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

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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 (18,630 firms)
- [2] Investments + training on I4.0 tech (1,963 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: 2012-2021
- 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

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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

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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 = 120,911		Obs = 18,630		Obs = 1,963	
	Mean	SD	Mean	SD	Mean	SD
Large projects	-	-	33%		44%	
Value Added 2016	1,057	9,555	5,989	37,229	6,532	33,224
Employees 2016	32	467	53	439	70	199

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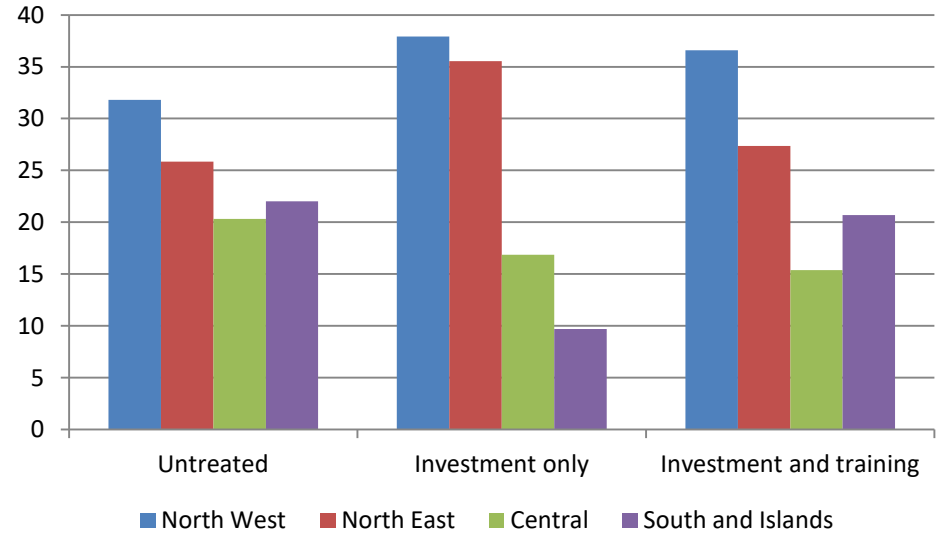
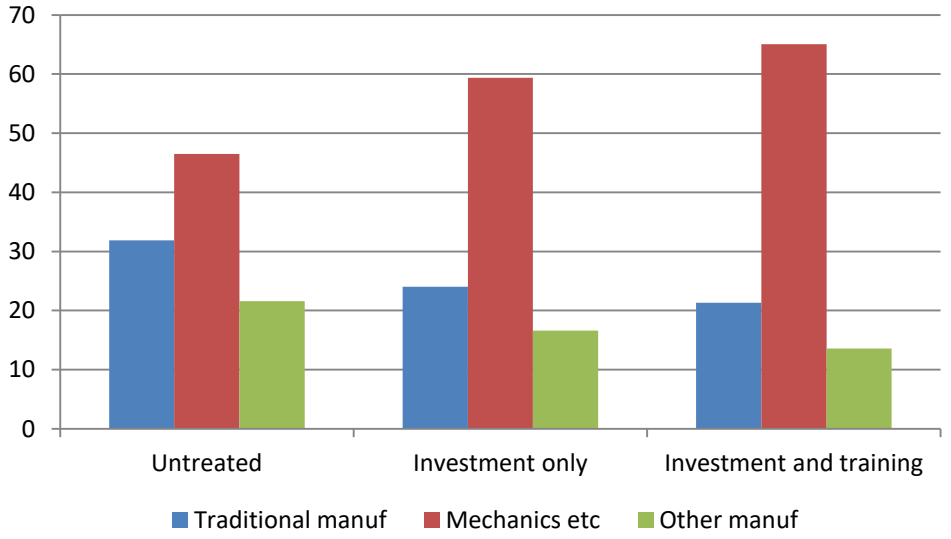
Descriptive statistics (2)

By geographical area



By industrial sector



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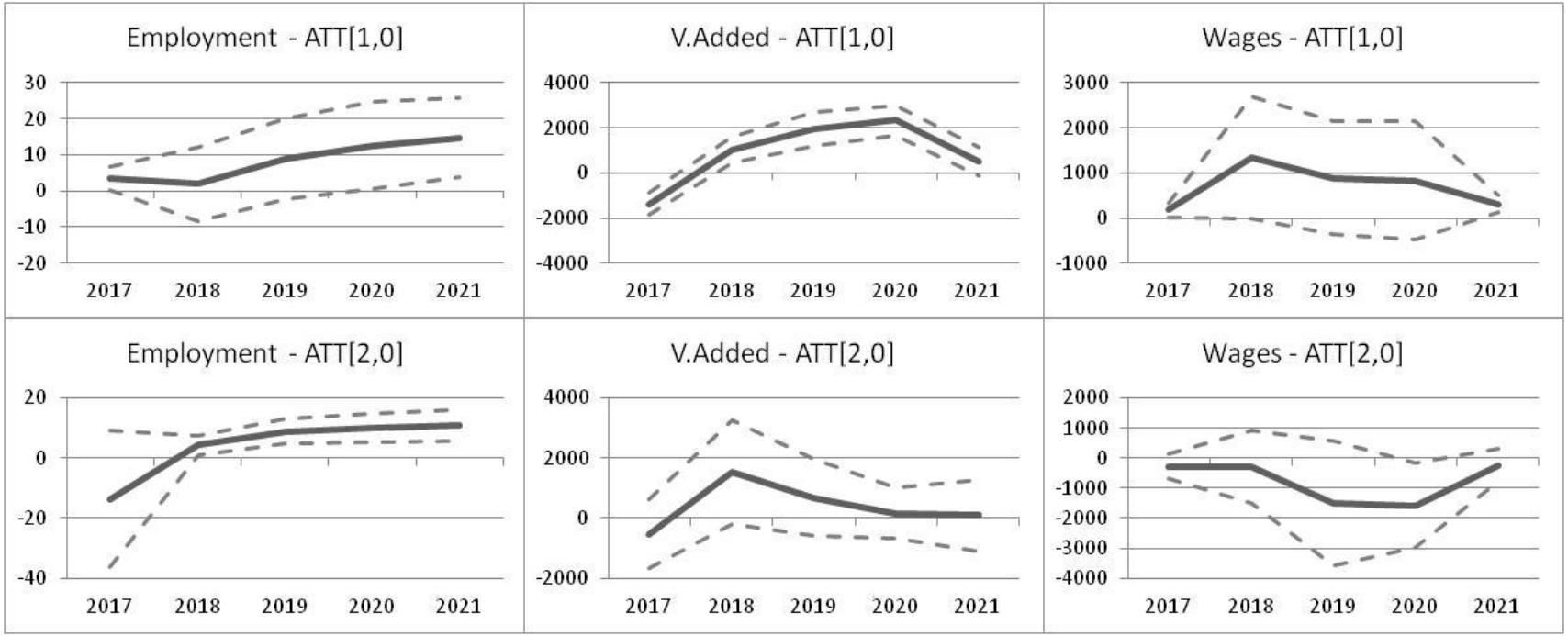
Estimated ATT(1,0)s and ATT(2,0)s



Investment incentive [1]

- improves employment and value added of firms that receive it

Investment with Training [2]

- Improves employment alone of firms that receive it

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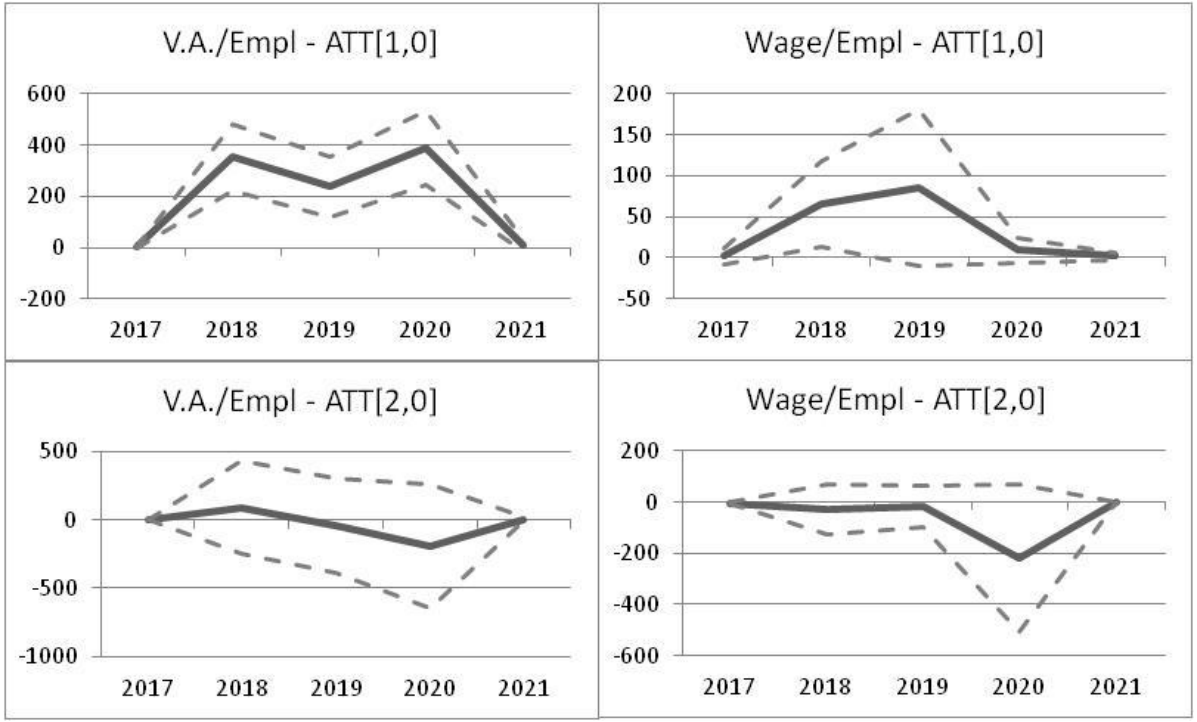
Estimated ATT(1,0)s and ATT(2,0)s



A look at relative effects:

- firms into investment do improve labor productivity and (more uncertain) average wages
- firms into I&T do not improve labor productivity and average wages

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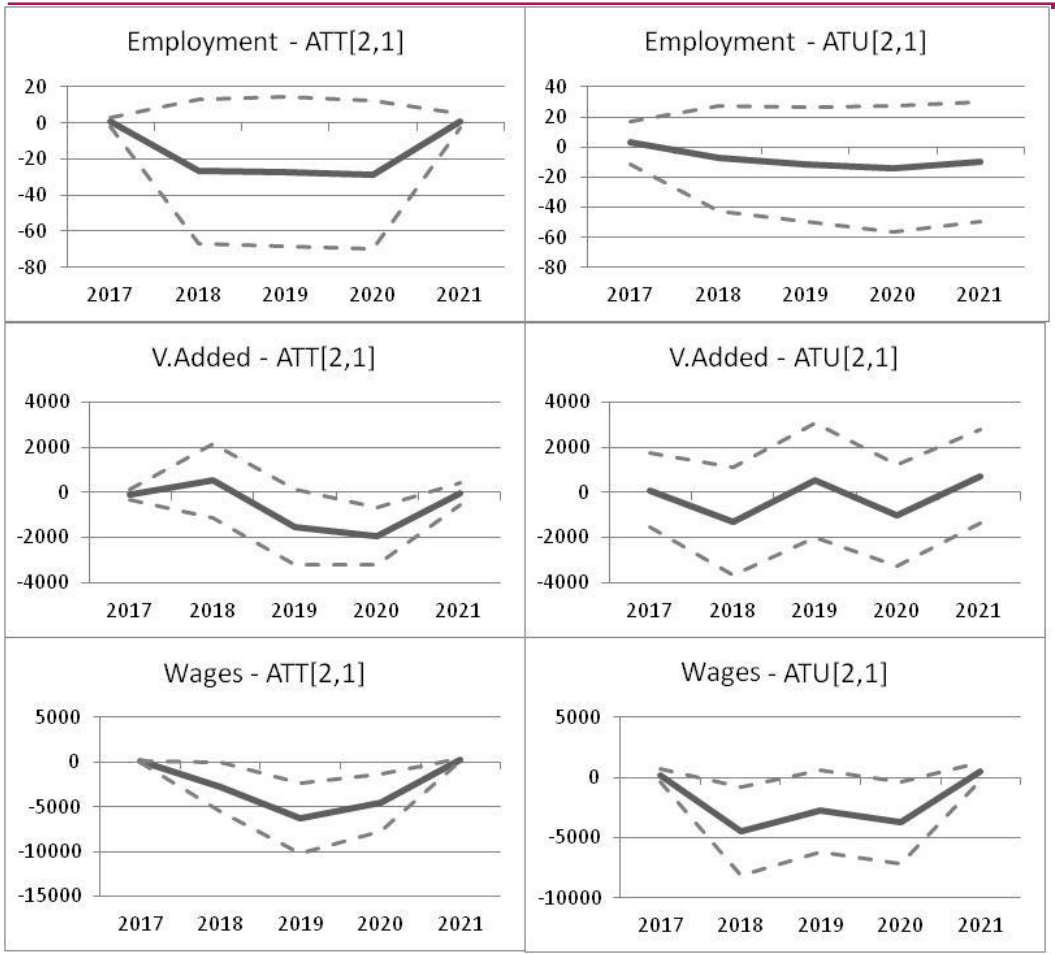
Estimated ATT(2,1)s and ATU(2,1)s



Additional training

- temporarily worsens value added and wages of firms that receive it
- would have perhaps (temporarily) worsened wages of firms that got the investment treatment alone

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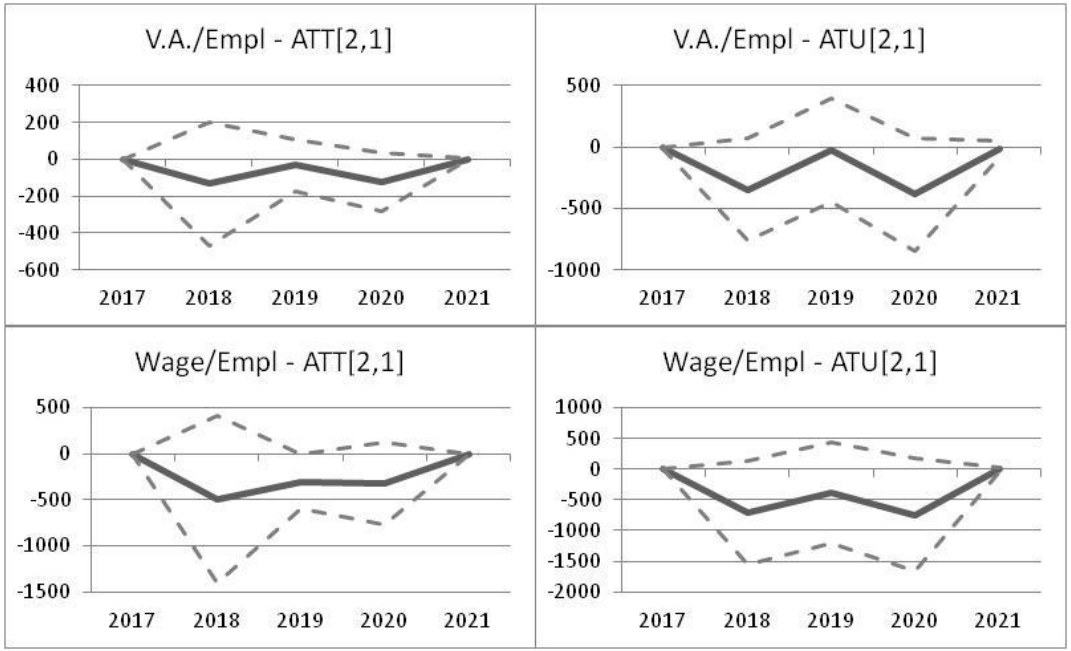
Estimated ATT(2,1)s and ATU(2,1)s



Additional training

- somewhat worsens average wage of firms that receive it
- would have perhaps a little worsened the situation of that got the investment treatment alone
- worsenings are temporary

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Concluding remarks

- We are currently investigating heterogeneity of effects by project size

	ATE [1,0]		ATE [2,0]		ATE [2,1]		ATU [2,1]	
	small	large	small	large	small	large	small	large
Employment	+	=	++	=	=	=	=	=
Value added	++	++	+	=		=	=	=
Wages	=	=	=	=	--	=	=	=
V.A./Employee	++	++	+	+	=	=	=	=
Wage/Employee	=	=	=	=	=	=	=	=

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