Sequential Choices, Option Values and the Returns to Education

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Introduction

Becker-Mincer models of schooling assume perfect certainty

- rate of return concepts based on comparisons of earnings streams for different schooling choices (Mincer, internal rate)
- focus on ability bias: recover counterfactual earnings

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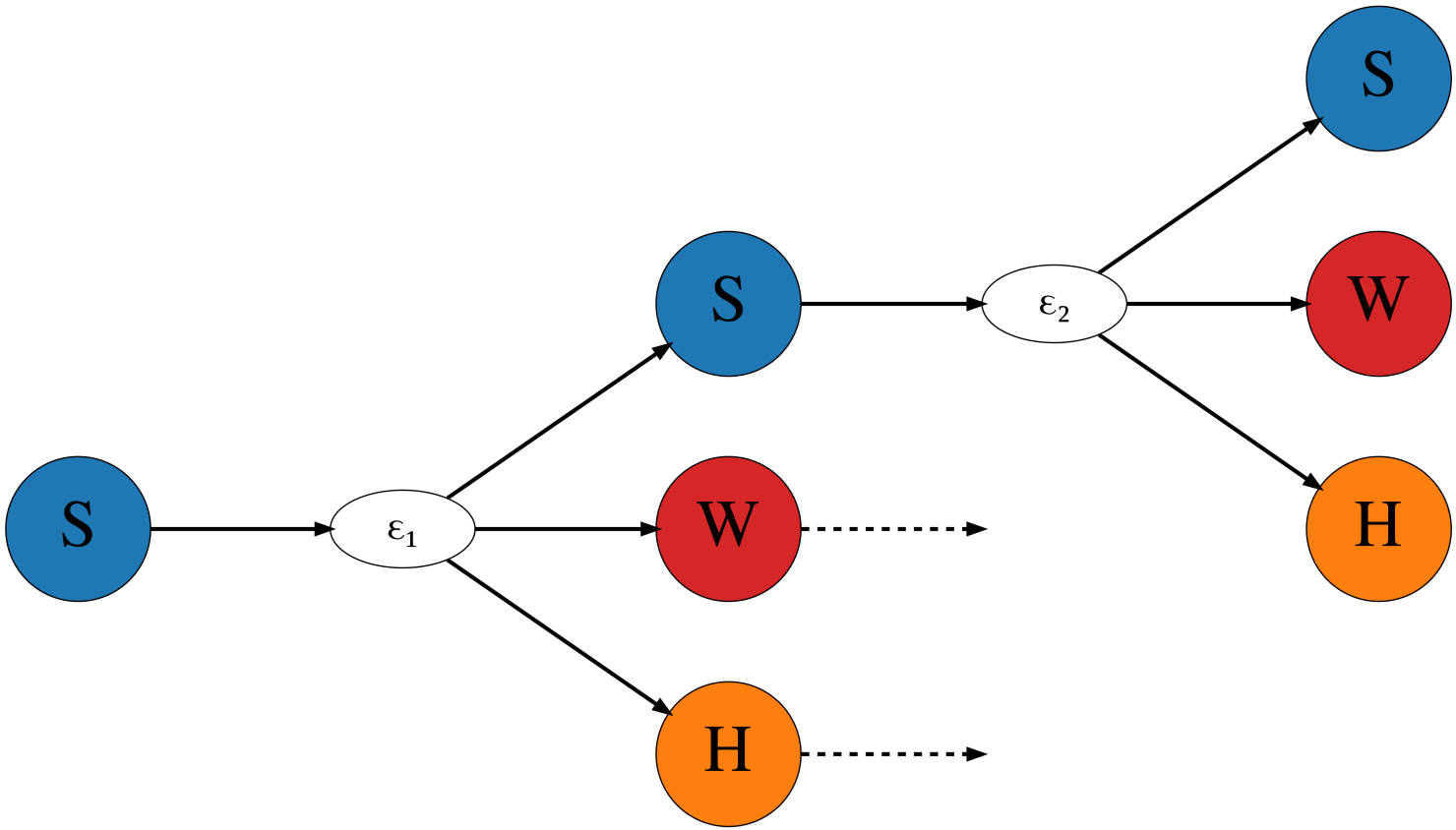
Human capital investments are uncertain – sequential choices

- costs: ability to learn, tastes for schooling
- returns: shocks to productivity, preferences for work

Rate of return concepts based on comparisons of value functions

- ex-ante returns, ex-post returns, option values, ...
- comparatively, little empirical evidence (Altonji, 1993; Heckman-Urzua 2008, Stange, 2012; Trachter, 2015, ...)

Illustration: Sequential Choice Under Uncertainty



Our Objectives

A flexible dynamic model of schooling choices

- many periods, many choices (e.g., academic/vocational track)
- observable heterogeneity by ability (IQ test scores)

Estimate on Norwegian administrative data

- lifelong earnings and education careers (only natural attrition)

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Quantify rates of return that account for uncertainty

- ex-ante returns (contrast to ex-post returns)
- the contribution of option values

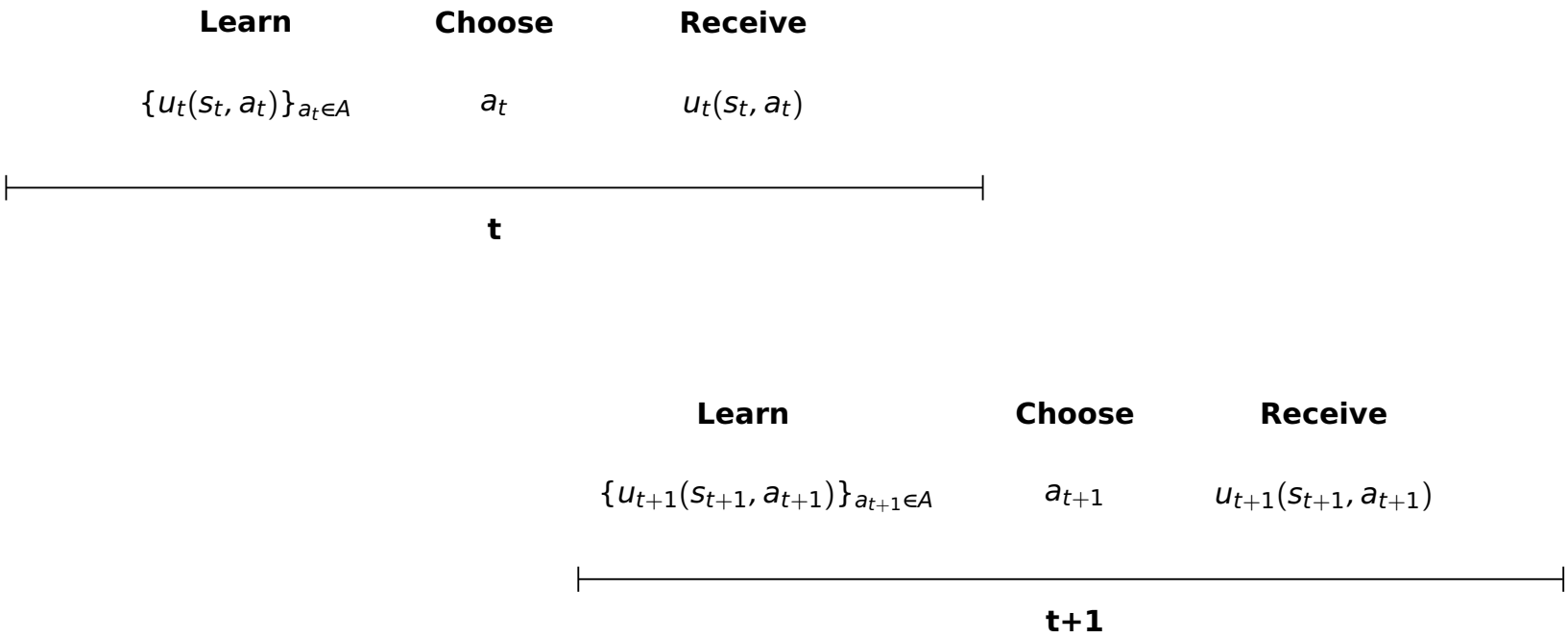
Model validation

- distribution of education interruptions
- compulsory schooling reform (out of sample)

Ex-ante policy evaluation

Outline

Timing of Events



Notation

$t = 1, \ldots, T$	decision period
$s_t \in \mathcal{S}$	state
$a_t \in \mathcal{A}$	action
$u_t(s_t, a_t)$	immediate utility

Objective Function

$$\max_{\pi \in \Pi} E^{\pi}_{s_1} \left[\sum_{t=15}^{55} \delta^{t-1} u(s_t, a^{\pi}_t(s_t)) \right] \tag{1}$$

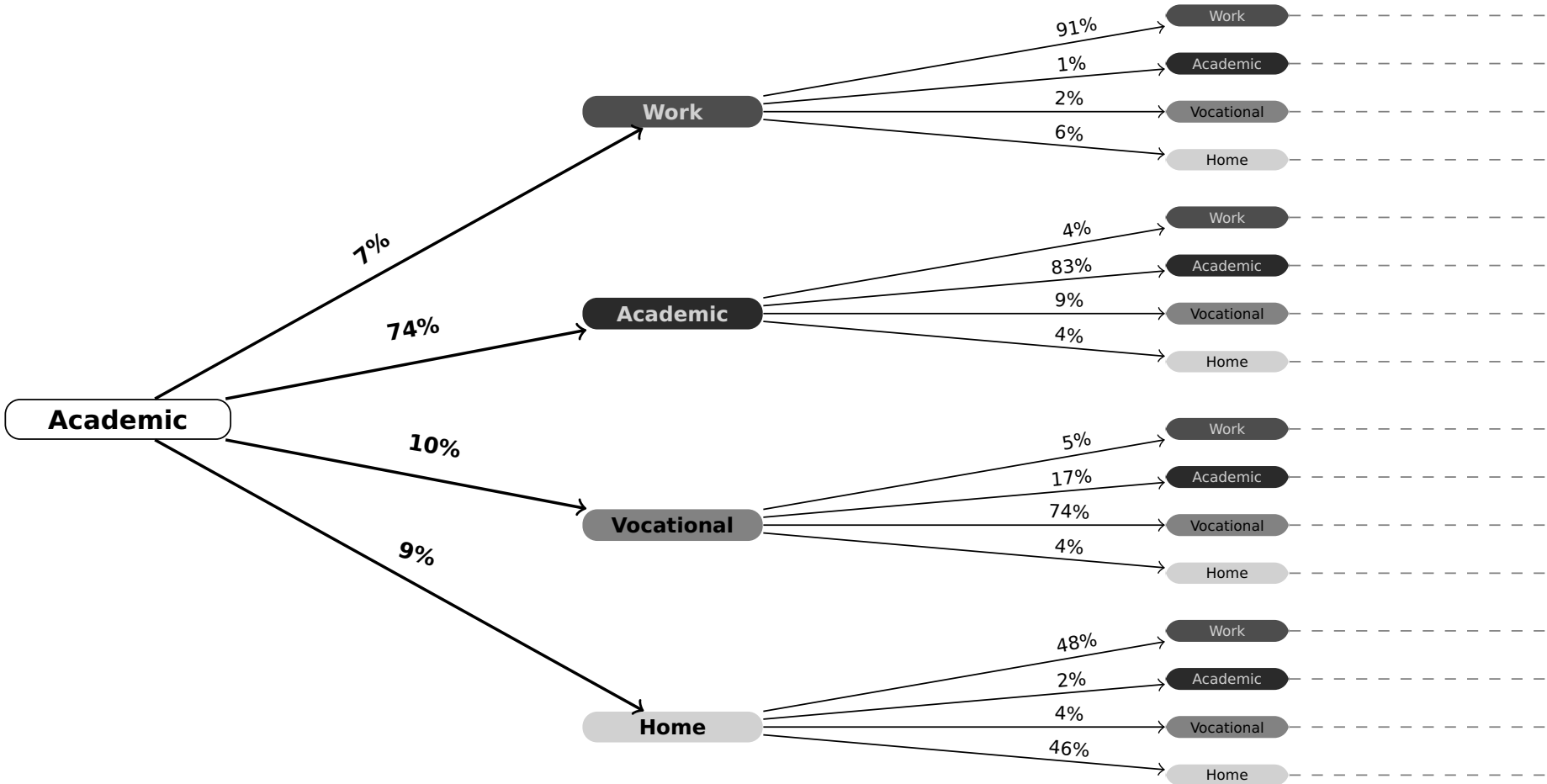
Standard assumptions

- Rational expectations
- Exponential discounting
- Time-separability

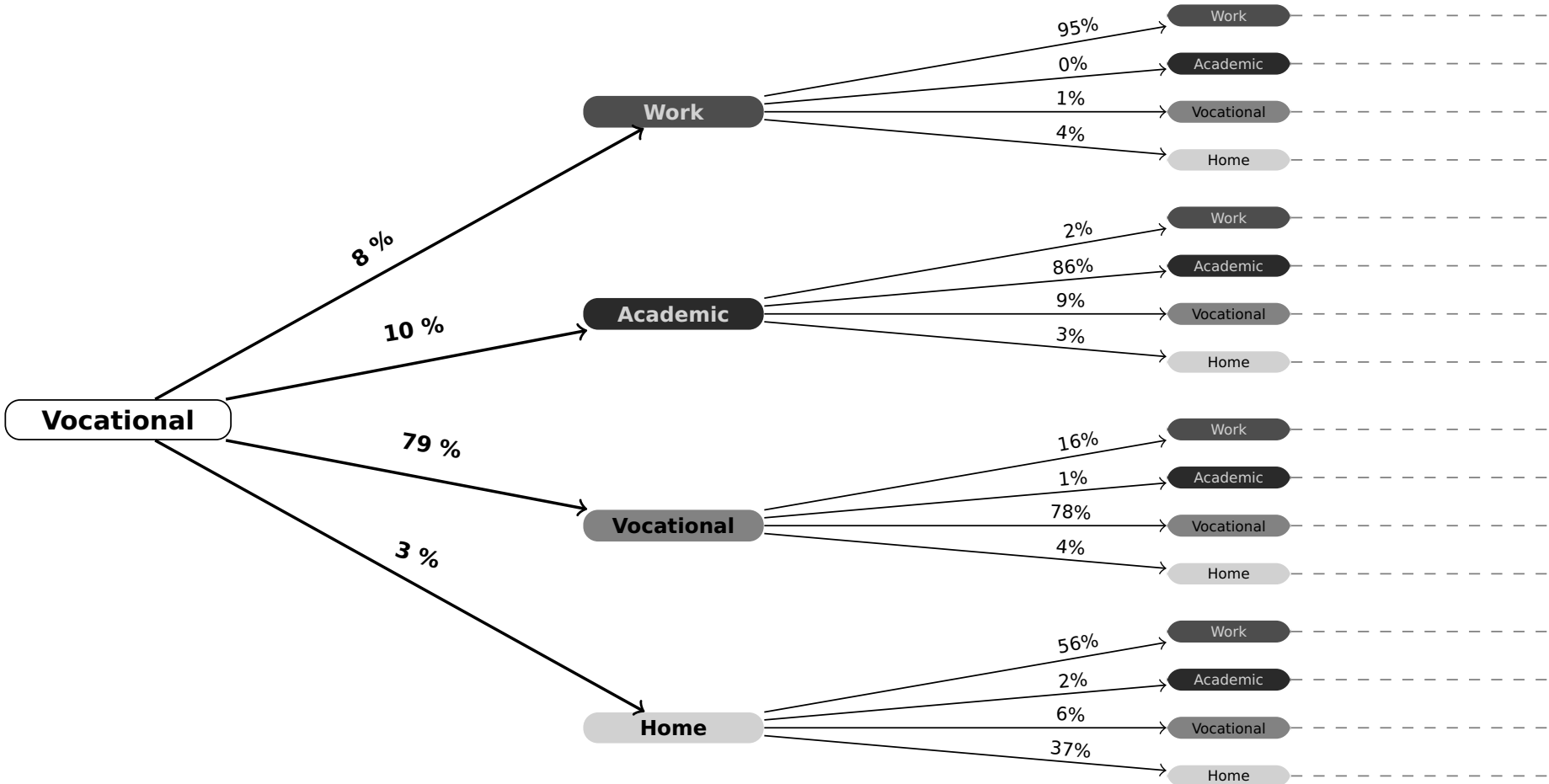
Notation

$a_t(s_t)$	decision rule
$\pi = (a^{\pi}_1(s_1), \ldots, a^{\pi}_T(s_T))$	policy
δ	discount factor

Decision Tree: Academic Schooling at Age 16



Decision Tree: Vocational Schooling at Age 16



Computational Setup

- When entering the model at age 15, all individuals have seven years of basic compulsory schooling.
- Individuals live up to age 55, and choose between an academic track, a vocational track, work or home in each period. Thus, accumulate human capital $\boldsymbol{h_t} = (h_{a,t})_{a \in \{A,V\}}$ and work experience k_t over the life-cycle.
- They have one of three different ability endowments (low/medium/high based on cutoffs of IQ test scores).
- They have one of three different $\mathcal{J} = \{1, 2, 3\}$ alternative-specific skill endowments $\boldsymbol{e} = \left(e_{j,a}\right)_{\mathcal{J} \times \mathcal{A}}$.

Immediate Utility

The general form is given by:

$$u(\cdot) = \begin{cases} \zeta_W(k_t, \boldsymbol{h_t}, t, a_{t-1}) + w(k_t, \boldsymbol{h_t}, t, a_{t-1}, e_{j,a}, \epsilon_{a,t}) & \text{if } a = W \\ \zeta_a(k_t, \boldsymbol{h_t}, t, a_{t-1}, e_{j,a}, \epsilon_{a,t}) & \text{if } a \in \{A, V, H\}. \end{cases}$$

- Wages: years of schooling (track-specific), work experience, diploma effects, and skill depreciation
- Work: costs of market entry and job mobility
- Schooling: re-enrollment, switching and psychic costs

▸ Parameterization

Transitions

- Work experience k_t and years of completed schooling in each track $\boldsymbol{h_t}$ evolve deterministically.

$$
\begin{aligned}
k_{t+1} &= k_t + \mathbb{I}[a_t = W] \\
h_{a,t+1} &= h_{a,t} + \mathbb{I}[a_t = a] \qquad \text{if } a \in \{A, V\}
\end{aligned}
$$

- The productivity shocks $\boldsymbol{\epsilon_t}$ are uncorrelated across time and follow a multivariate normal distribution with mean $\mathbf{0}$ and covariance matrix Σ.

Implementation, Solution, and Estimation

- Backward-induction algorithm
- Method of simulated moments, using moments:
  - fraction of individuals in each choice by age
  - distribution of final years of schooling by track
  - workers: mean and standard deviation of wages by age
  - workers: correlation of current and next period wages by age
- Codes available at `https://respy.readthedocs.io`
  - thanks to my incredibly skilled co-authors!

Objects of Interest: Exante Returns to Schooling

The value of schooling $S \in \{A, V\}$ and following policy π^*:

$$v^{\pi^*}(s_t, S) = u(s_t, S) + \delta E^{\pi^*}_{s_t}\left[v^{\pi^*}(s_{t+1})\right]$$

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The ex-ante return to an additional year of schooling $S \in \{A, V\}$:

$$\frac{v^{\pi^*}(s_t, S) - \tilde{v}^{\pi^*}(s_t)}{\tilde{v}^{\pi^*}(s_t)}, \quad \text{where} \quad \tilde{v}^{\pi^*}(s_t) = \max_{a \in \{W,H\}} \{v^{\pi^*}(s_t, a)\}$$

▸ Results: Plot

Objects of Interest: Expost Returns to Schooling

The value of choosing schooling S based on the *realized* stream:

$$\bar{v}^{\pi^*}(s_t, S) = u(s_t, S) + \sum_{j=0}^{T-t} \delta^j u(s_j, a_j)$$

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Objects of Interest: Option Value of Schooling

At any state s_t, we can compare the value of choosing an additional year of schooling $v^{\pi^*}(s_t, S)$ to the value of this choice in a scenario where no future schooling is available $\hat{v}^{\pi^*}(s_t, S)$.

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The option value contribution of schooling can be defined as:

$$\frac{v^{\pi^*}(s_t, S) - \hat{v}^{\pi^*}(s_t)}{v^{\pi^*}(s_t)}$$

▸ Results: Plot

Outline

Data Sources

We use Norwegian administrative records.

- Individual earnings records 1967–2015
- Individual education transitions 1970–2015
- Unique individual IDs – only natural attrition

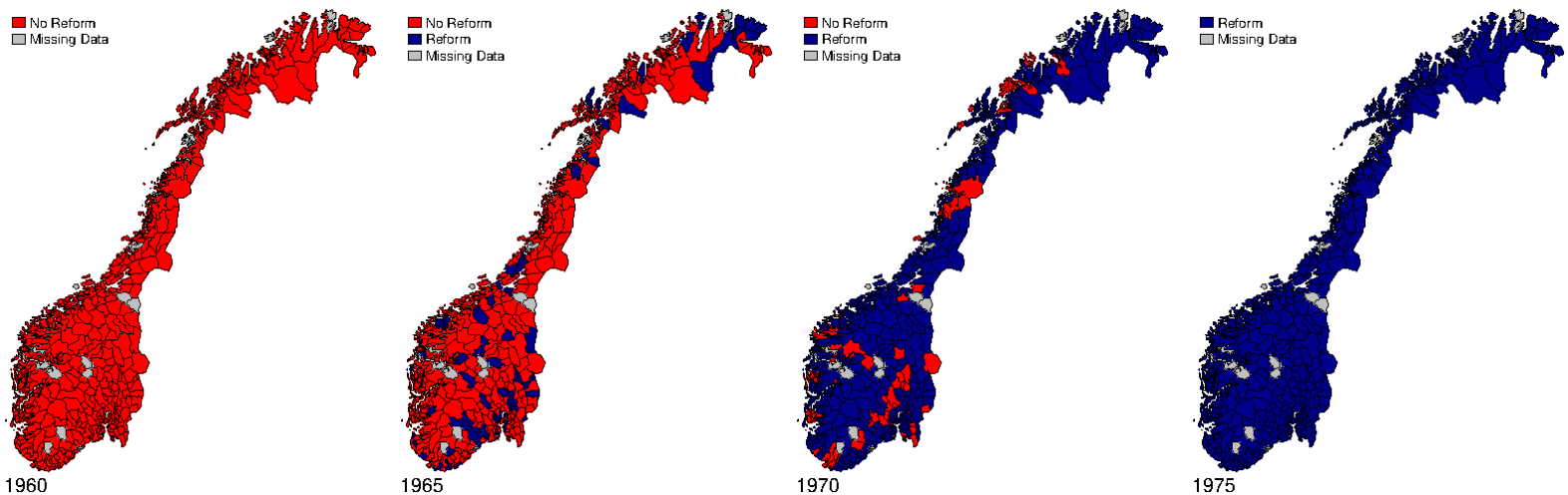
Analytical sample

- Norwegian males born 1955–1960
- Earnings and education over ages 15-55
- IQ test scores (9 point scale) and social background

For comparative purposes, also use cohorts born 1945–1965.

Compulsory Schooling Reform: From 7 to 9 Years

Gradual roll-out across Norway from 1960 to 1975.
Birth cohorts 1946–1961 had different school systems depending on cohort and location (Black et al., 2005; Bhuller et al., 2017).



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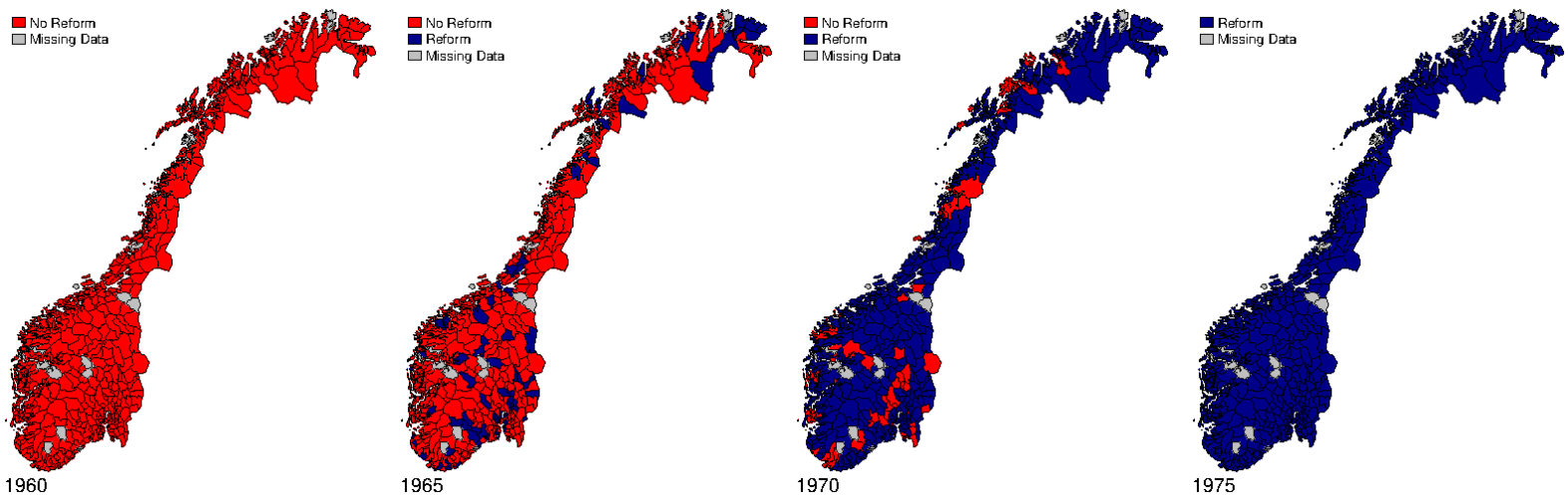
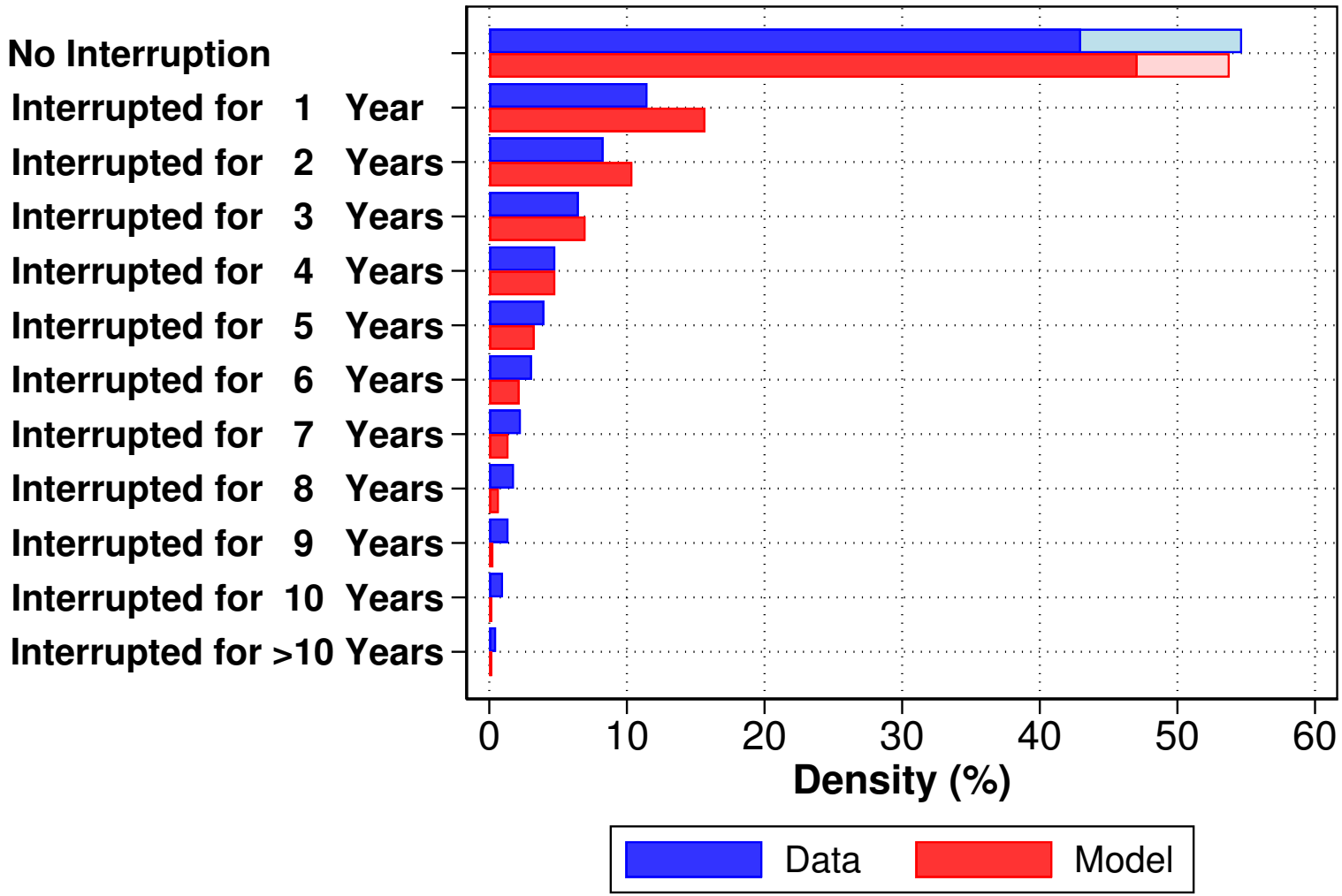


Use cohorts 1955-1960 facing the pre-reform system in estimation.

Outline

Model Validation: Distribution of Interruptions

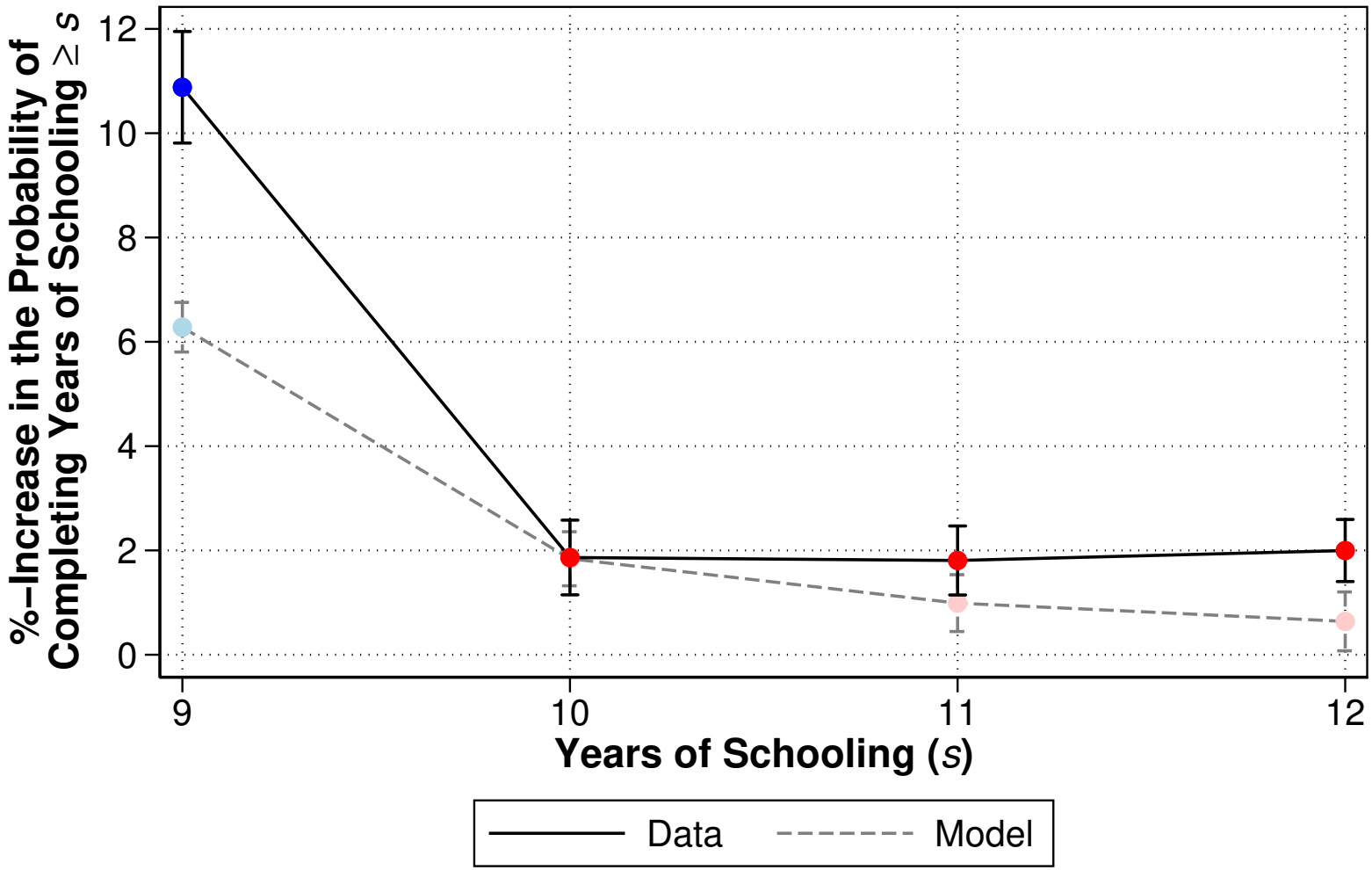


Data: Norwegian males born 1955–1960.
Model: 10,000 simulated histories from the baseline model.
Educational paths are measured from age 15 to 30 in each case.

▸ Model Fit

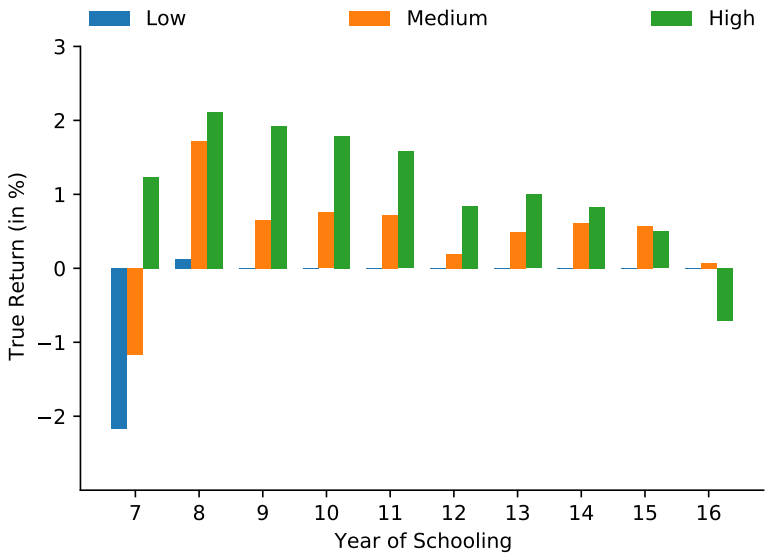
▸ Distribution (Dropouts)

Model Validation: Reform Impacts

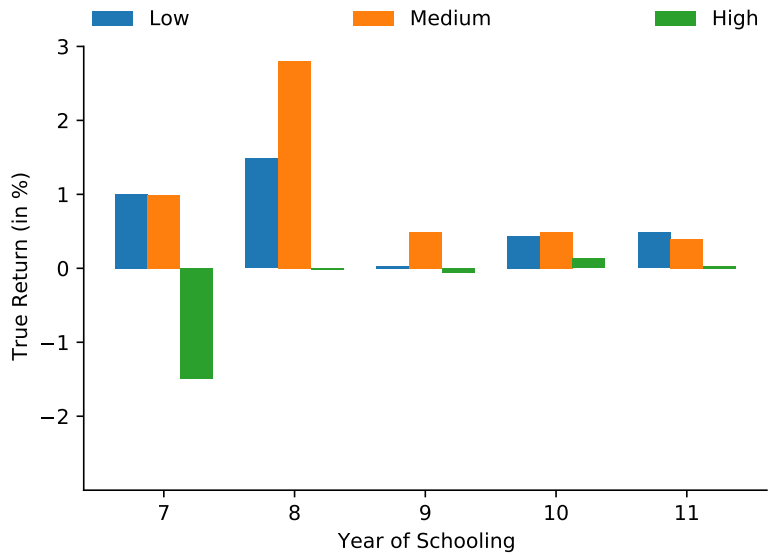


Data: Norwegian males born 1945–1965.
Model: 10,000 simulated histories from the baseline model.
Estimation: **1**(schooling ≥ *s*) on reform dummy, with cohort and municipality FEs (data) and individual FEs (model), 95% CIs.
Colors: Blue=marginal response, Red=inframarginal response.

Ex-ante Returns to Schooling – By Ability and Track



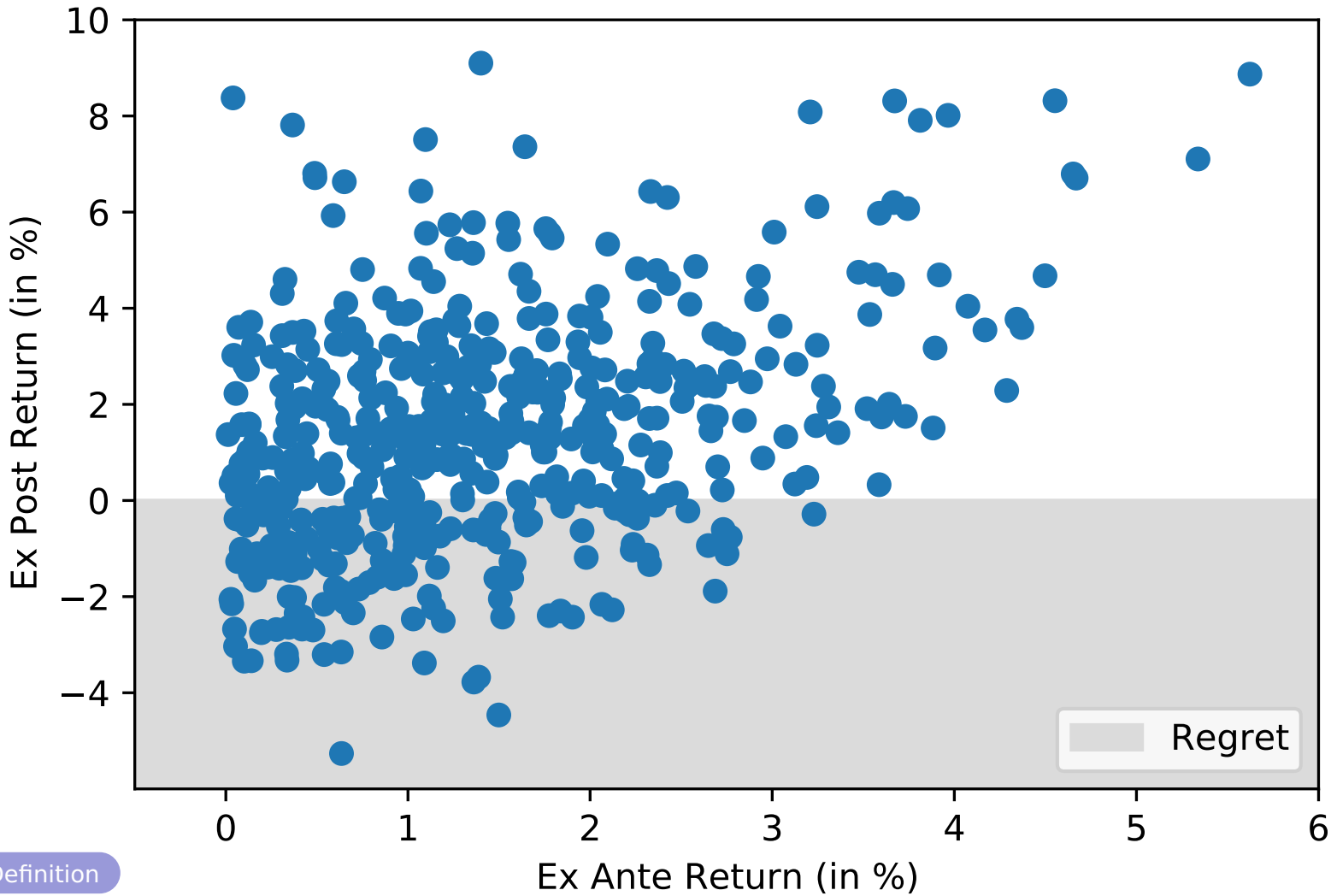
Academic



Vocational

▸ Definition

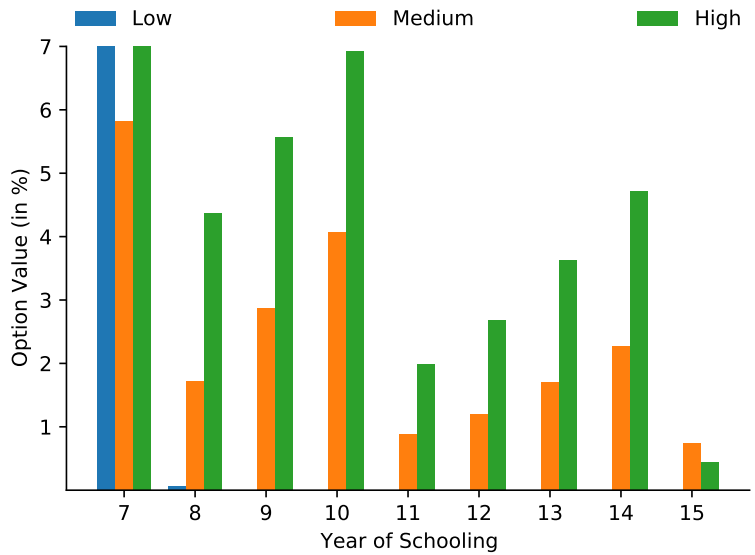
Distribution of Ex-ante and Ex-post Returns to Schooling



▸ Definition

Notes: The ex-ante and ex-post returns from a high school diploma (12 years) for individuals with uninterrupted schooling careers up to 11 years who end up receiving a high school diploma (i.e., complete 12 years).

The Contribution of Option Values



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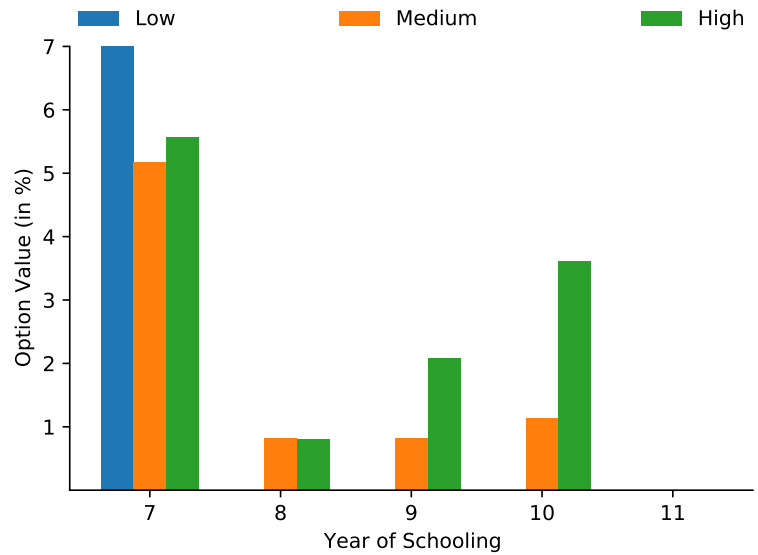

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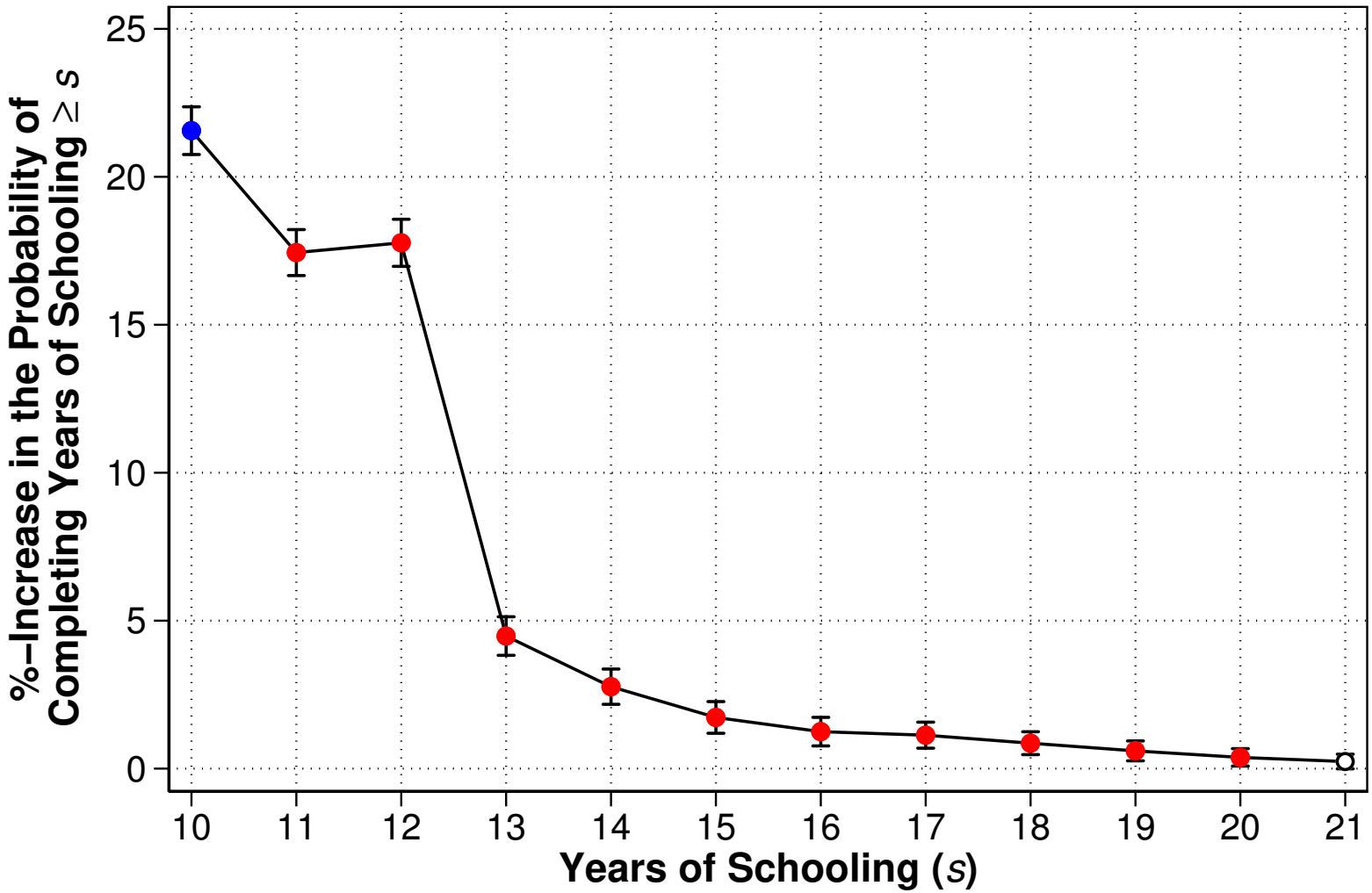
▸ Definition

Policy Evaluation: Compulsory High School Enrollment



Sample: 10,000 simulated histories from the baseline model.
Estimation: **1**(schooling ≥ *s*) on reform dummy, with individual FEs, 95% CIs.
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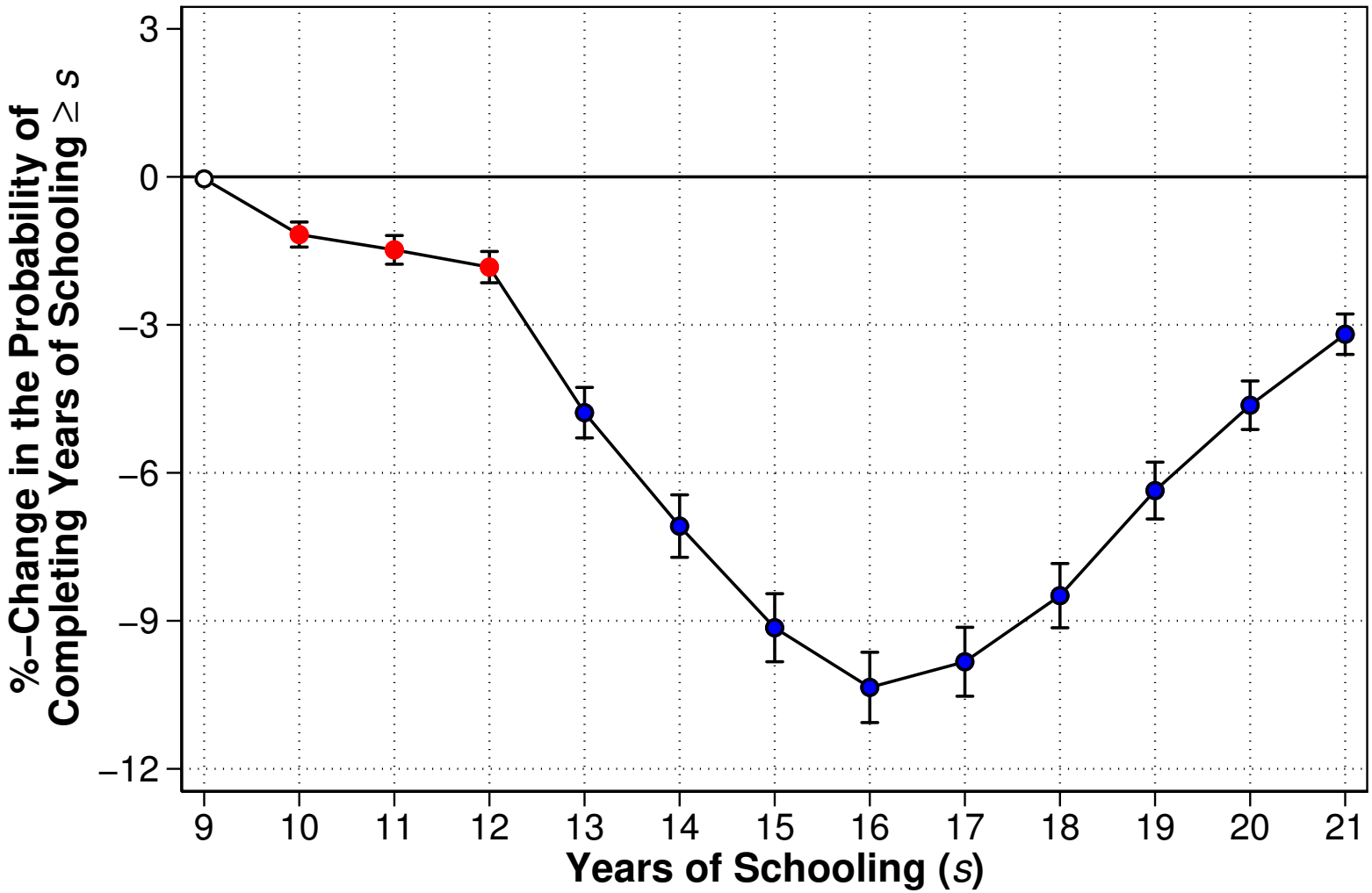
Policy Evaluation: Introduce College Tuition Costs



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Summary

This paper does the following

- flexible dynamic model of schooling
- estimated on Norwegian administrative data

Conceptualize and quantify rate of return measures

- ex-ante and ex-post returns
- option values of schooling

Model validations and policy evaluations

- distribution of education interruptions
- compulsory schooling reform (out of sample)
- alternative policy reforms

Future work

- embed/combine reduced-form evidence in the structural model
- contrast standard approaches to estimate returns