# **Evaluating Healthy Building Investments on the Workforce:**

**Evidence, Methods, and Application** 

### Presented by: Juan Palacios (jpalacio@mit.edu)



#### Types of Outcomes

Impact Outdoor Environment

Buildings and Adaptation

- Environmental studies show:
  - Outside air pollution effects on [Zivin and Neidell, 2013] :
    - Mortality
    - Human capital formation
    - Productivity
- Higher mortality rates at (extremely) high and low temperatures [Deschenes, 2014]

- We spend 90% of our time indoors. Buildings are key to avoid exposure to environmental hazards:
  - Sorting: moving away from the sources [Chay and Greenstone, 2005,Currie et al., 2015]
  - Spending more time indoors in highly polluted days [Zivin and Neidell, 2014]



#### **Healthy Building Headlines**



[1] New York Times
[2] Harvard Business Review
[3] Why COVID-19 Raises the Stakes for Healthy Buildings

#### **Healthy Building Industry Reports**



#### Types of Outcomes

Labs

Offices

Classrooms

- Relative to 600 ppm, at 1,000 ppm CO2, moderate & statistically significant decrements occurred in 6 of 9 scales of decision-making performance. At 2,500ppm, large and statistically significant reductions occurred in 7 scales of decision-making performance (raw score ratios, 0.06-0.56), but performance on the focused activity scale increased.(Satish et al. 2012)
- On average, cognitive scores were 61% higher on the Green building day and 101% higher on the two Green+ building days than on the Conventional building day. The largest effects were seen for Crisis Response, Information Usage, and Strategy, all of which are indicators of higher-level cognitive function and decision making. (Allen et al. 2016)
- Increasing outdoor air supply, by approximately 2x, led to improved operator talk performance by between 7% to 9% at higher temperatures. Decreasing temperature from a marginally warm thermal sensation to a marginally cool thermal sensation at lower ventilation rate also improved operator talk performance by between 5% and 13%. (Tham & Willem, 2005)
- Due to the intervention the fresh air supply increased from 0.3-05 to 13-16 L/s per person that increased pupils' work rate by ~7% in addition (Bakó-Biró et al. 2007)
- Performance was significantly improved in 4 of 4 performance tests when the outdoor air supply rate was increased from an average of 1.7 to 6.6 l/s per person. CO2 concentration was decreased from an average of approx. 1,500 ppm to 900 ppm due to the increased outdoor air supply rate.The performance improvements in the total sample,addition (6.3%), number comparison (4.8%), grammatical reasoning (3.2%), and reading & comprehension(7.4%), were all related to the number of correct answers made within the 10 min of each test. (Peterson et al. 2016)

#### Literature Dashboard

Literature Context	Participant Representation	Study Characteristics
<b>40</b> Peer-Reviewed Studies	~6,150 Participants	<b>22.5%</b> Lab Studies
<b>3</b> Continents	60% Students	<b>22.5%</b> Classroom Studies
<b>10</b> Countries	<b>9-45</b> ~24.1 Age Range Average Age	<b>50%</b> Controlled Environment



### **Geographical Representation**



#### Age Distribution and Counts



Participant Age

#### **Setting and Tasks**



**Cognitive Evaluation Type** 



\*Submarine Airplane Simulated Space Chamber

#### **Study Evaluation**



\*0% of studies gathered provided a performance-based compensations





## Moving to Productivity Estimating Benefits of Healthy Buildings

Palacios, Eichholtz, Kok

#### PLOS ONE

#### RESEARCH ARTICLE

Moving to productivity: The benefits of healthy buildings

#### Juan Palacios<sup>1,2</sup>, Piet Eichholtz<sup>3</sup>, Nils Koko<sup>3</sup>\*

1 Canter for Real Estate. Department Urban Studies and Planning, Massachusetts Institute of Technology Canterloge, Massachusetts, Urbald Bates of Anexics, 3 20, Bonn, Germany, 3 Department of Finance. School of Business and Economics, Maastricht University, Maastricht, The Netherlands

Abstract



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Data Austhability Statement: The data are available from the Harvard Datavense at https://doi.org/10. 7910/01/14412085.

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#### 1 Introduction

<sup>44</sup> Weeken seprenet a critical input factor for the modern firm, but our understanding of the effects of ovelapile environmental conditions on human performance in historical. Comparison per base without and the form of both absentions and presenteriors, that is preductively losses does to exolern such tong table to work at fill capacity [1]. Based on a supple of 20,502 and the state of the second state of the state of the second state of the preductive table of an overall state of the stat

authors estimate a loss of 84.2 billion per peur due to pair editent lost productivity. The literature provides some evidence on the basenful effosts of indoor envisonmental qualji (102) in the workplace on completyee productivity. Prove indoor any quality in the form of high levels of CO<sub>2</sub> or politizats has been linked to the prevalence of absentisem, eick building or syndrome (SSS) requestions [3]. Las deviced cognitive performance of volvering 1(4).

### **Moving to Productivity**

What is the impact of moving to a new healthy building? Evidence from <u>1,400</u> municipality workers



- $\circ$  Constructed in the 1980s
- No ventilation system

- Ventilation based on the principles of natural circulation
- o Green wall

### **The Moving Experiment**



#### **Difference in Difference Strategy**

$$Y_{it} = \mu_i + \tau_t + \delta Relocated * After Move_{it} + \beta X_{it} + \epsilon_{it}$$
(1)

- Yit includes the set of outcome variables describing the perceived working conditions and health status of individual *i* at time *t*. We include the scales describing the perceived noise, temperature, light, and air quality in the workplace. Finally, we consider a dummy variable indicating whether the individual suffers from SBS.
- Relocated: Group of individuals moved to the new building. After Move: Survey takes place after the moving date. Our prime parameter of interest is δ, describing the average change in the outcomes (Yit) after the move for the employees who relocated to the new building.
- The individual fixed effects (µi) should reduce bias resulting from differences between the movers and non-movers.
- In addition, we include time dummy variables *rt* for each survey wave, non-parametrically adjusting for possible shocks in the city or employer that coincide with the move (e.g., pollution reduction in the city).
- We include a set of individual time-varying controls, *Xit*. The set of controls includes the average working hours per week and the reported scales rating the *Office Layout*
- *eit* is the error term, which might be correlated within individuals. Therefore, we cluster standard errors at the individual level.

#### Stability of Results:

$$Y_{it} = \mu_i + \tau_t + \sum_{k=1}^{K} \delta_k \text{Relocated} * \text{AfterMove}_{it}^k + \beta X_{it} + \epsilon_{it}$$
(2)

Thus, *Relocated* \* *AfterMove<sub>kit</sub>* is an indicator for being *k* time periods relative to the moving date. The reference category is k = 0; hence, the post-treatment effects are relative to the year immediately before the treated individuals were relocated to the new building.

### **Measuring Perceived Working Conditions**

#### The scales

"Hoe tevreden bent u over de luchtkwaliteit op uw werkplek (bv. muffe lucht, zuiverheid, geuren)?"

(1) Zeer Tevreden 2 3	4	5	6	(7) Zeer Ontevreden ∎ৣি®
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"In zijn algemeenheid: ondersteunt of hindert de luchtkwaliteit op uw werkplek uw werkzaamheden?"

(1) Ondersteunt 2 ⊘∎	3	4	5	6	(7) Hindert ∎্টু
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#### **Changes in EQ Perception**



Summer 2018

#### **Changes in IEQ Perception**



○ Staying in Old Building ○ Moved to New Building

• Staying in Old Building • Moved to New Building

#### **Sensor Data**

#### Data From Measurement Campaigns



### Sick Building Syndrome





#### **Impact on Worker Health**



Estimates based on fixed effects regression



20

### Sick Building Syndrome

		(1) Full Sample	(2) Men	(3) Women	(4) Age Below 31	(5) Age 30-50	(6) Age Above 50
Health Indicator							
Sick Building Syndrome	Dummy $(1 = Yes)$	-0.216***	-0.277***	-0.223**	-0.355	-0.216*	-0.255**
		(0.056)	(0.075)	(0.078)	(0.223)	(0.085)	(0.078)
Wave-Fixed Effects		YES	YES	YES	YES	YES	YES
Individual-Fixed Effects		YES	YES	YES	YES	YES	YES
Controls		YES	YES	YES	YES	YES	YES

Robust standard error clustered at the individual level.

\* p<0.1,

\*\* p<0.05,

\*\*\* p<0.01.

#### **Mediation Analysis**

Impact on sick building syndrome symptoms



#### **Discussion**

- There is a shortage of field studies estimating the benefits of healthy buildings on real workforce.
- This study investigates the impact of the indoor environmental conditions in the workplace on the health and job satisfaction of employees, as core factors of productivity.
- We exploit a natural experiment, based on the relocation of 70% of the workforce of a municipality in the south of the Netherlands.
- We observe a 42% reduction in the prevalence of SBS symptoms.
- Results from a mediation analysis:
  - Job satisfaction increased by 1.2%
  - Drop in the prevalence of sick leave by 2%

# Thank you.

Juan Palacios (jpalacio@mit.edu)

