ECON-C4100 - Capstone: Econometrics I

Lecture 9: Causal parameters part I

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Learning outcomes

- At the end of this lecture, you understand

1. what causality means in empirical research.
2. the benefits of experiments in identifying causal parameters.
3. that in the case of experiments, a causal interpretation rests on assumption(s).

Starting point - causality

- Wikipedia:

  Causality (also referred to as 'causation',[1] *or 'cause and effect') is the agency or efficacy that connects one process (the cause) with another (the effect), where the first is understood to be partly responsible for the second. In general, a process has many causes, which are said to be causal factors for it, and all lie* ***in its past****. An effect can in turn be a cause of many other effects, which all lie* ***in its future***.

Wikipedia c'ed

- **Necessary causes:**

  If X is a necessary cause of Y, then the presence of Y necessarily implies the presence of X. The presence of X, however, does not imply that Y will occur.

- **Sufficient causes:**

  If X is a sufficient cause of Y, then the presence of X necessarily implies the presence of Y. However, another cause Z may alternatively cause Y. Thus the presence of Y does not imply the presence of X.

Causality in (empirical) science

- X causes Y

  $=$ a change in X changes the probability of Y happening (or the expected value of Y), keeping everything else the same.

  $=$ neither necessary nor sufficient.

Causality and timing

- Is it true that the cause always happens before the effect?
- You need to get a virus first for it to infect you.
- When do you take the vaccination?
- ... and why? To avoid getting a disease later.

Causality vs. determinism

- "X causing Y" $\neq$ "X determines Y".
- X determining Y is a (very) strong statement.
- Causality is best thought in terms of affecting
  1. the probability of Y happening (discrete 0/1 Y)
  2. the expected value of Y

Crucial distinction I

- As a deterministic relationship:

$$Y = f(X)$$

- As a probabilistic relationship:

$$Y = f(X, u)$$

Crucial distinction II

- As a description of the data:

$$Y = f(X, u)$$

- As a causal relationship:

$$Y = f(X, u)$$

Examples

- Income and age are positively correlated.
- Sales of stilton cheese and children's toys are positively correlated.
- Height and earnings are positively correlated.

Hoxby, C. & Paxson, A. (2008). Height, ability and labor market outcomes. *Journal of Political Economy*, *116*(4), 499–532.

Height and earnings

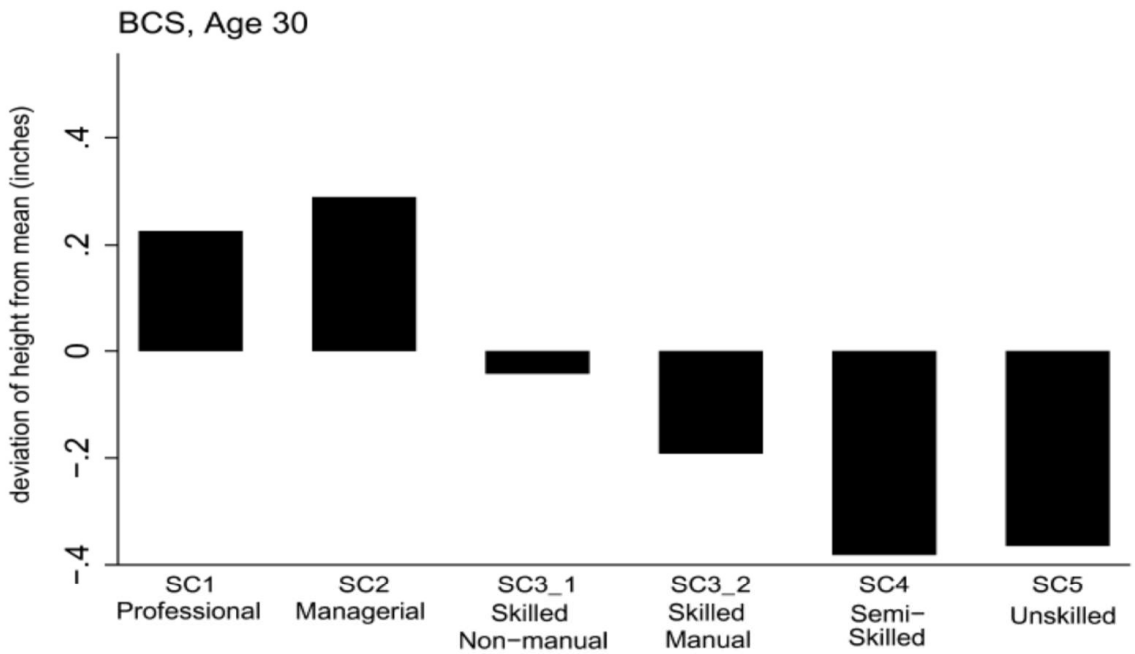

FIG. 1.—Heights across occupations, men. U.S. evidence is based on data from the National Health Interview Survey, and British evidence is based on data from the 1970 British Cohort Study.

Height and earnings

TABLE 1
LOG EARNINGS AND HEIGHT

	MEN		WOMEN	
DEPENDENT VARIABLE	Height Coefficient	Observations	Height Coefficient	Observations
	A. NCDS			
Log weekly gross earnings	.026 (.004)	4,927	.024 (.007)	5,033
Log average hourly gross earnings	.023 (.004)	4,860	.019 (.005)	4,995
	B. BCS			

Note.—OLS regression coefficients presented with standard errors in parentheses.

Hoxby, C. & Paxson, A. (2008). Height, ability and labor market outcomes. *Journal of Political Economy*, *116*(4), 499–532.

Height and earnings

- Height and earnings *are* positively correlated.
- H1: height increases earning, all else equal.
- H2: all else is not equal, and the positive correlation reflects this.

Height and earnings

- (Even identical) twins are of different weight at birth.
- The twin who is heavier at birth
  1. is taller as an adult
  2. has a higher IQ

Black, S., Devereux, P. & Salvanes, K. (2007). From the cradle to the labor market? the effect of birth weight on adult outcomes. *Quarterly Journal of Economics*, *122*(February), 409–439.

Crucial distinction II

- As a description of the data:

$$Y = f(X, u)$$

- As a causal relationship.

$$Y = f(X, u)$$

Height and earnings

TABLE 6
LOG AVERAGE HOURLY EARNINGS, TEST SCORES, AND THE RETURNS TO HEIGHT

	MEN				WOMEN			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	A. British Cohort Study (1970)							
Height at age 30	.010	.004	.002	.000	.015	.006	.008	.003
	(.003)	(.003)	(.003)	(.003)	(.004)	(.004)	(.004)	(.004)
Tests scores ages 5 and 10 *F*-test (*p*-value)	. . .	31.11	. . .	16.04	. . .	38.52	. . .	21.19
		(.000)		(.000)		(.000)		(.000)
Extended controls *F*-test (*p*-value)	. . .	. . .	5.39	3.00	. . .	. . .	4.39	2.01
			(.000)	(.000)			(.000)	(.000)
Marginal contributions to R^2 of:								
Test scores				.274				.352
Extended controls				.322				.225
Observations	2,253	2,253	2,253	2,253	2,127	2,127	2,127	2,127

Note.—OLS regression coefficients presented with standard errors in parentheses.

Hoxby, C. & Paxson, A. (2008). Height, ability and labor market outcomes. *Journal of Political Economy*, *116*(4), 499–532.

Height and earnings

- Great to explore the data through descriptive analysis.
- "Conditional distributions".
- To establish causality, need a convincing framework of analysis and data generation.

How to establish causality empirically

First, you need a theory...

How to establish causality empirically

1. **Knowing the mechanism** - light switch and light.
2. **Laboratory experiment** – medical research using mice.
3. **Field experiment** – agricultural research.
4. **Natural experiment** – birth of twins.
5. **Quasi-natural experiment** – ties in elections (96-12: 1351 candidates in Finnish municipal elections). Hyytinen, A., Meriläinen, J., Saarimaa, T., Toivanen, O. & Tukiainen, J. (2018). Public employees as politicians: Evidence from close elections. *American Political Science Review*, *112*(1), 68–81.

Laboratory experiment

Widely (though not unanymously) considered the *gold standard* of causal (empirical, statistical) research.

Laboratory experiment

- Genetically enginereed mice.
- Same temperature, same humidity, same food, same (kind of) room, same everything.
- One type of treatment (0/1).
- What needs to be done?

Laboratory experiment

- So, in a lab, everything else but the **treatment** is either
  1. equal across the groups, or at the very least
  2. random

Laboratory experiment

- What difference does equal vs. random make? Think of

$$Y = \beta_0 + \beta_1 X + u$$

- The more things are equal as opposed to random, the smaller is σ_u

  ... therefore the higher is R^2

  ... and the smaller the standard error of β_1 (and β_0).

Laboratory experiments

1. Calculate the mean of Y for the treatment group
2. Calculate the mean of Y for the control group
3. Test the statistical significance of the difference in means
4. You're done

A short sidestep: Power calculations

1. What determines whether you can detect a causal effect when one really exists?
2. Answer: think back to everything that affects the value of your t-test.
    1. The effect size (difference in means between the treatment and control samples)
    2. Variation in the outcome (=variance of Y)
    3. Sample size
    4. Required statistical significance

A short sidestep: Power calculations

- **Power calculations** are a tool to determine how large a sample size you need, given the other parameters.
- Obviously, one can also ask e.g. what the **Minimum Detectable Effect** size (MDE) is.
- Power = Pr[*HO rejected* | *H*1 *true*].
- Think of t-test:

$$t = \frac{\bar{Y}_{treated} - \bar{Y}_{control}}{\sigma/\sqrt{N}}$$

- One can find power calculators on the net (for simple cases).
- Example of a power calculator.

Example of a power calculation

mean | treated	2	1.5	1.2	1.1	1.05
mean | control	1	1	1	1	1
std. error	1	1	1	1	1
significance level	0.05	0.05	0.05	0.05	0.05
power	0.8	0.8	0.8	0.8	0.8
required N	16	63	393	1570	6280
mean | treated	2	1.5	1.2	1.1	1.05
mean | control	1	1	1	1	1
std. error	2	2	2	2	2
significance level	0.05	0.05	0.05	0.05	0.05
power	0.8	0.8	0.8	0.8	0.8
required N	63	252	1570	6280	25117

Laboratory experiment

$$Y = \beta_0 + \beta_1 X + u$$

What does it mean that X is randomly assigned?

$$cov(X, u) = 0$$

$$\rightarrow \quad \mathbb{E}[\hat{\beta}_1] = \beta_1 + \rho_{Xu}\frac{\sigma_u}{\sigma_X} = \beta_1$$

Laboratory experiment

- So, lab experiments are the gold standard.
- You should **believe** the results of a lab experiment to be causal if...
- ... you **believe** all else but the treatment is random.

Laboratory experiment

All causal results from empirical (statistical) research are based on assumption(s).

Laboratory experiment

$\rightarrow$ Crucial acid test:

1. What are the assumptions needed to make the result a causal one?
2. Are these assumptions *credible* ("believable")?

Laboratory experiment

- This may be a tough threshold to cross.
- Sorge & al. (2014). Olfactory exposure to males, including men, causes stress and related analgesia in rodents. *Nature Methods*, *11*(6), 629–632.
- Question: Does the gender of the lab experimenter affect the outcome of the experiment?

Laboratory experiment - setup

- Subjects and stimuli. Experimentally naive, adult (6–12 weeks) male and female CD-1 mice (ICR:Crl, Charles River) were used for most experiments (CD-1®IGS Mouse);
- Male and female subjects were tested in separate runs.
- Mice were housed 3–6 per cage in standard shoebox cages with wood-chip bedding, with ad libitum access to food (Harlan Teklad 8604) and tap water, in a light-(14:10 h, lights on at 07:00 h) and temperature-controlled (21 $\pm$ 2 °C) environment.

"Here we assess the most widely used outbred stocks of mice and present guidelines for their use."

Chia & al. (2005). The origins and uses of mouse outbred stocks. *Nature Genetics*, *37*, 1181–1186.

Laboratory experiment - setup

- One experiment used naive, adult (12–14 weeks) female C57BL/6J mice (Charles River, Fig. 3d), and one used naive, adult (225–250 g) Wistar rats.
- Most mice were bred in-house; others (in Figs. 2d and 3d) were purchased and acclimated to the vivarium for at least 7 d before testing.
- Husbandry was provided by male staff.
- Animals were used only once and were exposed to only one presentation of one of various stimuli described below.

Laboratory experiment - results

- We found that exposure of mice and rats to male but not female experimenters produces pain inhibition.
- Male-related stimuli induced a robust physiological stress response that results in stress-induced analgesia.
- I.e., male presence caused **physical (biological) reactions**, not only behavioral reactions.

Laboratory experiment - results

- This effect could be replicated with T-shirts worn by men, bedding material from gonadally intact and unfamiliar male mammals, and presentation of compounds secreted from the human axilla (=arm pit).
- Experimenter sex can thus affect apparent baseline responses in behavioral testing.
- Our findings strongly suggest that standard laboratory practice should account for experimenter sex when investigating any phenomenon possibly affected by stress.

Field experiments with humans

- Large and growing literature.
- For example: Latif Jameel Poverty Action Lab, J-PAL.
- *J-PAL affiliated researchers have 1110 ongoing and completed randomized evaluations in 91 countries*.
- For a look at what type of questions economists are addressing using an RCT let's look at a paper studying cheating on taxes.

Example: cheating on taxes

Kleven, H., Knudsen, M., Thustrup, C., Kreiner, S., Pedersen & Saez, E. (2011). Unwilling or unable to cheat? evidence from a tax audit experiment in denmark. *Econometrica*, *79*(3), 651–692.

Cheating on taxes

- What affects the degree of tax evasion?
  1. Type of income (self-reported vs. third party reported)
  2. Stake at play = marginal tax rate
  3. (random) auditing.
- Does the possibility to evade taxes generate behavioral responses, e.g., channeling income towards self-reported income?

Set-up

- 42 800 tax payers in a **stratified** random sample for filing and auditing seasons 2007 and 2008.
    - *pp. 660-1. The sample of employees was stratified by tax return complexity, with an over-sampling of filers with high-complexity returns*.
- First stage: Random selection into **unannounced** audits of 2006 income.
- Second stage: **Pre-announced** audits of 2007 income, with researcher-induced variation.

Set-up

- Second stage included both subjects that were part of the 1st stage audits, and those that were not.
- Three possibilities:
  1. Receiving a letter stating that the subject's 2007 income will be audited for sure (in 2008)
  2. Receiving a letter stating that the subject's 2007 income will be audited with probability 0.5 (in 2008)
  3. No letter.

Set-up

- This set-up is very rich and allows to study:
  1. How much tax avoidance there is (the first stage)?
  2. What affects the degree of tax avoidance?
  3. How past audits affect future tax reporting?
  4. How the threat of an audit affects tax reporting?

Danish taxes

TABLE I

DANISH INDIVIDUAL INCOME TAX IN 2006

A. Income Concepts

Income Concept	Definition
1. Labor income	Salary, wages, honoraria, fees, bonuses, fringe benefits, business earnings
2. Personal income	Labor income (1) + social transfers, grants, awards, gifts, received alimony − payroll tax, and certain pension contributions
3. Capital income	Interest income, rental income, business capital income − interest on debt (mortgage, bank loans, credit cards, student loans)
4. Deductions	Commuting costs, union fees, unemployment contributions, other work related expenditures, charitable contributions, alimony paid
5. Taxable income	= Personal income (2) + capital income (3) − deductions (4)
6. Stock income	Dividends and realized capital gains from corporate stock

B. Tax Rates and Tax Bases

Tax Type[a]	Tax Base	Bracket (DKK)[b]	Tax Rate
Payroll tax	Labor income	All income	8.0%
National income tax	Personal income + max(capital income, 0)	38,500–265,500	5.5%
		265,500–318,700	11.5%
		318,700–	26.5%[c]
Regional income tax	Taxable income	38,500–	32.6%[d]
Stock income tax	Stock income	0–44,400	28.0%
		44,400–	43.0%

[a]The national and regional income taxes are based on individual income (not family income). The stock income tax is based on family income with brackets for married tax filers twice as large as those reported in the table.

[b]All amounts are given in Danish kroner: U.S. $1 = 5.2 DKK as of January 2010.

[c]The top rate is reduced so that the combined national and regional income top marginal tax rate never exceeds 59%. The top marginal tax rate on labor income including the payroll tax is therefore $0.08 + 0.92 * 0.59 = 62.3\%$.

Experimental design

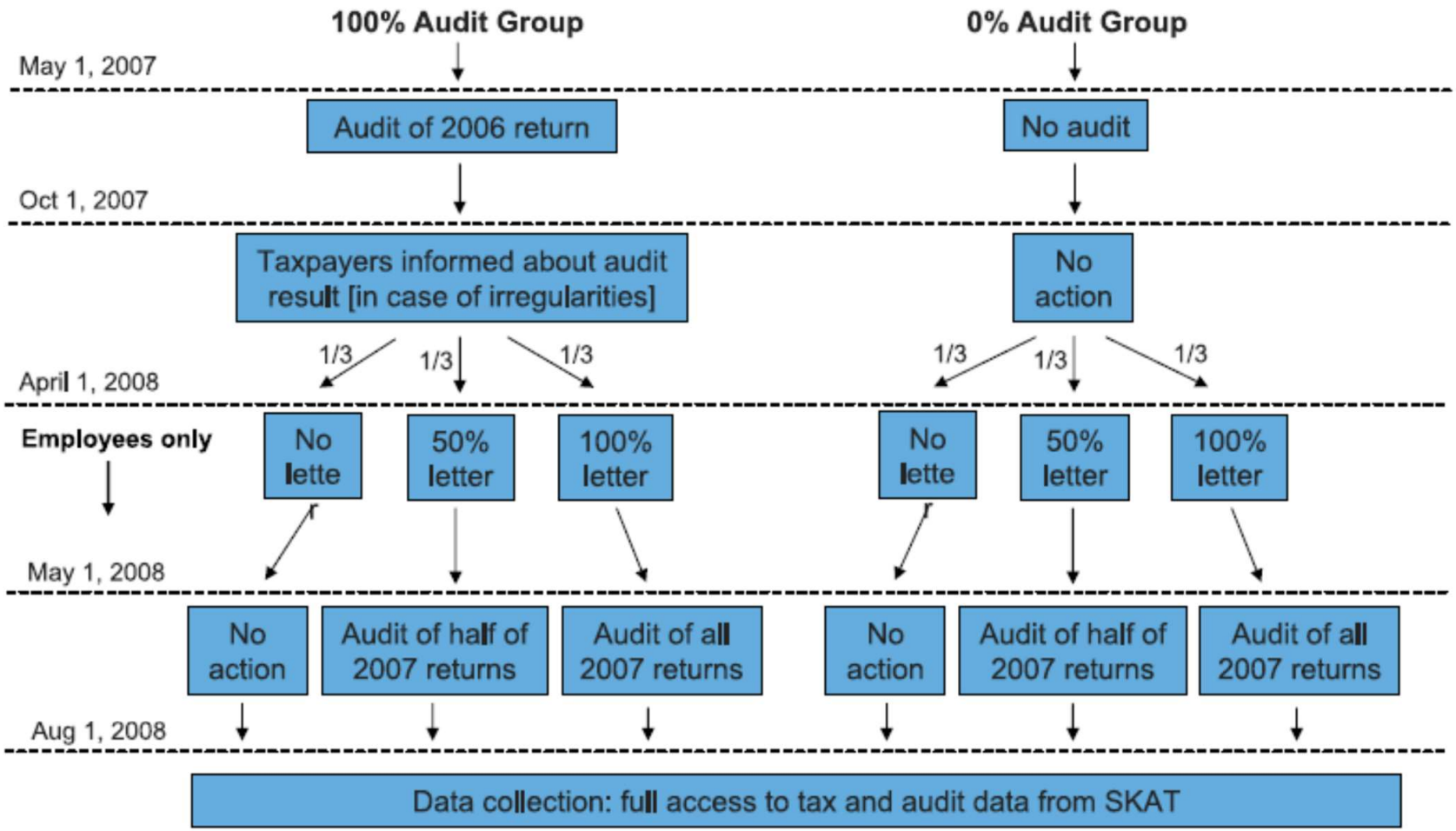

FIGURE 2 Overview of experimental design

Worries re experimental set-up

- Spillovers between treated and control individuals?
  1. No media coverage
  2. Taxpayers did not know there was an experiment
  3. Taxpayers would need to talk about their treatment by SKAT. (456 individuals whose spouse also in the sample)

Did randomization succeed?

- If randomization works well, then...
  1. All observables but those the researcher has decided to vary across groups should not differ across groups
  2. This is something that to greater or lesser extent can be checked

Randomization outcomes

2 differences statistically significant out of 39.

TABLE A.I

RANDOMIZATION CHECKS: AUDIT AND LETTER EXPERIMENTS[a]

	A. Audit Randomization				B. Letter Randomization				C. Within Letter Randomization			
	0% Audit Group	100% Audit Group	Difference 100% – 0%	Difference Standard Error	No-Letter Group	Letter Group	Difference Col. 6 – Col. 5	Difference Standard Error	50% Letter Group	100% Letter Group	Difference Col. 10 – Col. 9	Difference Standard Error
	1	2	3	4	5	6	7	8	9	10	11	12
Net income	265,209	263,485	−1724	(6047)	239,936	244,477	4541	(3425)	243,878	245,078	1200	(4422)
Total tax	100,968	100,460	−508	(3010)	82,443	84,230	1786	(1588)	84,022	84,438	415	(2073)
Personal income	216,418	217,426	1007	(2351)	257,022	259,748	2725	(2904)	259,374	260,123	749	(3730)
Capital income	−13,127	−12,805	323	(1015)	−16,554	−15,485	1068	(534)	−15,613	−15,358	255	(626)
Deductions	−11,839	−11,976	−138	(160)	−8333	−8304	29	(160)	−8268	−8341	−73	(193)
Stock income	18,141	15,880	−2261	(4928)	7371	8220	849	(1777)	7857	8584	727	(2243)
Self-employment	55,616	54,960	−656	(2869)	430	299	−131	(209)	527	70	−457	(268)
% with net income	99.55	99.52	−0.03	(0.07)	98.73	98.64	−0.09	(0.15)	98.52	98.76	0.24	(0.19)
% with total tax	96.71	96.61	−0.11	(0.17)	96.64	96.26	−0.38	(0.25)	96.26	96.25	−0.02	(0.31)
% with personal income	94.98	94.85	−0.13	(0.21)	97.29	97.11	−0.18	(0.22)	96.99	97.23	0.25	(0.27)
% with capital income	95.67	95.40	−0.27	(0.20)	97.02	96.90	−0.12	(0.23)	96.77	97.03	0.26	(0.28)
% with deductions	71.69	71.76	0.07	(0.44)	64.18	64.49	0.31	(0.65)	64.79	64.19	−0.60	(0.77)
% with stock income	40.30	40.23	−0.07	(0.47)	44.07	43.63	−0.44	(0.67)	43.59	43.68	0.09	(0.80)
% with self-employment	40.18	40.37	0.19	(0.47)	0.78	0.79	0.01	(0.12)	0.77	0.82	0.05	(0.14)
Female (%)	39.93	39.59	−0.33	(0.47)	49.80	50.10	0.30	(0.67)	49.83	50.38	0.55	(0.81)
Married (%)	58.46	58.13	−0.32	(0.48)	54.54	53.22	−1.32	(0.67)	53.79	52.65	−1.13	(0.80)
Church membership (%)	85.83	85.71	−0.12	(0.34)	86.82	86.86	0.04	(0.46)	87.06	86.66	−0.40	(0.54)
Copenhagen (%)	3.14	3.13	−0.01	(0.17)	3.17	3.33	0.16	(0.24)	3.32	3.34	0.02	(0.29)
Age	49.28	49.43	0.14	(0.16)	49.09	48.90	−0.19	(0.25)	49.01	48.80	−0.21	(0.30)
% filing in 2007	97.08	96.94	−0.14	(0.16)	100.00	100.00	0.00	(0.00)	100.00	100.00	0.00	(0.00)
Number of observations	23,148	19,630	42,778		9397	15,391	24,788		7706	7685	15,391	

[a]This table presents randomization checks for the audit experiment (part A, columns 1–4) and the letter experiment (part B, columns 5–8 and part C, columns 9–12). Part A compares baseline reported incomes in 2006 (before the audit experiment took place). Columns 1 and 2 present the baseline averages for the treatment group and control group, respectively. Column 3 presents the difference between the treatment group and the control group. The standard error of the difference is presented in column 4. Parts B and C compare prepopulated tax returns for 2007 incomes before the letters are sent. The columns in parts B and C are constructed as in part A. In part B, the sample is restricted to tax filers not registered as self-employed in the base year as the letter experiment could not be carried out for self-employed. In part C, the sample is further restricted to tax filers who received either the 50% threat-of-audit letter or the 100% threat-of-audit letter. Estimates are weighted according to the experiment stratification design. Weights do not reflect population weights. All the amounts are in Danish kroner (U.S. $1 = 5.2 DKK as of 1/2010).

Research question #1: How much tax evasion is there?

- Using 2007 data allows one to establish the level and type of tax evasion going on in 2006 (as reported in 2007).

Tax avoidance in 2007

TABLE II

AUDIT ADJUSTMENTS DECOMPOSITION[a]

		A. Total Income Reported				B. Third-Party vs. Self-Reported Income			
		Pre-Audit Income	Audit Adjustment	Under-reporting	Over-reporting	Third-Party Income	Third-Party Under-reporting	Self-Reported Income	Self-Reported Under-reporting
		1	2	3	4	5	6	7	8
I. Net Income and Total Tax									
Net income	Amounts	206,038	4532	4796	−264	195,969	612	10,069	4183
		(2159)	(494)	(493)	(31)	(1798)	(77)	(1380)	(486)
	% Nonzero	98.38	10.74	8.58	2.16	98.57	2.31	38.18	7.39
		(0.09)	(0.22)	(0.20)	(0.10)	(0.08)	(0.11)	(0.35)	(0.19)
Total tax	Amounts	69,940	1980	2071	−91				
		(1142)	(236)	(235)	(11)				
	% Nonzero	90.76	10.59	8.41	2.18				
		(0.21)	(0.22)	(0.20)	(0.10)				
II. Positive and Negative Income									
Positive income	Amounts	243,984	3776	3943	−167	223,882	516	20,102	3427
		(2511)	(485)	(485)	(27)	(1860)	(76)	(1693)	(478)
	% Nonzero	98.24	5.80	4.78	1.02	98.15	1.60	19.53	3.41
		(0.09)	(0.17)	(0.15)	(0.07)	(0.10)	(0.09)	(0.28)	(0.13)
Negative income	Amounts	−37,946	756	853	−97	−27,913	97	−10,033	756
		(1014)	(71)	(69)	(14)	(406)	(12)	(862)	(68)
	% Nonzero	79.09	6.45	5.13	1.32	78.21	0.75	29.49	4.99
		(0.29)	(0.18)	(0.16)	(0.08)	(0.29)	(0.06)	(0.33)	(0.16)

(Continues)

Tax avoidance in 2007

Note: most common strategy among those earning self-reported income and evading is to evade by 100%.

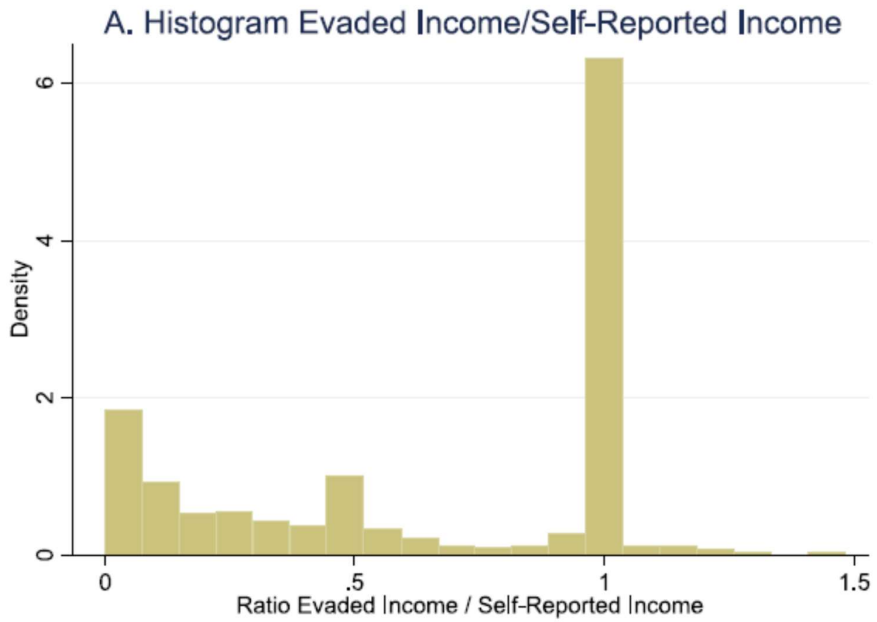

Figure 3.

Tax avoidance in 2007

Note #1: Probability of avoiding jumps immediately when some self-reported income

#2: share of evaded income increasing in share of self-reported income

#3: initially, share of evaded income follows the 45^o line, then tapers off

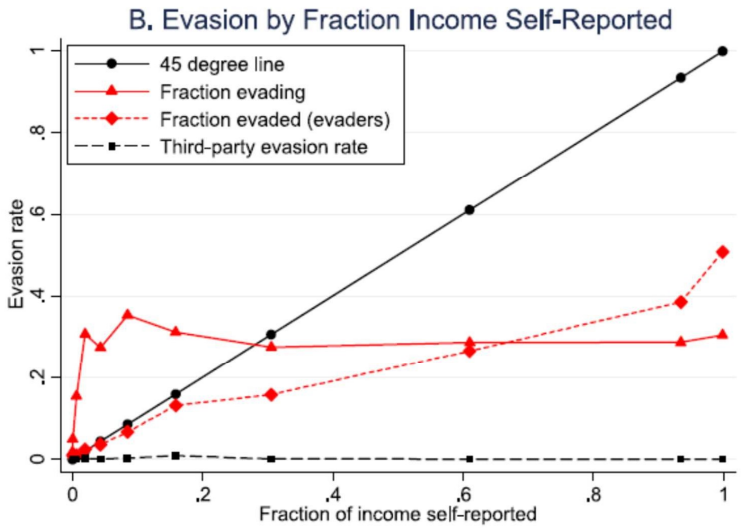

Figure 3B.

Research question #2: What affects the probability of evasion?

- Since the randomization was done well, can either
  - Do t-tests, comparing means of variables, or
  - Use a regression framework.
- Why use regression?
  1. Allows testing multiple hypotheses (variables) simultaneously
  2. Allows controlling for other observables, reducing thereby the variance of the error term

What affects evasion?

TABLE III

PROBABILITY OF UNDERREPORTING: SOCIOECONOMICS VERS

Coefficients (in Percent)		A. Basic Variables			
		Social Factors	Socio-economic Factors	Tax Return Factors	All Factors
		1	2	3	4
Constant		12.72	10.13	1.18	3.72
		(1.06)	(1.12)	(0.25)	(1.01)
Female dummy		−5.56	−4.17		−2.06
		(0.63)	(0.65)		(0.62)
Married dummy		1.22	−0.55		−1.50
		(0.70)	(0.72)		(0.72)
Member of church		−1.59	−2.27		−0.94
		(0.98)	(0.97)		(0.92)
Geographical location	Copenhagen	−1.49	−0.01		−0.25
	dummy	(1.52)	(1.51)		(1.47)
Age	Age > 45	−0.72	−0.63		−0.56
	dummy	(0.67)	(0.67)		(0.61)
Home ownership			5.49		0.15
			(0.65)		(0.66)
Firm size	Firm size < 10		5.07		3.47
	dummy		(1.26)		(1.05)
Industrial sector	Informal sector		4.37		0.27
	dummy		(1.15)		(0.92)
Self-reported				5.58	5.59
income dummy				(0.75)	(0.80)
Self-reported				21.68	21.09
income > 20,000 DKK				(1.38)	(1.40)
Self-reported				14.99	14.74
income < −10,000 DKK				(1.42)	(1.42)

Deterministic function of observables

TABLE III—*Continue*

Coefficients (in Percent)	A. Basic Variables			
	Social Factors	Socio-economic Factors	Tax Return Factors	All Factors
	1	2	3	4
Auditing flag dummy			13.22	13.07
			(1.58)	(1.53)
Self-employed dummy				
Capital income dummy				
Stock income dummy				
Deduction dummy				
Audit adjustment in 2004 or 2005 dummy				
Income controls				
R-squares	1.16%	2.46%	16.15%	16.53%
Adjusted *R*-squares	1.14%	2.42%	16.14%	16.48%

[a]This table reports coefficients of the OLS regression of dummy for underreporting on various standard errors are reported. Bottom rows report the *R*-square and adjusted *R*-squares. All estimates observations). Standard errors reported in parentheses. In part A (columns 1–4), we include a basic (columns 5–8). In part B, we do not report the full set of coefficients for geographical, age, firm size from an *F*-test that the coefficients of those dummies are all equal to zero (for each category). The six South Sealand, South Denmark, Middle Jutland, and North Jutland. The four age dummies are for a firms' size: 1, 2–10, 11–100, 101–1000, and 1001+. The six income group dummies are for each of the top percentile. For income categories, self-employed dummy means nonzero self-employment income

Figure 3B.

Research question #3: How does a past audit change future tax reporting?

- The first thing that was randomized was whether an individual was audited in 2007 (for 2006 income) or not.
- How did that affect reported income in 2008 (for 2007 income)?

How does a past audit change future tax reporting?

The level of tax avoidance detected in 2007

The change in reporting from 2007 to 2008

TABLE V

EFFECTS OF RANDOMIZED PRIOR AUDITS ON YEAR TO YEAR INCOME CHANGES[a]

	Change in Reported Income (Panels A1 and B1) and Probability of Income Increase (Panels A2 and B2) from 2006 to 2007	
	Baseline Audit Adjustment	Total Income
	1	2
A. Full Sample		
A1. Amounts [difference between the 100% and the 0% audit groups]		
Net income	8491	2557
	(827)	(787)
Total tax	3295	1375
	(257)	(464)
A2. Probability of audit adjustment and income increase [difference b		
Net income	19.09	0.89
	(0.28)	(0.48)
Total tax	19.17	0.99
	(0.28)	(0.49)
Number of observations	41,571	41,571
B. Sample Limited to Those Receiving No Threat-of-Audit Letter		
B1. Amounts [difference between the 100% and the 0% audit groups]		
Net income	12,835	2904
	(1310)	(1117)
Total tax	5019	1732
	(406)	(677)

Research question #4: How does the threat of an audit change tax reporting?

0% Audit group = no audit in 2007
100% Audit group = audited in 2007 (for 2006 income)

TABLE VI

THREAT-OF-AUDIT LETTER EFFECTS ON INDIVIDUAL UPWARD ADJUSTMENTS TO REPORTED INCOME[a]

	No Letter Group	Differences Letter Group vs. No-Letter Group									50% Letter – No Letter	100% Letter – 50% Letter
	Both 0% and 100% Audit Groups	Both 0% and 100% Audit Groups			0% Audit Group Only			100% Audit Group Only			Both 0% and 100% Audit Groups	
	Baseline	Any Adjustment	Upward Adjustment	Downward Adjustment	Any Adjustment	Upward Adjustment	Downward Adjustment	Any Adjustment	Upward Adjustment	Downward Adjustment	Upward Adjustment	Upward Adjustment
	1	2	3	4	5	6	7	8	9	10	11	12
A. Average Amounts of Individual Upward Adjustments												
Net income	−497	94	84	10	74	77	−3	115	92	23	58	52
	(31)	(42)	(22)	(34)	(55)	(29)	(45)	(64)	(35)	(52)	(26)	(26)
Total tax	−322	67	50	17	57	46	11	77	54	23	32	36
	(24)	(32)	(18)	(26)	(43)	(24)	(34)	(49)	(28)	(39)	(21)	(21)
Number of obs.	9397	24,788	24,788	24,788	14,145	14,145	14,145	10,643	10,643	10,643	24,788	24,788
B. Probability of Upward Adjustments (in percent)												
Net income	13.37	1.63	1.56	0.07	2.29	1.52	0.76	0.98	1.60	−0.62	1.10	0.93
	(0.35)	(0.47)	(0.28)	(0.40)	(0.62)	(0.37)	(0.53)	(0.73)	(0.44)	(0.61)	(0.33)	(0.33)
Total tax	13.69	1.52	1.57	−0.05	2.03	1.65	0.37	1.02	1.49	−0.47	1.03	1.07
	(0.35)	(0.48)	(0.29)	(0.40)	(0.63)	(0.37)	(0.54)	(0.73)	(0.44)	(0.61)	(0.33)	(0.33)
Number of obs.	9397	24,788	24,788	24,788	14,145	14,145	14,145	10,643	10,643	10,643	24,788	24,788

Summary

1. Tax evasion is pervasive
2. Both past audits and threat of future audits decrease evasion
3. Actual audits work better than threat-of-audit letters
4. Third-party reporting very effective at curbing evasion