Using Machine Learning to Translate Applicant Work History into Predictors of Performance & Turnover

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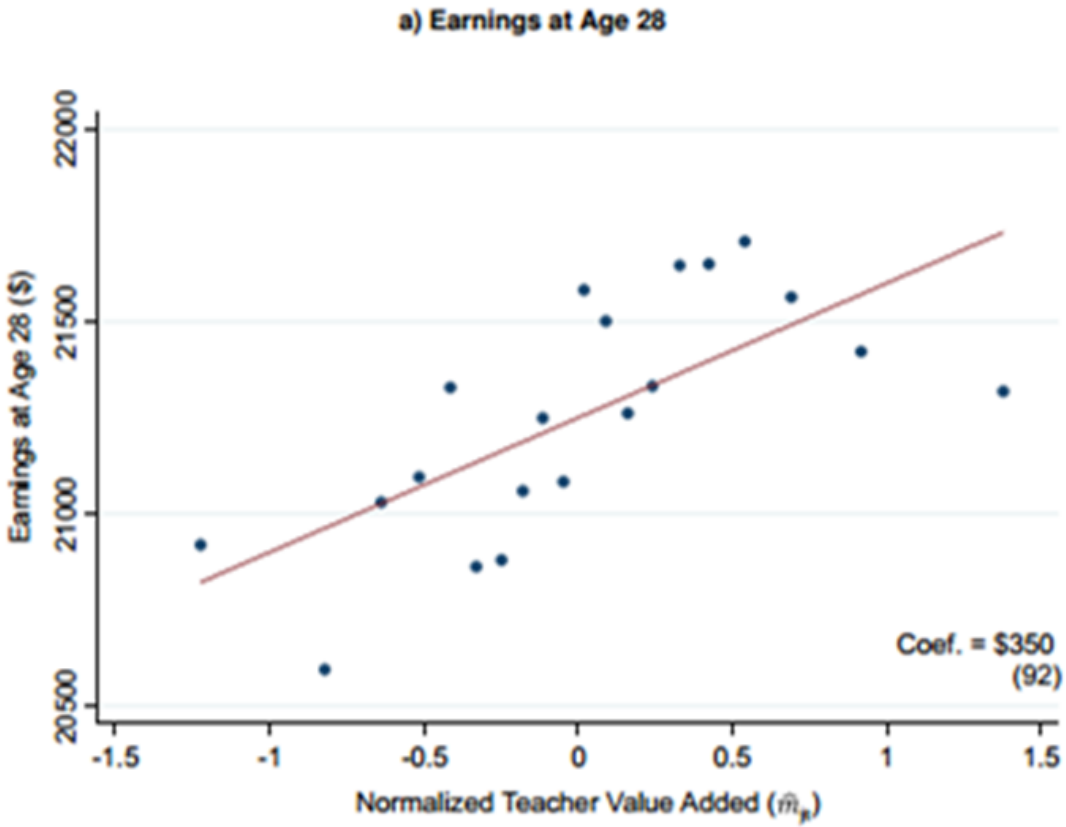
- link applicants' resumes to effectiveness & retention as hires
- create theory-informed predictor variables from resume data in automatable way
- evaluate prediction model's value

Motivation: teacher effectiveness varies & matters

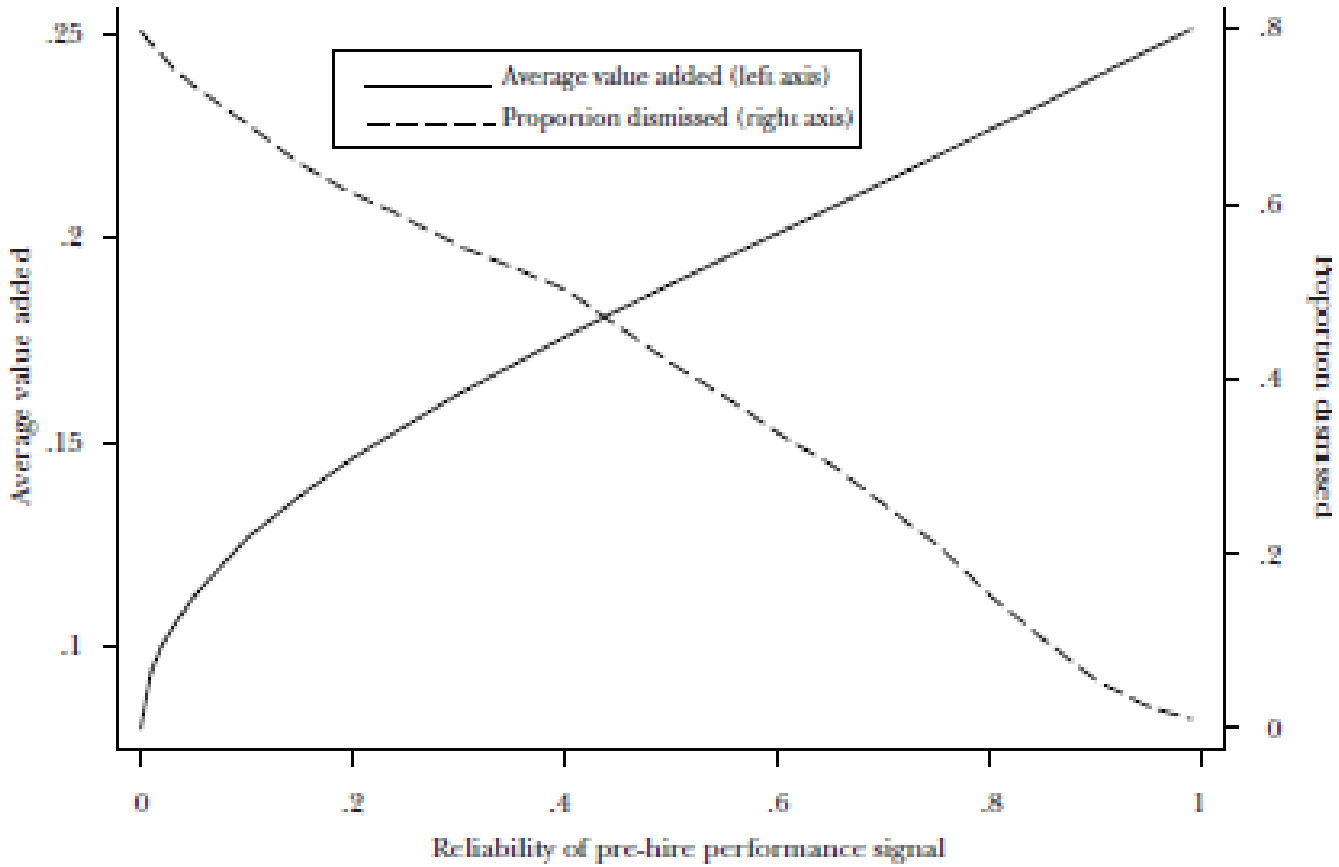
- One σ increase in teacher value-added causes \$150,000-\$400,000 increase in NPV of future student earnings per teacher-year [Hanushek (2011); Chetty, Friedman, & Rockoff (2012)]

Effect of Teacher Value-Added on Earnings



Motivation: improved pre-hire signals would pay off big

Effect of Increasing the Reliability of the Pre-hire Performance Signal on Value Added of Average Teacher and Proportion of Teachers Dismissed after One Year

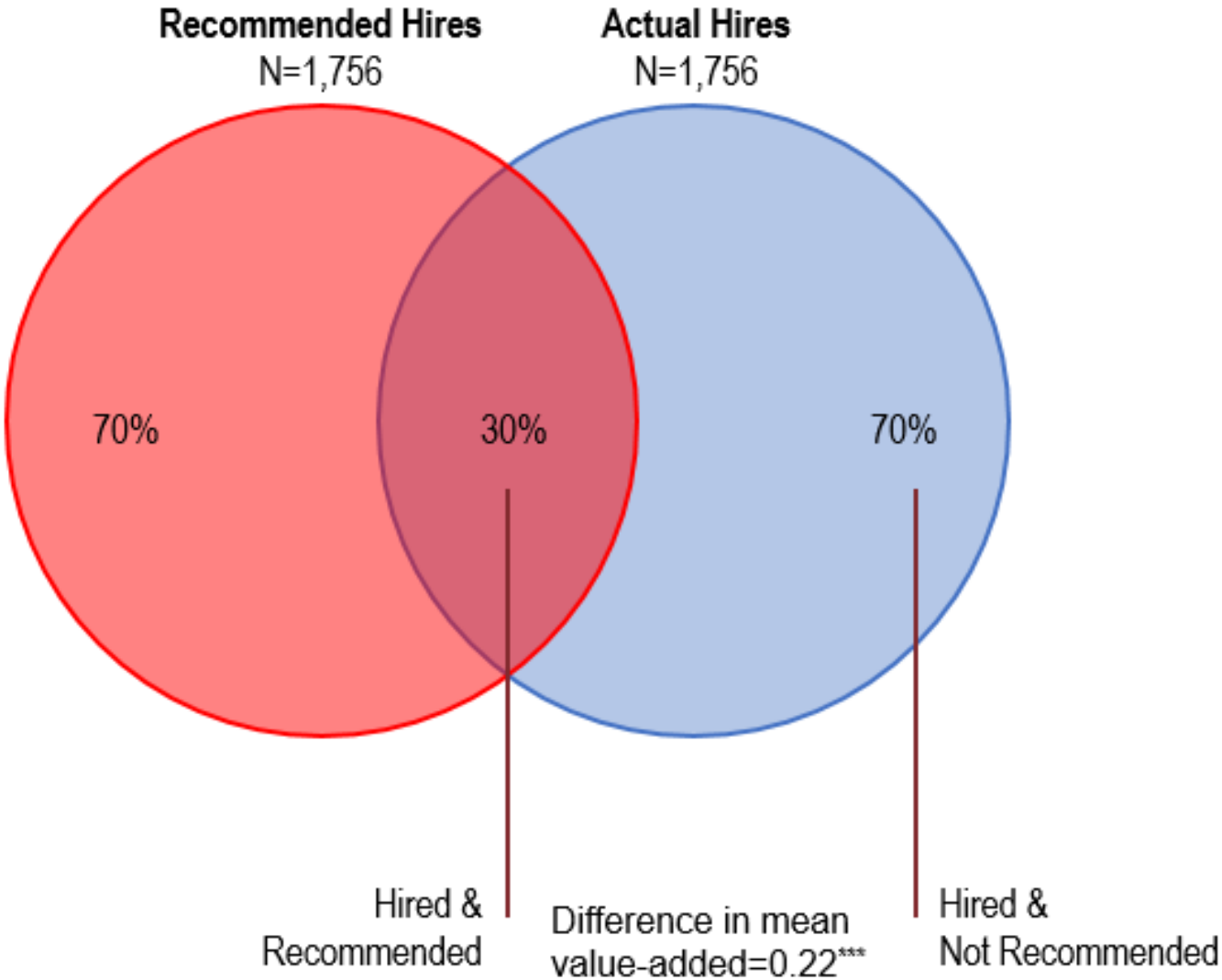


Staiger & Rockoff (2010)

Motivation: but it's really hard!

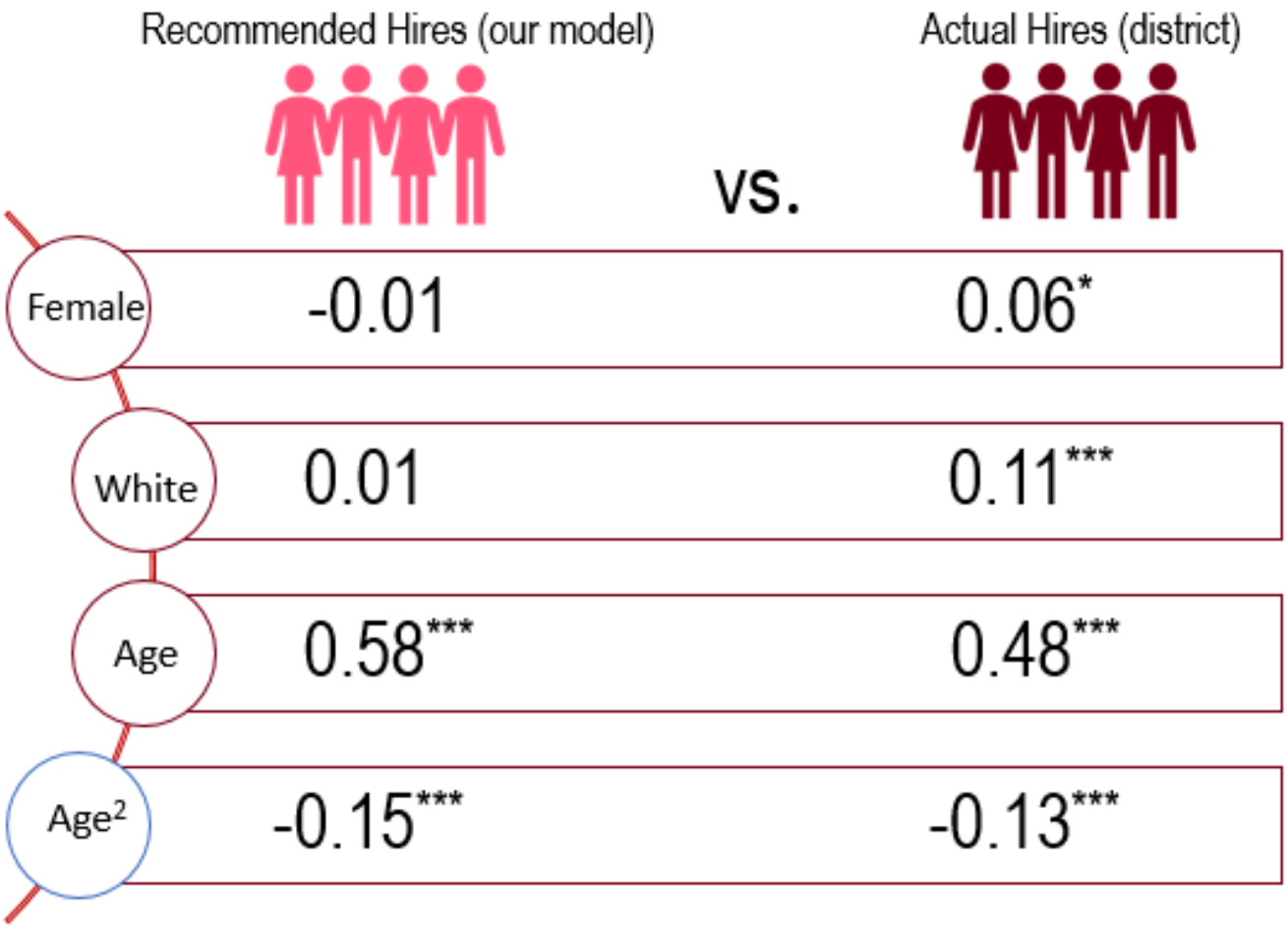
- "it is difficult to identify those teachers who will prove more effective at the time of hire." [Staiger & Rockoff (2010) JEP]
- Largest successes still modest: "students assigned to a teacher 1 σ higher [on either cognitive or noncognitive measures] have achievement that is 0.025 student-level σ higher." [Rockoff, Jacob, Kane, & Staiger (2011) EFP]
- " observable characteristics are unlikely to be able to predict most of the variation in teacher effects." [Jackson, Rockoff, & Staiger (2014) AnnRevEc]

Recommended vs Not-Recommended Hires' Effectiveness



Minimal cost buys $0.22\sigma_T = 0.044\sigma_S \geq$ \$44,000/year NPV

More fair: reduces adverse impact



* p <0.05, ** p<0.01, *** p<0.001; Controlled for application year & position type.

Outcome Variables

- 1756 hires from the applicant pool
- Process, outcome, and composite effectiveness over 2012-2017

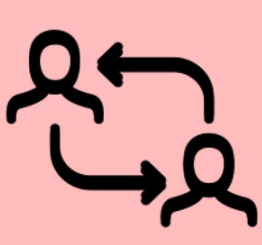
Effectiveness

Value-added (Outcome Performance)

Student Survey (Process Performance)

Class Observations (Process Performance)

Overall Effectiveness (Composite Performance)



- Whether left position?
- When?
- Why?

Turnover

Voluntary

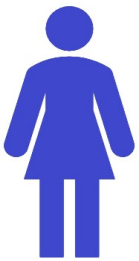
Involuntary

Pre-Hire Data

16,071 Applications (2007-2013)

APPLICANT INFORMATION					
Last Name		First		Date	
Gender			Ethnicity		
Position Applied for					
Have you ever worked for this district?			YES ☐ NO ☐		
EDUCATION					
School				Degree	
From		To		Major	
PREVIOUS EMPLOYMENT					
Company			Job Title		
Supervisor			Phone		
Job Description					
From		To			
Reason for Leaving					

Which One Would You Hire?



Sally

was **an administrative** assistant for **2 years.**

left to **follow her passion for teaching.**

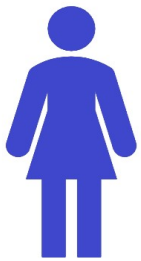
Molly

was an **elementary school teacher** for **9 months** and before that a **waitress** for **3 months.**

left first job because "**wanted to have a weekend night life of her own instead of watching everyone else have one**".

was laid off from her teaching position.

Which One Would You Hire?



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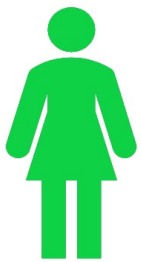

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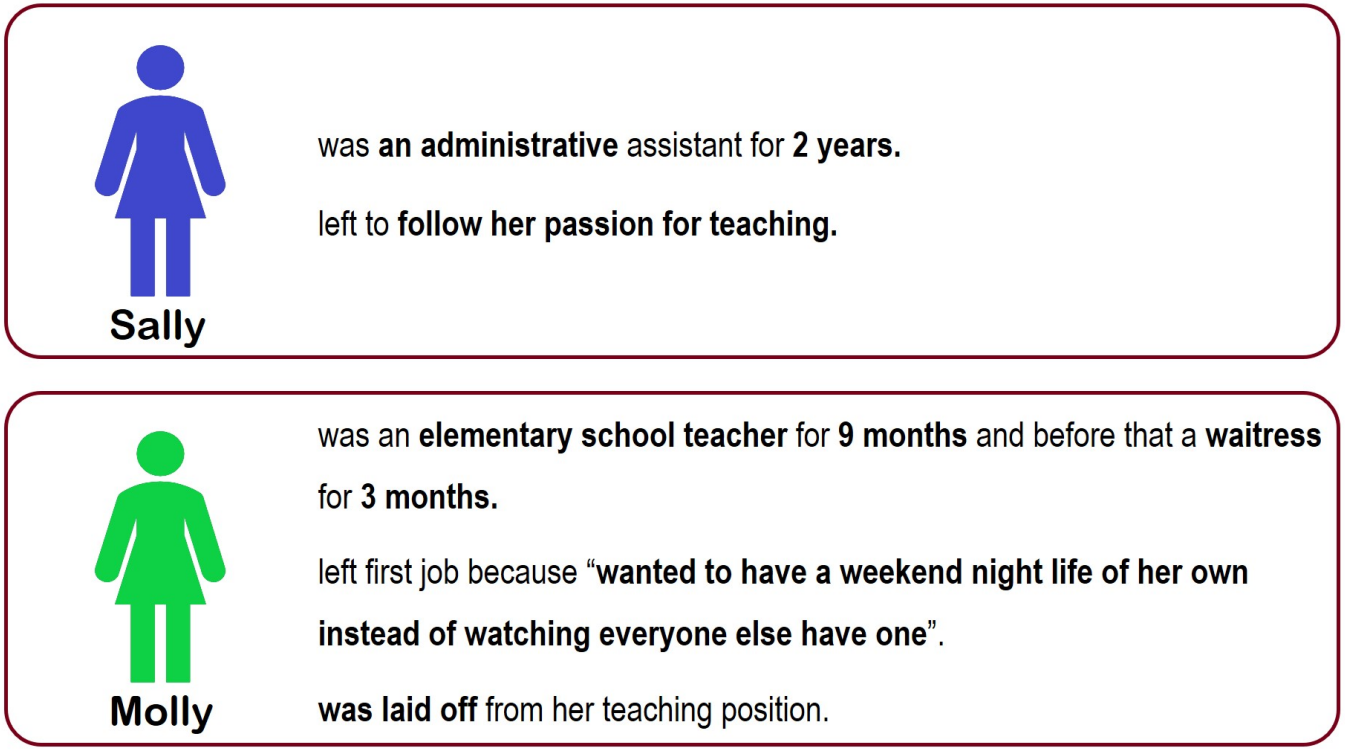
Work-experience relevance

JD text $\rightarrow$ Occ. Code $\rightarrow$ Occ. Dims. $\rightarrow$ Work-Exp. Relevance

Which One Would You Hire?



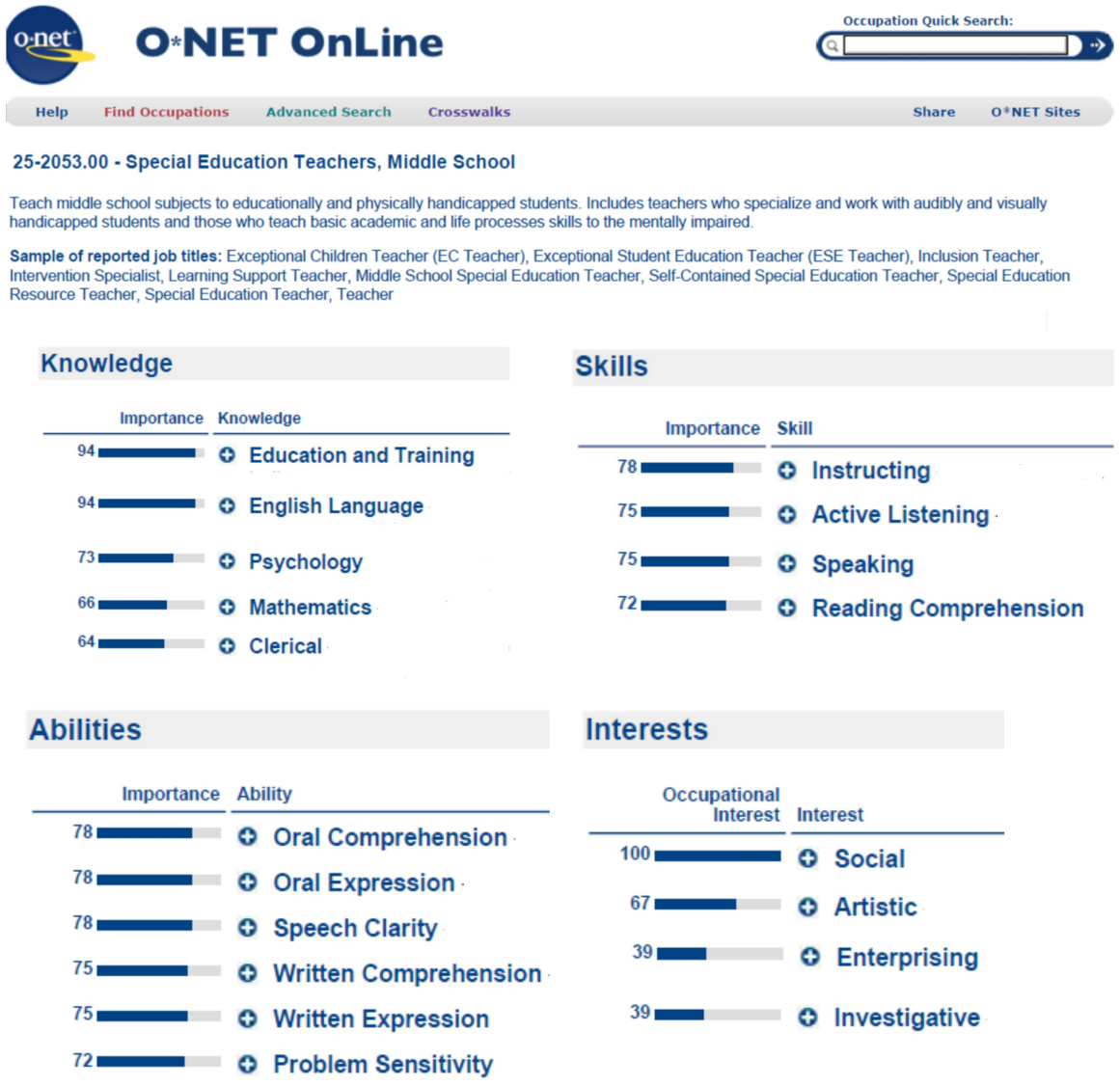
Work-experience relevance

JD text $\rightarrow$ Occ. Code $\rightarrow$ Occ. Dims. $\rightarrow$ Work-Exp. Relevance

Reasons for leaving

Text $\rightarrow$ 3 key topics: approach, avoidance, involuntary, other

Work Exp. Relevance: Occ. descriptions & characteristics



Selection Bias: Heckman Selection Model

- Non-random sample of applicants who are hired.
- No outcome data if not hired.

Exclusion Restrictions

Instrument 1: Quality of the competition faced by each applicant.

Instrument 2: Quantity of the competition.

(Goldhaber, Grout, & Huntington-Klein, 2014)

▸ Table

Demographic Variables

Race, Gender, and Age

- Not included in the main models, only in the adverse impact evaluation.
- Age imputed using undergraduate start date.
- 37% of applicants missing self-reported race & gender.
- Race & gender imputed using machine learning classification.
- Validation: 95% accuracy.

Prediction model: effectiveness: value-added

Predictors**Outcome**	**Value-added**	**Expert observ**	**Student evals.**	**Turnover hazard**
Work-exper. relevance	0.11**			
Reasons for leaving				
Avoid bad jobs	-0.11***			
Approach good jobs	0.09**			
Involuntary turnover	0.00			
1(past district employee)	0.07			
1(past work as teacher)	0.07			
1(advanced degree)	-0.02			
Job persistence	0.08*			
Spelling accuracy	0.03			
Years of work experience	0.02			
Mean employment gap	0.02**			
Inverse Mills ratio	0.23			
Observations	866			

Note: Indicators for position type & year included. Significant at *10% **5% ***1%

Prediction model: effectiveness

Predictors**Outcome**	**Value-added**	**Expert observ**	**Student evals.**	**Turnover hazard**
Work-exper. relevance	0.11**	0.05**	-0.04	
Reasons for leaving				
Avoid bad jobs	-0.11***	-0.17***	-0.14**	
Approach good jobs	0.09**	0.09**	0.09*	
Involuntary turnover	0.00	-0.06*	0.01	
1(past district employee)	0.07	-0.06	-0.19*	
1(past work as teacher)	0.07	0.07***	0.05	
1(advanced degree)	-0.02	0.18***	0.02	
Job persistence	0.08*	0.08**	0.00	
Spelling accuracy	0.03	0.01	0.04***	
Years of work experience	0.02	-0.09*	-0.08*	
Mean employment gap	0.02**	0.01	0.01	
Inverse Mills ratio	0.23	-0.10*	-0.11	
Observations	866	1,728	1,342	

Note: Indicators for position type & year included. Significant at *10% **5% ***1%

Prediction model: + turnover

Predictors**Outcome**	**Value-added**	**Expert observ**	**Student evals.**	**Turnover hazard**
Work-exper. relevance	0.11**	0.05**	-0.04	0.94*
Reasons for leaving				
Avoid bad jobs	-0.11***	-0.17***	-0.14**	1.06***
Approach good jobs	0.09**	0.09**	0.09*	0.97
Involuntary turnover	0.00	-0.06*	0.01	0.95
1(past district employee)	0.07	-0.06	-0.19*	0.89**
1(past work as teacher)	0.07	0.07***	0.05	0.83***
1(advanced degree)	-0.02	0.18***	0.02	1.10***
Job persistence	0.08*	0.08**	0.00	0.88*
Spelling accuracy	0.03	0.01	0.04***	1.03
Years of work experience	0.02	-0.09*	-0.08*	1.05
Mean employment gap	0.02**	0.01	0.01	0.98
Inverse Mills ratio	0.23	-0.10*	-0.11	0.92
Observations	866	1,728	1,342	2,225

Note: Indicators for position type & year included. Significant at *10% **5% ***1%

Value of model: select on predicted value-added

E[Rec-NotRec] on:	Value-added	Expert observ	Student evals.	Years Retained
Select on:				
Value-added	*0.22* *(0.18,0.25)*			
Retention				

Note: Recommended – NotRec mean difference in test samples & (95% CI) in 200 iterations.

Value of model: select on predicted value-added

E[Rec-NotRec] on:	Value-added	Expert observ	Student evals.	Years Retained
Select on:				
Value-added	*0.22*	0.27	0.08	0.46
	(0.18,0.25)	(0.25,0.29)	(0.06,0.11)	(0.40,0.51)
Retention				

Note: Recommended – NotRec mean difference in test samples & (95% CI) in 200 iterations.

Value of model: select on predicted value-added

E[Rec-NotRec] on:	**Value-added**	**Expert observ**	**Student evals.**	**Years Retained**
Select on:				
Value-added	*0.22*	0.27	0.08	0.46
	(0.18,0.25)	(0.25,0.29)	(0.06,0.11)	(0.40,0.51)
Retention	0.14	-0.13	-0.08	*3.53*
	(0.09,0.19)	(-0.16,-0.10)	(-0.11,-0.04)	*(3.49,3.58)*

Note: Recommended – NotRec mean difference in test samples & (95% CI) in 200 iterations.

Conclusions & Future Directions

- New measures from common, strategically-provided data
- Cheap, useful prediction of effectiveness & retention
- Lowers risk of adverse impact

- Implement at MPS
- Validate externally

Appendix

Calculating Relevance Using Profile Analysis

- How similar are an applicant's previous occupations to the teaching job to which they are currently applying?
- Profile Similarity Indices (PSIs): a single value representing the extent to which person's and job's profiles are (dis)similar across multiple variables.
- Profile Level (L2 Distance):

$$\sqrt{\sum_{i=1}^{n}(x_{ic} - x_{ia})^2}$$

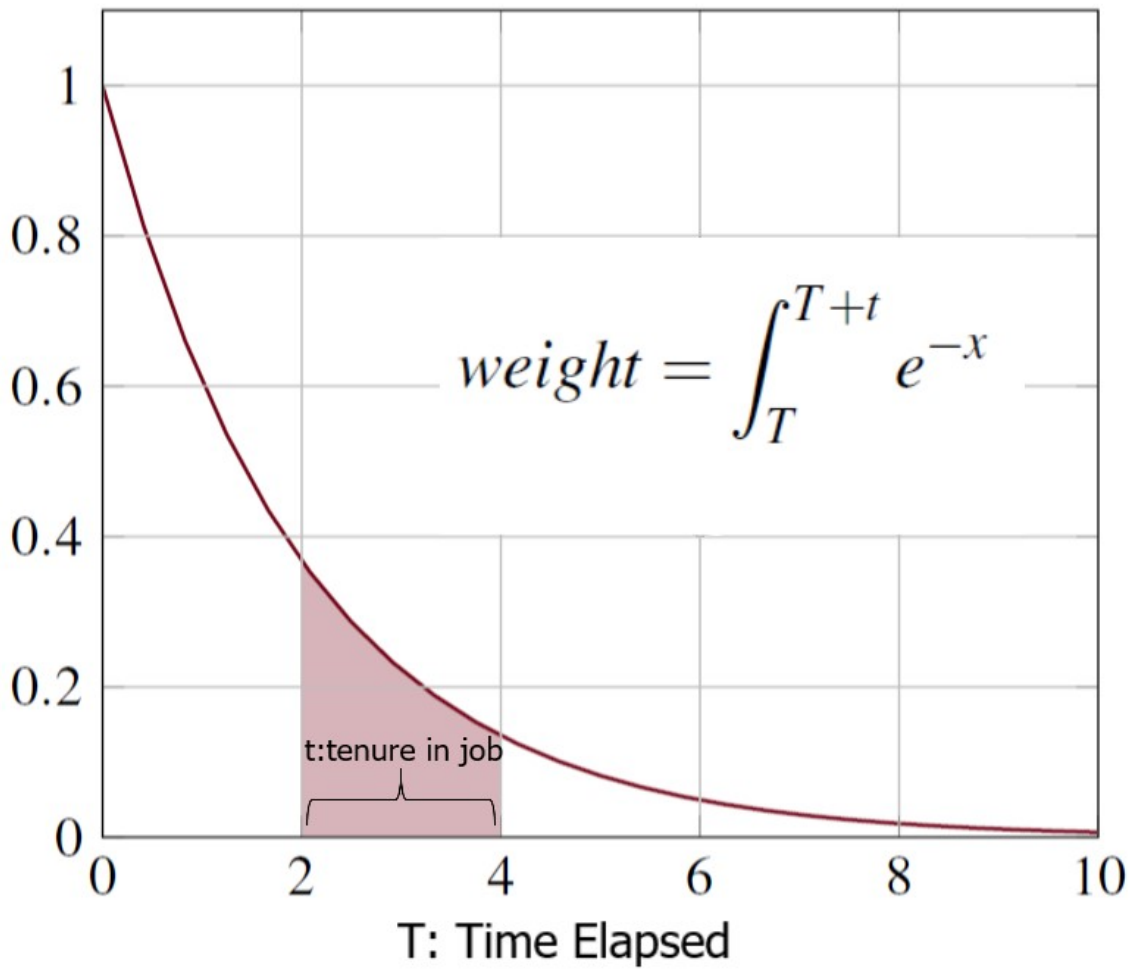
where:

- c Occupation of position applied for
- a Applicant's previous occupation
- i O*NET variable index
- n Number of O*NET variables

(Converse, Oswald, & Gillespie, 2004; Edwards, 1993)

Weighting Previous Jobs

- Define weight as a function of **elapsed time** since the person left the previous job & the **tenure in the previous job**.



Variable	N	Mean	SD
Outcome Variables			
Performance composite	1756	-0.17	0.75
Expert observation	1728	2.92	0.25
Student evaluation	1342	82.71	6.14
Value-Added	866	2.98	0.63
Voluntary turnover	2225	0.16	0.36
Involuntary turnover	2225	0.18	0.38
Work experience relevance	16071	16.07	4.93
Tenure history	16071	-1.66	4.5
History of leaving previous jobs			
Involuntary turnover	16071	0.15	0.23
Avoiding bad jobs	16071	0.13	0.19
Approaching better jobs	16071	0.20	0.26
Instruments			
Competition-Quantity	16071	0.84	0.13
Competition-Quality	16071	0.14	0.08
Control variables			
Spelling accuracy	16071	0.74	1.42
Years of experience	16071	7.8	7.08
Prior district employment	16071	0.23	0.42
Prior work as a teacher	16071	0.17	0.38
Advanced degree	16071	0.47	0.49
Employment gap	16071	0.44	0.82
Demographic variables			
Female	16071	0.76	0.42
White	16071	0.84	0.37
Age	16071	33.12	10.62

Correlations

Table 4
Intercorrelations for the Study Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
Outcome Variables																			
1.Student evaluation	1.00																		
2.Expert observation	0.35	1.00																	
3.Value-added	0.13	0.25	1.00																
4.Performance composite	0.35	0.96	0.34	1.00															
5.Voluntary turnover	-0.10	-0.13	-0.05	-0.16	1.00														
6.Involuntary turnover	-0.09	-0.17	-0.04	-0.18	-0.20	1.00													
7.Work experience relevance	-0.05	0.05	0.06	0.05	-0.10	0.02	1.00												
8.Tenure history	-0.02	0.11	0.08	0.15	-0.12	0.02	0.09	1.00											
History of leaving previous jobs																			
9.Involuntary turnover	-0.00	-0.03	-0.01	-0.03	-0.06	-0.03	0.10	-0.08	1.00										
10.Avoiding bad jobs	-0.14	-0.22	-0.13	-0.22	0.03	0.12	-0.01	0.00	-0.09	1.00									
11.Approaching better jobs	0.13	0.13	0.10	0.15	-0.11	-0.01	0.04	0.10	-0.24	-0.13	1.00								
Instruments																			
12.Competition-Quantity	0.01	-0.05	0.02	-0.07	0.11	-0.03	-0.14	-0.41	-0.09	-0.01	-0.05	1.00							
13.Competition-Quality	-0.03	0.06	-0.03	0.06	-0.07	0.02	0.08	0.32	0.03	-0.04	0.07	-0.59	1.00						
Control variables																			
14.Spelling accuracy	0.07	0.03	0.03	0.04	0.00	-0.03	-0.02	0.11	-0.09	-0.07	0.01	0.06	-0.00	1.00					
15.Years of experience	-0.03	0.03	0.04	0.07	-0.14	0.08	0.13	0.61	0.03	0.01	0.06	-0.41	0.26	-0.19	1.00				
16.Prior district employment	-0.04	0.05	-0.01	0.09	-0.10	0.03	0.17	0.27	0.12	0.00	0.09	-0.33	0.25	-0.06	0.26	1.00			
17.Prior work as a teacher	0.00	0.05	-0.02	0.06	-0.04	-0.03	-0.03	0.02	0.07	-0.02	-0.06	-0.01	0.06	-0.00	-0.04	0.23	1.00		
18.Advanced degree	0.03	0.07	-0.00	0.09	-0.07	0.06	0.08	0.27	0.04	-0.02	0.08	-0.26	0.22	-0.06	0.32	0.16	-0.01	1.00	
19.Employment gap	0.03	0.00	0.02	0.01	-0.06	0.01	0.07	0.02	0.01	-0.01	-0.02	-0.14	0.06	0.02	0.27	0.04	0.01	0.06	1.00

Note. Values greater than or equal to 0.07 are significant at $p<0.05$.

Stage 1: who got hired

Variable	Hired	Hired
Work experience relevance	0.12***	0.09***
	(0.03)	(0.02)
Tenure history	0.08***	0.05
	(0.03)	(0.03)
History of leaving previous jobs		
Involuntary turnover	-0.01	-0.02
	(0.01)	(0.01)
Avoiding bad jobs	-0.02**	-0.02*
	(0.01)	(0.01)
Approaching better jobs	0.05***	0.03***
	(0.01)	(0.01)
Control variables		
Spelling accuracy	0.04***	0.03**
	(0.01)	(0.01)
Years of experience	0.02	-0.02
	(0.01)	(0.01)
Prior district employment	0.99***	0.83***
	(0.06)	(0.04)
Prior work as a teacher	0.44***	0.44***
	(0.04)	(0.04)
Advanced degree	0.09**	0.02
	(0.03)	(0.03)
Employment gap	-0.02	-0.01
	(0.02)	(0.02)
Instruments		
Competition-Quantity		-0.45***
		(0.02)
Competition-Quality		-0.07***
		(0.02)
Controlled for application year and position type	Yes	Yes

Stage 2: effectiveness

Variable	Student evaluation	Expert observation	Value-Added	Performance composite
Work experience relevance	-0.04	0.05**	0.11**	0.05**
	(0.04)	(0.02)	(0.03)	(0.02)
Tenure history	0.00	0.08**	0.08*	0.07*
	(0.05)	(0.03)	(0.03)	(0.03)
History of leaving previous jobs				
Involuntary turnover	0.01	-0.06*	0.00	-0.07**
	(0.02)	(0.03)	(0.01)	(0.03)
Avoiding bad jobs	-0.14**	-0.17***	-0.11***	-0.18**
	(0.06)	(0.02)	(0.02)	(0.02)
Approaching better jobs	0.09*	0.09**	0.09**	0.09**
	(0.04)	(0.03)	(0.03)	(0.04)
Inverse Mills Ratio	-0.11	-0.10*	0.23	-0.09***
	(0.09)	(0.04)	(0.13)	(0.04)
Control variables				
Spelling accuracy	0.04***	0.01	0.03	0.02
	(0.01)	(0.01)	(0.03)	(0.01)
Years of experience	-0.08*	-0.09*	0.02	-0.06
	(0.03)	(0.04)	(0.02)	(0.03)
Prior district employment	-0.19*	-0.06	0.07	-0.01
	(0.08)	(0.16)	(0.12)	(0.18)
Prior work as a teacher	0.05	0.07***	0.07	0.07***
	(0.05)	(0.02)	(0.04)	(0.02)
Advanced degree	0.02	0.18***	-0.02	0.19***
	(0.02)	(0.05)	(0.04)	(0.05)
Employment gap	0.01	0.01	0.02**	0.01
	(0.01)	(0.02)	(0.01)	(0.02)
Controlled for application year and position type	Yes	Yes	Yes	Yes
Observations	1,342	1,728	866	1,756

Stage 2: retention

Survival Models Predicting Voluntary & Involuntary Turnover

Variable	Voluntary Turnover	Involuntary Turnover	All Turnover
Work experience relevance	0.92***	0.96	0.94*
	(0.02)	(0.04)	(0.03)
Tenure history	0.89*	0.87*	0.88*
	(0.05)	(0.07)	(0.05)
History of leaving previous jobs			
Involuntary turnover	0.87**	1.03	0.95
	(0.05)	(0.03)	(0.03)
Avoiding bad jobs	1.02	1.10***	1.06***
	(0.03)	(0.02)	(0.02)
Approaching better jobs	0.94	1.00	0.97
	(0.04)	(0.03)	(0.03)
Inverse Mills Ratio	0.93	0.92	0.92
	(0.09)	(0.07)	(0.05)
Control variables			
Spelling accuracy	1.01	1.05	1.03
	(0.01)	(0.05)	(0.03)
Years of experience	0.95	1.13***	1.05
	(0.07)	(0.03)	(0.04)
Prior district employment	0.71***	1.01	0.89**
	(0.05)	(0.09)	(0.03)
Prior work as a teacher	0.78**	0.88	0.83***
	(0.06)	(0.07)	(0.03)
Advanced degree	0.97	1.23***	1.10***
	(0.06)	(0.04)	(0.03)
Employment gap	1.03	0.93*	0.98
	(0.03)	(0.03)	(0.01)
Controlled for application year and position type	Yes	Yes	Yes
Observations	2225	2225	2225

Adverse Impact?

	Recommended Based on Performance composite	Recommended Based on Student evaluation	Recommended Based on Expert observation	Recommended Based on Value-added	Recommended Based on Turnover	Actual Hires
Female	-0.02 (0.03)	-0.00 (0.03)	-0.01 (0.03)	-0.01 (0.03)	-0.01 (0.03)	0.06* (0.03)
White	0.02 (0.04)	0.02 (0.04)	-0.01 (0.03)	0.01 (0.04)	-0.09* (0.04)	0.11** (0.04)
Age	0.35*** (0.02)	-0.10*** (0.02)	0.26*** (0.02)	0.58*** (0.02)	0.59*** (0.02)	0.48*** (0.02)
Age^2	-0.13*** (0.01)	-0.05*** (0.01)	-0.11*** (0.01)	-0.15*** (0.01)	-0.08*** (0.01)	-0.13*** (0.01)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.82*** (0.09)	-0.96*** (0.09)	-0.83*** (0.09)	-0.1.00*** (0.09)	-1.05*** (0.09)	-1.44*** (0.09)
Observations	16071	16071	16071	16071	16071	16071

Note. Standard errors in parentheses, n=16071, * p<0.05, ** p<0.01, *** p<0.001. Standard Errors adjusted for 7 clusters in application year. Controlled for application year and position type.

Improvement?

Comparison Between Outcomes of the Recommended and Not-Recommended Groups among hires in the hold-out sample.

		Actual scores				
		performance composite	student evaluation	expert observation	value-added	retention
Select on…	Performance composite	0.40 (.38,.43)	0.10 (.07,.13)	0.35 (.33,.37)	0.31 (.27,.35)	0.65 (.59,.70)
	Student evaluation	0.14 (.11,.17)	0.26 (.22,.29)	0.16 (.13,.19)	0.03 (-.01,.07)	0.23 (.16,.30)
	Expert observation	0.40 (.37,.42)	0.12 (.09,.14)	0.37 (.35,.40)	0.30 (.26,.34)	0.09 (.04,.15)
	Value-added	0.32 (.29,.34)	0.08 (.06,.11)	0.27 (.25,.29)	0.22 (.18,.25)	0.46 (.40,.51)
	Retention	-0.01 (-.04,.02)	-0.08 (-.11, -.04)	-0.13 (-.16, -.10)	0.14 (.09,.19)	3.53 (3.49,3.58)

The columns show the mean difference between recommended and not-recommended among hires in the hold-out sample. Numbers in parentheses show the 95% confidence interval around the average value over 200 iterations.