The Shelf Life of Incumbent Workers during Accelerating Technological Change

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Motivation

What will I do when all my new colleagues have more technological advanced skills than me?

Motivation

- Incumbent workers are more productive than graduates
- Graduates learn most advanced technology
- Incumbent workers incurring high opportunity costs for investing in new skills
  - Workers who do not spend five to ten hours a week in online learning will become obsolete with technology. Randell Stephenson, CEO at AT&T (NYT, 02/2016)

Research question

Do incumbent workers' careers respond to the market entry of technological advanced graduates in times of fundamental technological change?

- Will incumbent workers experience lower wage growth?
- Will incumbent workers leave their occupations?
- Will incumbent workers become unemployed?

Approach

- *Quasi-experimental setting* based on micro-evidence of a German manufacturing occupation.
- Mandatory training regulation.
- Supply shock of graduates with technological advanced skills (in response to fundamental technological change).

Identification strategy: Treatment

- Mandatory change in the training regulation of machining metal operators.
- **Introduction of CNC programming skills in training curriculum**
- Supply shock of machining metal operators with CNC skills in 1991

Treatment: Supply shock of workers with CNC training in 1991

What will I do when all my new colleagues can program CNC?

Treatment group: Workers "**without**" CNC training during apprenticeship

Institutional setting

- **German apprenticeship training system**
  - 2/3 of each cohort start apprenticeship training
  - Training courses in many occupations
  - Training lasts between 3 and 4 years
- **Mandatory training regulations** define the training content.
  - Externally monitored
  - Final exams by independent institutions
  - Training firms need a permission for training

Adoption of training and technology

Content of new apprenticeship training regulation

- Programming (8 weeks)
  - Writing and coding programs
  - Debugging and changing existing programs
  - Produce own products on CNC machines
- Producing goods on non-manual machines (26 weeks)

Produce own product on CNC machine during final examination

Identification strategy: Treatment vs. control group

Treatment group:

machining metal operators

- Apprenticeship graduation cohorts 1984-1989.
- CNC was "**not**" part of their mandatory training

- Similar training content
- Same firms
- Same collective bargaining agreements
- Produce same final goods

Control group:

non-machining metal mechanics

- Apprenticeship graduation cohorts 1984-1989.
- Only workers trained in the "**same**" firm as workers of the treatment group.
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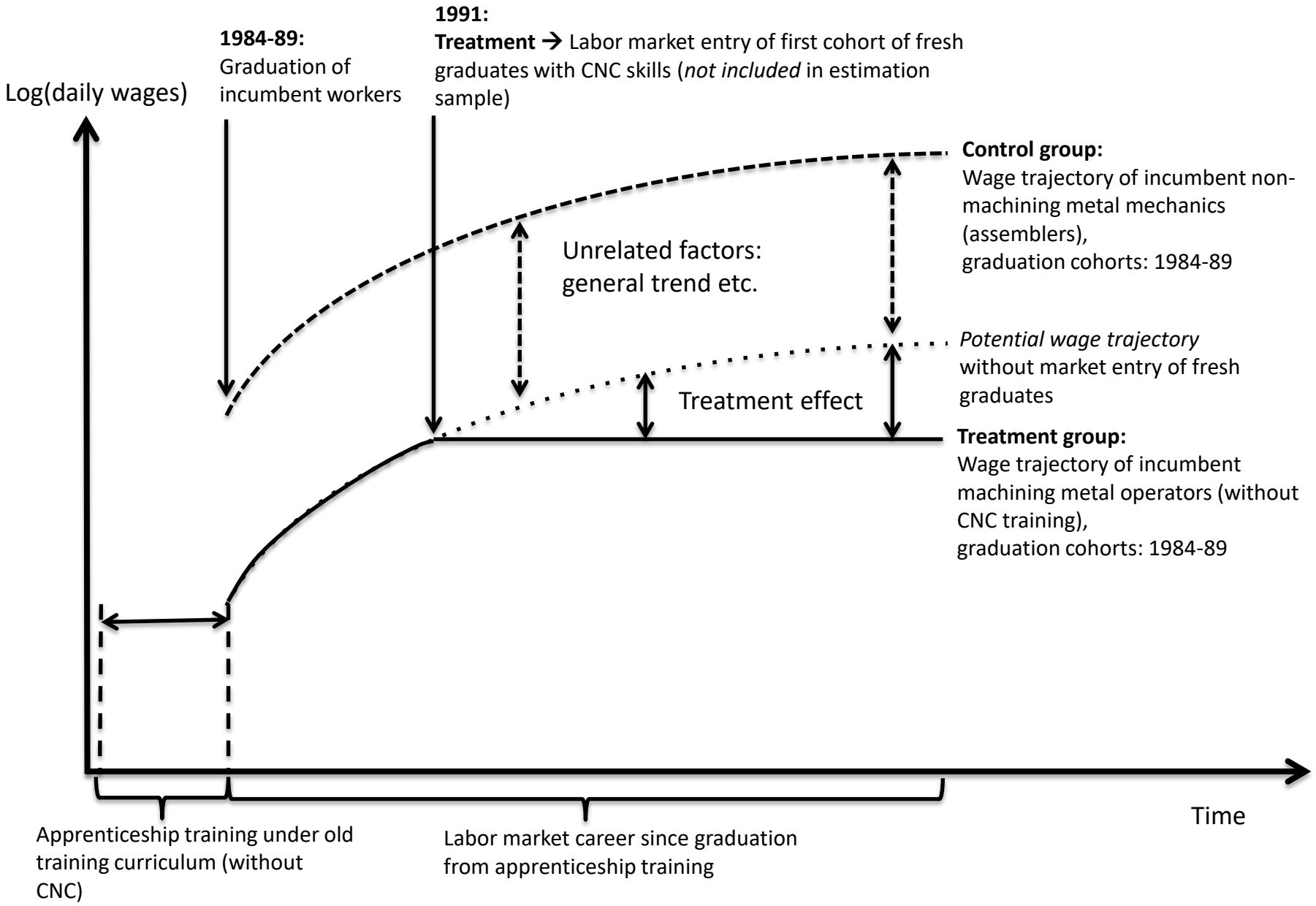
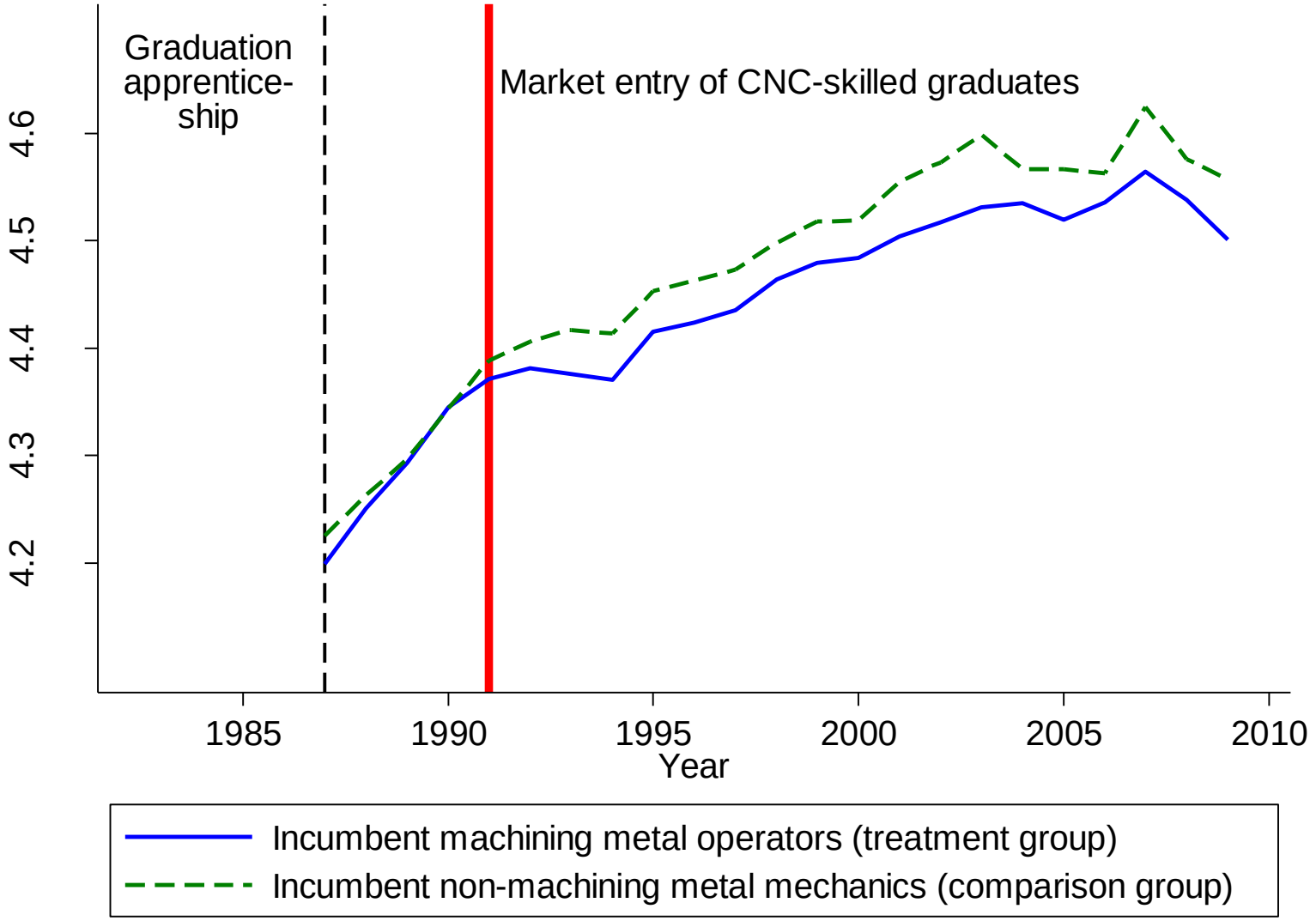


Panel data difference-in-differences

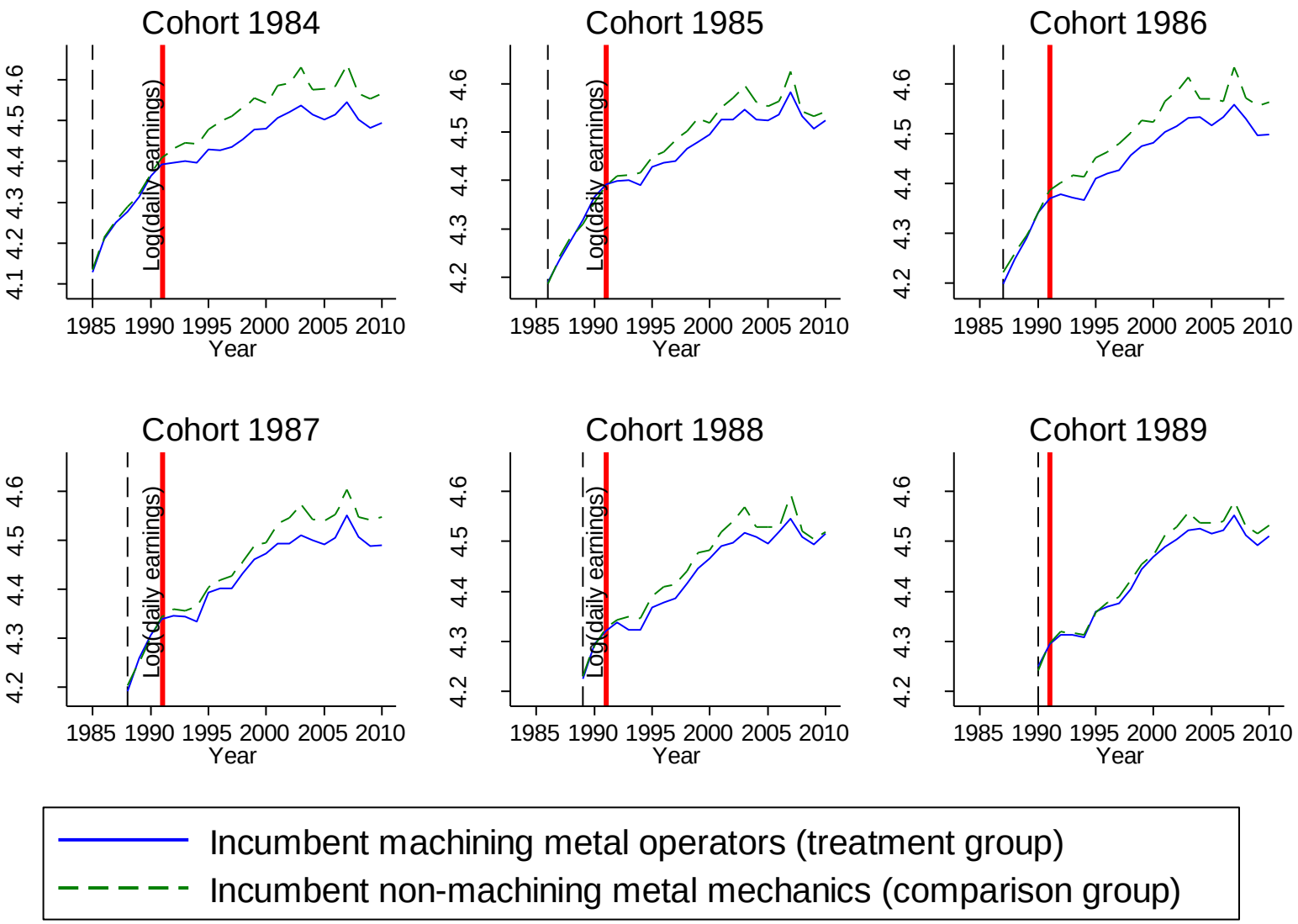
Data

- German Social Security Data (BEH)
- 80 per cent sample of machining metal operators (treatment occupation)
- 50 per cent sample of non-machining metal mechanics (control occupation)
- Apprenticeship graduates 1984 – 1989
- Follow their careers (wages, jobs) until 2010
- **Only establishment with apprentices of the treatment and control group**

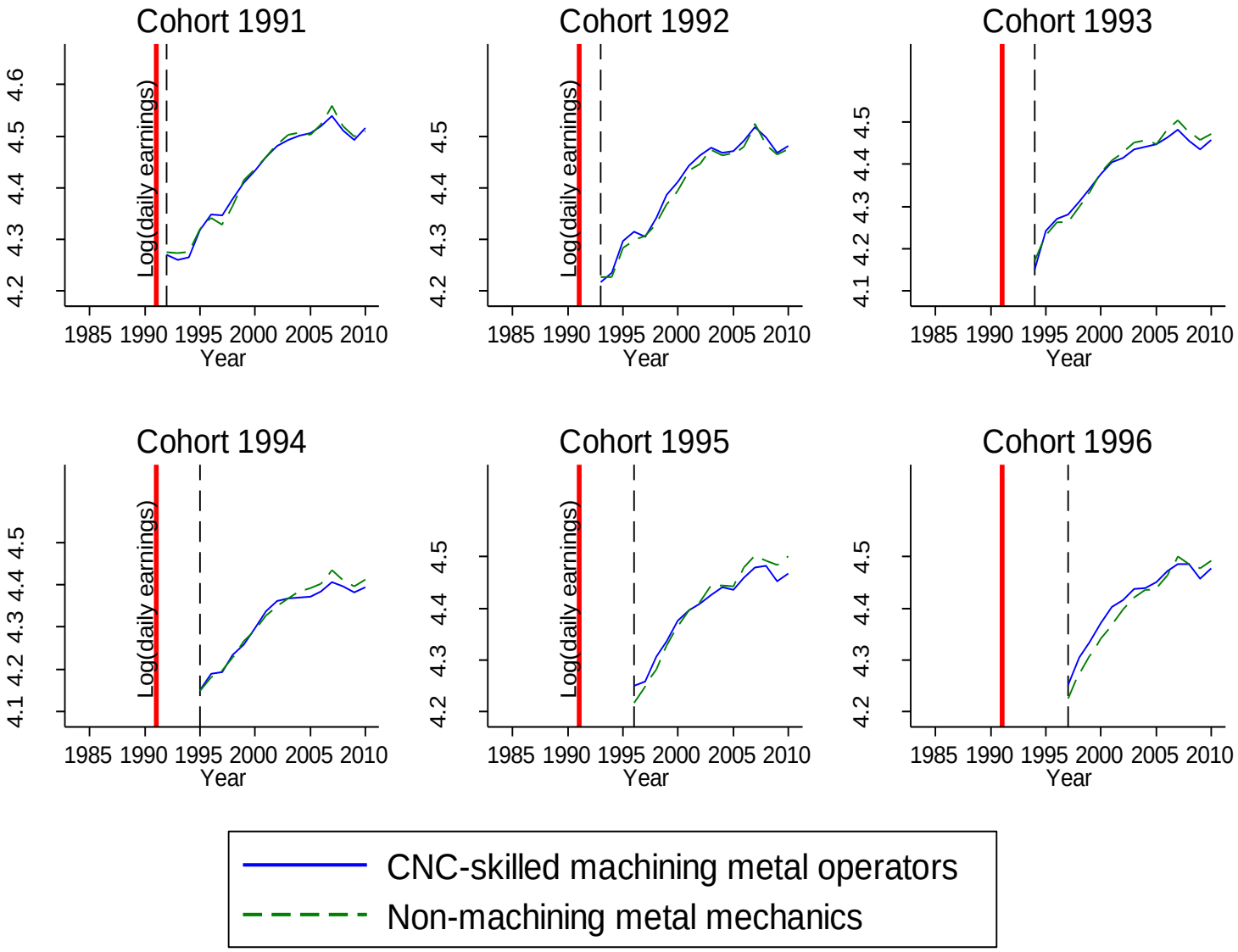
Earnings trajectory for cohort of 1986
(example)



Earnings trajectories: all cohorts



Earnings trajectories non affected cohorts
(with CNC)



Mechanisms

- Supply shock leads to a lower wage growth of incumbent workers because of
  - Forwent promotions
  - Crowding-out of occupation but remained in firm/sector
  - Short period of unemployment
  - Crowding-out of industry, particularly switch to low-level service jobs

Summary and conclusion:

Main results:

If the supply of workers with CNC training increases (treatment), workers without CNC apprenticeship training (treatment group)…

- … have lower earnings growth.→ Total earnings loss: 0.70 years of earnings in 25 years!
- … forwent crucial promotions

- Incumbent workers careers respond to increasing supply of modern skills → Irrespective of institutional changes and macro-economic conditions

Implications

- Even young workers can be affected by fundamental technological change
- Young workers are more likely to compete with graduates for similar jobs but seem to be at a disadvantage to update their skills, possible reasons:
  - High opportunity costs
  - Credit constraints
  - Employer engagement in technological driven training crucial
  - Restricted access to public training courses

Sensitivity analysis

Adoption of training and technology

Graduation cohort	Training curriculum	
	without CNC (old)	With CNC (new)
1990	55 %	45 %
1991	11%	89%
1992	5%	95%

Adoption of training and technology

	Year of first adoption	Largest order	„In-house“ programming
France	1987.5	1989.2	7.48%
UK	1981.5	1984.2	7.83%
Germany	1987.6	1987.6	66.0%

Source: Backes-Gellner (1996)

Descriptive statistics for observations

Table 2: Number of observations for treatment and control group

	Machining metal operators (TG)		Non-machining metal mechanics (CT)	
	80% sample	Estimation sample	50% sample	Estimation sample
1984	2616	1654	7897	2001
1985	2471	1505	8138	1804
1986	2407	1452	8840	1741
1987	2545	1484	9038	1777
1988	2623	1454	8964	1807
1989	2960	1526	8988	1716
Total	15622	9075	51865	10846

Notes: The estimation is restricted to apprentices who have graduates in the same establishments. Source BEH 1984-2010.

Descriptive statistics, main variables

Table 3: Baseline characteristics of treatment and control group before market entry of CNC-skilled graduates

	Machining metal operators	Non-machining metal mechanics	Difference
Female	0.047	0.014	-0.032***
Foreigner	0.090	0.064	-0.025***
Age	20.980	21.525	0.546***

Notes: Only the first observation per individual after graduation before treatment. * p<0.1; ** p<0.05; *** p<0.01.
Source BEH 1984-2010

Unconditional earnings differences

TABLE 4:
LOG DAILY WAGE DIFFERENCES BETWEEN TREATMENT AND COMPARISON GROUP

	All	1984	1985	1986	1987	1988	1989
			Before market entry of CNC-skilled graduates				
Non-machining mechanics	4.272	4.273	4.279	4.284	4.255	4.261	4.245
Machining operators (difference)	-0.005*	-0.010*	0.001	-0.011*	-0.000	-0.002	0.007
			After market entry of CNC-skilled graduates				
Non-machining mechanics	4.492	4.532	4.506	4.513	4.476	4.465	4.455
Machining operators (difference)	-0.032***	-0.062***	-0.026***	-0.042***	-0.024***	-0.019***	-0.012*
				After - Before			
Unadjusted diff.-in-diff. estimator	-0.026***	-0.052***	-0.026***	-0.030***	-0.023***	-0.016**	-0.017**
Number of observations	379717	76548	67132	61979	60705	58150	55203

Notes. The Table presents descriptive statistics for average wage differences between individuals of the treatment and comparison group before and after the supply shock of CNC-skilled graduates. Daily earnings are deflated with the consumer price index and measured in Euros of 2010. Standard errors are clustered at the individual level. * $p<0.1$; ** $p<0.05$; *** $p<0.01$. Source BEH 1984-2010.

Earnings: main estimation results

TABLE 5:
EFFECT OF CNC-SKILLED GRADUATES ON INCUMBENT WORKERS' DAILY WAGES

	No controls	Full controls	Individual Fixed effects
Machining metal operator#	-0.004*	-0.001	—
	(0.003)	(0.003)	
Treatment effect	-0.029***	-0.033***	-0.036***
	(0.003)	(0.003)	(0.003)
Individual controls	No	Yes	Yes
Cohort-by-training-firm f.e.	No	Yes	No
Individual f.e.	No	No	Yes
Cohort f.e.	Yes	Yes	No
Time f.e.	Yes	Yes	Yes
R-square	0.137	0.274	0.672
Number of observations	379717	379717	379717

Notes. The Table presents the results from regression equation (1). The dependent variable are log daily wages that are deflated by the CPI and measured in EUROS of 2010. The standard errors (in parenthesis) are clustered on the individual level. Individual control variables contain four age categories, a dummy for being female, and a dummy for holding a foreign nationality. Column three only contains the age categories as individual controls, because the remainder individual variables are time-constant. # dummy for training occupation * $p<0.1$; *** $p<0.01$; Source: BEH 1984-2010.

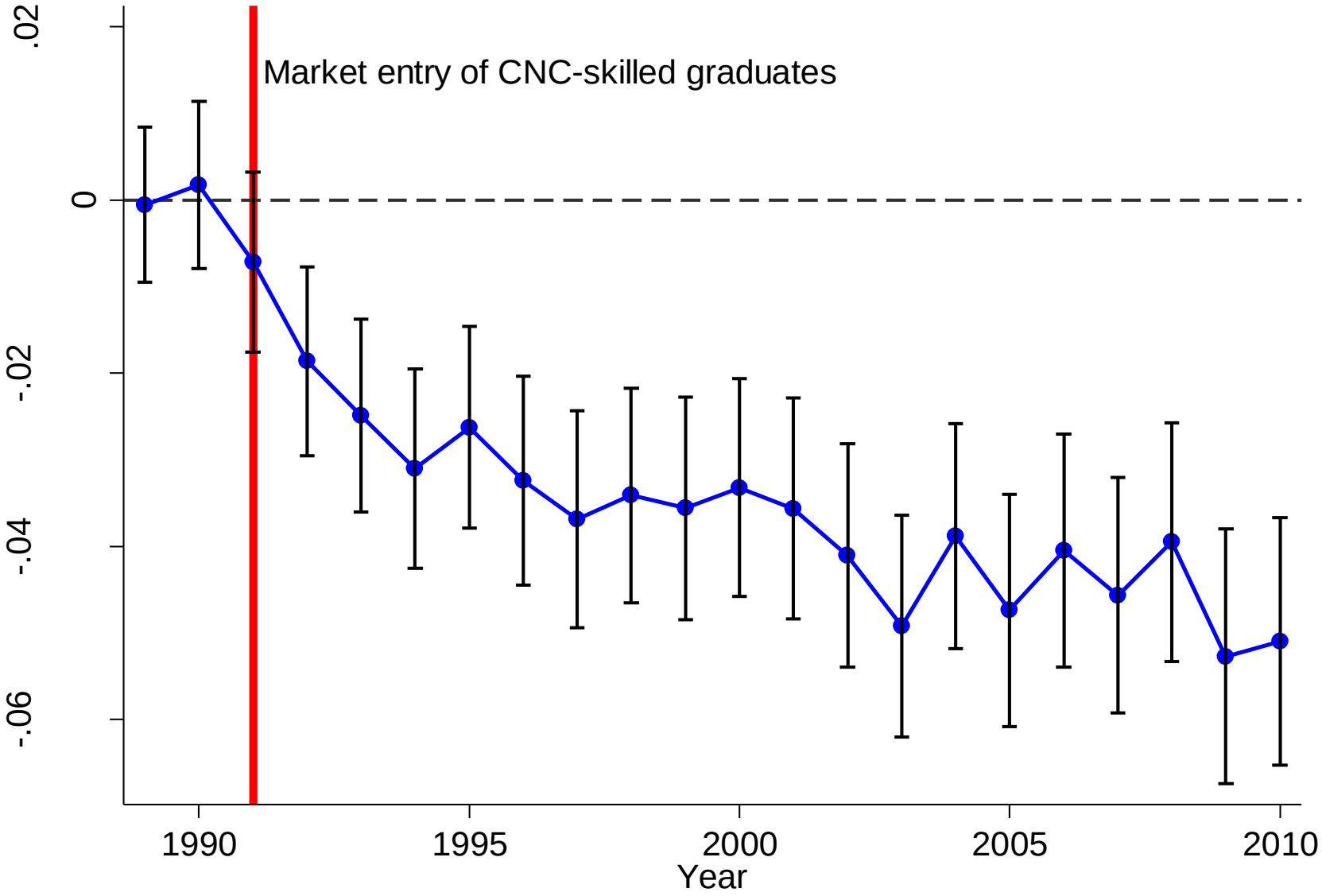
Earnings by cohort

TABLE 6:
EFFECT OF CNC-SKILLED GRADUATES ON INCUMBENT WORKERS' DAILY WAGES (BY GRADUATION COHORT)

	1984	1985	1986	1987	1988	1989
Treatment effect	-0.057***	-0.034***	-0.030***	-0.027***	-0.020***	-0.024***
	(0.007)	(0.008)	(0.008)	(0.007)	(0.008)	(0.008)
Individual f.e.	Yes	Yes	Yes	Yes	Yes	Yes
Individual controls	Yes	Yes	Yes	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes	Yes	Yes	Yes
R-square	0.688	0.674	0.670	0.677	0.665	0.656
Number of observations	76548	67132	61979	60705	58150	55203

Notes. The Table presents the results from regression equation (1), separately for each graduation cohort. The dependent variable are log daily wages that are deflated by the CPI and measured in EUROS of 2010. The standard errors (in parenthesis) are clustered at the individual level. Individual control variables contain four age categories. *** p<0.01; Source: BEH 1984-2010.

Earnings: Long-term effects



Unemployment

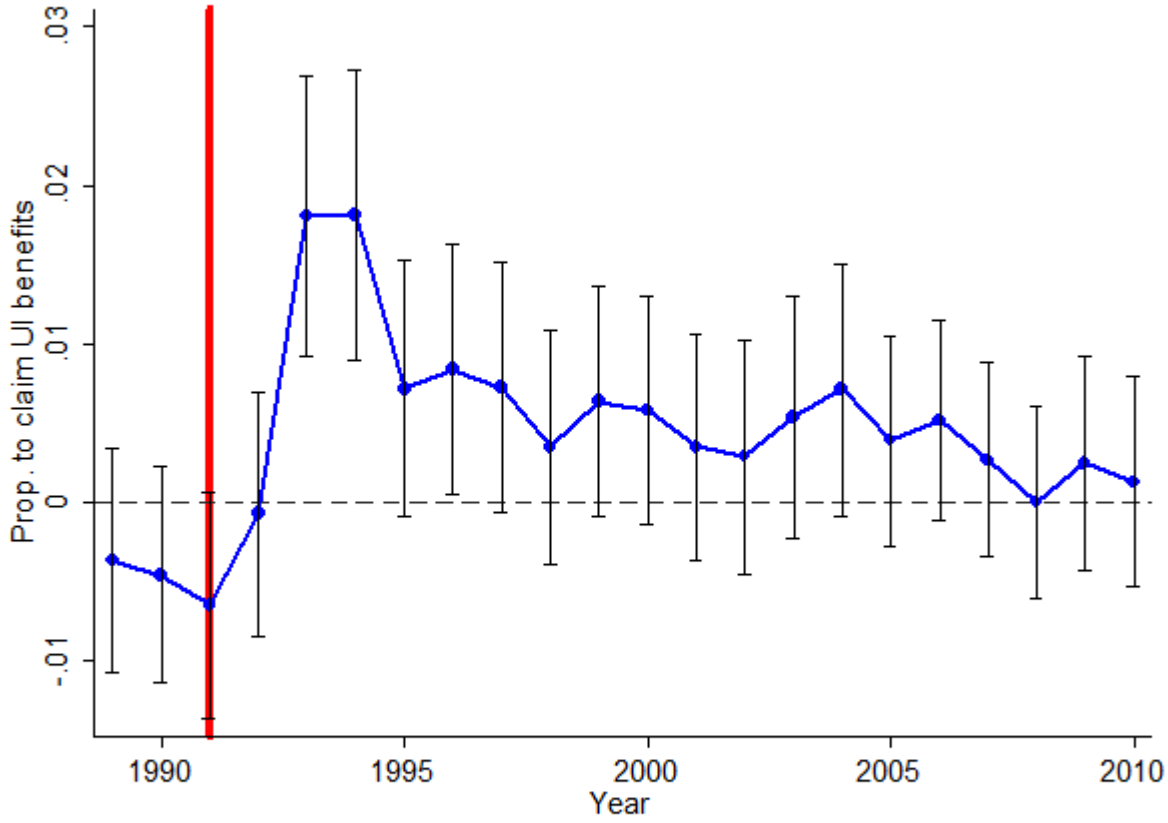


FIGURE 8:

Long-term effect of supply shock on unemplyoment.

Job changes

TABLE 7:
EFFECT OF CNC-SKILLED GRADUATES ON INCUMBENT WORKERS' PROBABILITY TO REMAIN IN TRAINING OCCUPATION

	Occ. stayer	Occ. stayer within establishment
Treatment effect	-0.104***	-0.077***
	(0.006)	(0.008)
Individual controls	Yes	Yes
Individual f.e.	Yes	Yes
Time f.e.	Yes	Yes
R-square	0.680	0.789
Number of observations	379717	140894

Notes. The Table presents the results of a version of regression equation (1) for which we have replaced the dependent variable by a dummy indicating whether a worker remains in his or her training occupation or not. The first column presents a specification that relies on the entire sample. The second column presents a specification that only relies on individuals who have remained in their training establishment. The standard errors (in parenthesis) are clustered at the individual level. Individual control variables contain four age categories. *** $p<0.01$; Source: BEH 1984-2010.

Industry changer

TABLE 8:
EFFECT OF CNC-SKILLED GRADUATES ON INCUMBENT WORKERS' PROBABILITY TO REMAIN IN METAL WORKING SECTOR

	Stay in metal ind.	Move to service sector	
		Low wage	High wage
Treatment effect	-0.037***	0.020***	0.001
	(0.006)	(0.004)	(0.002)
Individual controls	Yes	Yes	Yes
Individual f.e.	Yes	Yes	Yes
Time f.e.	Yes	Yes	Yes
R-square	0.658	0.624	0.541
Number of observations	379717	379717	379717

Notes. The Table presents the results of a version of regression equation (1) for which we have replaced the dependent variable by a dummy indicating whether a worker remains in the metal working industry (column one), move to the low wage service sector (column two), or moves to the high wage service sector (column three). Low wage service jobs include jobs, such as, for example, waiters, office clerks, cleaning and sales personnel. High wage service jobs include, for example, teachers, lawyers, and physicians. The first column presents a specification that relies on the entire sample. The second column presents a specification that only relies on individuals who have remained in their training establishment. The standard errors (in parenthesis) are clustered at the individual level. Individual control variables contain four age categories. *** $p<0.01$; Source: BEH 1984-2010.

Promotions

TABLE 9:
EFFECT OF CNC-SKILLED GRADUATES ON INCUMBENT WORKERS' PROBABILITY TO BECOME A MASTER/TECHNICIAN.

	Master craftsman/technician
Treatment effect	-0.045***
	(0.004)
Individual f.e.	Yes
Time f.e.	Yes
R-square	0.576
Number of observations	379717

Notes. The Table presents the results of a version of regression equation (1) for which we have replaced the dependent variable by a dummy indicating whether a worker has become a master craftsman or technician. The first column presents a specification that relies on the entire sample. The second column presents a specification that only relies on individuals who have remained in their training establishment. The standard errors (in parenthesis) are clustered at the individual level. Individual control variables contain four age categories. *** p<0.01; Source: BEH 1984-2010.

Price and employment effect

TABLE 10:
DISCOUNTED PRESENT VALUE OF TOTAL EARNING EFFECT

	Total effect (excl. zeros)	Total effect (incl. zeros)	Price effect
Observation period	-0.684	-0.707	-0.517
Lifetime (extrapolated)	-1.157	-1.195	-0.847
Number of obs.(1st stage)	379,717		379,717

Notes. The Table presents discounted present values (DPV) of incumbent workers' total earnings losses. We have calculated the DPVs by summing up the earnings of all employment spells in a given year and use this measure as independent variable of regression equation (2) to calculate $\hat{\delta}_k$ in a first step. In a second step, we calculate the DPVs according to equation (3). Row one presents results for the entire observation period until 2010. Row two extrapolates the effects until 2031. To predict unobserved future earnings losses, we have used a cubic function of time in a regression on estimated earnings losses from equation (2). Column one includes only positive wage observations, column one replace missing wage observations by zeros, and column three estimates the DPVs under the assumption that each worker had been employed for each day throughout the observation period.

Contribution to literature

- Literature on skill-biased technological change
  - Autor et al. 1998, 2003, 2008
- Literature on depreciation of human capital
  - Ben-Porath 1967; Rosen, 1975; Neuman/Weiss, 1995
- Literature on skill supply and returns to education
  - Card Lemiuex, 2001; Bowlus and Robinson, 2014

Alternative control group

Table 11: Alternative control group of non-machining mechanics in non-CNC firms

	No-CNC firms	All
Treatment effect	-0.040***	-0.031***
	(0.003)	(0.002)
Individual controls	Yes	Yes
Individual fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
R-square	0.674	0.679
Number of observations	831373	1145140

Notes: Dependent variable: log real daily earnings, OLS regressions with standard errors clustered on training establishment, standard errors in parenthesis; Control variables: age, female, foreigner, training establishment fixed effects, year fixed effects, and cohort fixed effects; # training occupation * p<0.1; ** p<0.05; *** p<0.01; Source: BEH 1984-2010.

Sensitivity analysis

Table 13: Further robustness checks

	Trends	Collapse
Treatment effect	-0.050***	-0.038***
	(0.002)	(0.007)
Individual controls		
Individual fixed effects		
Year fixed effects		
R-square	0.669	0.307
Number of observations	379717	39824

Notes: Dependent variable: log real daily earnings, OLS regressions with standard errors clustered on training establishment, standard errors in parenthesis; Control variables: age, female, foreigner, training establishment fixed effects, year fixed effects, and cohort fixed effects; # training occupation * p<0.1; ** p<0.05; *** p<0.01; Source: BEH 1984-2010.

Identification assumptions:

- **Common trends assumption:**
  - Trained in the same firms
  - Similar training programs
  - Same unions
  - Same macro economic conditions

Identification assumptions

- **No effect on pre-treatment population (NEPT):**
- School leavers may anticipate the change in training curriculum and the more able ones postpone their training
  - School leavers are 16 and face difficulties to quantify the magnitude and meaning of technology.
  - First cohorts start their training in 1981.
- Firms anticipate change in the training curriculum and start training their workers earlier
  - Lower bound estimate

Identification assumptions

- **Stable unit treatment value assumption (SUTVA):**
- Substitution vs scale effects
  - Constant returns to scale
- Alternative control group