TECHNOLOGY AND EMPLOYMENT

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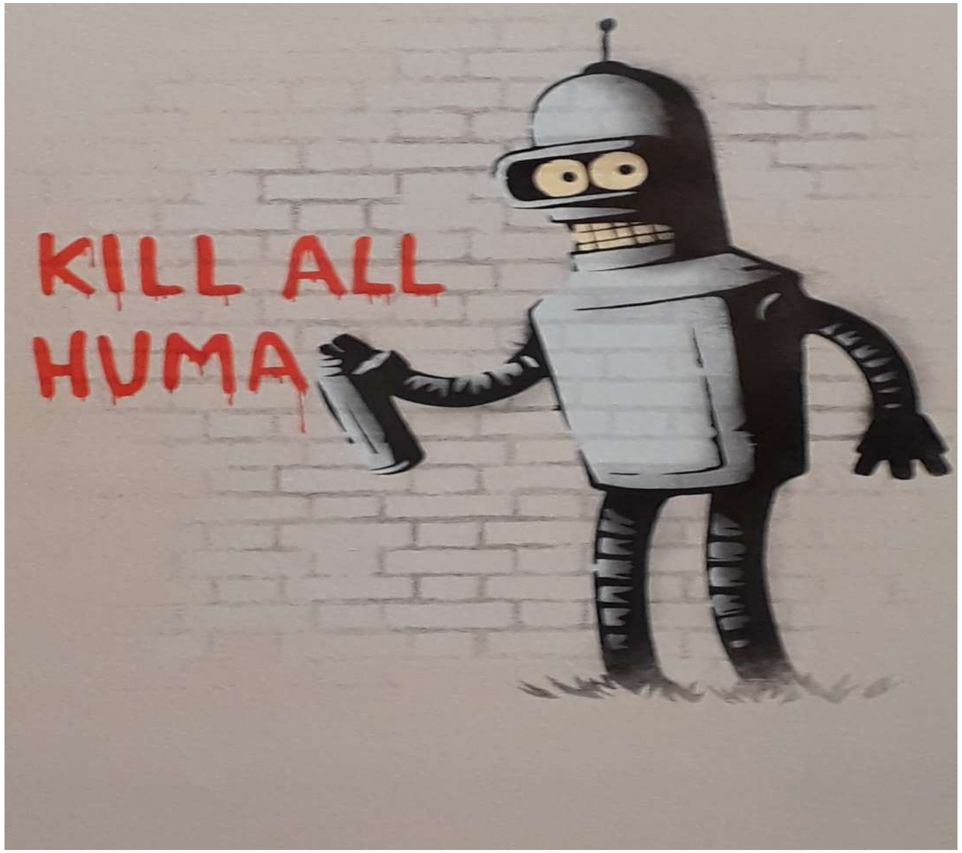


"Capitale e lavoro nell'era digitale" Workshop in onore di Giorgio Lunghini
Dipartimento di Economia e Management, Università di Ferrara, 5 Novembre 2019

TODAY ALARM…

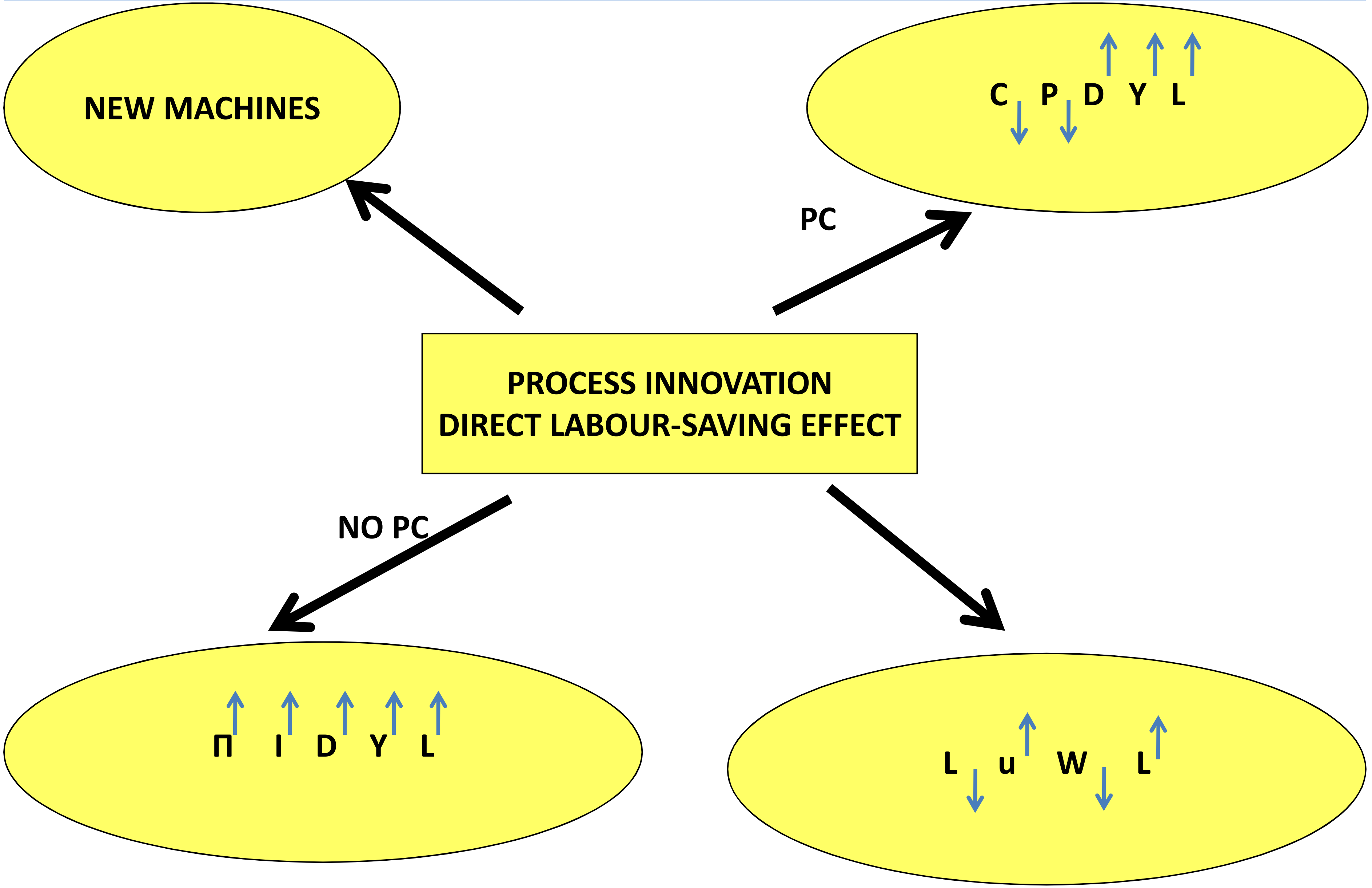
- The arrival of internet of things, self-driving autonomous cars (Tesla, Apple, Google) and widespread robots has raised again a fear of a new wave of '**technological unemployment**'.
- According to Brynjolfsson and McAfee (2011 and 2014), the root of the current employment problems is not the Great Recession, but rather a "Great Restructuring" characterized by an exponential growth in computers' processing speed having an ever-bigger impact on jobs, skills, and the whole economy: "**This time is different**".
- Moreover, not only agricultural and manufacturing employment appears at risk, but employees in services (Uber, airbnb, Amazon) - including **cognitive skills** - are no longer safe. Frey and Osborne (2017) predict that 47% of the occupational categories are at high risk of being automated, including a wide range of service/white-collar/cognitive tasks such as accountancy, logistics, legal works, translation and technical writing, etc.
- Compared with these comprehensive pictures, **mainstream economists** put forward on the one hand an overall long-run and general equilibrium optimism and on the other hand a narrow empirical focus on the labour-saving impact of the solely robots on the user sectors (mainly car factories): Acemoglu and Restrepo (2017;2018 and 2019).

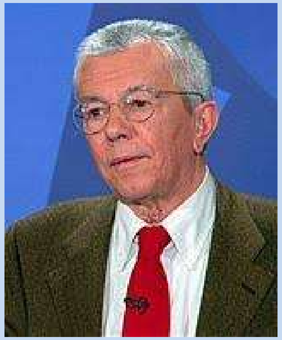
RICARDO’S SURPRISE? NOT AT ALL
A LONG TRADITION OF MAINSTREAM ECONOMICS OPTIMISM

“….the opinion, entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy” (Ricardo, 1951, vol 1, p. 387; third edition, 1821)

However, technological unemployment is considered an exception, occurring only when production does not grow, otherwise a “**compensation**” always occurs:

THE MAINSTREAM COMPENSATION THEORY





«CRITICA DELL'ECONOMIA POLITICA»

« La storia delle teorie della disoccupazione tecnologica (e delle **consolatorie teorie della compensazione**) è lunga quasi quanto quella dell'economia politica» (Lunghini, Giorgio, *L'età dello spreco: Disoccupazione e bisogni sociali*, Bollati Boringhieri, Torino, 1995, p. 26).

«L'introduzione delle nuove tecnologie nei processi produttivi non si traduce in grandi progetti di investimento capaci di effetti moltiplicativi che almeno in parte compensino il risparmio di lavoratori, bensì in una **diminuzione generalizzata dei coefficienti tecnici**» (*ibidem*, p. 42).

«Oggi non è sostenibile nessuna teoria della compensazione, e non è pensabile che la crescita del prodotto, ai tassi ai quali essa può **effettivamente e durevolmente** realizzarsi, comporti una crescita dell'occupazione» (*ibidem*, p. 43).

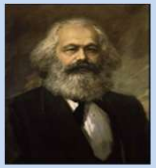
MAINSTREAM ECONOMICS PUTS FORWARD A TRICKLE-DOWN «FAIRY TALE»

Examples of "fairy tales": Neary, 1981; Stoneman, 1983; Kautsolacos, 1984; Hall and Heffernan, 1985; Waterson and Stoneman, 1985; Dobbs *et al*., 1987; Layard *et al.*, 1991.

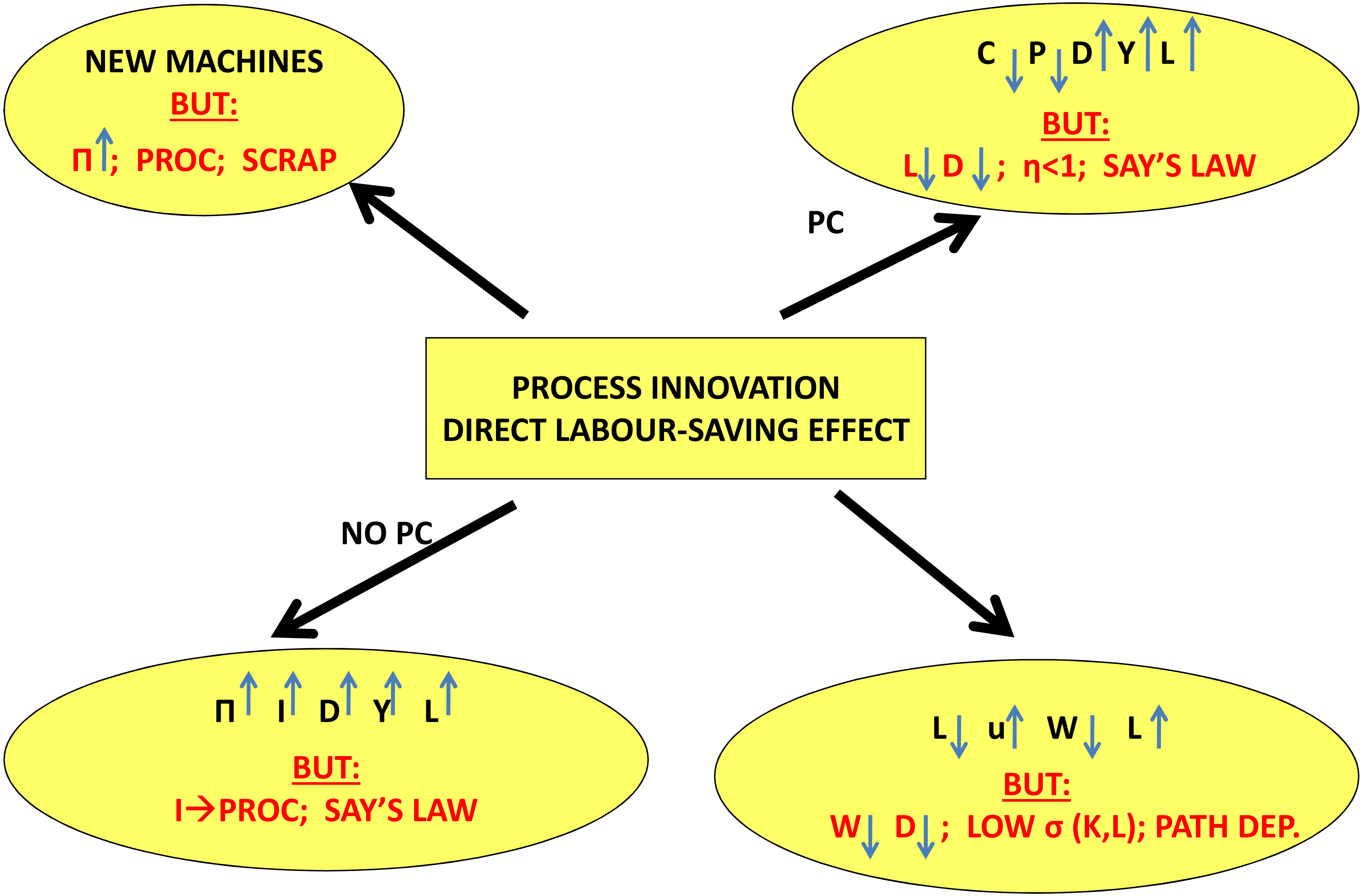
"*This neo-classical general equilibrium framework can be said to correspond most closely to present-day traditional economic views on technical change and employment. Technological change may indeed result in some temporary unemployment, but with efficiently operating labour and capital markets there is no basic economic problem arising from the introduction of new technology*"

(Freeman, C. and Soete, L., ***Work for All or Mass Unemployment***, London: Pinter, 1994, p.25)

In the real world, non competitive markets, price rigidities, pessimistic expectations may severely hinder and delay the compensation of the initial job losses.



THE CRITIQUE

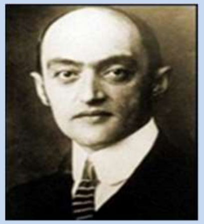


ON THE WHOLE, ECONOMIC THEORY IS INCONCLUSIVE
THE KEY ROLE OF EMPIRICAL STUDIES

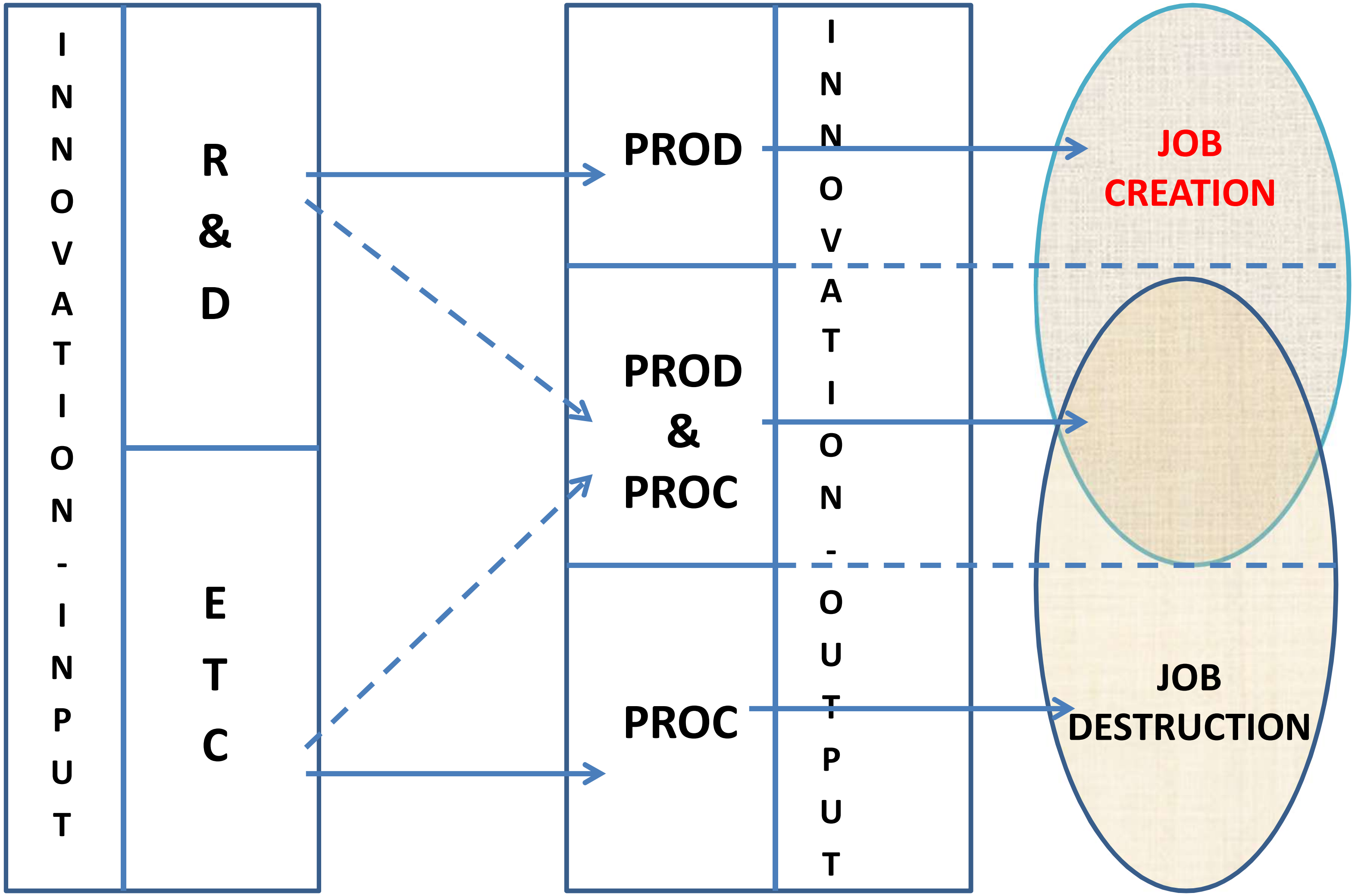
Compensation cannot be assumed ex ante (as implicitly done by mainstream theoretical studies; see Neary, 1981; Stoneman, 1983; Kautsolacos, 1984; Hall and Heffernan, 1985; Waterson and Stoneman, 1985; Dobbs et al., 1987; Layard et al., 1991), since the final employment outcome depends on crucial parameters such as the % of product innovation, expectations, the demand elasticity, the elasticity of substitution between K and L, and so on so forth.

In fact, since the ’90s, no further relevant theoretical contributions are put forward, with the focus moving to the **empirical studies** (for a critical discussion of the theoretical models and for aggregate and sectoral empirical studies, see Vivarelli, 1995; Vivarelli and Pianta, 2000; Vivarelli 2013 and 2014).

Empirical literature is developed at three levels depending on the disaggregation of data (macroeconomic, sectoral and firm level analysis) and using different proxies for technology. The recent literature focuses on the **micro level, with *pros* and *cons*.** The **advantage** of the firm-level analysis is the possibility to better proxy technological change and innovation and to deal with large datasets; the **disadvantage** is that we cannot take into account the complex (intersectoral) nature of the compensation theory.



SINCE ECONOMIC THEORY IS INCONCLUSIVE THE FOCUS HAS TO BE MOVED ONTO EMPIRICAL STUDIES: ETC AS ANOTHER MISSING LINK IN MAINSTREAM ECONOMICS



PREVIOUS MICROECONOMETRIC STUDIES (1)

The **advantage** of the firm-level analysis is the possibility to better proxy technological change and innovation and to deal with large datasets; the **disadvantage** is that we cannot take into account the complex (intersectoral) nature of the compensation theory.

CROSS-SECTIONAL STUDIES

Entorf-Pohlmeier, 1990: **positive** impact of product innovation, West Germany.

Zimmermann, 1991: **negative** impact, West Germany.

Klette-Førre, 1998: not clear-cut (**negative)** impact of R&D intensity, Norway .

Brouwer *et al*., 1993: **negative** effect of R&D, **positive** of product innovation, the Netherlands.

Cross section analyses (mainly based on OLS and or probit) are severely limited by **endogeneity** problems, cannot take into account the **unobservables** and may over-estimate the positive impact of innovation because of the **business stealing** effect.

Since the second half of the ’90s, attention has been moved to **longitudinal datasets and panel methodologies** (GMM-DIF; GMM-SYS; LSDVC).

PREVIOUS MICROECONOMETRIC STUDIES (2)

Cross section analyses in the 80s and 90s were severely limited by **endogeneity** problems,they were not able to take into account the **unobservables** and they tended to over-estimate the positive impact of innovation because of the **business stealing** effect. Since the end of the '90s, attention has been moved to **longitudinal datasets and panel methodologies** (GMM-DIF; GMM-SYS; LSDVC).

Van Reenen, 1997: **positive** impact of innovation, UK.

Doms *et al.,* 1997: **positive** effect of advanced manufacturing technologies, US.

Smolny, 1998: **positive** impact of product innovation, West Germany.

Greenan and Guellec, 2000: **positive** effect of innovation at the firm-level, but negative at the sectoral level (still positive for product innovation), France.

Greenhalgh *et al.,* 2001: **positive** impact of R&D, UK, but **only in the High-Tech**.

Hall *et al* (2008): **positive** impact of product innovation , Italy.

Lachenmaier and Rottmann (2011): **positive** impact of innovation (including process innovation), no sectoral differences, Germany.

Coad and Rao (2011), **positive** impact of innovation, stronger for fast-growing firms, US (data only from **high-tech manufacturing**).

Harrison *et al.* (2014): **positive** effect of product innovation and (slightly) **negative** of process innovation (strong compensation in **services**), Germany-France-UK-Spain.

MY PREFERRED ECONOMETRIC SPECIFICATION

i = 1,..,n; t = 1,..,T

$$l_{i,t} = \beta_1 y_{i,t} + \beta_2 w_{i,t} + \beta_3 gi_{i,t} + \beta_4 LagInno_i + (\varepsilon_i + \nu_{i,t})$$

Taking into account **viscosity in the labor demand** (Arellano and Bond, 1991; Van Reenen, 1997), we move to the proper dynamic specification:

$$l_{i,t} = \alpha l_{i,t-1} + \beta_1 y_{i,t} + \beta_2 w_{i,t} + \beta_3 gi_{i,t} + \beta_4 LagInno_i + (\varepsilon_i + \nu_{i,t})$$

Panel methodologies:

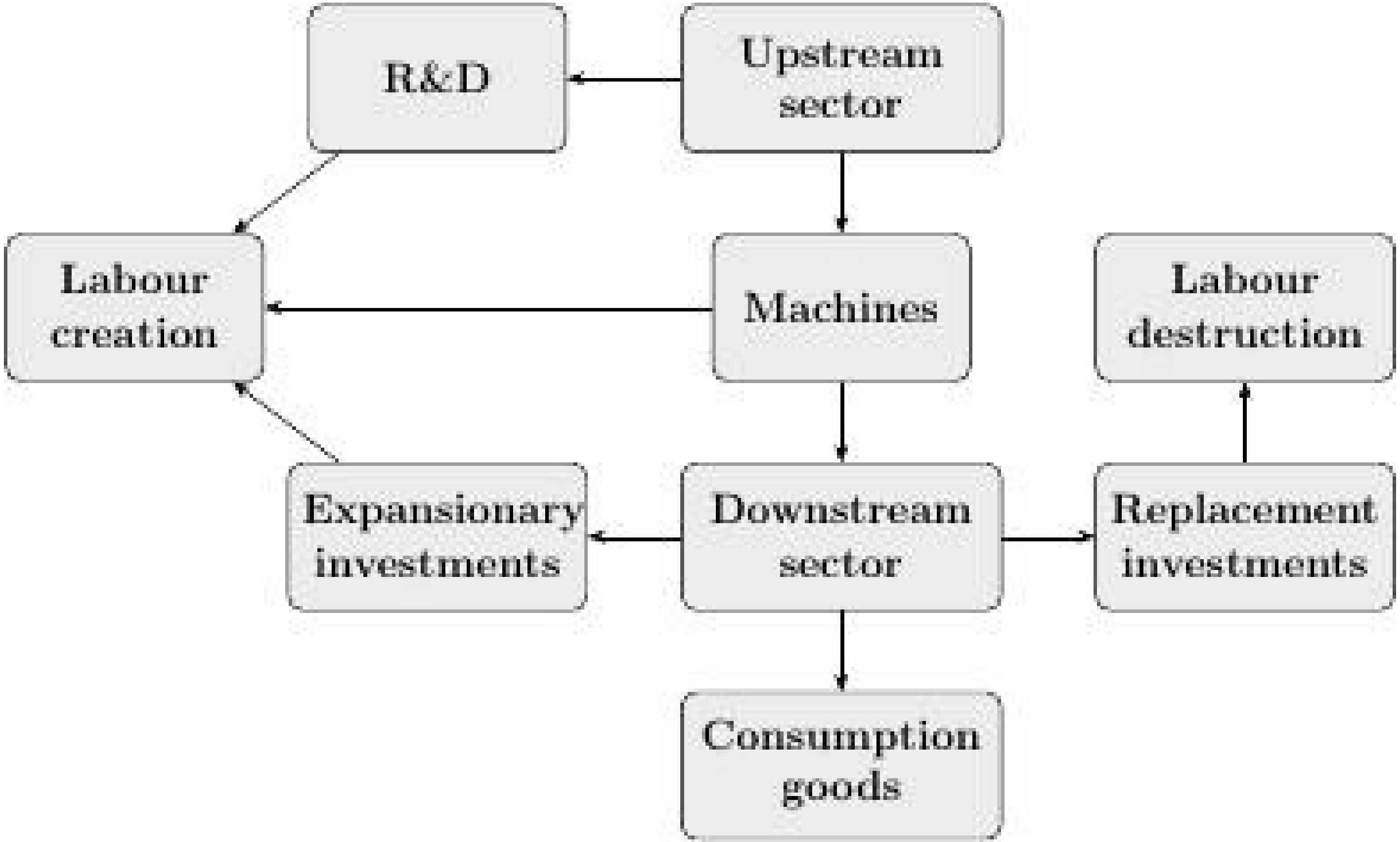
- **POLS** with time and sector dummies (endogeneity, unobservables)
- **FE/RE** according to the Hausman's test, with time dummies (endogeneity)
- **GMM-SYS** better than GMM-DIF because of strong persistence and dominant cross sectional variability; see Blundell and Bond, 1998 (preferred methodology, when feasible)
- **LSDVC** better than GMM-SYS when the panel is severely unbalanced and n is not so large

SOME REFERENCES

- Vivarelli, M., 1995. **The Economics of Technology and Employment: Theory and Empirical Evidence**. Aldershot: Elgar.
- Vivarelli, M., Pianta, M. (eds), 2000. ***The Employment Impact of Innovation: Evidence and Policy***. London: Routledge.
- Piva, M., Vivarelli, M., 2005. Innovation and employment: Evidence from Italian microdata. ***Journal of Economics***, 86, 65-83.
- Piva, M., Santarelli, E., Vivarelli, M., 2005. The skill bias effect of technological and organisational change: Evidence and policy implications. ***Research Policy***, 34, 141-157.
- Bogliacino, F., Piva, M., Vivarelli, M., 2012. R&D and employment: An application of the LSDVC estimator using European data. ***Economics Letters***, 116, 56-59.
- Vivarelli, M., 2014. Innovation, employment and skills in advanced and developing countries: A survey of economic literature. ***Journal of Economic Issues***, 48, 123-154.
- Van Roy, V. - Vertesy, D. - Vivarelli, M. (2018), Technology and Employment: Mass Unemployment or Job Creation? Empirical Evidence from European Patenting Firms, ***Research Policy***, 47, 1762-1776.
- 13) Piva, M. - Vivarelli, M. (2018), Technological Change and Employment: Is Europe Ready for the Challenge?, ***Eurasian Business Review***, 8, 13-32.
- Barbieri, L. - Piva, M. - Vivarelli, M. (2019), R&D, Embodied Technological Change and Employment: Evidence from Italian Microdata, ***Industrial and Corporate Change***, 28, 203-218.
- Pellegrino, G. - Piva, M. - Vivarelli, M. (2019), Beyond R&D: The role of Embodied Technological Change in Affecting Employment, **Journal of Evolutionary Economics**, 29, 1151-1171.

EMBODIED AND DISEMBODIED TECHNOLOGICAL CHANGE: THE SECTORAL PATTERNS OF JOB-CREATION AND JOB-DESTRUCTION

Dosi, Piva, Virgillito, Vivarelli (2019)



DATA

- **Sectoral** STAN OECD and ANBERD OECD data covering **19 European countries** over the period **1998-2016 (unbalanced panel)**.
- Upstream and downstream sectors are singled out applying a refined Pavitt (1984) taxonomy, as in **Bogliacino and Pianta (2010)**. The "Science-based" and "Specialized Suppliers" sectors are considered upstream, while the "Scale and information intensive" and the "Supplier dominated" industries are considered downstream.
- In order to split the two components of investments (EI and SI), we consider the **Consumption of Fixed Capital (CFCC) as the scrapping component (SI)**. The extra investment given by **(GFCF – CFCC) - where GFCF is the Gross Fixed Capital Formation - represents the expansionary component**. When CFCC resulted to be higher than GFCF, we set expansionary investments equal to 0 to avoid unreliable negative values.

Table A3: Descriptive statistics

		Employees	Value Added	Cost of Labour per Employee	R&D	Consumption of Fixed Capital	Expansionary Investments
UP	Mean	81.29	8,850.32	58.36	701.14		
	St.dev.	136.42	14,405.51	41.59	1,280.53		
DOWN	Mean	184.04	14,275.35	43.93		1,948.61	1,289.75
	St.dev.	397.61	53,491.72	41.08		9,239.55	6,452.03

Note: While the Employees are expressed in thousands of persons engaged, the monetary variables are expressed in millions (thousands in the case of Cost of labour per employee) of constant PPP 2010 US dollars.

SPECIFICATION AND METHODOLOGY

$$l_{i,t} = \alpha l_{i,t-1} + \beta_1 y_{i,t} + \beta_2 w_{i,t} + \beta_3 R\&D_{i,t-1} + (\varepsilon_i + \nu_{i,t})$$ UPSTREAM

i = 1, … 177; t = 1998…2016

$$l_{i,t} = \alpha l_{i,t-1} + \beta_1 y_{i,t} + \beta_2 w_{i,t} + \beta_3 \mathrm{EI}_{i,t-1} + \beta_4 SI_{i,t-1} + (\varepsilon_i + \nu_{i,t})$$ DOWNSTREAM

i = 1, … 297; t = 1998…2016

As common in the literature (see Van Reenen, 1997; Lachenmaier and Rottmann, 2011; Bogliacino, Piva and Vivarelli, 2012) The specifications above can be seen as **dynamic labor demands augmented by proxies of disembodied** (*R&D*) **and embodied technological change** (expansionary investments, *EI*, and scrapping, *SI*).

The specifications above have been tested through : Pooled Ordinary Least Squares (**POLS**) controlled for time effects; Fixed Effects (**FE**), in order to take into account country/sector unobservables; and the preferred **GMM-SYS** methodology to solve the obvious endogeneity problem brought about by the inclusion of the lagged dependent variable.

Moreover, **endogeneity** problems may also arise from other covariates in the model (for instance, it may well be the case that wage, investment and employment decisions are jointly and simultaneously adopted). Hence, all the explanatory variables will be cautiously considered as potentially endogenous to labour demand and instrumented when necessary, using up to thrice lagged instruments.

Since all the variables are expressed in log, the estimated coefficients can be interpreted as **elasticities**.

RESULTS

	UPSTREAM			DOWNSTREAM		
	POLS	FE	GMM-SYS	POLS	FE	GMM-SYS
Log(Employees)$_{-1}$	0.971*** (0.005)	0.689*** (0.038)	0.872*** (0.031)	0.967*** (0.007)	0.796*** (0.052)	0.964*** (0.019)
Log(Value Added)	0.025*** (0.005)	0.187*** (0.026)	0.110*** (0.028)	0.047*** (0.007)	0.104*** (0.024)	0.089*** (0.019)
Log(Cost of labour per Employee)	-0.041*** (0.007)	-0.201*** (0.026)	-0.139*** (0.035)	-0.310*** (0.007)	-0.095*** (0.028)	-0.015 (0.017)
Log(R&D)$_{-1}$	**0.004*** (0.001)**	**0.009* (0.005)**	**0.011* (0.006)**			
Log(Consumption of Fixed Capital)$_{-1}$				**-0.018*** (0.002)**	**-0.003 (0.010)**	**-0.064*** (0.011)**
Log(Expansionary Investments)$_{-1}$				**0.003*** (0.000)**	**0.004*** (0.001)**	**0.005* (0.002)**
Constant	0.044* (0.023)	0.377*** (0.092)	0.100 (0.064)	-0.004 (0.014)	0.324** (0.135)	-0.101*** (0.031)
Wald time-dummies (p-value)	6.8*** (0.000)	4.4*** (0.000)	93.8*** (0.000)	12.7*** (0.000)	11.3*** (0.000)	164.7*** (0.000)
Hansen test (p-value) AR (p-value)			0.138 AR(3) 0.40			0.092* AR(2) 0.68
R^2 (overall) R^2 (within)	0.99	 0.83		0.99	 0.89	
Obs.	1,732			3,349		
N. of sectors	170			297		

RESULTS (ZOOM)

Log(R&D)$_{-1}$	0.004*** (0.001)	0.009* (0.005)	0.011* (0.006)			
Log(Consumption of Fixed Capital)$_{-1}$				-0.018*** (0.002)	-0.003 (0.010)	-0.064*** (0.011)
Log(Expansionary Investments)$_{-1}$				0.003*** (0.000)	0.004*** (0.001)	0.005* (0.002)

KEY FINDINGS FROM MY STUDIES AND POLICY IMPLICATIONS

- **R&D and patents** foster labor-friendly product innovation that leads to job creation; however, the overall job-creation impact is often **negligible** in magnitude with employment elasticities lower than 1%.
- The job-creation impact of innovation is limited to **product innovation and to the high-tech sectors** → Need for structural, industrial and innovation policies.
- **Process innovation and embodied technological change** may displace labor and create technological unemployment in supplier dominated/traditional sectors → Need for safety nets, labor policies and education/training policies.
- **Price and income compensation mechanisms** can counterbalance the initial displacement of workers that occurs following process innovation. However, **market and institutional rigidities** can hinder the price and income compensation mechanisms that work to lessen job destruction → Need for competition policy.

THANK YOU