Education as Signaling

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Roadmap

1. Introduction

2. The Model (Part I)

3. The Model (Part II) $*$

4. Empirical Studies

Introduction

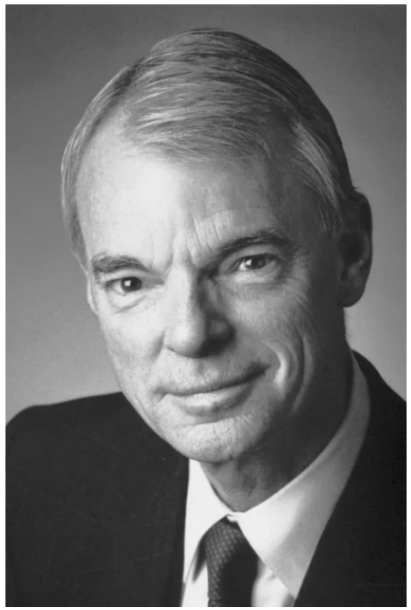
- Becker's human capital theory: education increases a worker's productivity, hence raising wages (in competitive labor market)
- A different view from Spence (1973): education does not increase worker's productivity, but credentials (e.g. a high school or college diploma) signal a worker's innate ability to potential employers
- Key assumption: it is difficult for employers to observe the worker's ability directly but have to rely on signals to infer

The Nobel Price for Asymmetric Information (intro paper)

Photo from the Nobel Foundation archive.

George A. Akerlof

Prize share: 1/3



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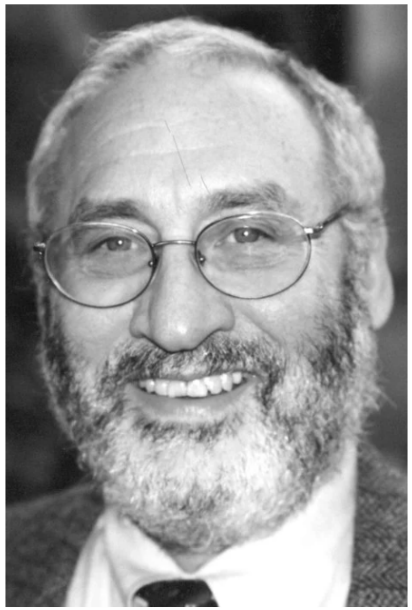
A. Michael Spence

Prize share: 1/3



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Joseph E. Stiglitz

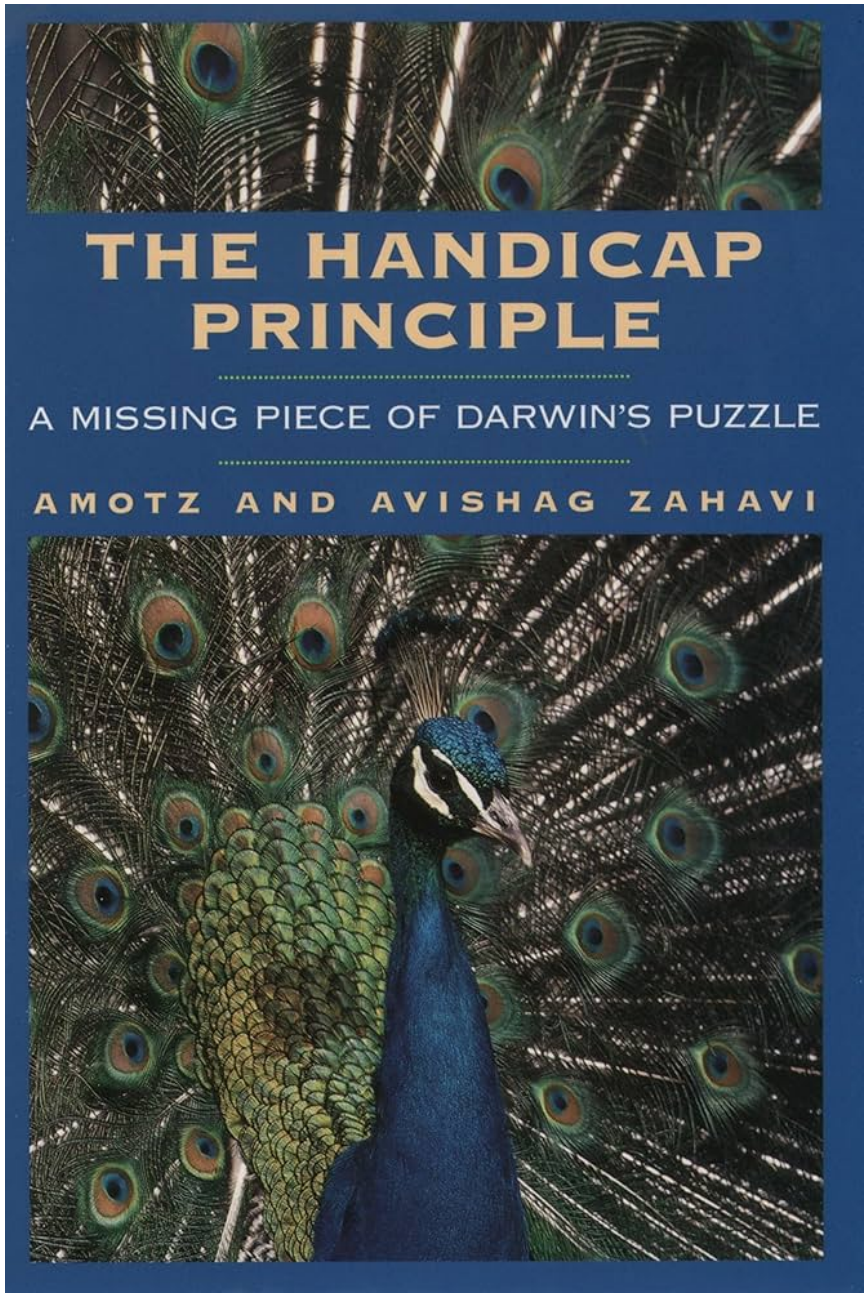
Prize share: 1/3

The Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel 2001 was awarded jointly to George A. Akerlof, A. Michael Spence and Joseph E. Stiglitz "for their analyses of markets with asymmetric information"

Asymmetric Information

- The key issue here is that there is asymmetric information
- Even though a particular worker knows his ability (private info), it is not easy for the employer to learn that
- Mere assertion of quality is not credible; It can be cheap talk
- This justifies why employers take large costs in assessing the ability and suitability of job applicants (esp. with limited prior experience)
- However, the idea of signaling theory is (largely) not about third-party certifications confirming abilities directly
- Rather, the idea is that an action can be credible proof of quality if taking it would be costly for those less able
- The logic has be applied even beyond human behaviors

Signaling in Evolutionary Biology



"Sheepskin" Effect (Card, 1999)

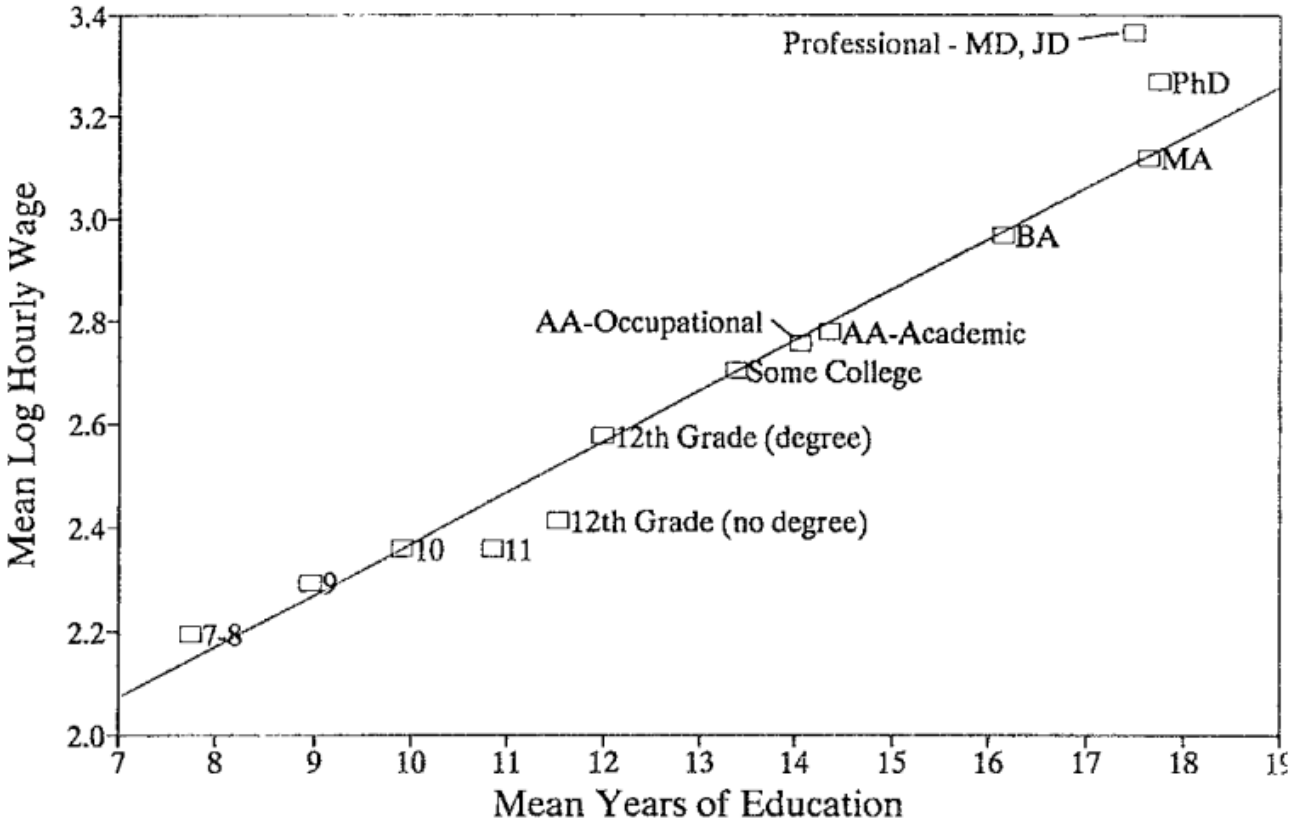


Fig. 2. Relationship between mean log hourly wages and completed education, men aged 40–45 in 1994–1996 Current Population Survey. Mean education by degree category estimated from February 1990 CPS.

However, sheepskin effect is not enough to prove the existence of signaling

Is Signaling Efficient or Inefficient?

- It seems that, in a pure signaling model, the education investment is ”wasted”
- However, in the first place, asymmetric information can lead to the malfunctioning of markets
  - E.g. market for lemons with adverse selection (Akerlof, 1970)
- Signaling is a way that the markets find to (partially) resolve the problem of information asymmetry, but itself also introduces inefficiencies (the cost of signaling)
- The questions are:
  - Under what market condition will signaling occur?
  - What market equilibrium will it result?
  - With how much efficiency?

Human Capital v.s. Signaling

- Both theories imply that education should improve earnings; Which one plays the major role?
- The first note is that they are not mutually exclusive:
  - One can build a model with both mechanisms
- Second, multiple empirical studies convincingly show both explains a nonzero portion of the returns to education
- However, it turns out to be very difficult to identify the relative importance
  - They act through similar mediating variables that are unobserved
  - In the cases where employers can easily find ways to learn workers, signaling is likely to be irrelevant
  - The recent consensus perhaps leans more toward the human capital theory

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Setup

- Agent:
  - Two types of workers
  - A large number of firms
- Choice & Timing:
  - Workers first choose education level
  - Firms then set wage
- Information
  - Incomplete information
- Equilibrium
  - Perfect Bayesian Equilibrium

Setting

- Consider a simple model
-

	Fraction of Population	Output	Education Cost
High Ability Workers (H)	λ	y_H	c_H
Low Ability Workers (L)	$1-\lambda$	y_L	c_L

- Workers know their types, but employers do not observe them but only observe education
- Denote the education decision as $e \in \{0, 1\}$
- Crucial assumption: $c_L > c_H$
- For simplicity, assume that education does not increase productivity (i.e. pure signaling)
- Assume a competitive labor market, so workers will be paid their expected productivity (conditional on education)

Concept of Equilibrium

- This environment corresponds to a dynamic game of incomplete information
- The concept of equilibrium in this case is Perfect Bayesian Equilibrium (PBE)
  - (A refinement of Nash Equilibrium)
  - A PBE consists of strategies (σ) and briefs (μ)
  - Strategy (σ) is rational for each player given belief (μ)
  - Belief (μ) is derived from strategy (σ) (using Bayes's rule)
  - In the equilibrium, no one has incentive to deviate
- Here
  - Workers select education strategies (σ) given firms' belief (μ)
  - Firms form belief (μ) and set wage based on workers' strategy (σ)
- For a rigorous treatment and explanation of dynamic game and PBE, see Jonathan Levin's game theory (Econ 203) lecture notes

Two Types of Equilibria

- From the definition of PBE, it's not difficult to see that there can have multiple equilibria
  - See page 5 of Philip Dybvig's Nobel Lecture slides
- 1. Separating
  - High and low ability workers choose different levels of schooling
  - As a result, in equilibrium, employers can infer worker ability from education
- 2. Pooling
  - High and low ability workers choose the same level of education
  - Employers cannot distinguish workers and set one wage

A Separating Equilibrium

- Suppose that we have $y_H - c_H > y_L > y_H - c_L$
- Then the following is an equilibrium:
- Workers' strategy
  - All high ability workers obtain education
  - All low ability workers choose no education
- Firms' belief and wage setting
  - Beliefs (on if a worker is type H) are: $\mu(e = 1) = 1$ and $\mu(e = 0) = 0$
  - Wages are: $w(e = 1) = y_H$ and $w(e = 0) = y_L$
    (More rigorously, this comes from $w(e) = \mu(e)y_H + (1 - \mu(e))y_L$)

Confirm The Equilibrium

- Let us now check that all parties are playing best responses and no one wants to deviate
- Firms:
  - Given the strategies of workers and market competition, no firm can change its behavior and increase its profits
- Hight ability workers:
  - If a H worker deviates to no education, she will obtain $w(e=0)=y_L$, whereas she is currently getting $w(e=1)-c_H=y_H-c_H>y_L$
- Low ability workers:
  - If a L worker deviates to obtaining education, the market will perceive him as a H worker, and pay him $w(e=1)=y_H$, whereas he is currently getting $w(e=0)=y_L>y_H-c_L$
- We thus prove that the separating allocation is indeed an equilibrium

Education as Signal

- In this equilibrium, education is valued simply because it is a signal about ability
  - If perfect information, there could never be education investments
  - This is an extreme result, but it illustrates the forces at work
- Education can be a signal about ability because of the separation conditions $c_H < c_L$
  - I.e. education is more costly for low ability workers
  - Note $y_H - c_H > y_L > y_H - c_L$ does not hold if $c_L \leq c_H$
  - Intuition: we need to convince H workers to obtain education, while deterring L workers from doing so

Efficiency and Inefficiency

- If signaling is not available, the firms will set wage at $w^* = \lambda y_H + (1-\lambda) y_L$ and this the total wage
  - L workers enjoy a gain $w^* - y_L$
  - H workers suffer a loss $y_H - w^*$
- With signaling, the total wage is $(y_H - C_H)\lambda + y_L(1-\lambda)$
  - The $-C_H\lambda$ is an efficiency loss
  - But the economy is more fair now
- However, missing signals may induce malfunctioning of the market
  - If H workers have reservation wage higher than w^* (e.g. from homework or self-employment), they will exit the market
  - If high ability can be achieved through investment, it will deter such investments
- The most efficient case will be a tiny C_H
  - But recall that we must have $C_L > y_H - y_L$ for separation
  - In contrast, signaling can be very inefficient when C_H is close to $y_H - y_L$, yielding $w_H < w^*$ esp. when λ is large

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Continuous Education Choices

- Now we consider a case where e is a continuous variable and education cost functions are $c_L(e) = e$, $c_H(e) = e/\delta$, with $\delta > 1$
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	Fraction of Population	Output	Education Cost of e
High Ability Workers (H)	λ	y_H	$c_H(e)$
Low Ability Workers (L)	$1-\lambda$	y_L	$c_L(e)$

- An obvious form of belief to try out: there is a threshold e^* such that L if $e < e^*$, and H if $e \geq e^*$
- Given this belief, the wage functions are $w = y_L$ if $e < e^*$, and $w = y_H$ if $e \geq e^*$
- For the belief to be confirmed in equilibrium, we want both groups not to deviate:
  - $y_H - e^*/\delta > y_L - 0 \Rightarrow e^* < \delta(y_H - y_L)$
  - $y_L - 0 > y_H - e^* \Rightarrow e^* > y_H - y_L$
- Any e^* in this interval can serve as a belief threshold to support an equilibrium that separates the two groups

Indifference Curves and Wage Schedule

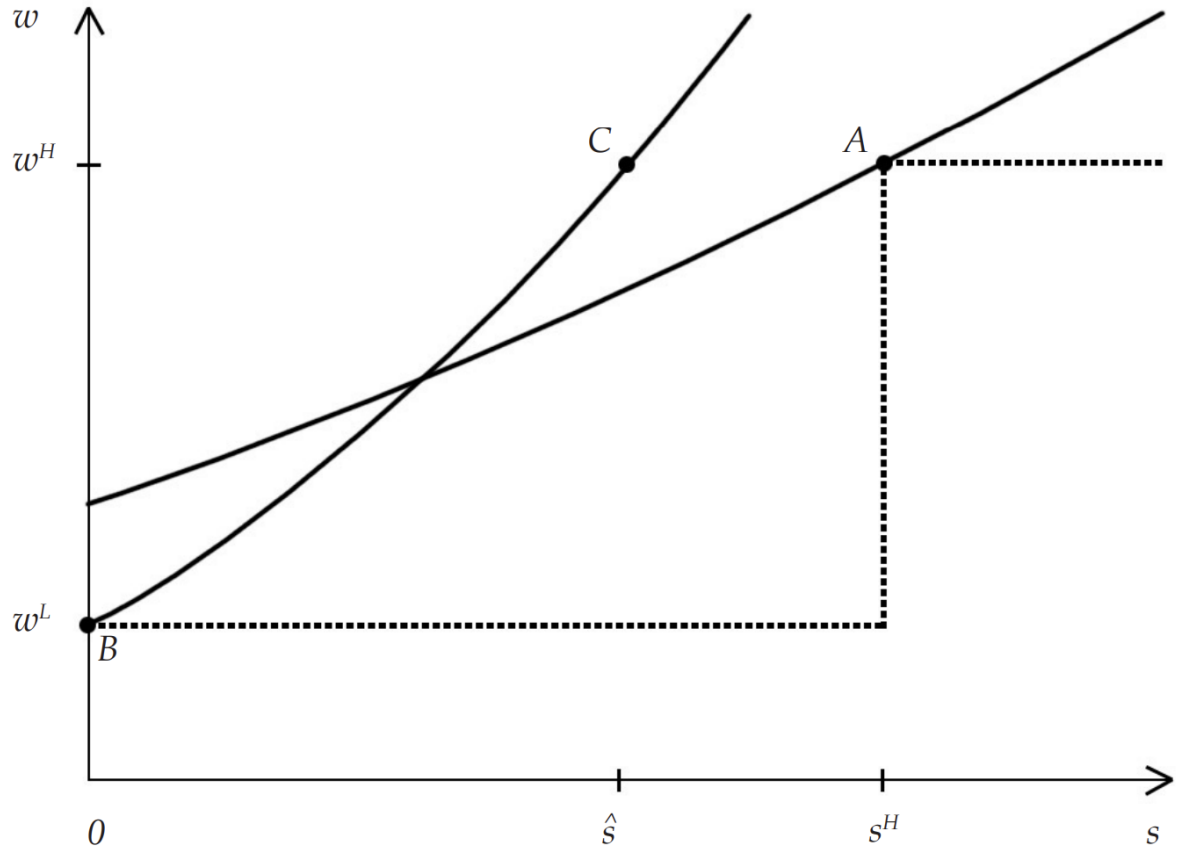

Figure 1.

Indifference curve for low-productivity job applicants (steep).
Indifference curve for high-productivity job applicants (flat).

(Hence, the condition ($C_H < C_L$ in discrete case; $\delta > 1$ in continuous case) is, more generally, called a "single-crossing condition" or Mirrlees-Spence condition)

A Pooling Equilibrium

- Now we consider another allocation:
  - Both low and high ability workers do not obtain education
  - Firms cannot distinguish and have belief $\mu(e = 0) = \mu(e = 1) = \lambda$
  - Wage structure is $w(e = 0) = w(e = 1) = (1 - \lambda)y_L + \lambda y_H$
- We can easily check that no players will deviate as in this equilibrium well
  - Since no one chooses education, wage is the expected productivity
  - Given the wage, no worker has any incentive to obtain education
- This equilibrium is being supported by the belief that the worker who gets education is no better than a worker who does not
- This is a PBE. But is it reasonable? Economists think the answer is no.

Refinement of Equilibrium

- If education is more costly for L workers, they should be less likely to deviate to obtaining education
- Various refinements of the Nash equilibrium concept have been developed to rule out ”unreasonable” beliefs
- Perhaps the simplest is the Intuitive Criterion
  - Idea: If L type will never benefit from a deviation to $e = 1$ and H type benefits from it , then firms can deduce that the deviation must be coming from the H type, thus breaking the pool equlibrium
  - It also selects the socially most efficient equilibrium from multiple signaling equilibria in the continuous education case

Intuitive Criterion

- To illustrate the main idea, let us slightly strengthening condition to $y_H - c_H > (1-\lambda)y_L + \lambda y_H$ and $y_L > y_H - c_L$
- Now take the pooling equilibrium above; The L type would never benefit from a deviation to $e = 1$
- Therefore, firms can deduce that the deviation to $e = 1$ must be coming from the H type, and offer her a wage of y_H
- As condition above also ensures that this deviation is profitable for H type, this breaks the pooling equilibrium
- Overall conclusion: as long as the separating condition is satisfied, we expect a separating equilibrium, where education is valued as a signal

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Empirical Questions on Labor Market Signaling

- Q1. Is signaling role of education existing?
- Q2. Is signaling role of education more important than human capital role?
- Difficult to find direct evidence as unobserved ability differences
- Different approaches have been taken by econometricians
- It's also important to distinguish between selection and signaling story

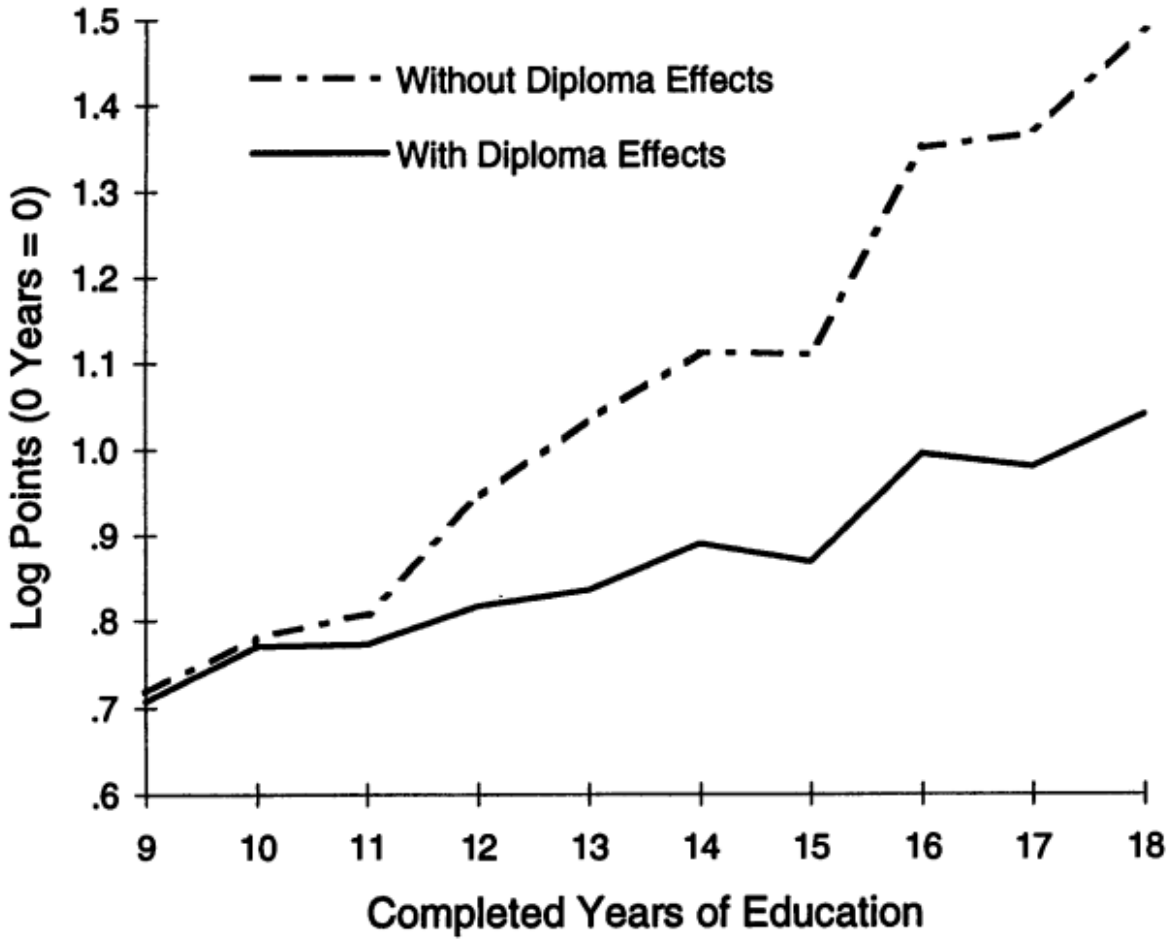
Early Approach: Sheepskin Effects (Jaeger and Page, 1996)

TABLE 2.—ESTIMATED DIPLOMA EFFECTS FOR WHITE MEN USING DIFFERENT SPECIFICATIONS

	Model			
Coefficient	(1)	(2)	(3)	(4)
Completed Years of Education (Spline)				
Years of Education (S)	0.076	0.076		
	(0.018)	(0.018)		
$S \geq 8$	−0.141	−0.112		
	(0.080)	(0.078)		
$(S \geq 8) \cdot (S - 8)$	0.002	−0.022		
	(0.027)	(0.023)		
$S \geq 12$	0.034			
	(0.053)			
$(S \geq 12) \cdot (S - 12)$	−0.006	−0.019		
	(0.022)	(0.017)		
$S \geq 16$	0.114			
	(0.035)			
$S = 17$	−0.055			
	(0.042)			
$S = 18$	−0.006			
	(0.031)			
Completed Years of Education (Dummy)				
9			−0.227	−0.109
			(0.049)	(0.061)
10			−0.164	−0.046
			(0.040)	(0.054)
11			−0.137	−0.044
			(0.043)	(0.051)
12			ref.	ref.
13			0.089	0.020
			(0.027)	(0.033)
14			0.167	0.073
			(0.022)	(0.031)
15			0.166	0.052
			(0.038)	(0.044)
16			0.406	0.178
			(0.019)	(0.045)
17			0.422	0.164
			(0.039)	(0.057)
18 or more			0.544	0.224
			(0.023)	(0.054)
Diploma Effects				
High School		0.106		0.123
		(0.037)		(0.041)
Marginal Effect Over High School				
Some College, No Degree		0.074		0.083
		(0.022)		(0.027)
Occupational Associate's		0.074		0.076
		(0.039)		(0.043)
Academic Associate's		0.188		0.191
		(0.042)		(0.046)
Bachelor's		0.273		0.245
		(0.038)		(0.045)
Marginal Effect Over Bachelor's				
Master's		0.032		0.050
		(0.030)		(0.041)
Professional		0.271		0.286
		(0.050)		(0.059)
Doctoral		0.052		0.067
		(0.058)		(0.067)
R^2	0.145	0.153	0.147	0.154
Adjusted R^2	0.144	0.151	0.145	0.151

Early Approach: Sheepskin Effects (Jaeger and Page, 1996)

FIGURE 1.—TOTAL RETURNS TO COMPLETED YEARS OF EDUCATION FOR WHITE MEN



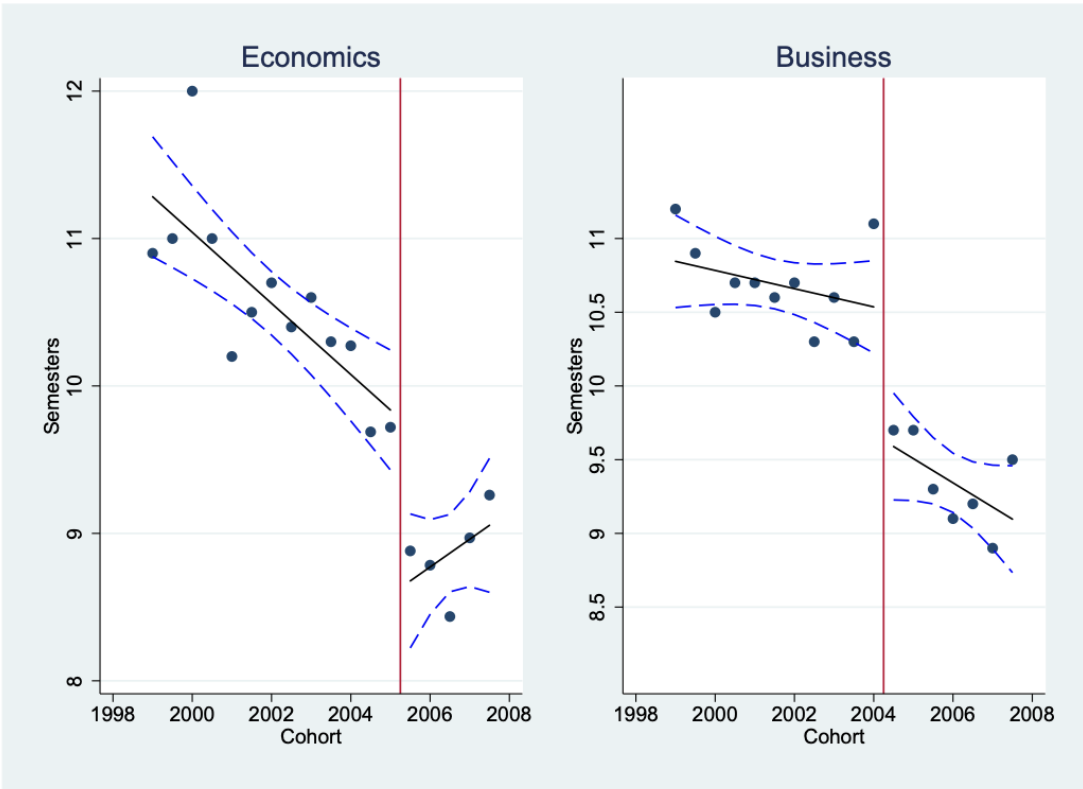
Problems of Sheepskin Effects

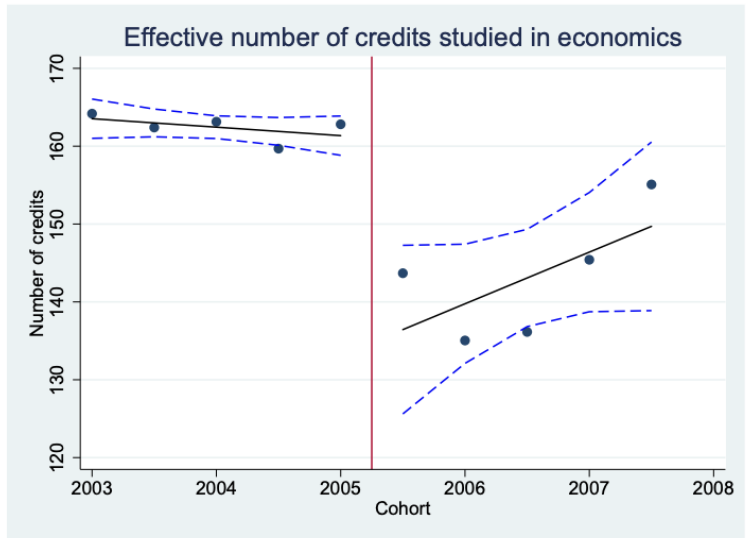
- The sheepskin/diploma effects can be due to
  - Final year education of college (or high school) or education required to obtain diploma may in fact be more useful than previous years
  - Those who drop out maybe have lower learning effects (on human capital) than those who compete
  - Those who drop out maybe have lower ability levels comparing to those who complete, and they are observed by employers

Recent Approach: Natural Experiment

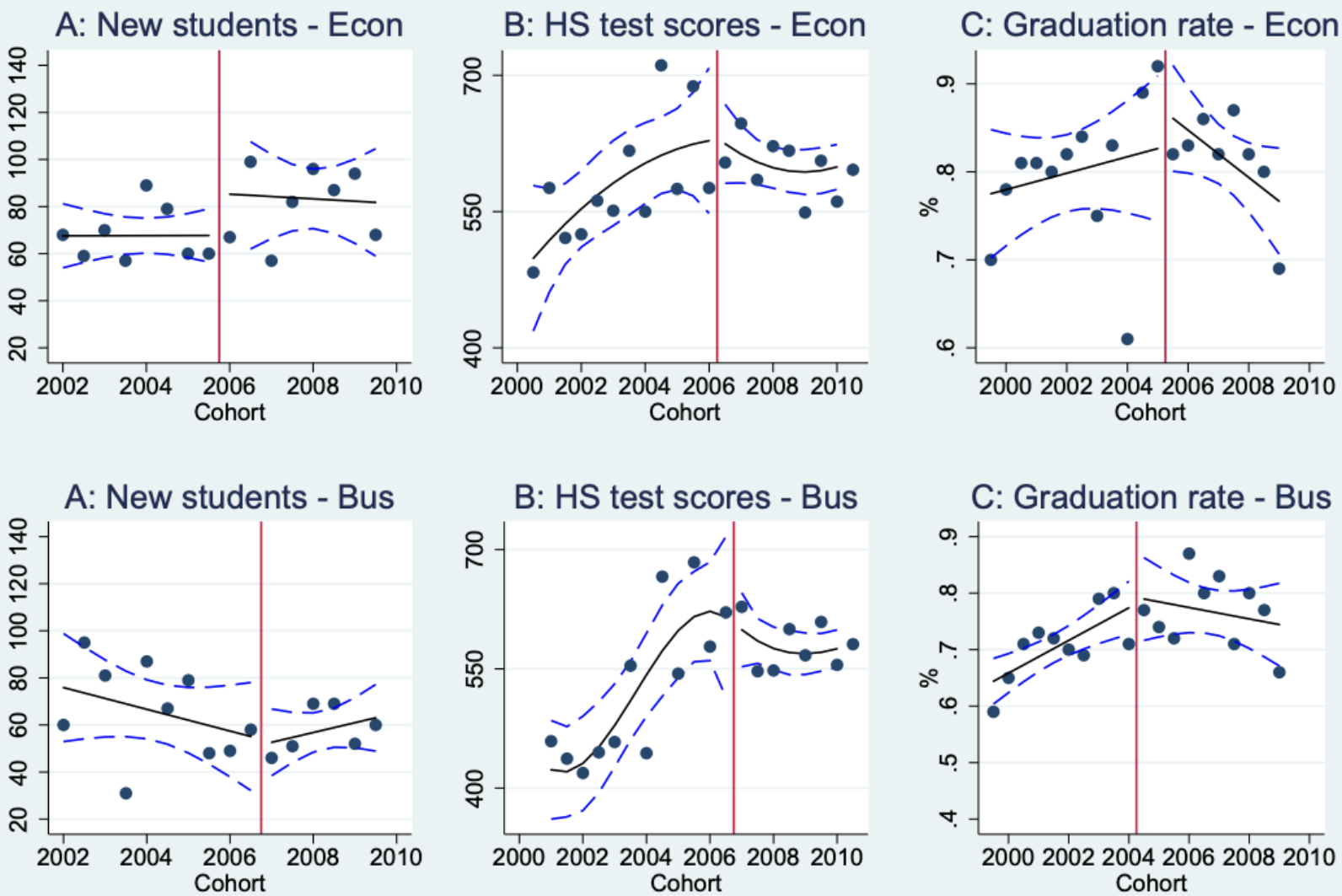
- Arteaga (2018) exploits a curriculum change at Universidad de Los Andes, the top university in Colombia
  - In 2006, # of credits required to earn a college degree in economics and business decreased by 20% and 14% (12 and 6 courses)
- This ”natural experiment” helps to separate human capital effects from signaling effects
  - As the reform did not alter the selection of entering students, which is through the national exam
- Thus the HC model predicts a decline in wages as a result of the reform, whereas a pure signaling model does not

Effect of the Reform in Duration and Credits Studied



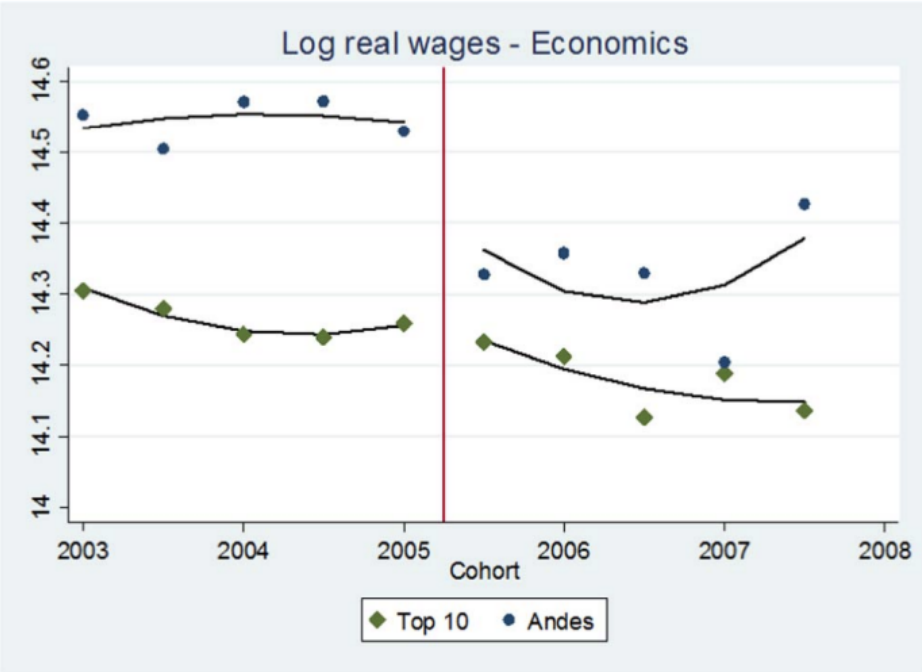


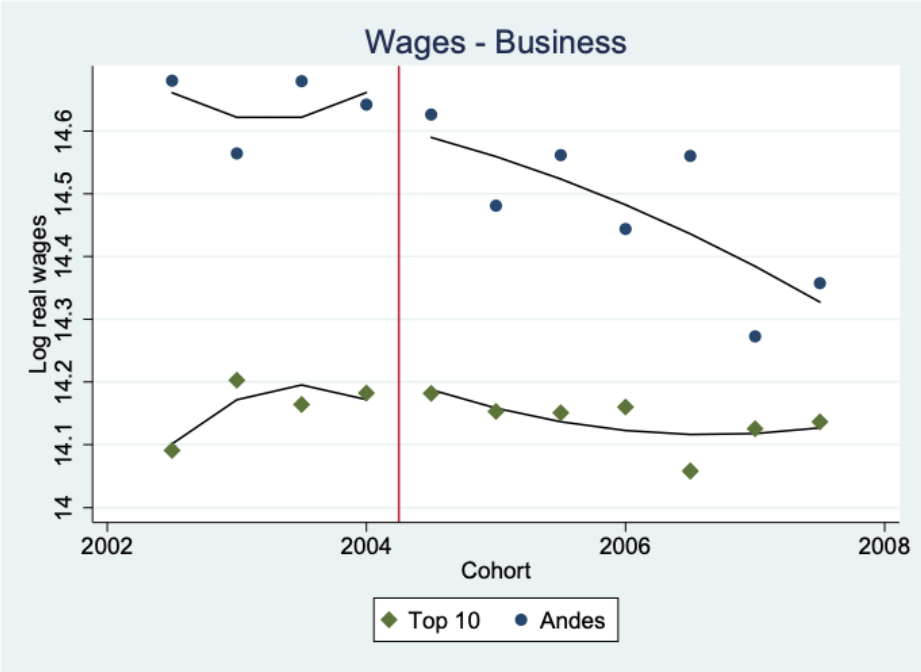
Effect of the Reform in Class Selection



Source: Universidad de los Andes. The solid lines are the fitted values and dashed lines the 95% CI.

Effect of the Reform on Wages





Mechanism of the Reform Effect on Wages

- To know the mechanism, the author interviewed employers and learned
  1. Most knew about the reform from talking to recent graduates
  2. They believe they can detect changes in human capital through tests they administered in the recruitment process
  3. They argue that for some jobs, the content made optional in the new curriculum is critical

- The author thus suggests that after reform, the economics graduates had worse jobs b.c. they cannot succeed in the recruitment process
  - In other words, employers can learn rapidly through the availability of tests on specific content in the recruitment process

- For business, however, the recruitment process relies less on testing specific knowledge, thus we don't see the effects
  - Interviews suggest that this is b.c. openings for business graduates also available to graduates from other majors

Another Natural Experiment

- In contrast, Choudhury et al. (2023) uses a natural experiment to separate signaling effects from human capital effects
- In India, Indian Institutes of Technology (IITs) are prestigious and highly selective technical universities
  - Graduates from IITs are more likely to migrate (mainly to U.S. and for graduate school & Ph.D.)
- One institution unexpectedly received IIT status and changed its name, without any concomitant changes to its staff or curriculum
  - Quality of education/human capital acquired by the students in the cohorts before and after the change remained constant

Effect of the Name-Change on Migration

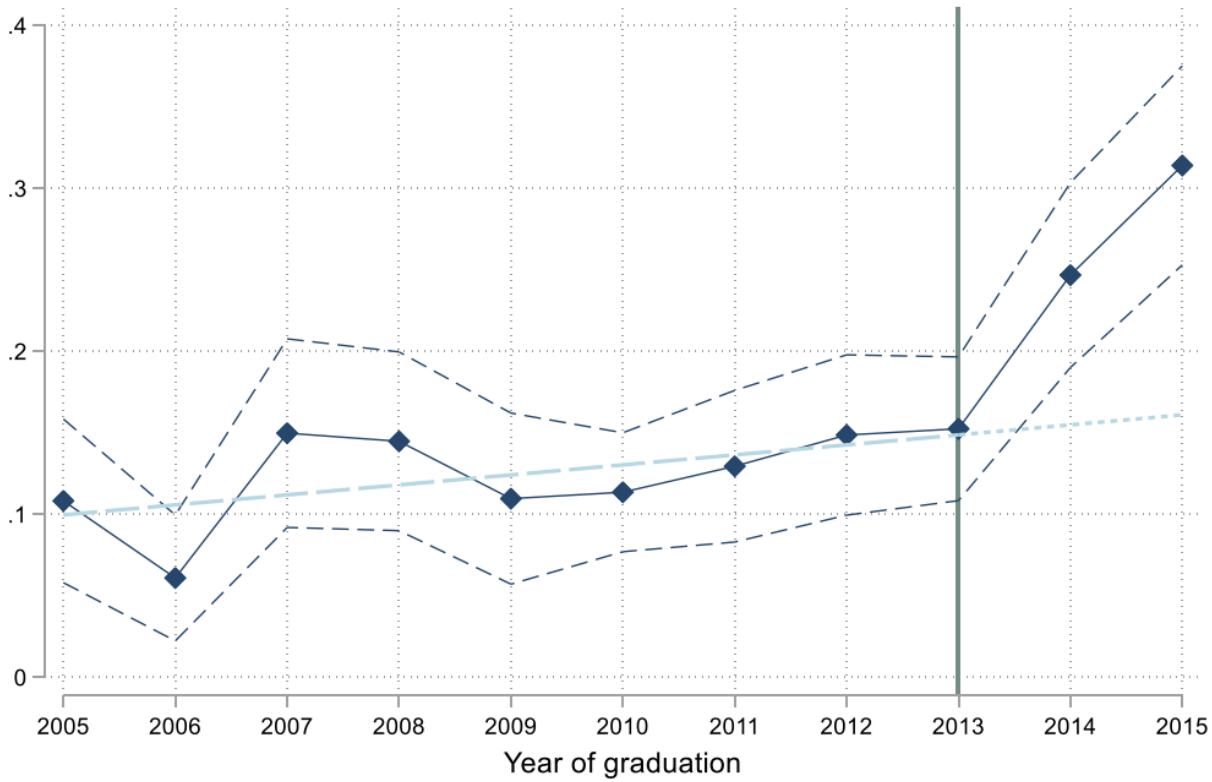


Fig. 3. Share of BHU Graduates Migrating Before and After BHU Acquired IIT Designation

Notes: The Figure displays the share of Banaras Hindu University (BHU) graduates migrating within five years of graduation, by year of graduation. In June 2012, the Institute of Technology at BHU became Indian Institute of Technology (BHU) Varanasi, without concomitant changes to its staffing or curriculum. The first cohort potentially affected would be the one graduating in 2013. Individuals graduating in 2014 (respectively 2015) would have enrolled in 2010 (respectively 2011), when it was not known if/when BHU would become an IIT (discussions about designating BHU as an IIT had been ongoing since the 1970s). Superimposed is a linear fit based on the years 2005–2013.

The Causal Model of Education (Huntington-Klein, 2021)

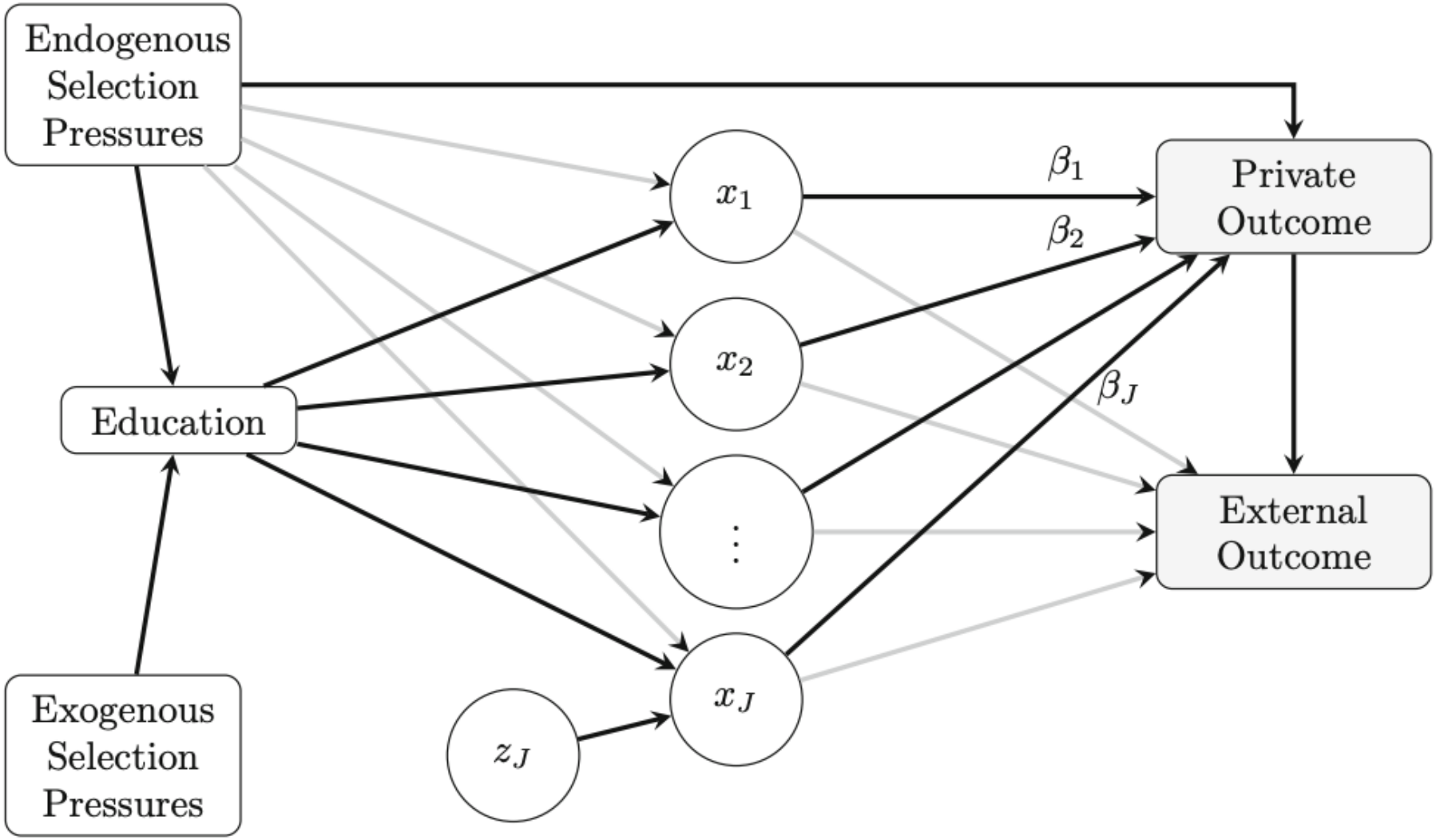


Fig. 1 General causal model of the effect of education on the labor market

($x_1, \ldots x_J$ can be various skills as well as employer beliefs about one's skills; Each effect β_j can be further broken up $\beta_j = \beta_j^h + \beta_j^s$)

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