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Using distribution regression difference-in-differences to evaluate the effects of a minimum wage introduction on the distribution of hourly wages and hours worked

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Motivation

- Stark increase in wage inequality in Germany from mid-1990s onwards (e.g., Dustmann et al., 2009, Biewen/Seckler, 2019)
- Federal government introduced **national statutory minimum wage** in 2015 to counter this development
- Implied a considerable 'bite' (11% of workforce affected)
- Inequality increase indeed stopped in 2015 . . .
- But to what extent was minimum wage introduction really responsible?
- In addition, we study impact on hours worked

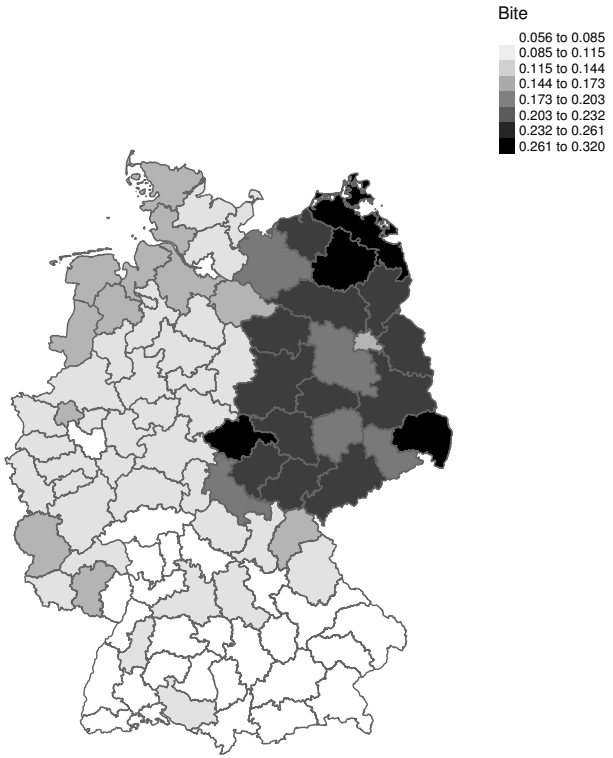
This paper

1) Innovative combination of two large-scale/administrative data bases for hourly wages and hours worked in Germany
   - **GSES** (2014/18) + **IAB-DGUV** (pre-trend analysis 2011-2014)
   - Only large-scale data sets for Germany comprising information on hourly wages and hours worked
2) **Full distributional analysis** of hourly wages and hours distribution (spill-over effects, inequality measures)
3) Straightforward, transparent methodology for evaluating distributional effects of a minimum wage introduction
   - **Distribution Regression Difference-in-Differences**
   - Use of alternative bite measures

Data

- **German Structure of Earnings Survey (GSES)**, two most recent waves (2014, 2018); only available on-site
  - Linked employer-employee data, provided by Statistical Offices of the German federal states
  - High **data quality**: Legal obligation to participate, very low non-response rates; ca. 1 million observations per wave
  - Highly reliable information on worker- and firm level characteristics (data from firms' internal accounting systems)
- **Pre-trend analysis:** administrative data from the *Deutsche Gesetzliche Unfallversicherung (DGUV)* 2011-2014

Bite measure 1 – German Planning Regions



- **German Planning Regions (ROR)**
- Borders of high bite in 2014 pretty much separates East and West Germany along former borders
- Most affected areas in the East, least affected in the South

Comparison of bite measures

	German Planning Regions	Occupations+East/West	Industry+East/West
Descriptives			
# groups	96	72	152
Minimum bite	0.057	0.010	0.004
Maximum bite	0.320	0.637	0.761
Average bite	0.130	0.130	0.130
Standard deviation	0.062	0.130	0.139

Source: GSES 2014, own calculations.

Econometric methods

- **Distribution Regression DiD** (inspiration: Dube, 2019)
- DiD regression formulation for the (conditional) cdf of wages/hours worked at threshold z

$$1[y_{igt} \leq z] = \alpha_z + D_g\,\gamma_z + \lambda_z \times D_t + \beta_z(Bite_g \times D_t) + X_{igt}\theta_z + (X_{igt} \times D_t)\eta_z + \varepsilon_{igt},$$

  where $1[y_{igt} \leq z]$ is a binary indicator variable of being below z
- Consider large set of thresholds, e.g. for hourly wages: $\{3.49, 4.49, \ldots, 49.49$ €/hour $\}$ (similarly for hours bins)
- Viewing problem as distribution regression naturally leads to recent analysis of DiD by **Roth and Sant'Anna (2021)**!

Distributional effect of the minimum wage

- Models the **conditional cdf** $F(z|Bite_g, D_g, D_t, X_{igt})$ (Chernozhukov et al., 2013)

- **Counterfactual cdf** in t=1: subtract effect due to min wage

$$F^{cf}(z|D_g, D_1, X_{ig1}) = F(z|Bite_g, D_g, D_1, X_{ig1}) - \beta_z \times Bite_g$$

- **Unconditional factual and counterfactual cdf** in the post-treatment period (LIE):

$$F(z|D_t = 1) = \int F(z|Bite_g, D_g, D_t, X_{igt})\, dF(Bite_g, D_g, X_{igt}|D_t = 1)$$

$$F^{cf}(z|D_t = 1) = \int \left[F(z|Bite_g, D_g, D_t, X_{igt}) - \beta_z Bite_g\right]\, dF(Bite_g, D_g, X_{igt}|D_t = 1)$$

Pre-trend analysis

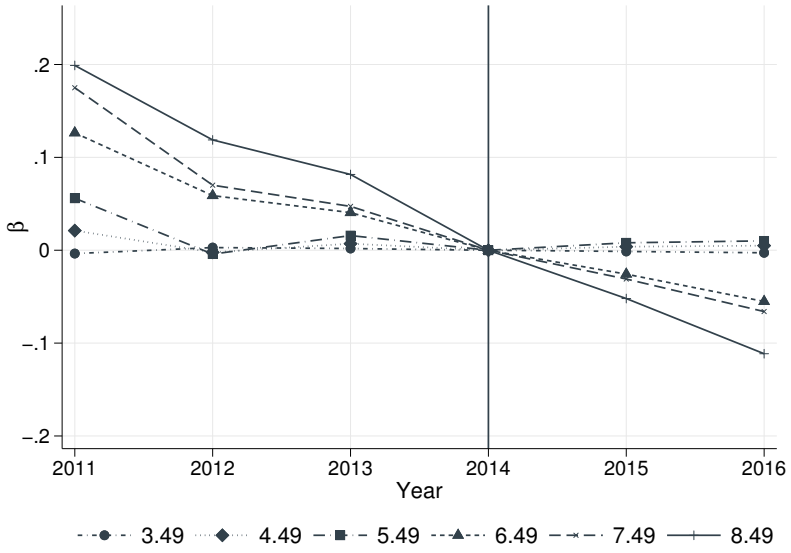
- What if distributional mass at low wages already began to vanish in high-bite groups before introduction?
- Estimate/extrapolate differential pre-trends using *DGUV-IAB* data from pre-treatment periods 2011 to 2014

$$1[y_{igt} \leq z] = \alpha_z + \sum_{t=2011}^{2014} \lambda_z^t \times 1[year = t] + D_g\gamma_z + X_{igt}\theta_z + \sum_{t=2011}^{2014} (X_{igt} \times D_t)\eta_z^t + \sum_{t=2011}^{2014} \beta_z^t(Bite_g \times 1[year = t]) + \varepsilon_{igt},$$

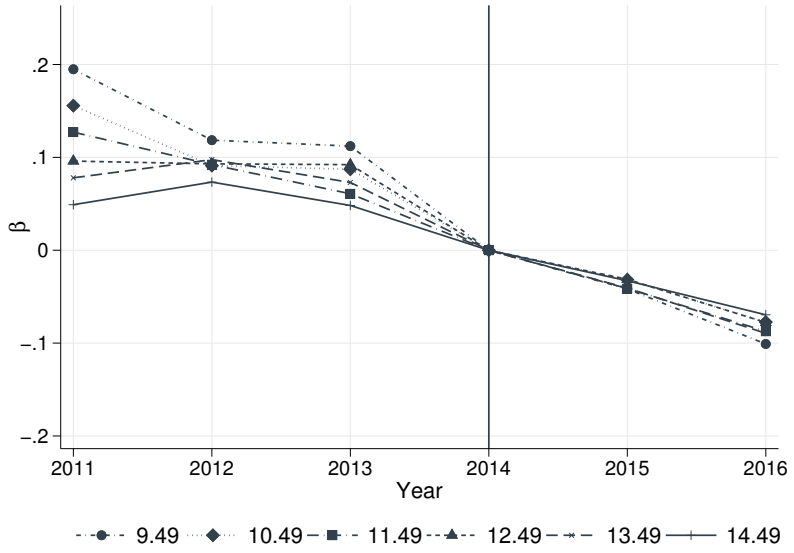
- **Pre-trend correction** in t=1 using extrapolated trend $\bar{\delta}_z$:

$$F^{cf}(z|D_g, D_1, X_{ig1}) = F(z|Bite_g, D_g, D_1, X_{ig1}) - (\beta_z - \bar{\delta}_z) \times Bite_g$$

Pre-treatment trends do exist (Example: Bite 1)



(a) Lower thresholds (3.49 to 8.49)



(b) Upper thresholds (9.49 to 14.49)

Notes: Estimates for the treatment effect, $\hat{\beta}_z^t$, in the pre-treatment periods 2011-2014 for bins below and above the minimum wage level. Reference year = 2014.

▸ p-values

Distributional effect of the minimum wage

- Compute **wage bins** from cdfs:

$$f_{j,t} = F(z_j|D_t) - F(z_{j-1}|D_t),$$

$$f^{cf}_{j,1} = F^{cf}(z_j|D_t = 1) - F^{cf}(z_{j-1}|D_t = 1),$$

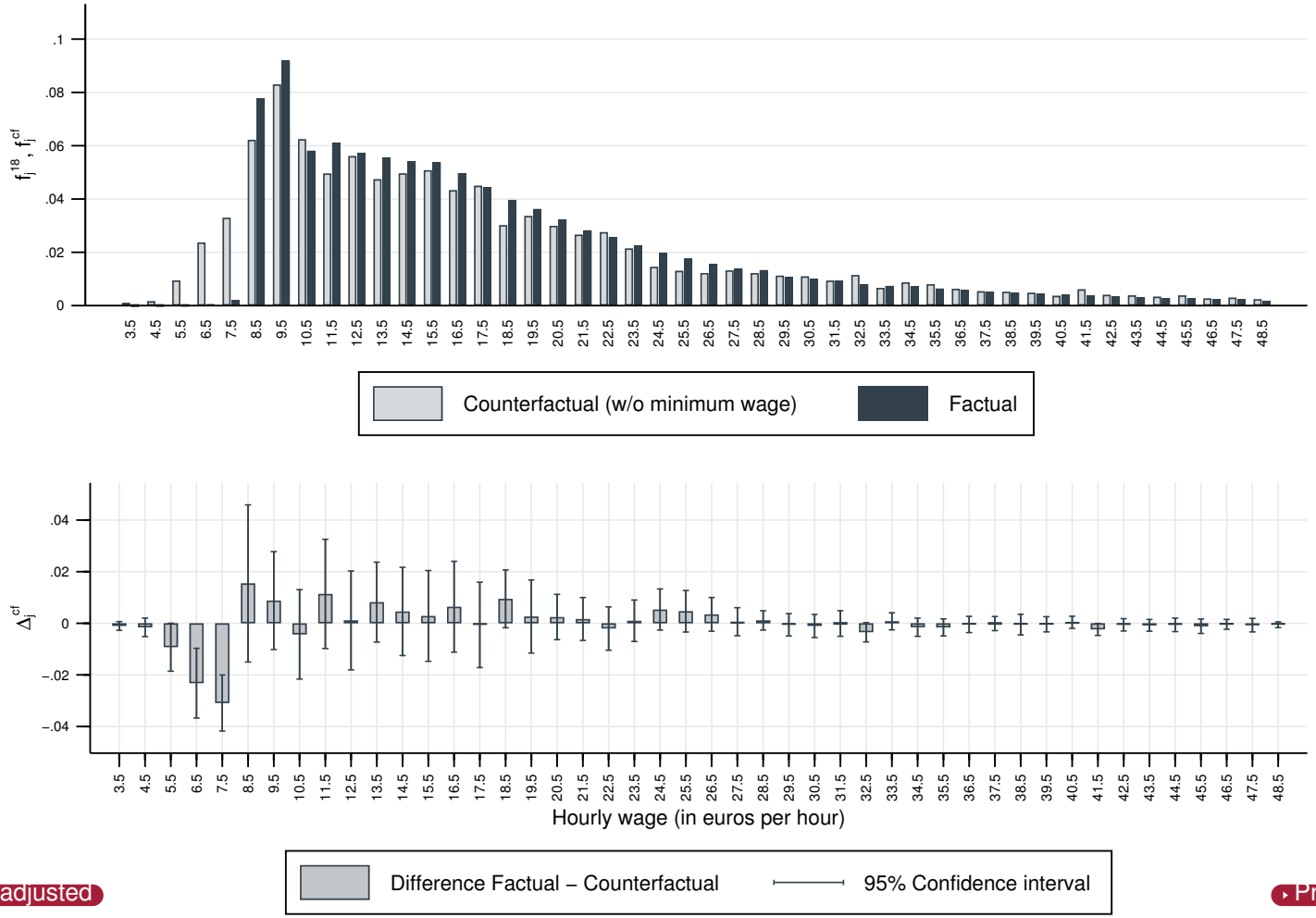
- Compute **distributional statistics** $v(\cdot)$ from grouped data (Tillé and Langel, 2012); c.p. effect of the minimum wage:

$$\Delta^{cf}_j := f_{j,1} - f^{cf}_{j,1}, \quad j = 1, \ldots, J$$

$$\Delta^{cf}(v(\cdot)) := v(F(z|D_t = 1)) - v(F^{cf}(z|D_t = 1))$$

- **Bootstrap standard errors** clustered at bite group (= treatment level)

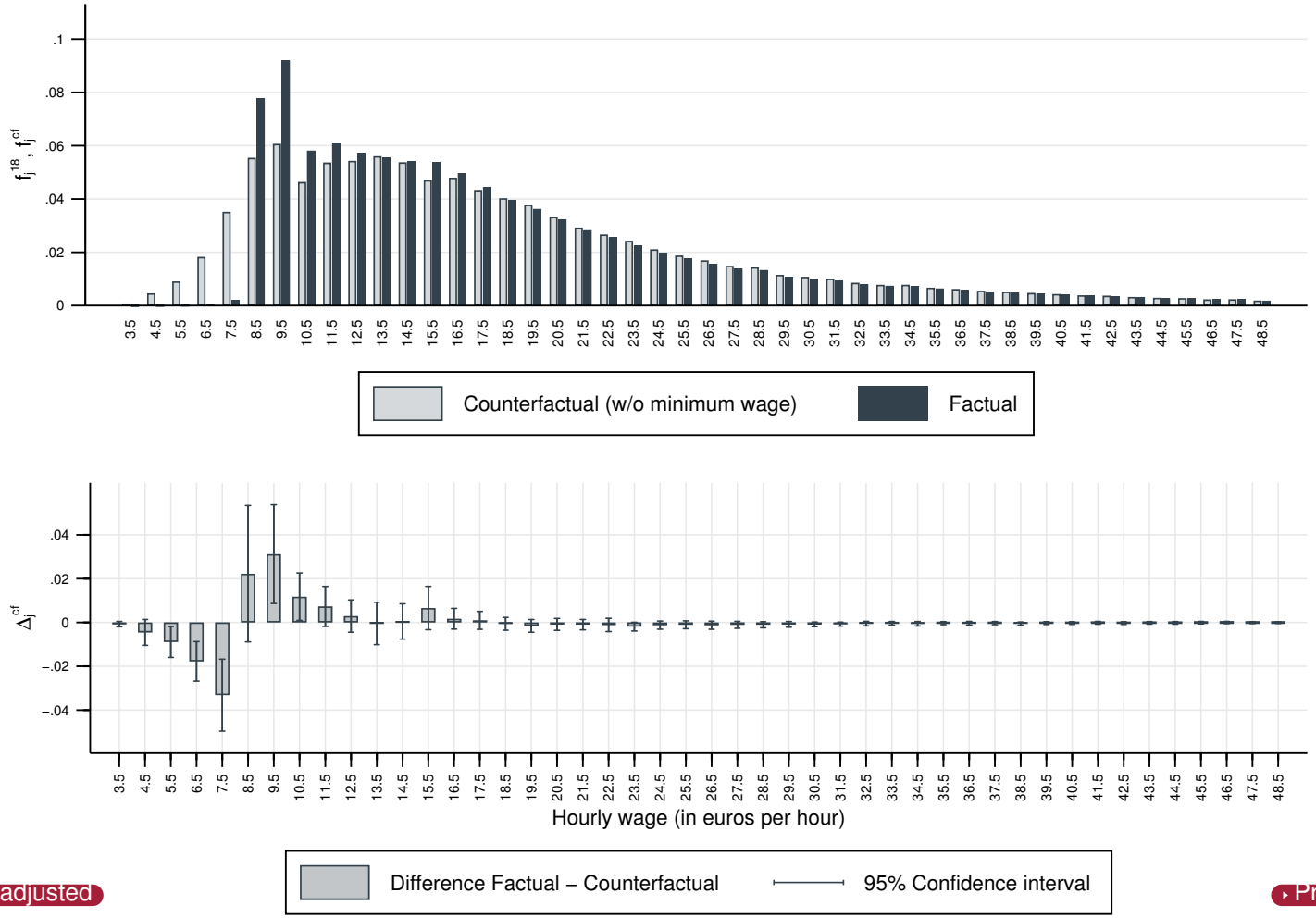
Hourly wages: bite measure 1 (regions)



Trend adjusted

Pre-trend

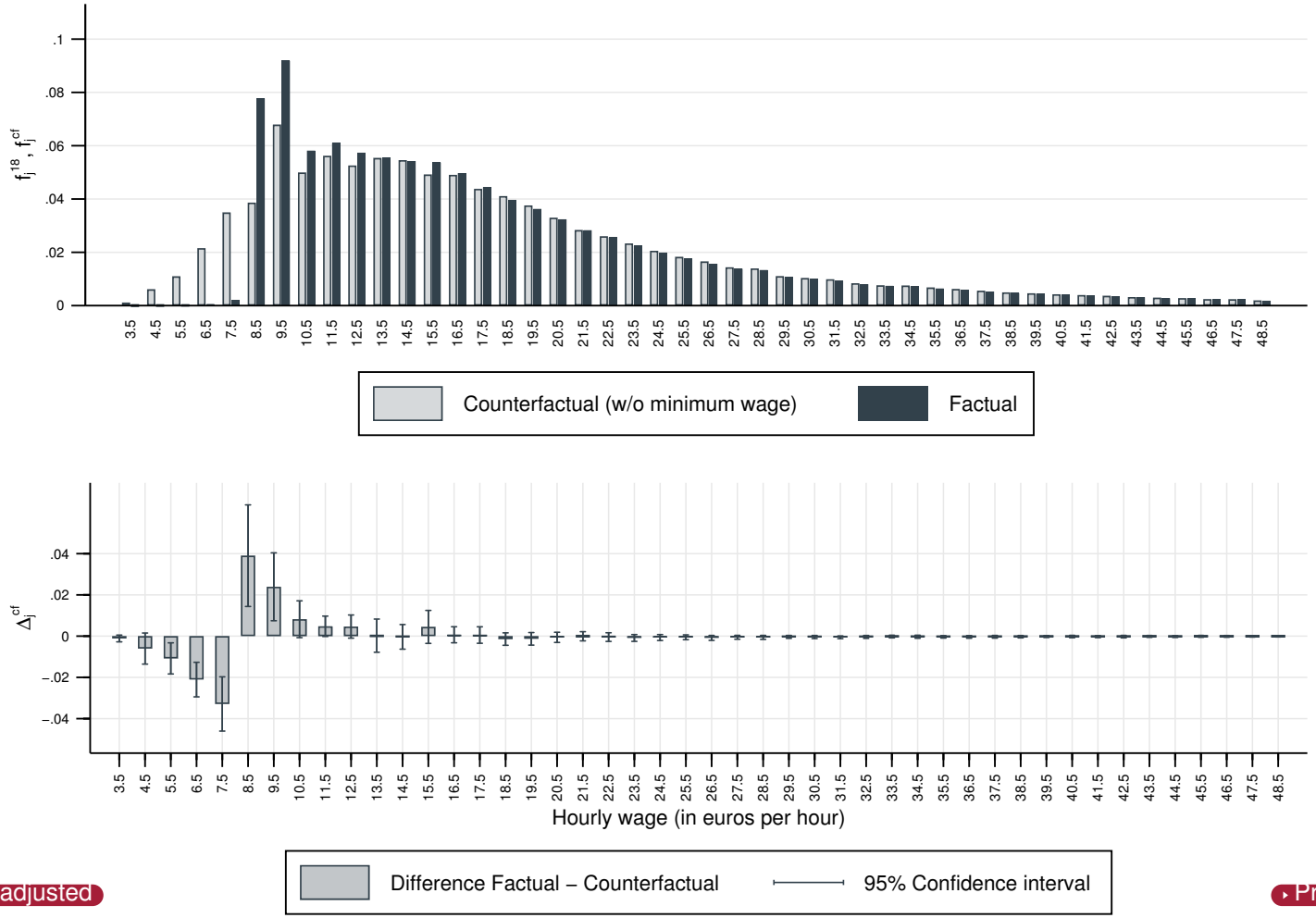
Hourly wages: bite measure 2 (occupations + East/West)



Trend adjusted

Pre-trend

Hourly wages: bite measure 3 (industries + East/West)



Trend adjusted

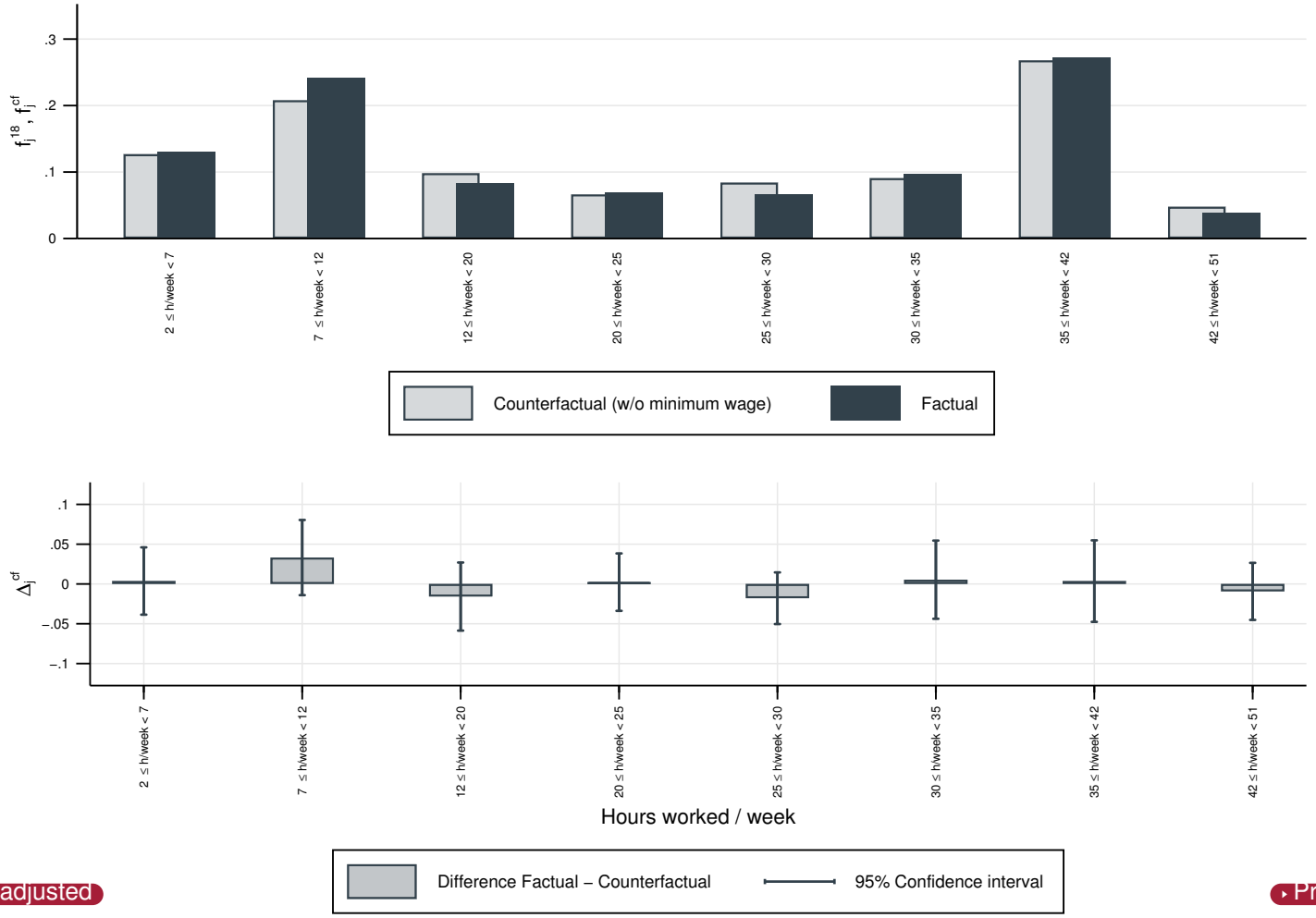
Pre-trend

Factual vs. counterfactual inequality measures: hourly wages

	2014	2018	CF^{region}			CF^{occup}			CF^{ind}		
			No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$	No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$	No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$
Statistic											
Gini	0.260	0.240	0.264	0.262	0.260	0.253	0.251	0.249	0.253	0.250	0.248
	(0.002)	(0.002)	(0.006)	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)	(0.006)	(0.007)	(0.007)
Q90	29.592	32.374	34.083	34.083	34.083	32.850	32.850	32.850	32.882	32.882	32.882
	(0.831)	(0.882)	(1.315)	(1.346)	(1.45)	(1.726)	(1.742)	(1.802)	(1.548)	(1.563)	(1.603)
Q50	14.698	16.264	15.901	15.999	16.106	16.585	16.494	16.416	16.499	16.407	16.327
	(0.242)	(0.235)	(0.46)	(0.483)	(0.524)	(0.838)	(0.839)	(0.846)	(0.674)	(0.679)	(0.679)
Q10	8.464	9.703	8.993	9.087	9.206	9.063	9.161	9.253	9.132	9.304	9.458
	(0.100)	(0.039)	(0.199)	(0.187)	(0.192)	(0.328)	(0.331)	(0.338)	(0.326)	(0.309)	(0.299)
Q90/Q10	3.496	3.337	3.790	3.751	3.702	3.624	3.586	3.550	3.601	3.534	3.477
	(0.074)	(0.080)	(0.146)	(0.149)	(0.160)	(0.159)	(0.163)	(0.171)	(0.154)	(0.153)	(0.154)
Q90/Q50	2.013	1.991	2.143	2.130	2.116	1.981	1.992	2.001	1.993	2.004	2.014
	(0.030)	(0.030)	(0.111)	(0.115)	(0.124)	(0.068)	(0.070)	(0.074)	(0.063)	(0.064)	(0.067)
Q50/Q10	1.737	1.676	1.768	1.761	1.749	1.830	1.800	1.774	1.807	1.763	1.726
	(0.013)	(0.018)	(0.052)	(0.051)	(0.052)	(0.067)	(0.065)	(0.063)	(0.067)	(0.064)	(0.062)

▸ Differences / stat. sign.

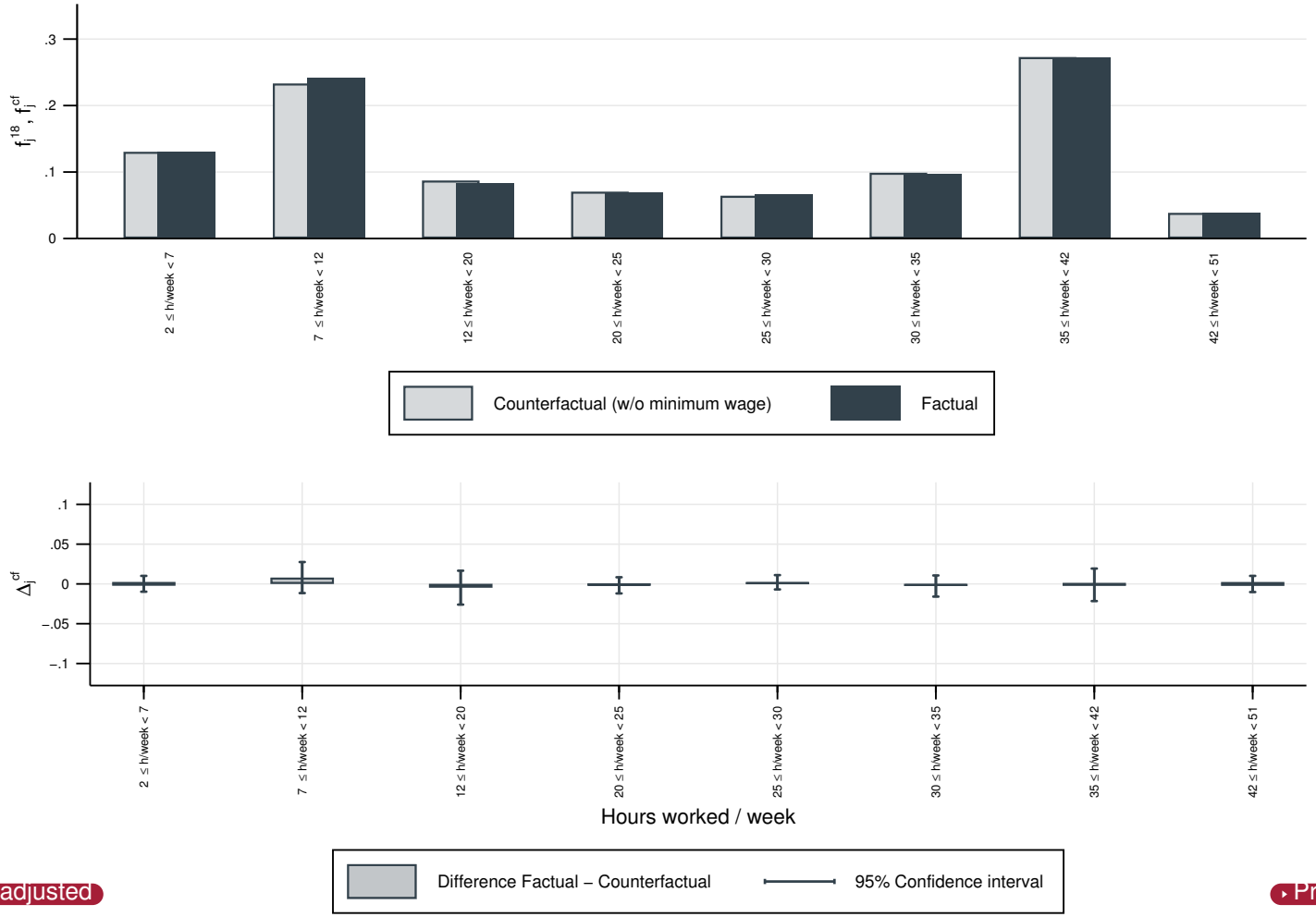
Hours worked: bite 1 (regions) (worker group: 0-12 €/hour)



Trend adjusted

Pre-trend

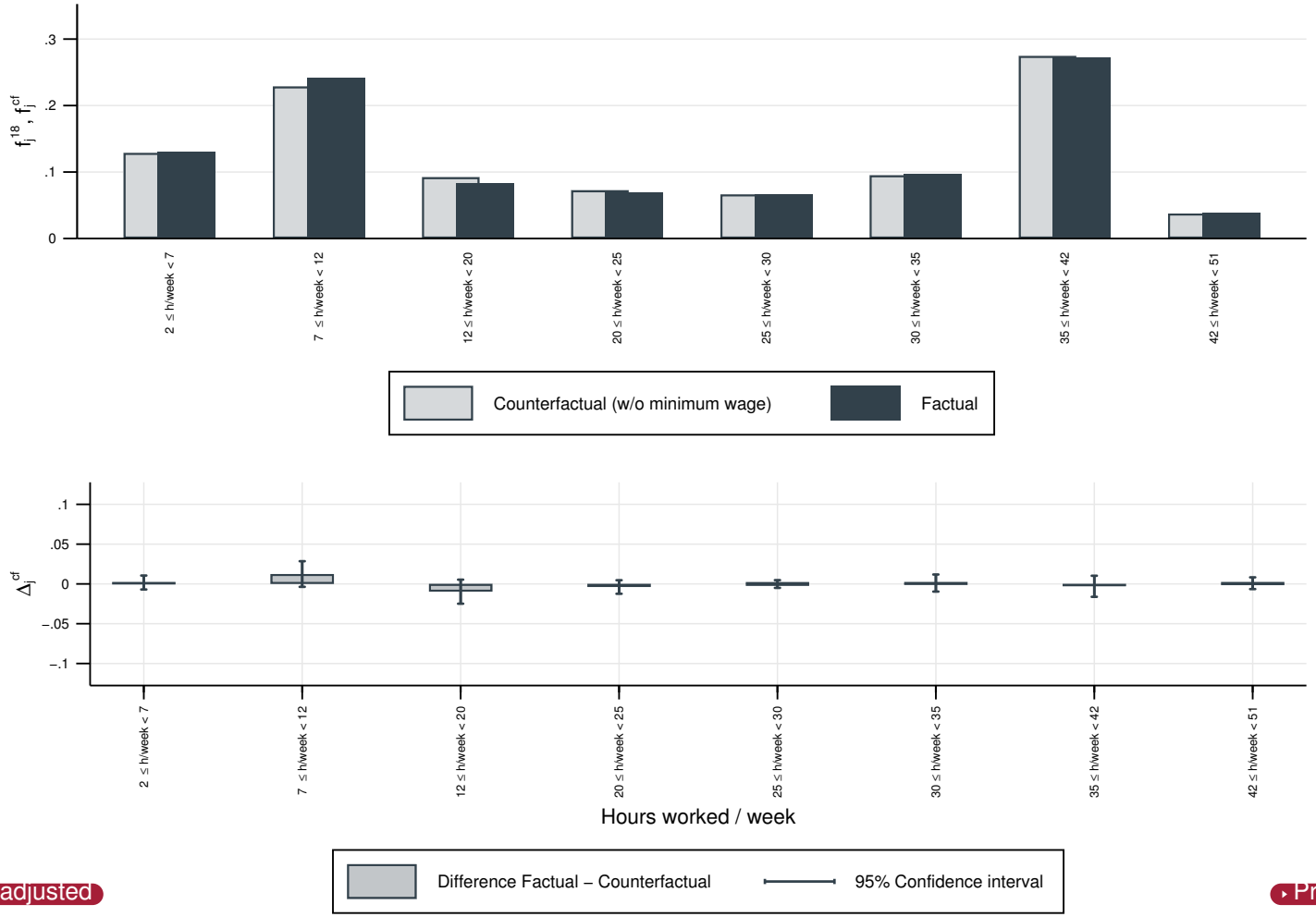
Hours worked: bite 2 (occ.+E/W) (worker group: 0-12 €/hour)



Trend adjusted

Pre-trend

Hours worked: bite 3 (ind.+E/W) (worker group: 0-12 €/hour)



Trend adjusted

Pre-trend

Conclusion

- Minimum wage practically eliminated wages below it
- Evidence for **spill-over** effects (up to 20% above MW level)
- **Wage inequality** decreased between 2014 and 2018
  - Minimum wage explains large part of decrease
- But **inequality trend** would already have been flat between 2014 and 2018 without minimum wage
- **Pre-trend analysis**: Low-wage growth already higher in most affected groups, upwardly biasing non-adjusted MW effect
- No measureable impact on distribution of **working hours**!
- Results robust to alternative bite measures

Thank you!

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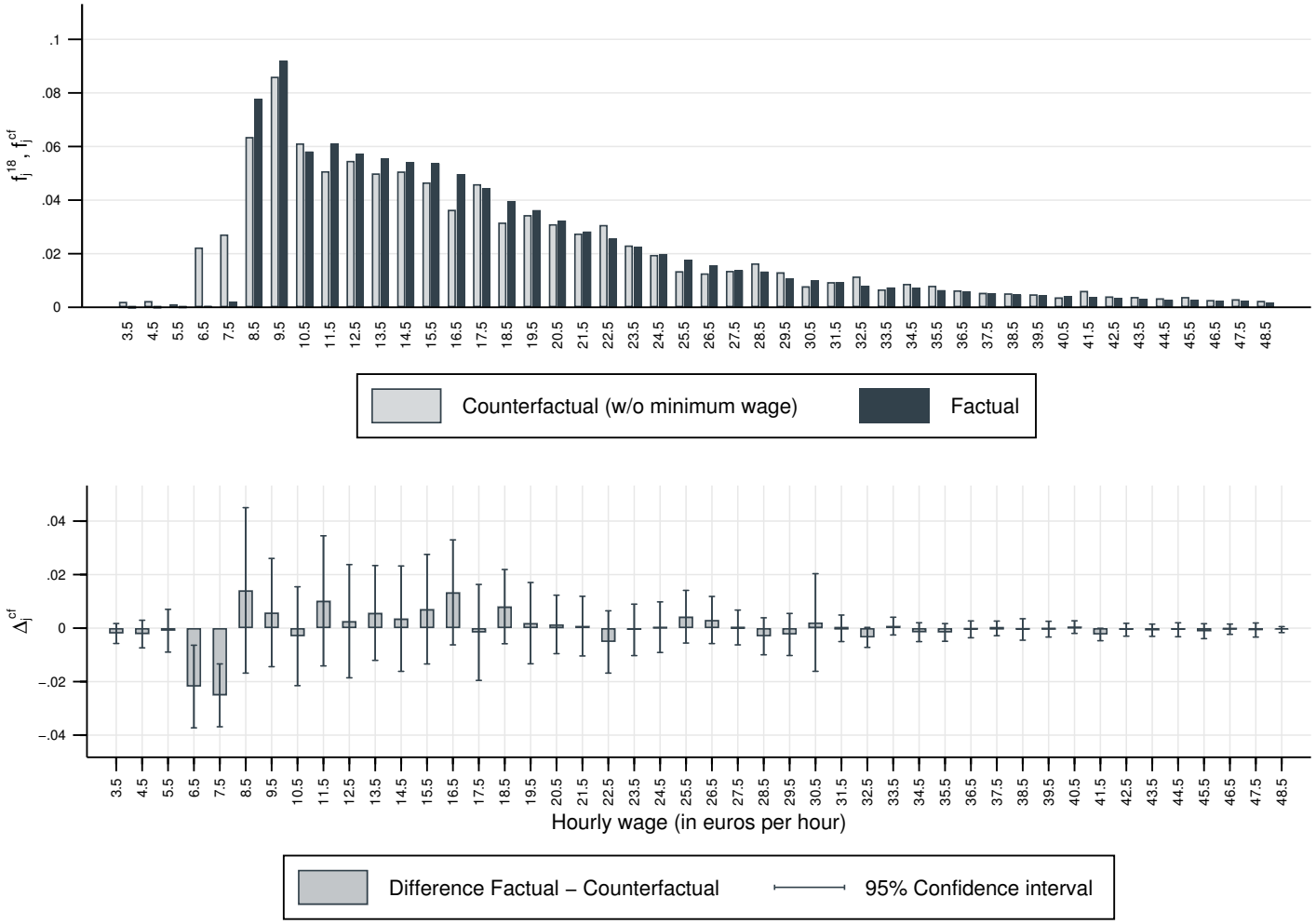
Hourly wages: bite measure 1 (two year trend adjustment)



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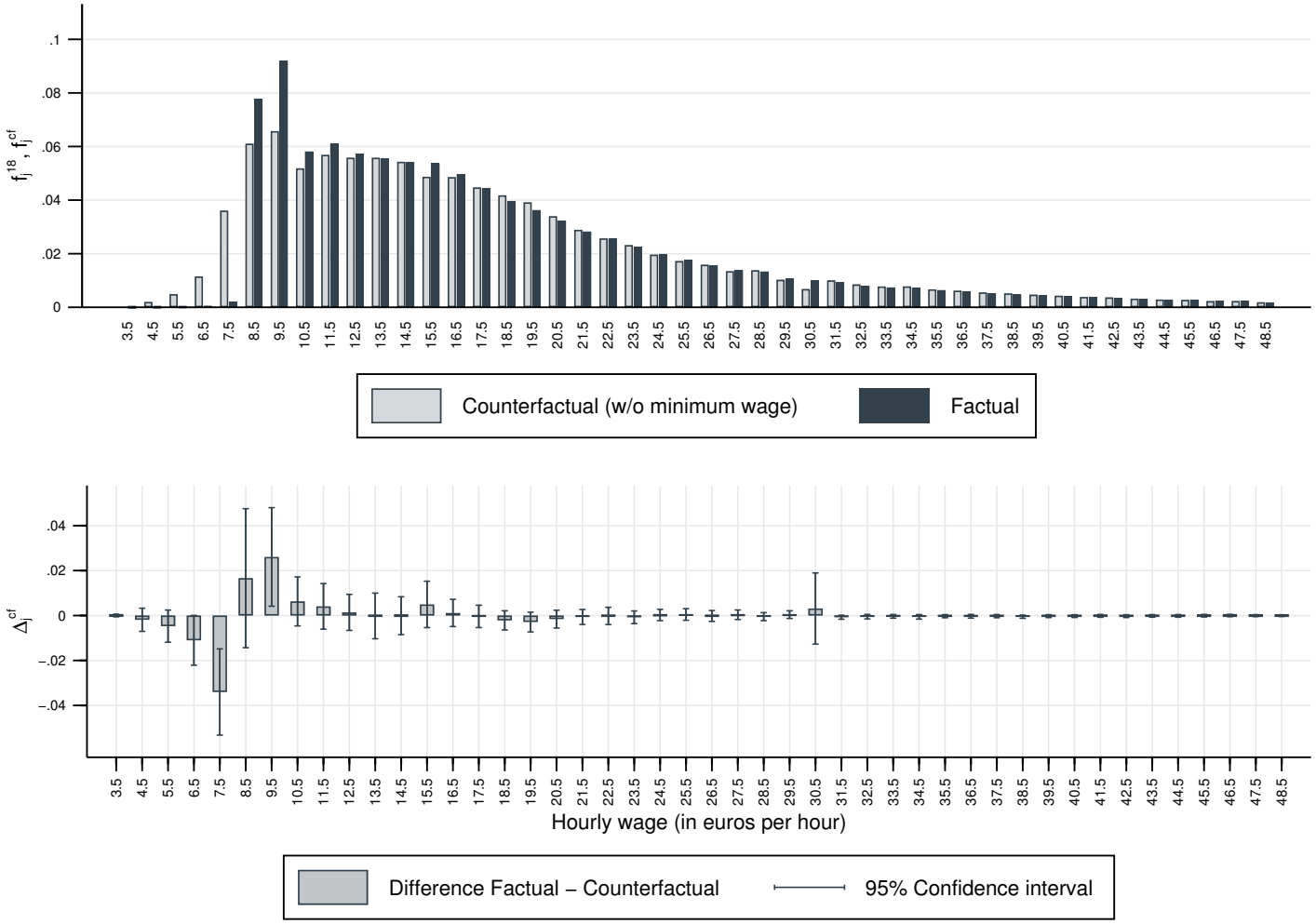
Hourly wages: bite measure 2 (two year trend adjustment)



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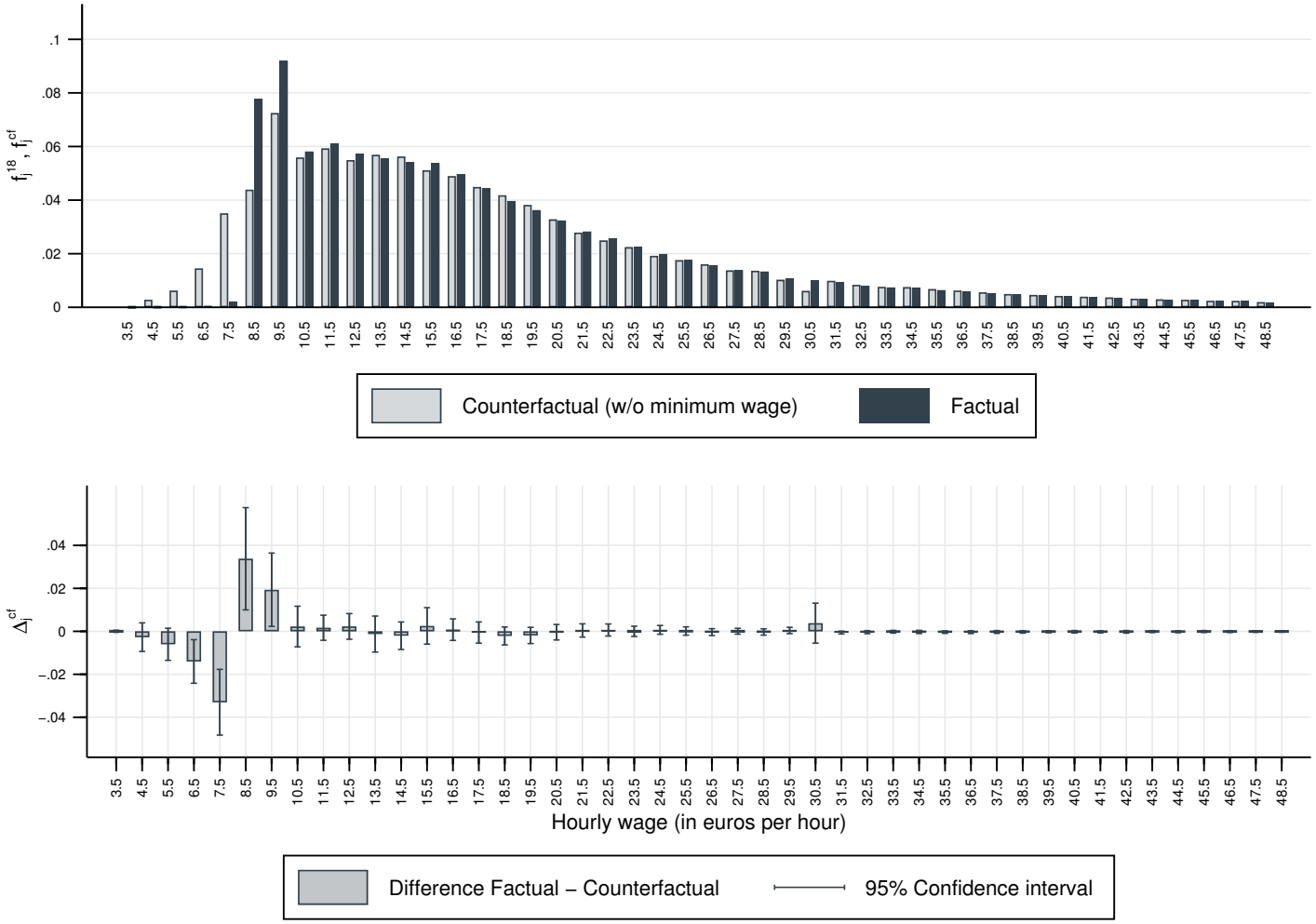
Hourly wages: bite measure 3 (two year trend adjustment)



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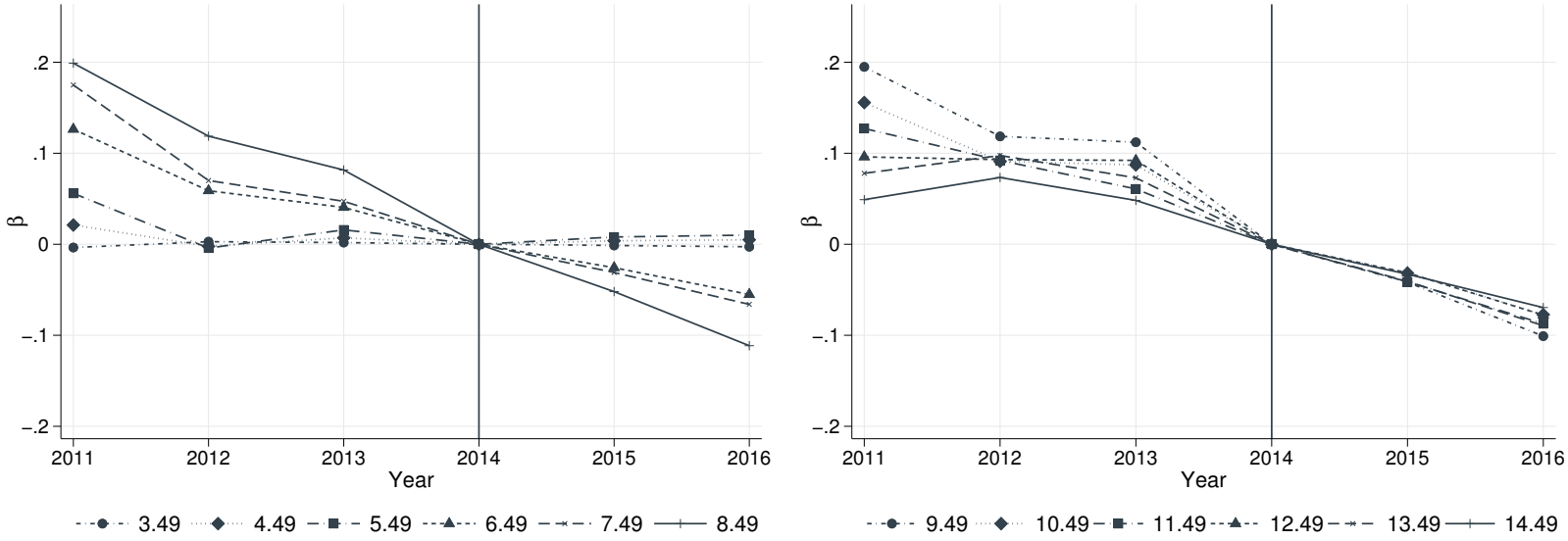
Pre-treatment estimates (DGUV-IAB) – Bite 1



(a) Lower thresholds (3.49 to 8.49)

(b) Upper thresholds (9.49 to 14.49)

Notes: Estimates for the treatment effect, $\hat{\beta}_z^t$, in the pre-treatment periods 2011-2014 for bins below and above the minimum wage level. Reference year = 2014.

p-values

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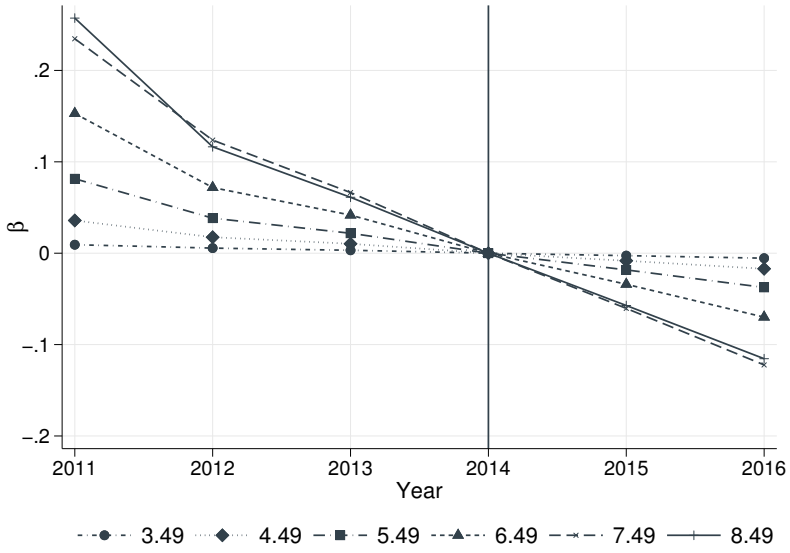
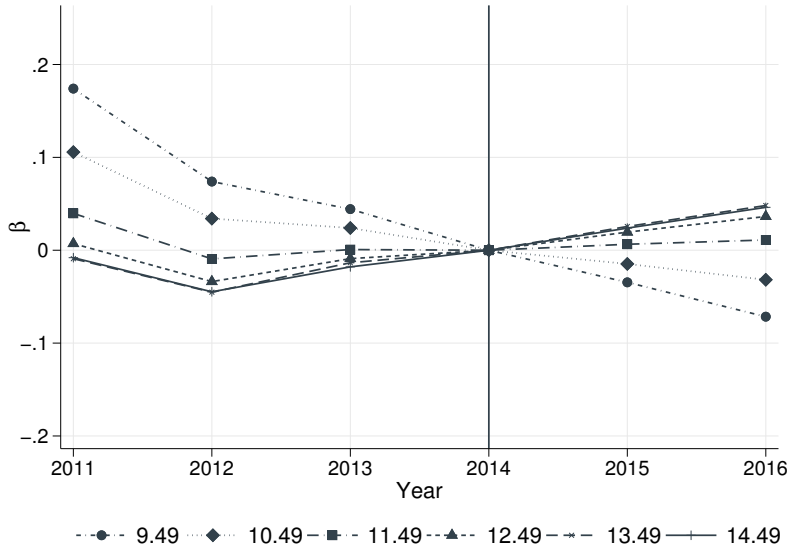
Pre-treatment estimates (DGUV-IAB) – Bite 2



(a) Lower thresholds (3.49 to 8.49)



(b) Upper thresholds (9.49 to 14.49)

Notes: Estimates for the treatment effect, $\hat{\beta}_z^t$, in the pre-treatment periods 2011-2014 for bins below and above the minimum wage level. Reference year = 2014.

p-values

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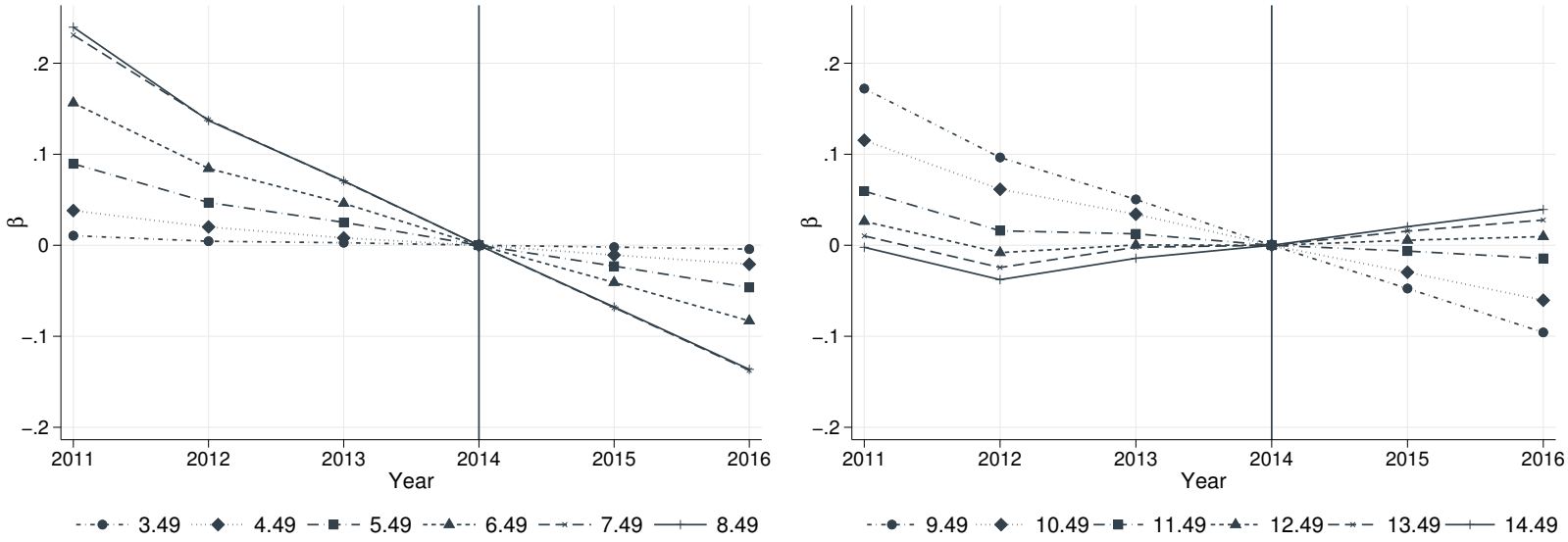
Pre-treatment estimates (DGUV-IAB) – Bite 3



(a) Lower thresholds (3.49 to 8.49)

(b) Upper thresholds (9.49 to 14.49)

Notes: Estimates for the treatment effect, $\hat{\beta}_z^t$, in the pre-treatment periods 2011-2014 for bins below and above the minimum wage level. Reference year = 2014.

p-values

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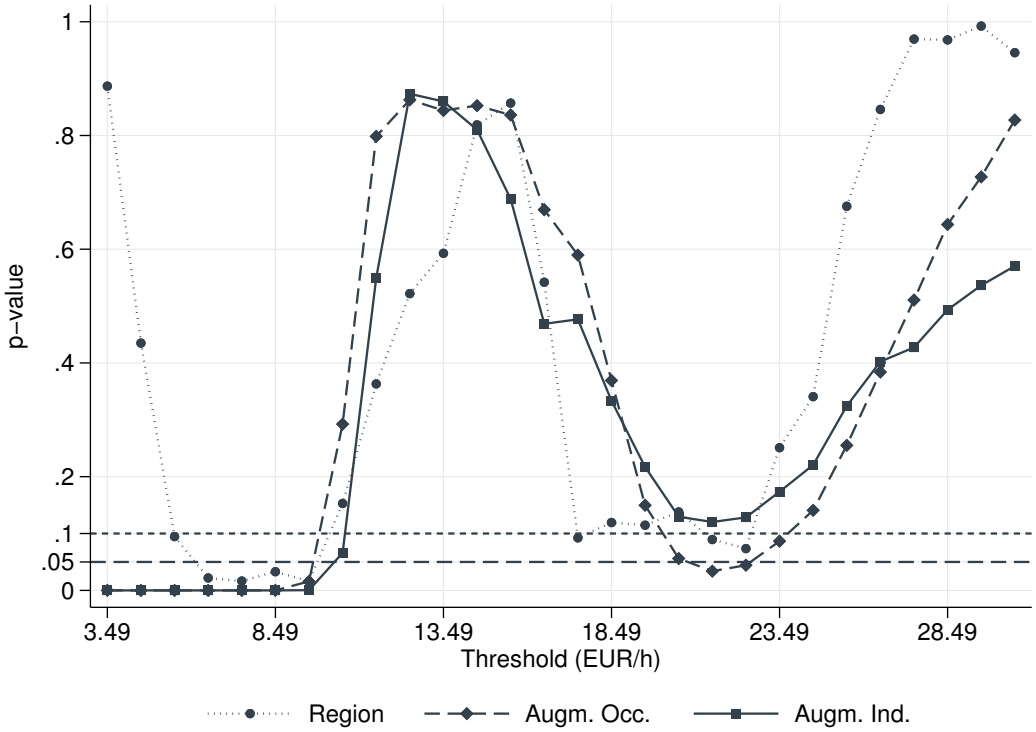
P-values: Joint significance pre-trend estimates



Notes: Values indicate p-values from a Wald test for joint significance of all pre-trend estimates ($\widehat{\beta}_z^{2011}$, $\widehat{\beta}_z^{2012}$, and $\widehat{\beta}_z^{2013}$ for a given threshold z based on bootstrap (100 replications, clustered at treatment level).

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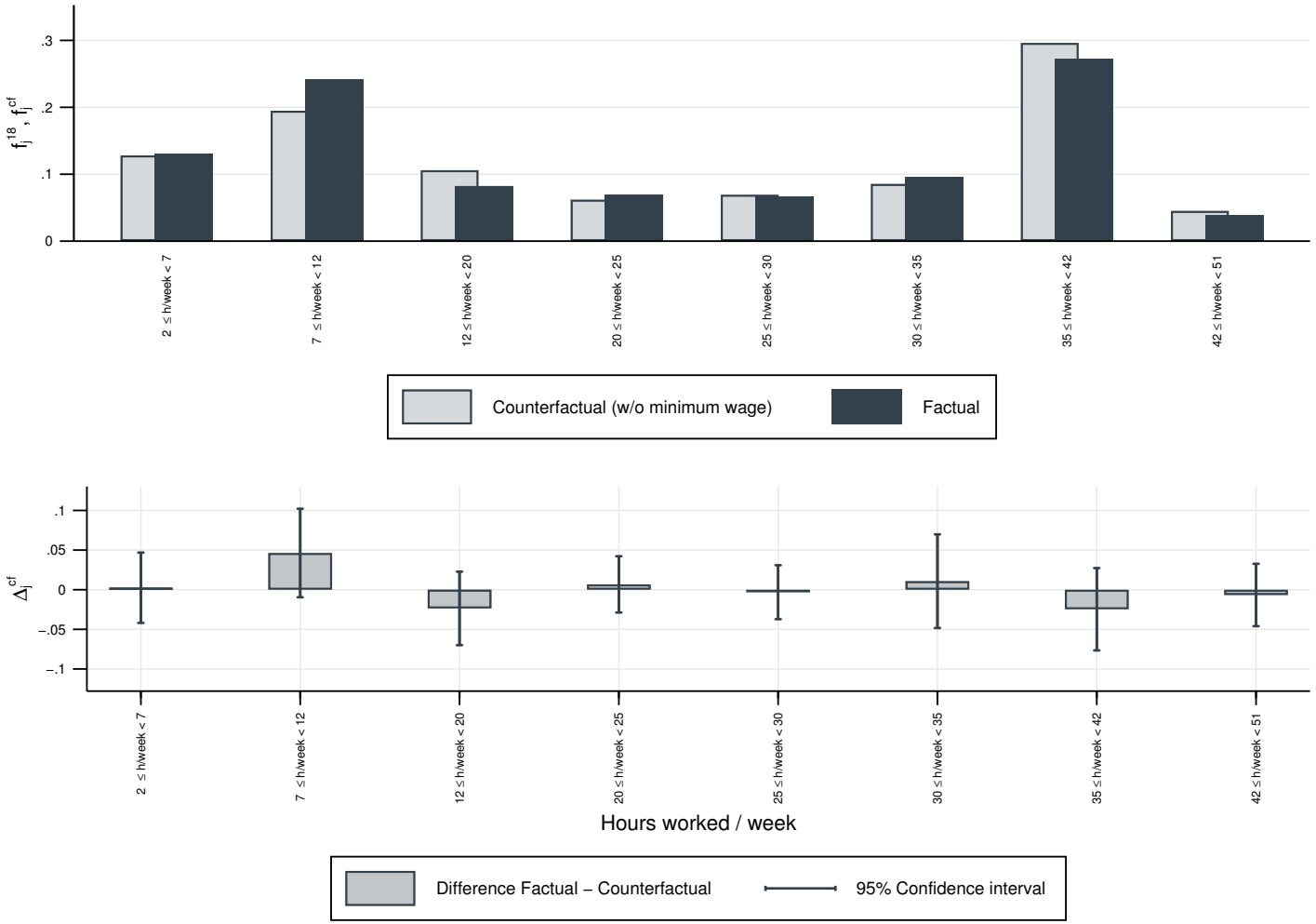
Bite 1 Bite 2 Bite 3

Hours worked (0-12€/hour): bite 1 (two year trend adjustment)



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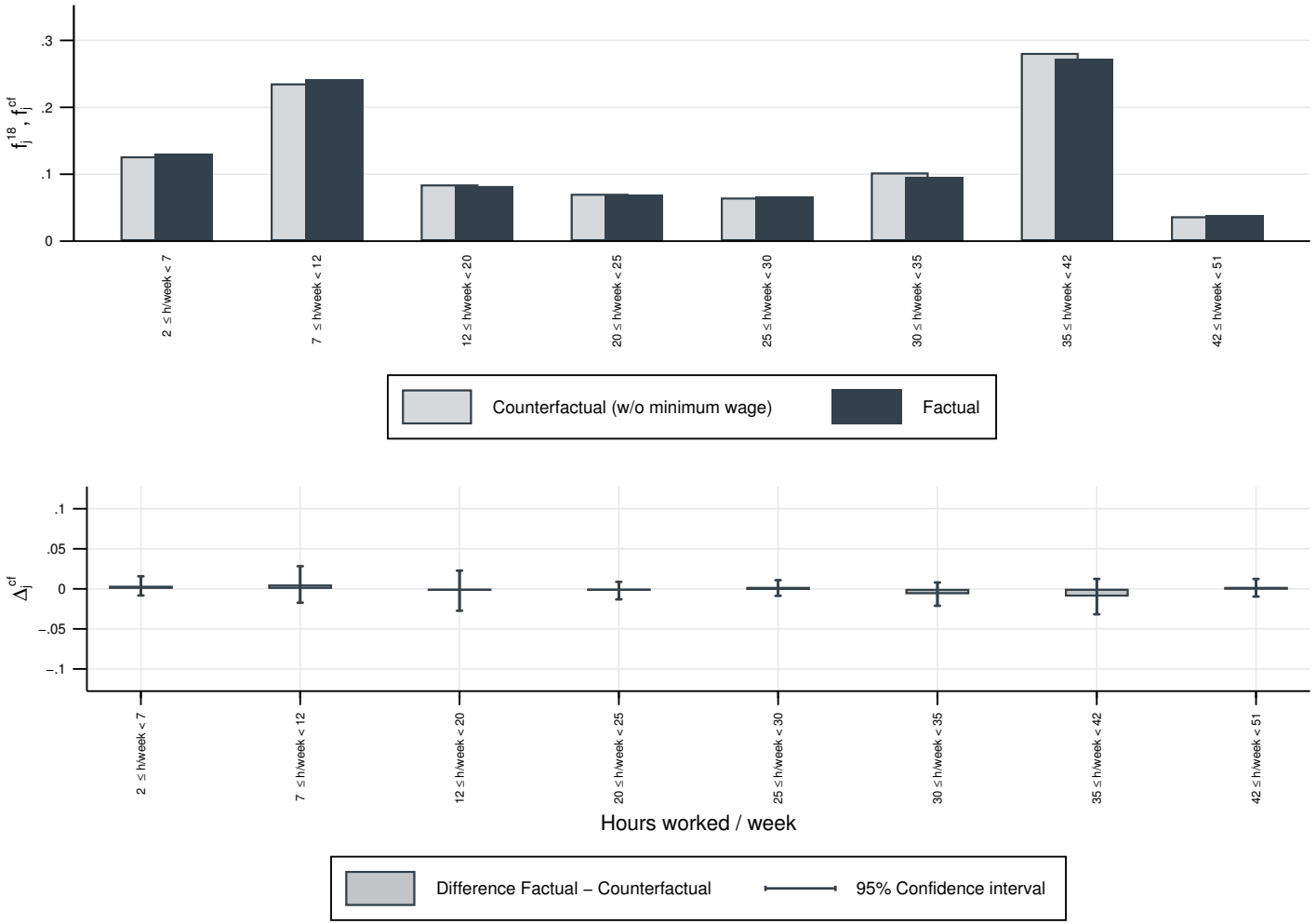
Hours worked (0-12€/hour): bite 2 (two year trend adjustment)



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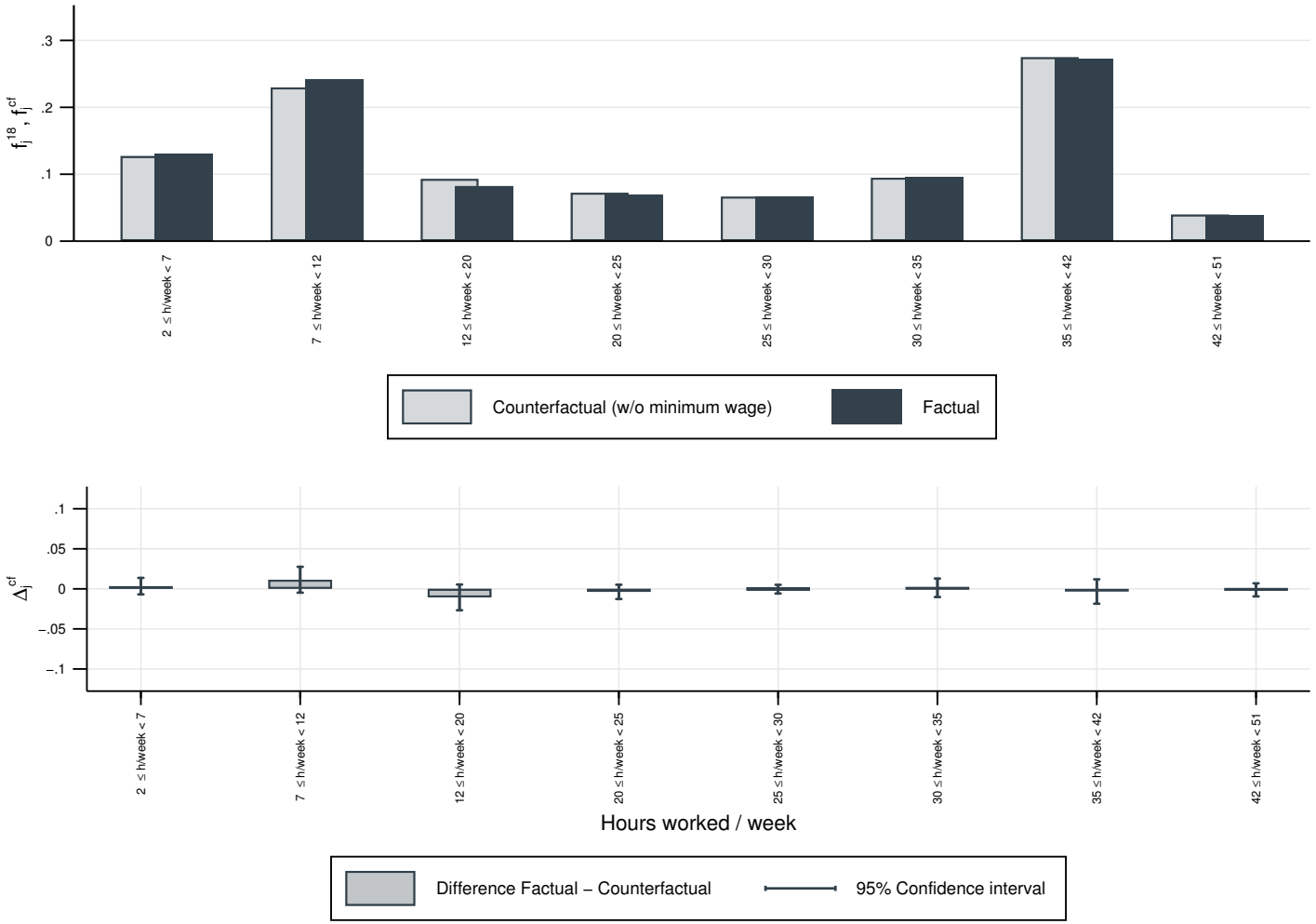
Hours worked (0-12€/hour): bite 3 (two year trend adjustment)



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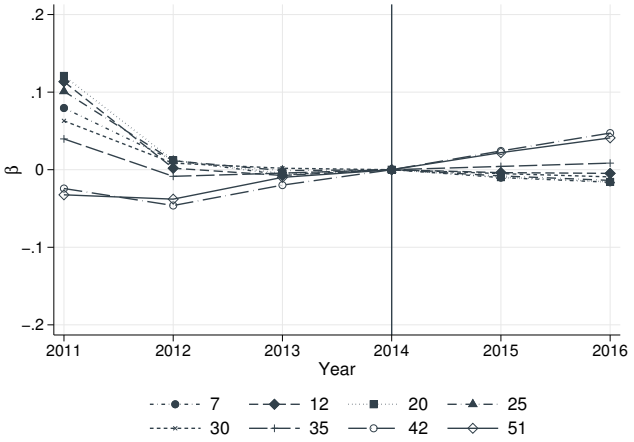
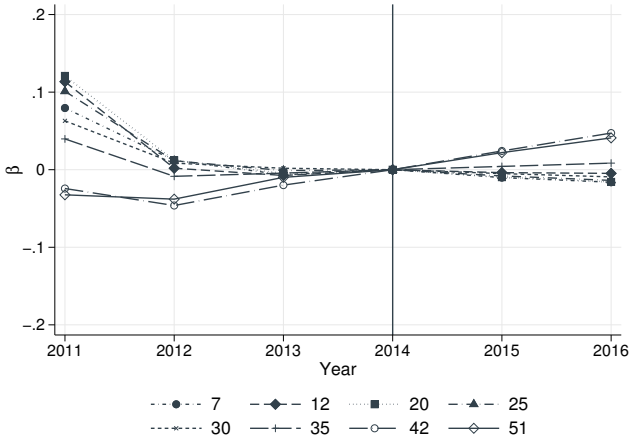
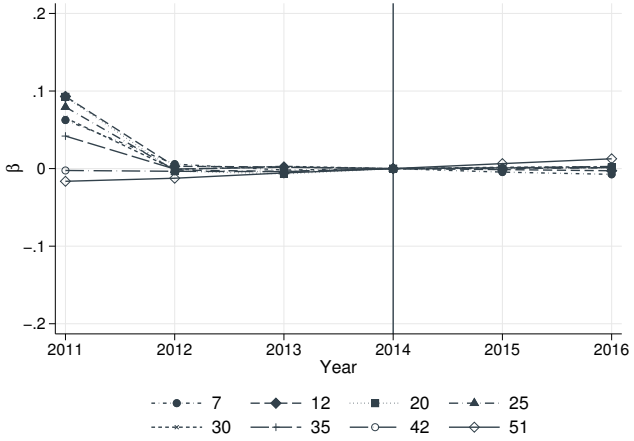
Pre-treatment estimates (DGUV-IAB) - 0-12 €/hour



(a) Bite 1



(b) Bite 2



(c) Bite 3

Bite 1 Bite 2 Bite 3

Quantiles and Gini index from grouped data

- Distributional statistics for grouped data (wage/hours bins) (Tillé and Langel, 2012)

$$Q_t(\tau) = z_j + \frac{\tau - F(z_{j-1}|D_t)}{f_{j,t}}(z_j - z_{j-1}) \text{ for } F(z_{j-1}|D_t) \leq \tau < F(z_j|D_t)$$

$$Gini_t = \frac{1}{2\bar{z}}\frac{N_t}{N_t - 1}\sum_{j=1}^{J}\sum_{k=1}^{J} f_{j,t} f_{k,t}|z_j^c - z_k^c| + \frac{1}{\bar{z}}\sum_{j=1}^{J}\frac{\left(N_t f_{j,t}^2 - f_{j,t}\right) L_{j,t}}{6(N_t - 1)}$$

- $z_j^c = (z_j + z_{j-1})/2$ is the center of the group j
- $\bar{z} = \sum_{j=1}^{J} f_{j,t} z_j^c$ is the group-implied estimator for the mean
- $L_j = z_j - z_{j-1}$ is the length of the jth group
- Last group (J) sometimes requires choices (upper limit)

Factual vs. counterfactual inequality measures: Differences

	$\widehat{\Delta}^{18-14}$	$\widehat{\Delta}^{cf}_{reg}$			$\widehat{\Delta}^{cf}_{occ}$			$\widehat{\Delta}^{cf}_{ind}$		
		No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$	No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$	No adj.	$\bar{\delta}_1$	$\bar{\delta}_2$
Statistic										
Gini	−0.020***	−0.024***	−0.023***	−0.021***	−0.013**	−0.011*	−0.009	−0.013***	−0.011**	−0.008*
	(0.003)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.007)	(0.004)	(0.005)	(0.005)
Q90	2.782**	−1.709	−1.709	−1.709	−0.476	−0.476	−0.476	−0.509	−0.509	−0.509
	(1.263)	(1.337)	(1.361)	(1.443)	(0.820)	(0.872)	(0.905)	(0.551)	(0.546)	(0.562)
Q50	1.566***	0.363	0.265	0.158	−0.321**	−0.230	−0.152	−0.235*	−0.143	−0.063
	(0.348)	(0.376)	(0.406)	(0.452)	(0.159)	(0.194)	(0.236)	(0.136)	(0.155)	(0.179)
Q10	1.239***	0.709***	0.615***	0.497***	0.639***	0.542***	0.449**	0.571***	0.398**	0.245
	(0.110)	(0.18)	(0.170)	(0.178)	(0.193)	(0.189)	(0.196)	(0.216)	(0.199)	(0.191)
Q90/Q10	−0.160	−0.453***	−0.414**	−0.366**	−0.288**	−0.249*	−0.213	−0.264**	−0.198*	−0.140
	(0.113)	(0.164)	(0.164)	(0.172)	(0.129)	(0.133)	(0.139)	(0.109)	(0.101)	(0.099)
Q90/Q50	−0.023	−0.153	−0.140	−0.126	0.010	−0.001	−0.011	−0.003	−0.014	−0.023
	(0.045)	(0.115)	(0.119)	(0.128)	(0.057)	(0.062)	(0.066)	(0.042)	(0.043)	(0.046)
Q50/Q10	−0.060***	−0.092*	−0.084*	−0.073	−0.154***	−0.124***	−0.098**	−0.130**	−0.087*	−0.050
	(0.022)	(0.052)	(0.050)	(0.051)	(0.047)	(0.046)	(0.046)	(0.054)	(0.050)	(0.047)

Notes: $\widehat{\Delta}^{18-14}$ is the factual difference between 2014 and 2018. $\widehat{\Delta}^{cf}_{reg}$, $\widehat{\Delta}^{cf}_{occ}$, $\widehat{\Delta}^{cf}_{ind}$ and the respective trend adjusted versions thereof are the differences of the factual measure in 2018 and the counterfactual one in the absence of the minimum wage (representing the isolated effect of the minimum wage on the change between 2014 and 2018). Bootstrap standard errors in parentheses. Bootstrap standard errors for factual values (columns 1, 2, in the upper and column 1 in the lower panel) are clustered at the regional level. Bootstrap standard errors for the counterfactual values and differences are clustered at the respective treatment level (region, augmented occupation or augmented industry level). All bootstrap standard errors were obtained using 100 bootstrap replications.
***/**/* indicate statistical significance for the factual/counterfactual differences at the 1%/5%/10% level.

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