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The effects of Italy's Industry 4.0 adoption and training program on firms' productivity and employment

Annalisa Caloffi, Francesca Gastaldi,
Marco Mariani, and Maria Grazia Pazienza

14th Geoffrey J.D. Hewings Workshop in Regional Economics
WIFO, Vienna, October 2-3 , 2023

Growing debate

What are the effects of digitalization on productivity and employment?

• Investment in digital technologies is supposed to have positive effects on productivity. Yet, the evidence at industry and firm-level has been mixed → this can be due to the ambiguous effect on work:

• While pure automation is job displacing, digitalization can, at the level of society, be reinstating for both low-(e.g., riders) and high skilled (e.g., software expert developers); neutral to mid-skilled (e.g. computer geeks)

• At firm level, many expect a gap between skilled and unskilled workers, the latter being at risk of “marginalization”, unless re-trained

• Several authors report a widening wage gap between skilled and unskilled workers

Contribution of this work

- Firm level analysis, potential-outcomes framework for causal inference
- We investigate what happens when digitalization is paired with training (policy mix) and when it is not
- Management literature emphasizes that the digital transition may require changes in business models and new skills to be acquired through training or new personnel
- Focus on Italy's 4.0 transition program, which provided incentives for digital investments, and additional incentives to match them with training
- Previous firm- level causal inference regarding only the investment-side of the program is provided in Bratta et al. (2022) : no job displacement, instead new hirings especially of young people (actually not always well paid)
- We will see that when training is also involved, things are a little more complex and controversial

Policies supporting digitalization in Italy

• First **I4.0 plan** (2017 Italian Budget Law):

• **Tax depreciation measure** (hyper depreciation) to support private investments in advanced digital production technologies embedded in industrial machinery and equipment

- works as a 150% increase in the cost of the eligible capital good: for each 100 thousand euro of investment, a firm could save up to 36 thousand euros over the years of the asset's life
- All firms are eligible (except those which are about to fail)
- No cap on the amount of investments that can benefit from the enhanced tax depreciation allowance
- Tanglible goods that are eligible: machine tools, robots, 3D printings, warehouse systems, measurement, monitoring, inspection, testing, marking and tracing equipment, human-machine integration devices

Policies supporting digitalization in Italy (II)

• **Tax credit I4.0 training**: The measure aims to support companies in the process of technological and digital transformation by creating or consolidating skills in the enabling technologies necessary to realise the 4.0 paradigm.

The tax credit:

- Is recognized in the extent of: 70% of the eligible expenses up to a maximum annual limit of EUR 300,000 for small enterprises/ 50% of the eligible expenses up to a maximum annual limit of EUR 250,000 for medium-sized enterprises / 30% of the eligible expenses for large enterprises up to a maximum annual limit of EUR 250,000;
- Is related to training activities that can be provided by a list of accredited organizations;
- Topics of training activities: big data and data analysis; cloud and fog computing; cyber security; simulation and cyber-physical systems; rapid prototyping; virtual and augmented reality systems; advanced and collaborative robotics; human-machine interface; additive manufacturing; IoT; digital integration of business processes.

Data

[treated] Manufacturing firms benefiting from I4.0 incentives (UPB for fiscal data + Aida-Bureau van Djik for balance sheets). Multiple "active" treatments:

- [1] tax-depreciation measure to foster investments (19,401 firms)
- [2] Investments + training on I4.0 tech (353 firms)

[controls] [0] Manufacturing firms that are not benefiting from I4.0 incentives (UPB for fiscal data + Aida-Bureau van Djik for balance sheets)

Outcomes, treatments, and potential outcomes

- Ys of interest: employees, value added, wages, value added and wages per employee
- Observation period: 2012-2019; we are extending to 2021
- Treatment assignment occurs in $t^* = 2017$ (focus on first entry cohort)
- Treatment levels T: tax-depreciation for [1] investment [2] investment & tax-credit for training [0] untreated
- For each i, and for each $t >= t^*$, there are three potential outcomes $Y_{it}(1)$, $Y_{it}(2)$ and $Y_{it}(0)$, only one observed corresponding to actual treatment

Causal estimands

For “active” treatment levels and for each $t >= t^*$

- $ATT_t(1,0) = E(Y_{it}(1) - Y_{it}(0)) \mid T_{it} = 1$

Avg effect of investment on those who took investment

- $ATT_t(2,0) = E(Y_{it}(2) - Y_{it}(0)) \mid T_{it} = 2$

Avg effect of I&T on those who took I&T

- $ATE_t(2,1) = E(Y_{it}(2) - Y_{it}(1)) \mid T_{it} > 0 =$

Avg effect of adding training for all participants

$$= \pi[E(Y_{it}(2) - Y_{it}(1)) \mid T_{it} = 2] + (1- \pi)[E(Y_{it}(2) + Y_{it}(1)) \mid T_{it} = 1]$$

ATT(2,1): Avg effect of adding training for those who get also training

ATU(2,1): Avg effect of adding training for those who do not get training

Observed and unobserved potential outcomes

	T = 0	T = 1	T = 2
Observed	$Y_{it}(0) = Y_{it} \mid T=0$	$Y_{it}(1) = Y_{it} \mid T=1$	$Y_{it}(2) = Y_{it} \mid T=2$
Unobserved	$Y_{it}(1)$, $Y_{it}(2)$	$Y_{it}(0)$, $Y_{it}(2)$	$Y_{it}(0)$, $Y_{it}(1)$

Need to estimate unobserved quantities (counterfactuals) involved in previous estimands (red below)

- $ATT_t(1,0) = E(Y_{it} - Y_{it}(0)) \mid T_{it} = 1$
- $ATT_t(2,0) = E(Y_{it} - Y_{it}(0)) \mid T_{it} = 2$
- $ATE_t(2,1) = E(Y_{it}(2) - Y_{it}(1)) \mid T_{it} > 0 = \pi[E(Y_{it} - Y_{it}(1)) \mid T_{it} = 2] + (1- \pi)[E(Y_{it}(2) - Y_{it}) \mid T_{it} = 1]$

ATT(2,1)

ATU(2,1)

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Identification and estimation

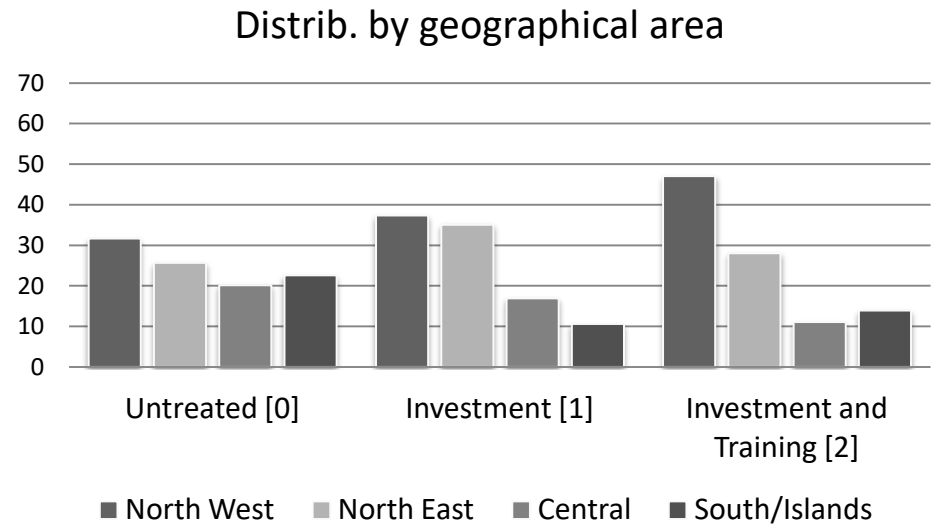
- Unconfoundedness assumption: counterfactuals can be reconstructed from the post-treatment Y of units under alternative treatment condition having same $\mathbf{X}_i = \boldsymbol{x}$ prior to treatment
- Pre-intervention Xs have to be relevant and, preferably, many
- Leading role of pre-intervention values of outcomes: employees, value added, wages 2012-2016
- Other Xs: sector, geographical area, firm age
- Bias-corrected matching estimator (Abadie and Imbens, 2007), doubly robust procedure combining nearest-neighbor matching and regression-based adjustment of counterfactual potential outcomes

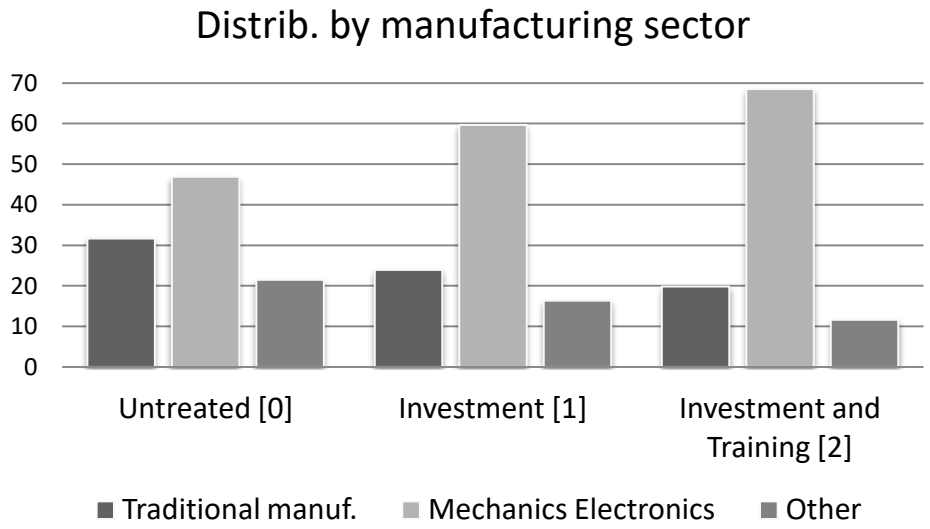
Descriptive statistics (1)

Value added and wages X 1000 euros

	T = 0		T =1		T = 2	
	Obs = 104,548		Obs = 19,401		Obs = 353	
	Mean	SD	Mean	SD	Mean	SD
Wages 2016	517	4,742	1,684	8,121	5,848	18,415
Value Added 2016	1,081	9,062	4,048	19,472	13,817	47,892
Employees 2016	16	88	48	179	149	409
Employees 2016 >0	86%		97%		100%	

Descriptive statistics (2)





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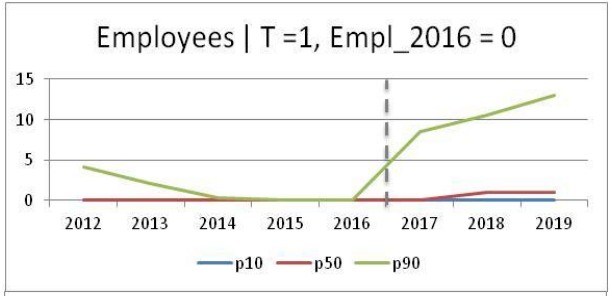
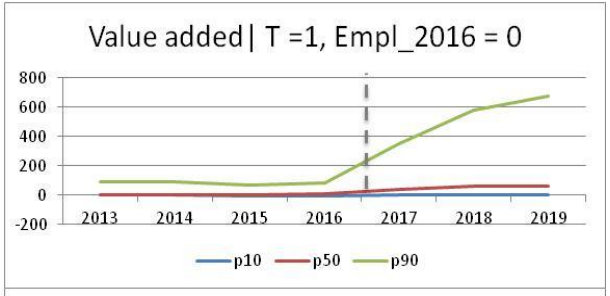
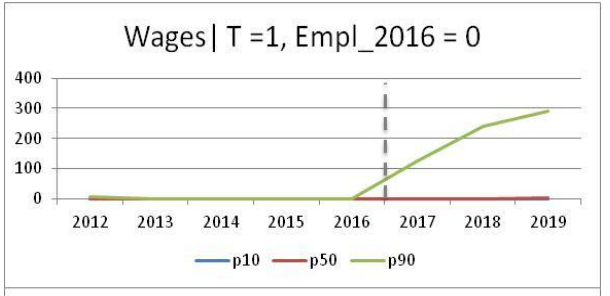
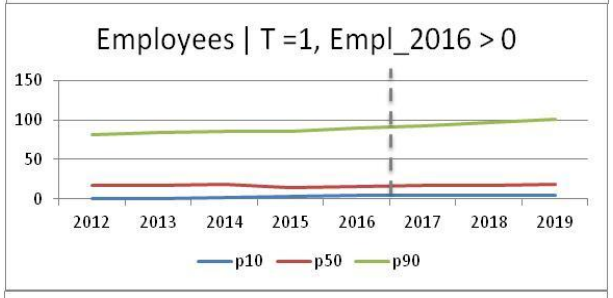
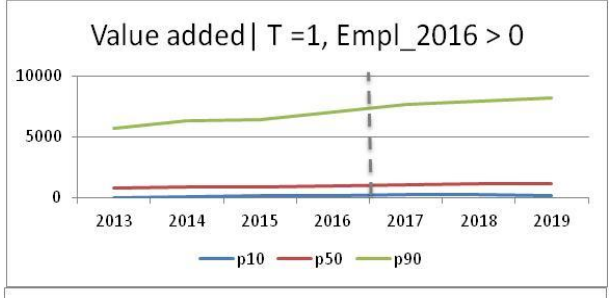
Outcome histories

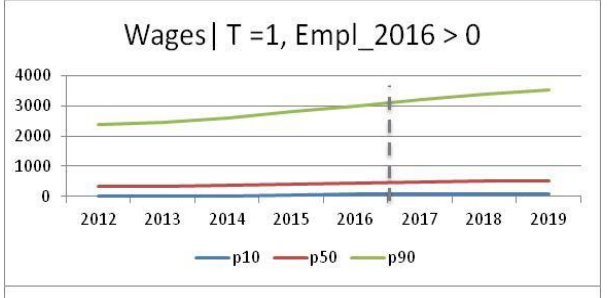


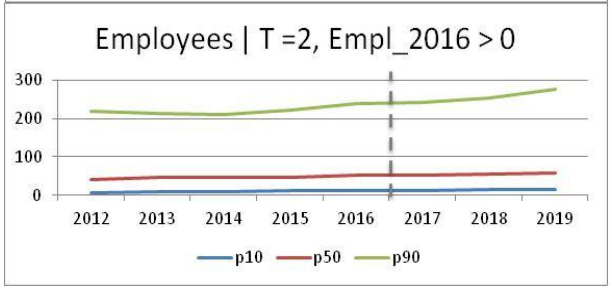


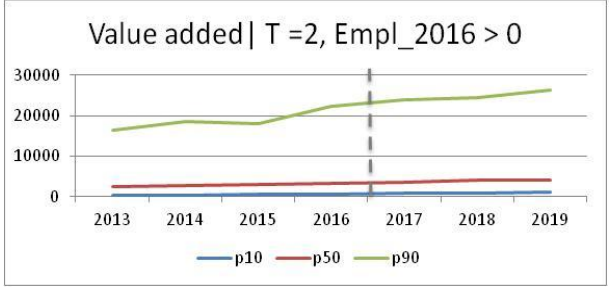


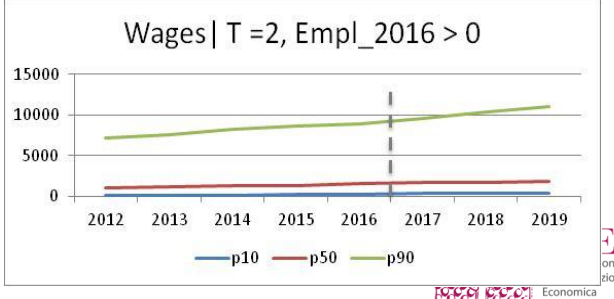




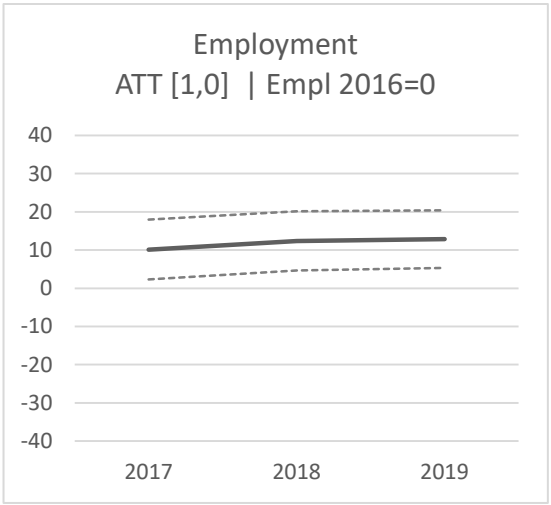


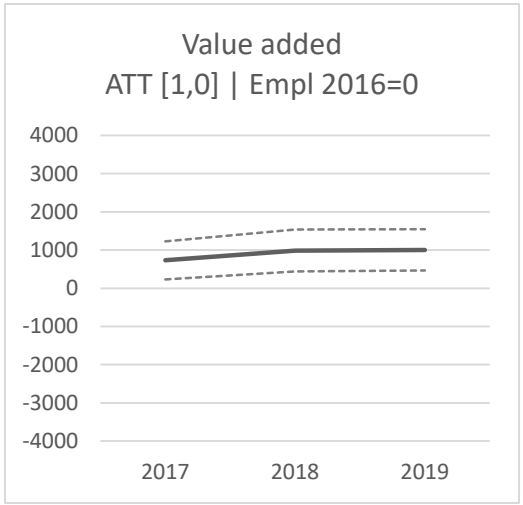


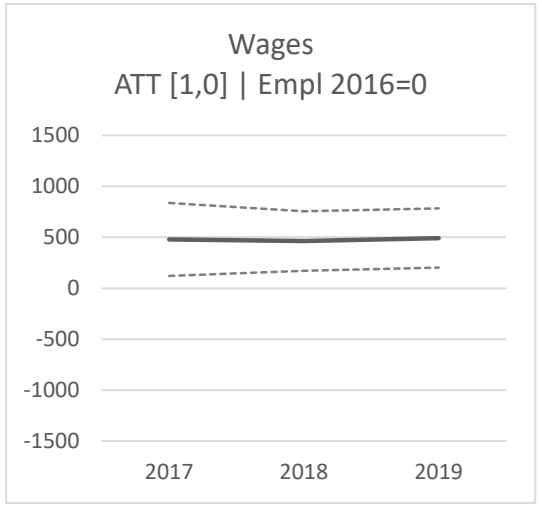




Estimated ATT(1,0)s for firms with Empl_2016 = 0







Micro-firms with no employees just prior to entry:

- hire new personnel and increase value added because of the investment

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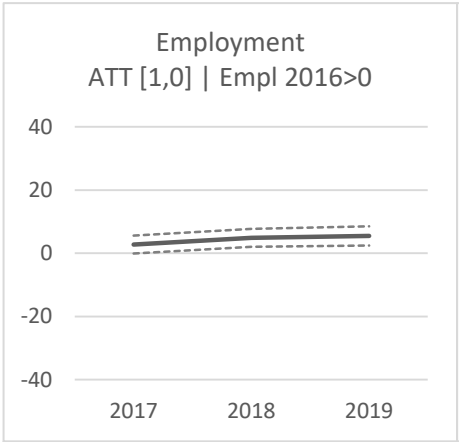
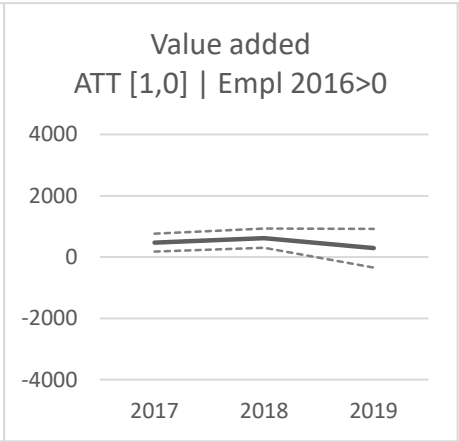
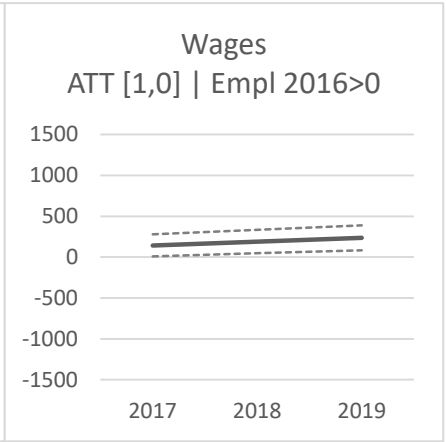
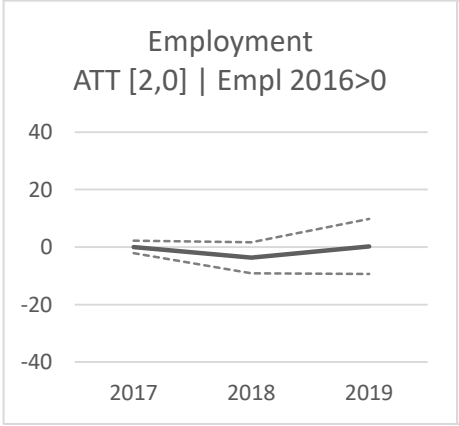
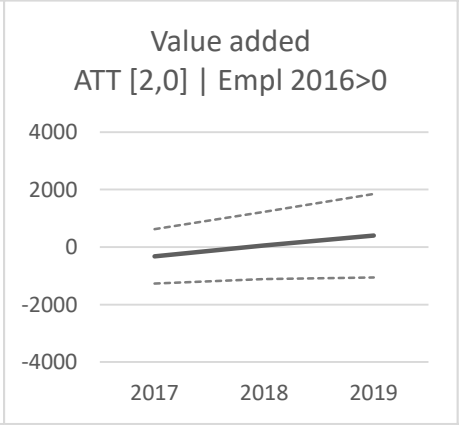
Estimated ATT(1,0)s and ATT(2,0)s for firms with Empl_2016 > 0

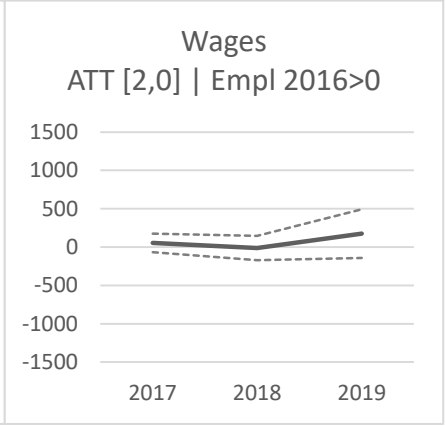












Firms with employees prior to entry into investment:
- improve all outcomes because of the investm.

Firms with employees prior to entry into I&T:
- do not improve outc.
- more complex 4.0 transition? Requires more time?

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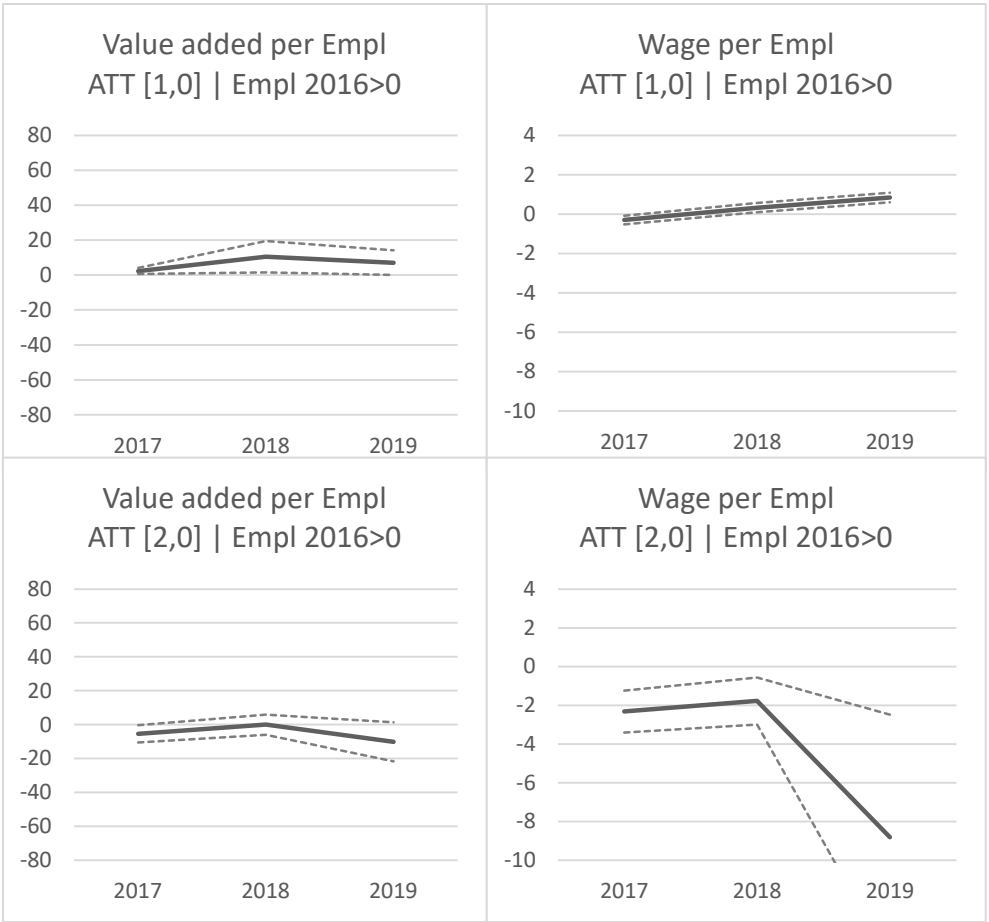
Estimated ATT(1,0)s and ATT(2,0)s for firms with Empl_2016 > 0



A look at relative effects:

- firms into investment improve labor productivity and average wages

- firms into I&T do not improve labor productivity and act some downward pressure on average wages

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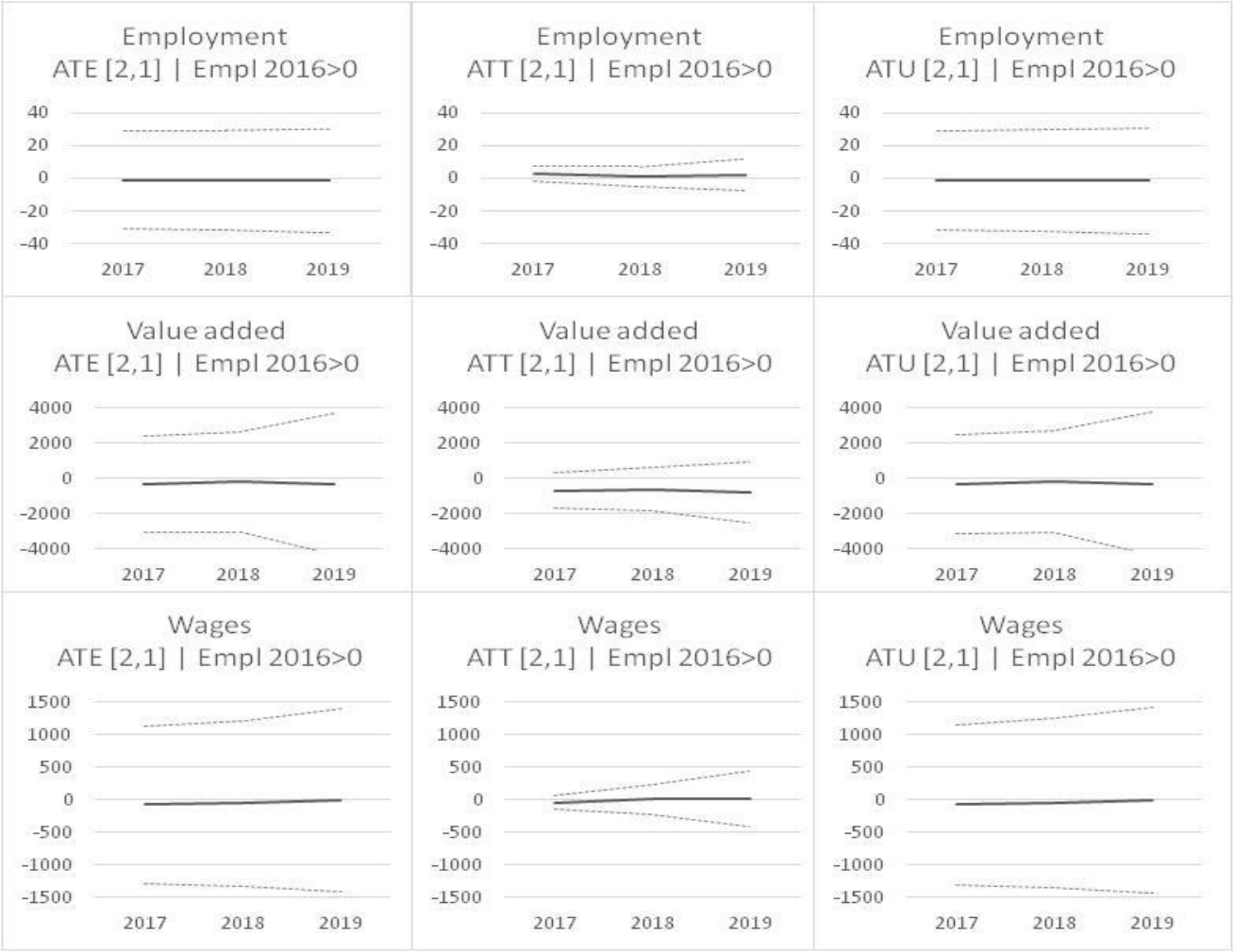
Estimated ATE(2,1)s, ATT(2,1)s and ATU(2,1)s for firms with Empl_2016 > 0



ATEs are not significant because of overwhelming weight of firms with T = 1

- had these firms engaged also into training, nothing would have happened

- few firms actually engaging into training in addition to investment: strong signs of productivity stagnation

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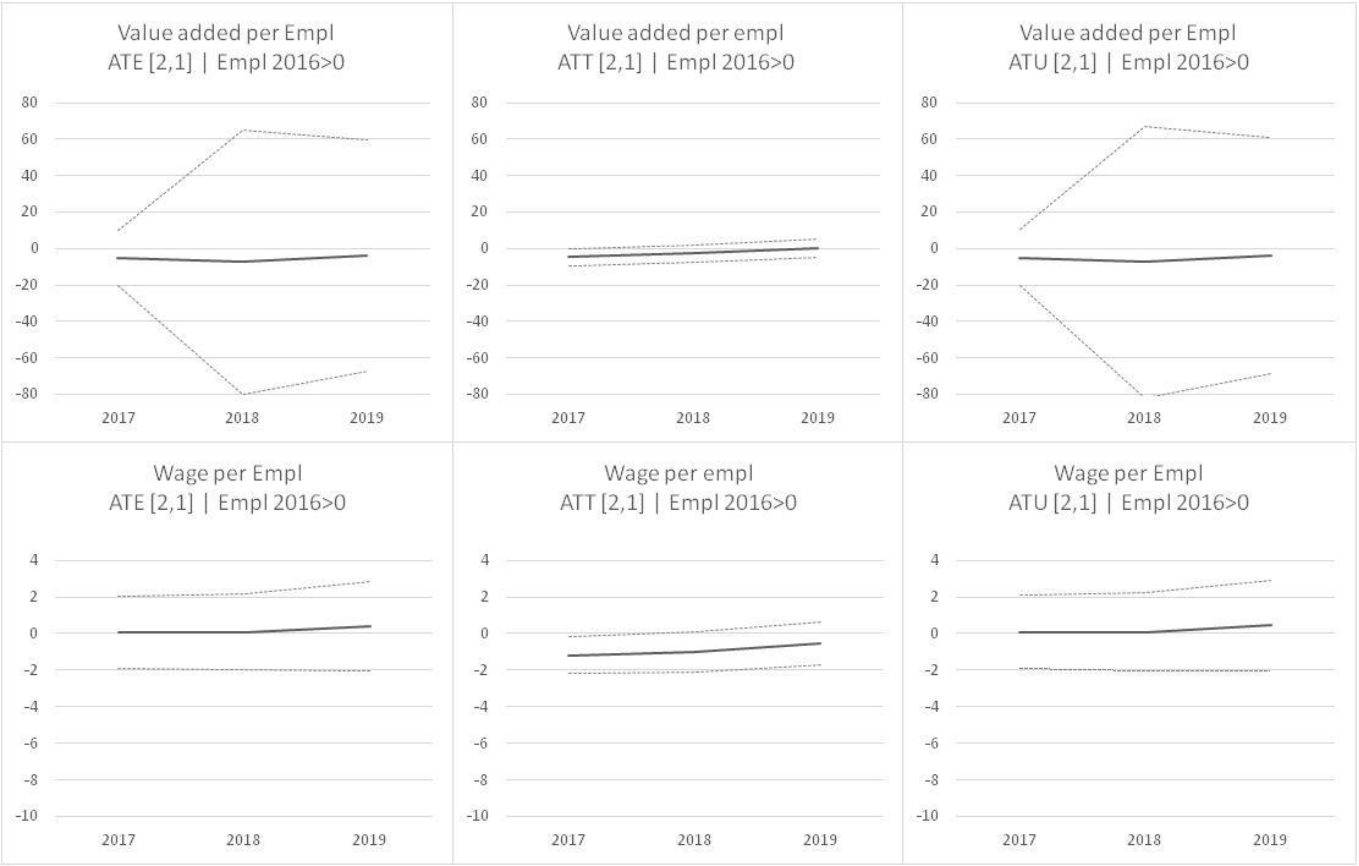
Estimated ATE(2,1)s, ATT(2,1)s and ATU(2,1)s for firms with Empl_2016 > 0



ATEs are not significant because of overwhelming weight of firms with T = 1

- had these firms engaged also into training, nothing would have happened

- few firms actually engaging into training in addition to investment: productivity stagnation and some pressure on average wages are confirmed

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Concluding remarks

These are very preliminary results! Thanks for your help in interpretation / further development

We are carrying forward the analysis to 2021.

- the time frame becomes more congruous for assessing effects of more complex 4.0 transitions, as those under I&T likely are
- 2020 is a year to be handled with care, however, because of Covid-related restrictions that had differential implications by sector

We are also planning to investigate heterogeneity of effects by firm size and sector, and to examine differential effects for different investment intensities