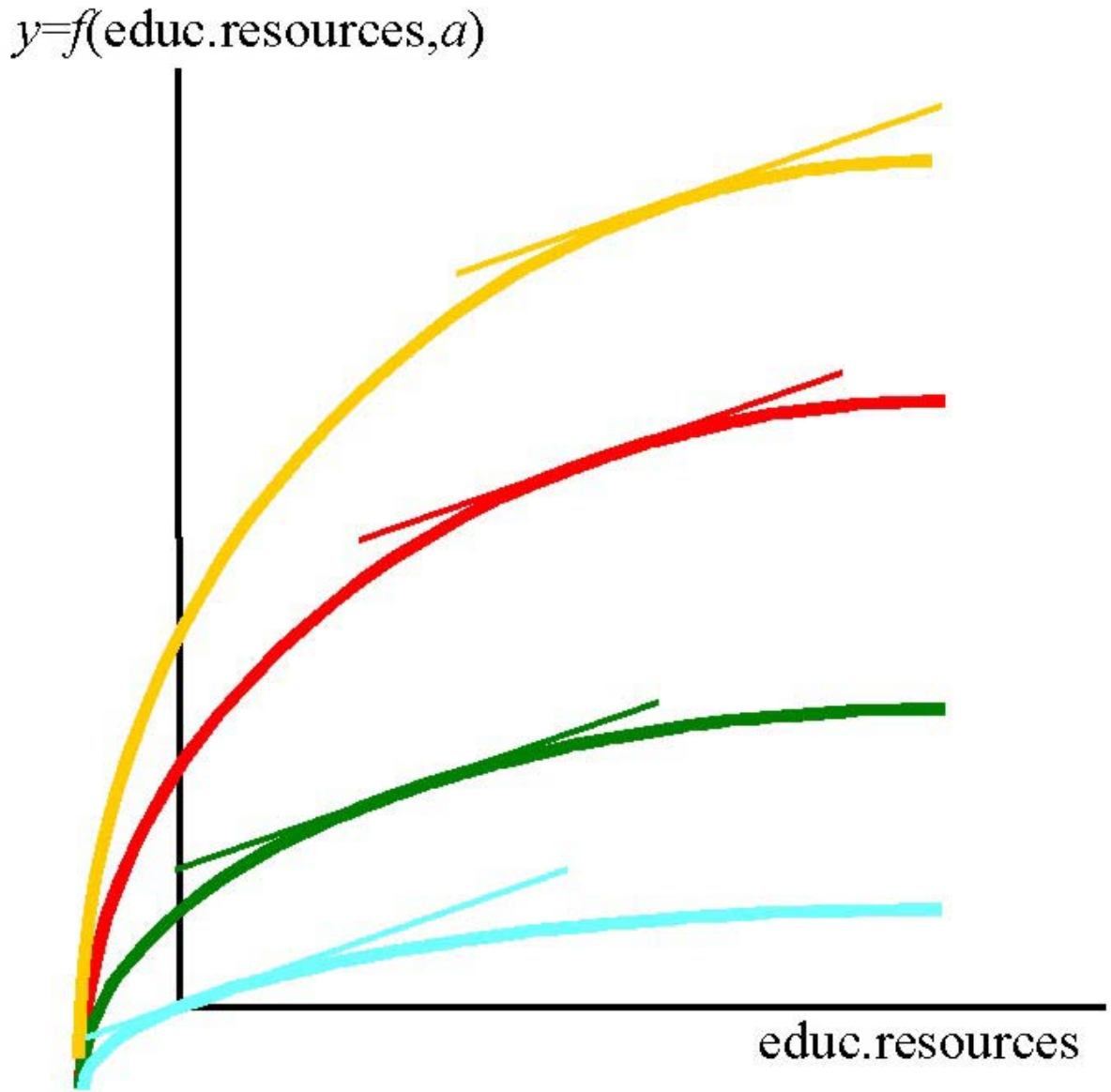
Limitation: I know of no general fix for nonselective vs. no-postsecondary-at-all selection. Thus, we learn about productivity relative to the *least selective institutions*.

Limitation: I derive a measure of the average productivity of a dollar of resources, not the marginal productivity.

Suppose the market contained 4 institutions (efficient capital market shown)



Measuring productivity relative to the least selective institution is equivalent to:



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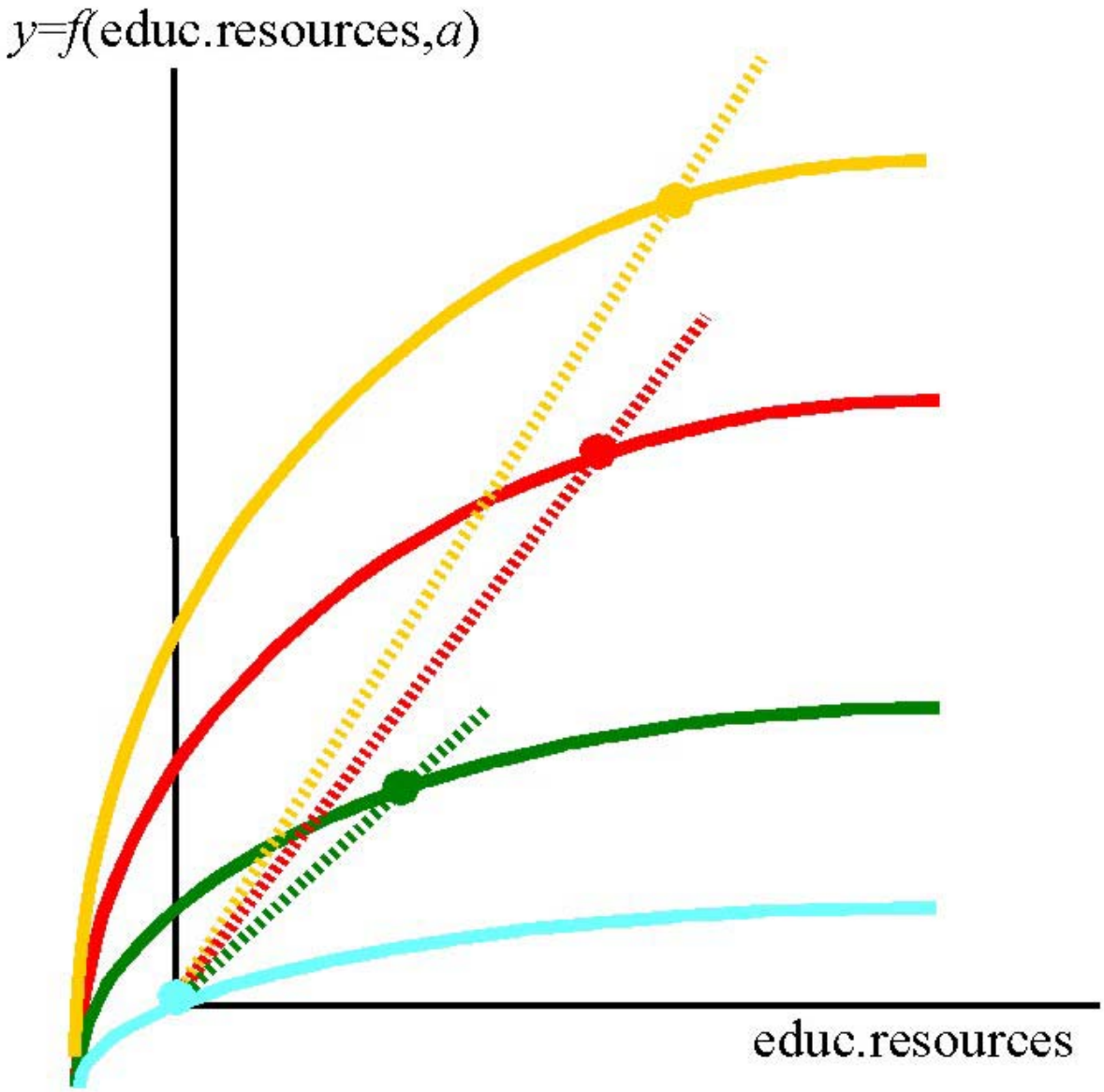
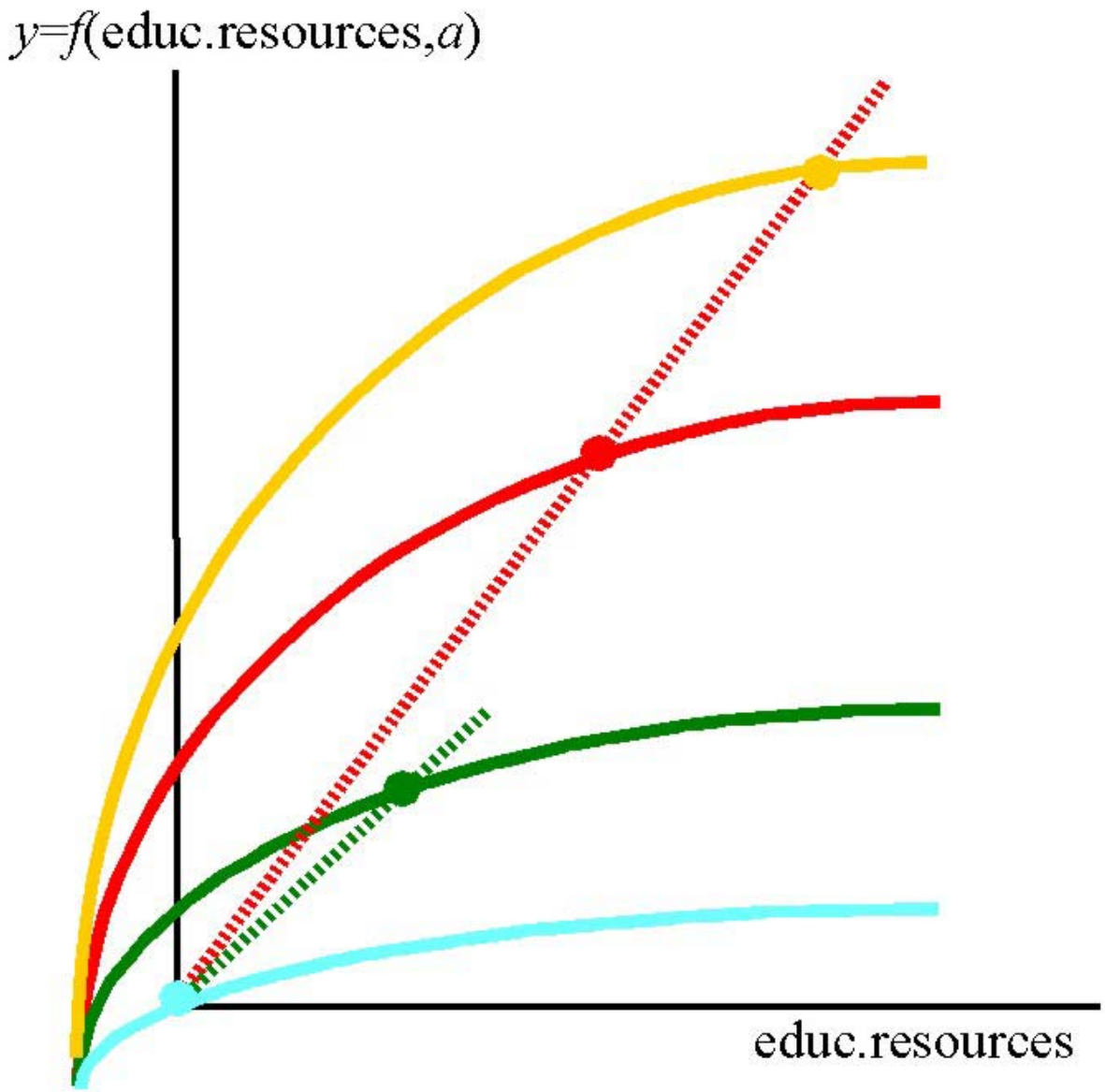
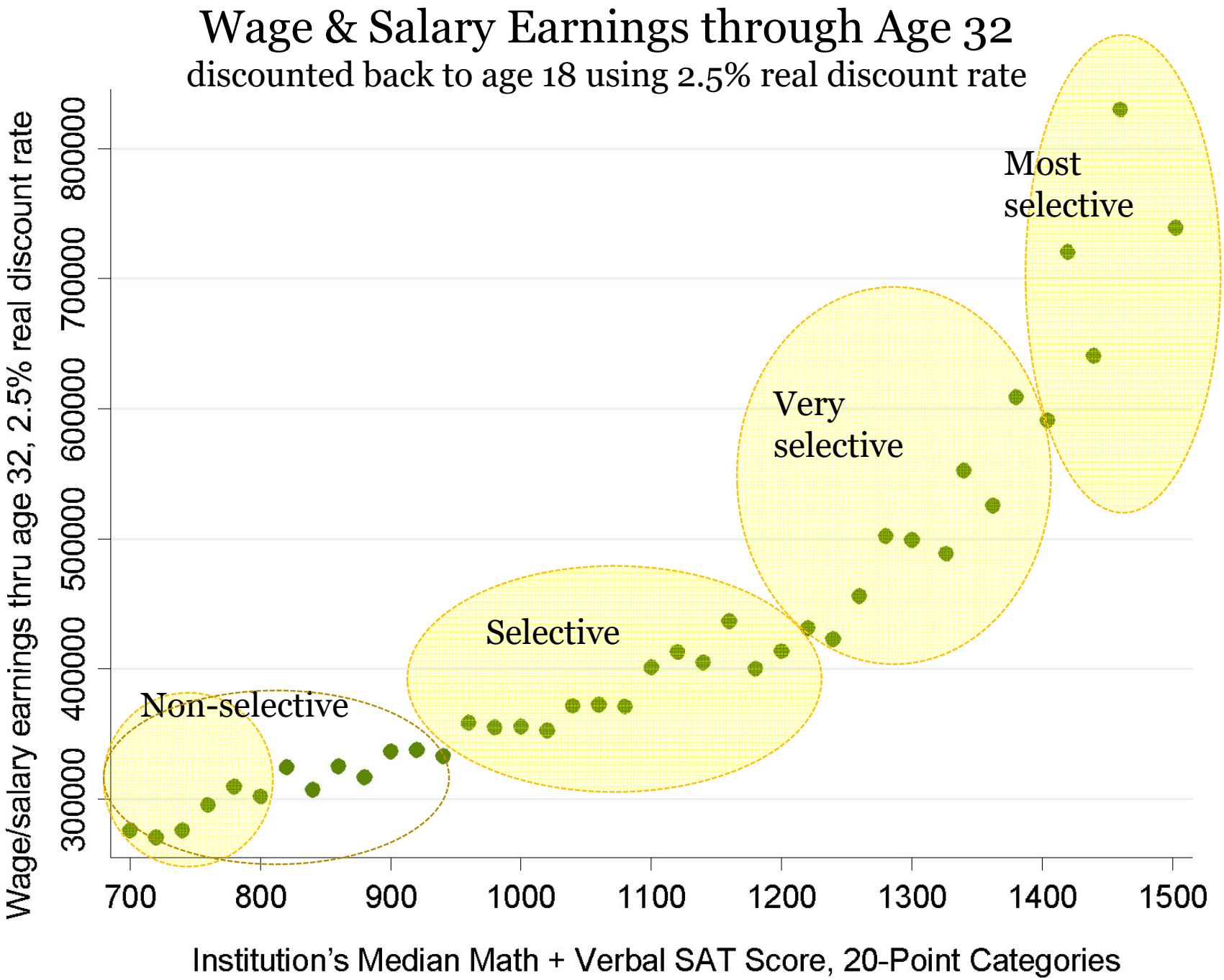


But I won't impose an efficient capital market

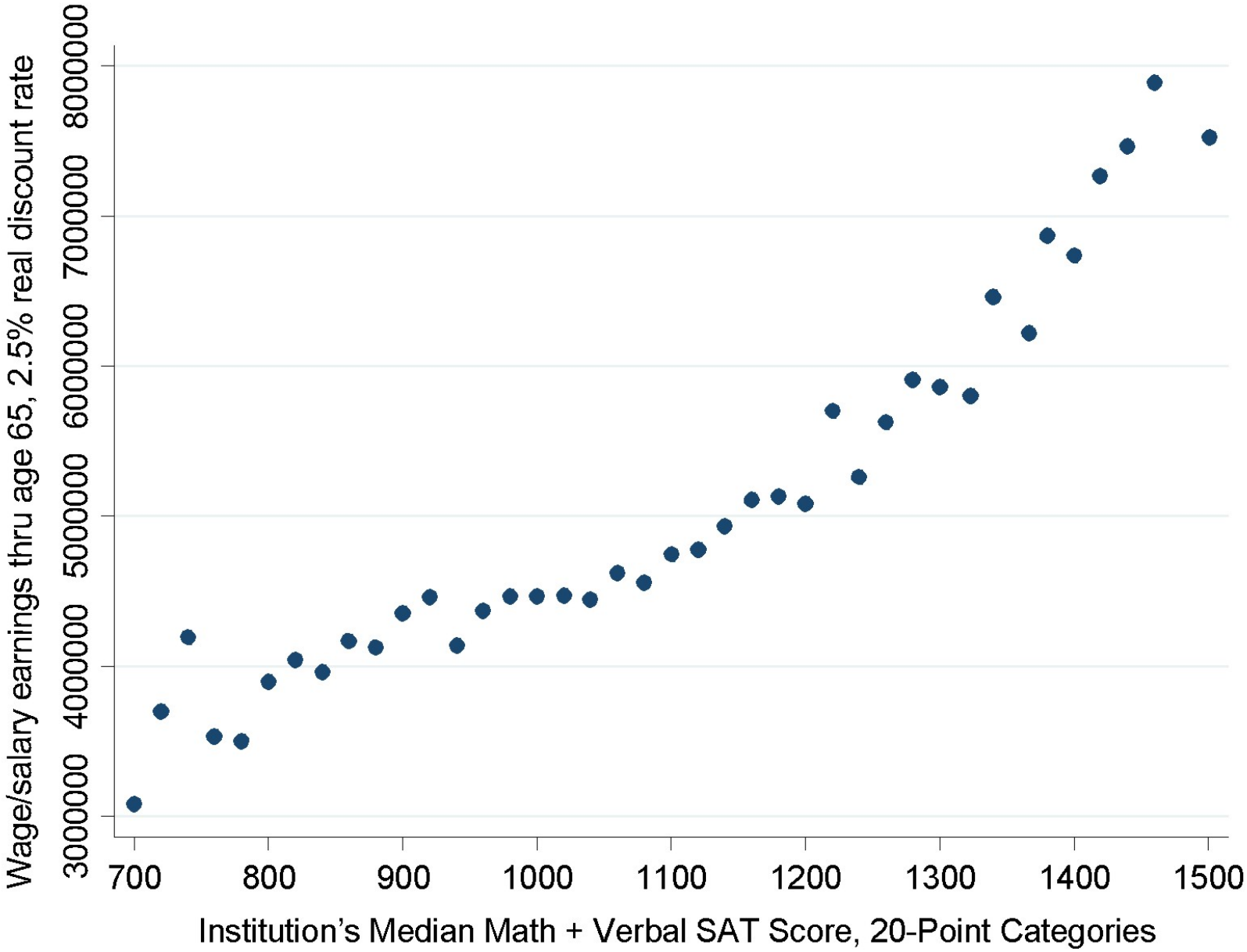


Now for results


Wage & Salary Earnings through Age 32
discounted back to age 18 using 2.5% real discount rate
Wage/salary earnings thru age 32, 2.5% real discount rate
300000
400000
500000
600000
700000
800000
700
800
900
1000
1100
1200
1300
1400
1500
Institution's Median Math + Verbal SAT Score, 20-Point Categories
Non-selective
Selective
Very selective
Most selective

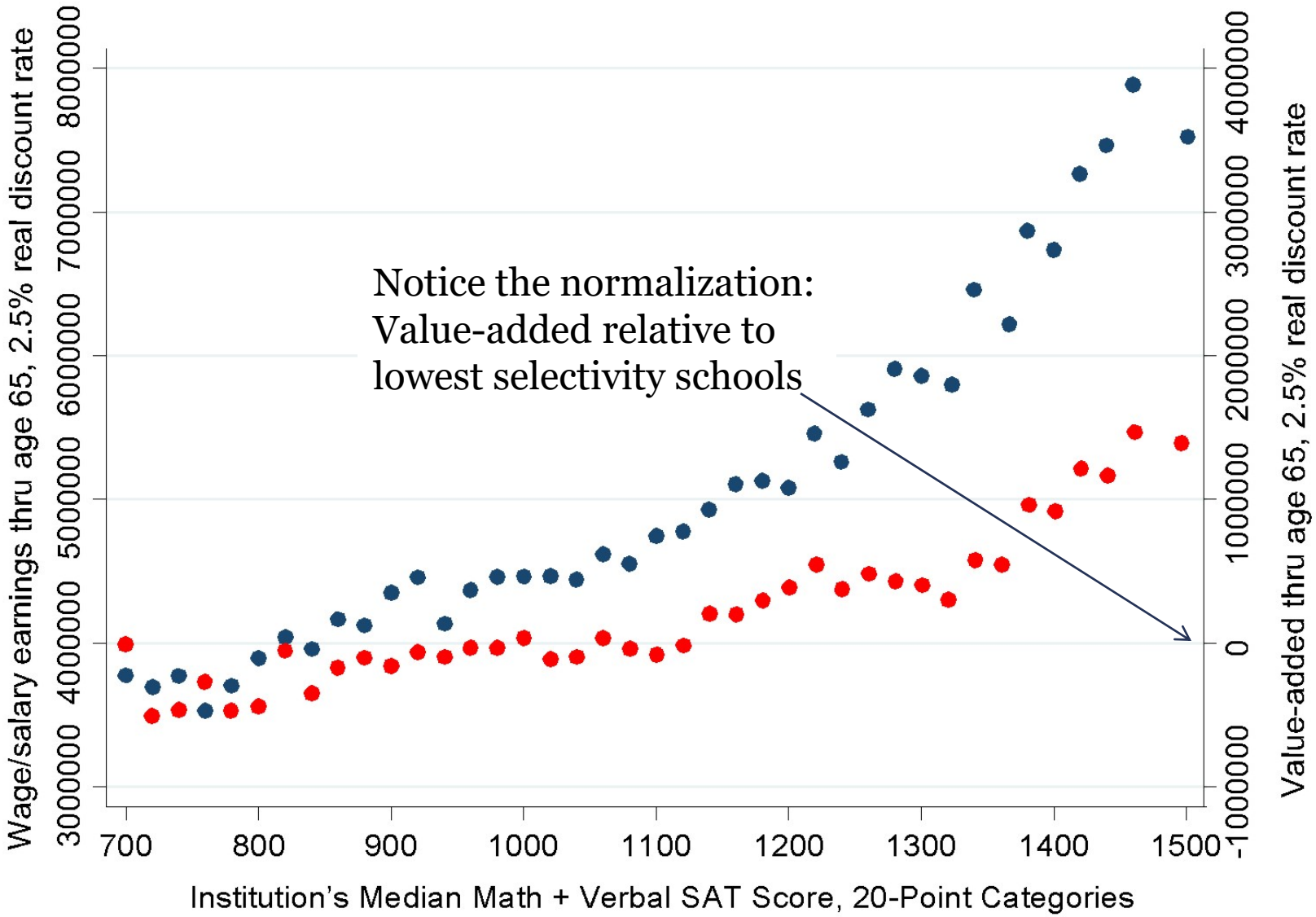
Wage & Salary Earnings Projected through Age 65

discounted back to age 18 using 2.5% real discount rate



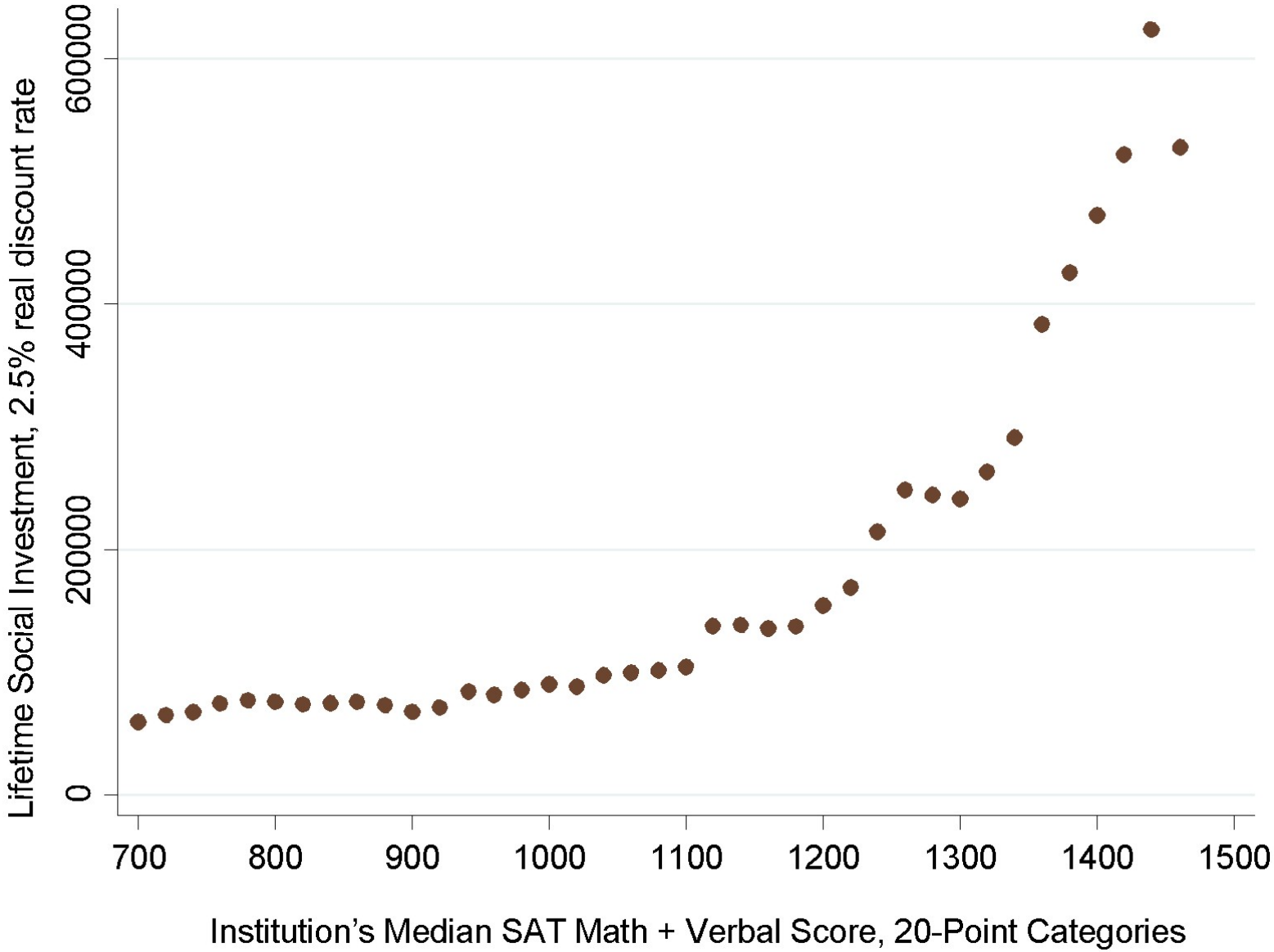
Wage & Salary Earnings and *Value-Added* Projected through Age 65

discounted back to age 18 using 2.5% real discount rate



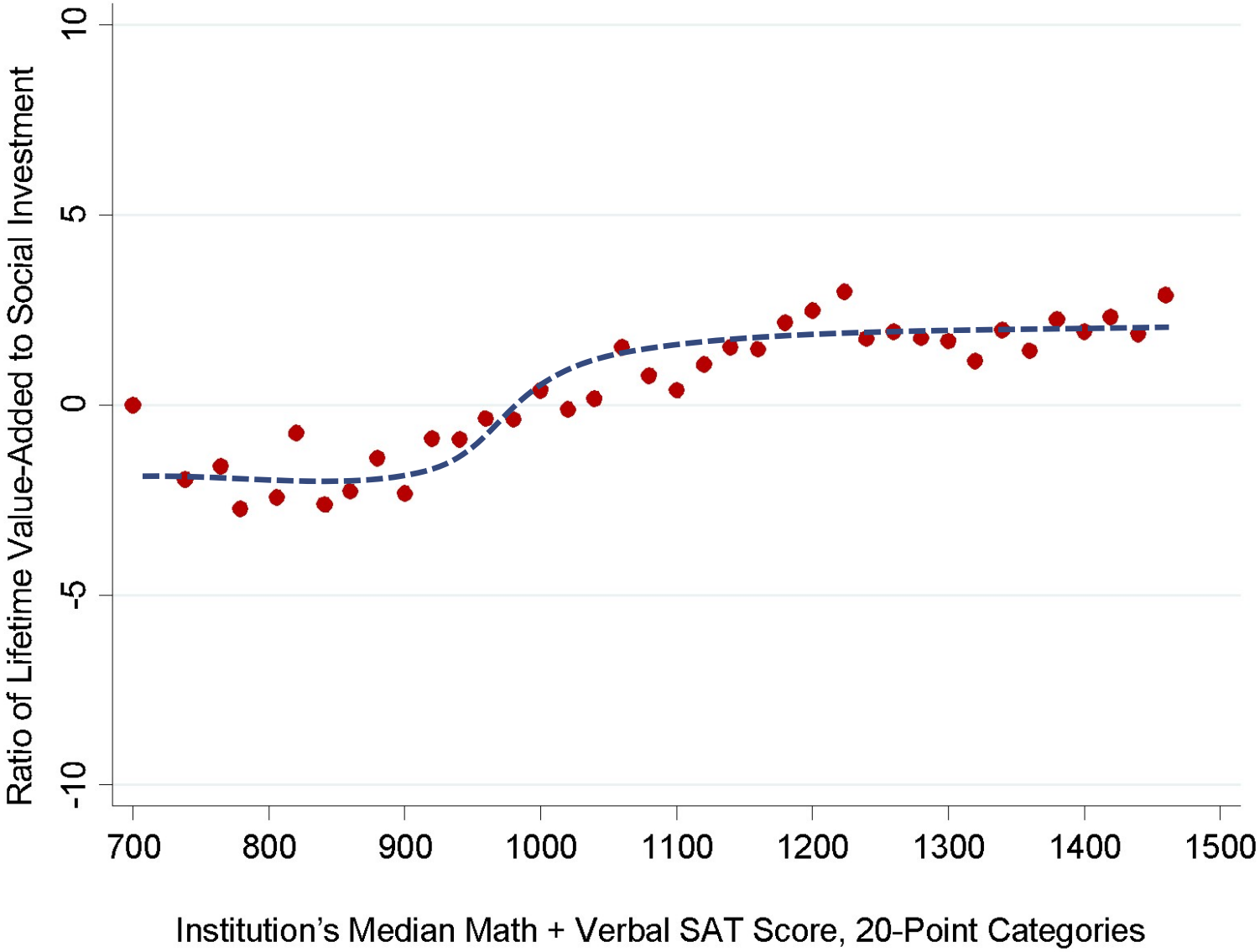
Lifetime Social Investment in Postsecondary Education

(through age 32), discounted back to age 18 using 2.5% real discount rate



Average Productivity of a Dollar of Social Investment

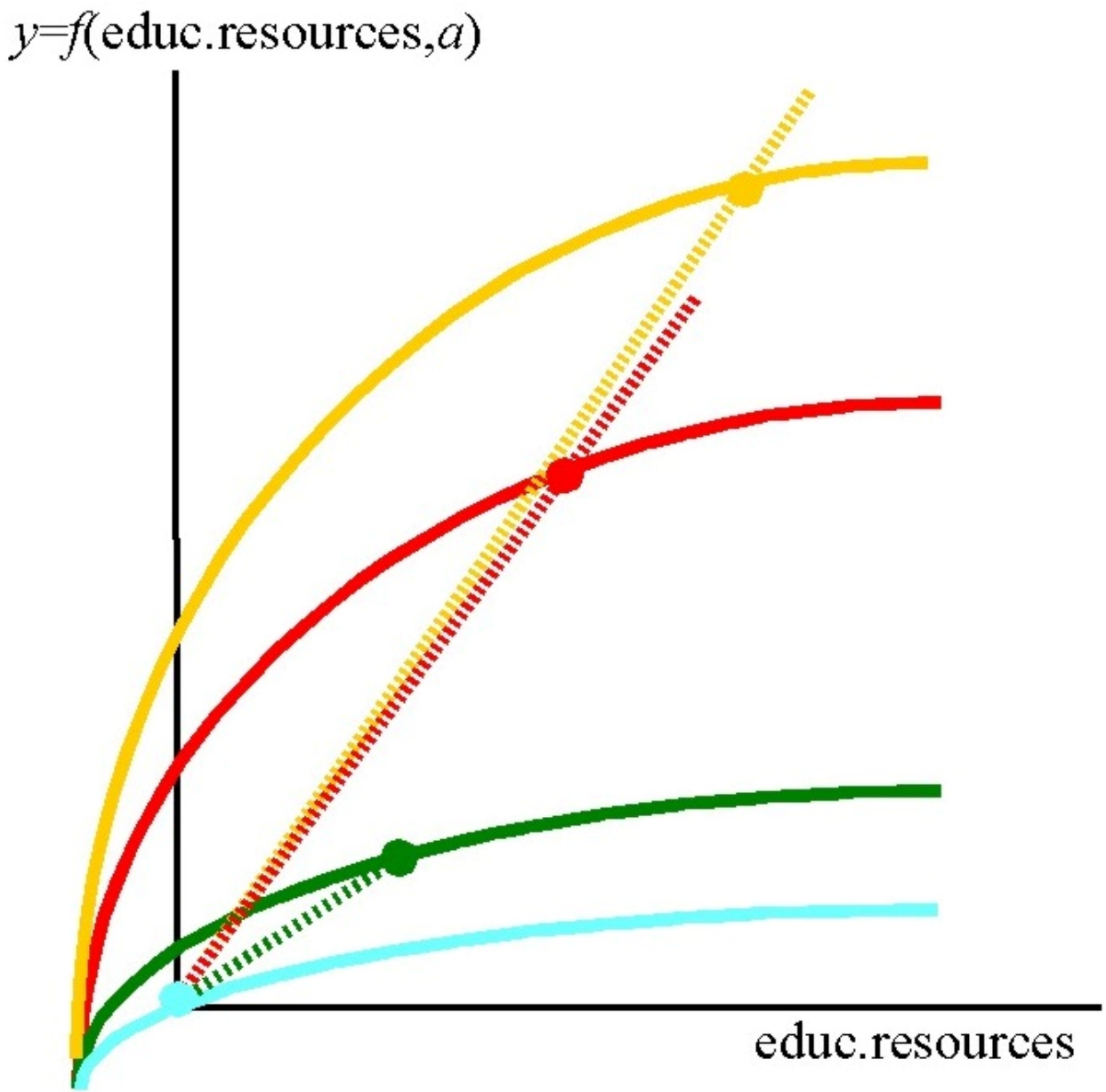
= Lifetime Value-Added/Lifetime Social Investment
(relative to least selective institutions)



Assess Where We Are

- The average productivity of a dollar of educational resources is rather flat (rising just slightly) across a fairly wide range of selectivity.
  - Striking because these schools have very different educational resources.
  - Suggests that resources are scaling up with students' ability.
  - There may be some gains from reallocating dollars among selective schools (because marginal productivity≠average productivity) but no *easy* gains.
  - The evidence does not imply that selective schools make maximally productive use of resources. They could just be similarly inefficient.

That is, the situation looks approximately like:



Assess Where We Are, cont.

- Relative to the least selective institutions, productivity of a dollar is sufficiently positive at selective institutions that their additional resources seem like a good investment for the students who attend them.
- Non-selective institutions are less productive on average. but their productivity is also much more dispersed.
  - Students choosing among non-selectives can make big mistakes.
  - Potentially problematic that the non-selectives are expanding much faster than the selectives.
- Hard to say whether the non-selective institutions are a good investment vis-à-vis alternatives like the military, on-the-job training, etc.

A decentralized market model consistent with the evidence

SUPPOSE:

- There is single-crossing in the productivity of educational resources and ability.
- Students maximize their return on educational investments.
- Students are insensitive to arbitrary features like geography so all institutions are integrated in the market.
- Students are fully informed and not liquidity constrained.

Single-Crossing for a Decentralized Market

$a_i =$ ability of student i

$r_j =$ educational resources at institution j

$p_j =$ (undistorted) price of a unit of resources at institution j

$$-\frac{\dfrac{\partial Y_i^{lifetime}(a_i, r_j, p_j)}{\partial r_j}}{\dfrac{\partial Y_i^{lifetime}(a_i, r_j, p_j)}{\partial p_j}} \equiv M(a_i, r_j, p_j)$$

Single-crossing: *M()* is monotonic in ability. That is, a student with higher ability is always willing to pay more for a unit of educational resources than a student with lower ability.

Under these assumptions:

- Student choices and market forces will generate an assortatively matched allocation in which:
  - students with higher ability are paired with more educational resources
  - each institution's marginal dollar of resources generates the same value-added;
  - institutions are forced to be x-efficient.

In addition to assortative matching, the market equilibrium would exhibit:

- Allocative efficiency: the return to marginal dollar of educational resources forced into equality across institutions.
- Productive efficiency: institutions will be forced to produce on the production possibility frontier.

$$\frac{dp_j}{dr_j} = -\frac{\dfrac{\partial Y_i^{lifetime}(CR_i, r_j, p_j)}{\partial r_j}}{\dfrac{\partial Y_i^{lifetime}(CR_i, r_j, p_j)}{\partial p_j}} \equiv M(CR_i, r_j, p_j)$$

It is not the only model consistent with the evidence, but…

- It fits the selective sector, where its assumptions are fairly reasonable, fairly well.
- It does not fit the non-selective sector, where its assumptions are implausible.
- Even if we do not "buy" the strong versions of the efficiency implications, it is hard to think of a model consistent with the evidence that does not rely on single-crossing with *M()* <u>strongly rising</u> in ability.
- In the Becker notation:

$$\frac{\partial^2 f}{\partial s \, \partial a} >> 0$$

Strong single-crossing has important economic implications

- To make its maximum contribution to growth, a higher education sector allows educational resources to scale up with cognitive skill.
- This is probably especially important in highly developed economies.
- Notice that nothing in this model suggests that relative ability matters: <u>everyone</u> could have high cognitive skill & invest greatly in educational resources.

Strong single-crossing has important economic implications

- Currently, however, all adults do not appear to have high cognitive skill—at least at the time they reach higher education.
- If ability is indeed fixed or predetermined, what is good for growth could therefore be bad for income equality and require substantial redistribution *ex post*.
- Thus, there should be some urgency in figuring out whether and when ability/cognitive skill is plastic and determined: next lecture!

Simple take-aways

- Single-crossing is not merely a convenient assumption. It appears to be a serious business: people who enter higher education with great cognitive skill appear to be able to engage an order of magnitude greater educational resources while achieving similar average productivity with them.
- Dealing with selection makes a huge difference.
- Measuring educational resources by years of schooling makes little sense, especially in higher education.