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WORKING PAPER FDV

A quantitative analysis of the European Construction sector: Productivity, investment and competitiveness

Un'analisi quantitativa del settore europeo delle Costruzioni: Produttività, investimenti e competitività

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Un'analisi quantitativa del settore europeo delle Costruzioni:

Produttività, investimenti e competitività.[1]

Alessandro Bellocchi, Giuseppe Travaglini [2]

Abstract in italiano

L'industria delle costruzioni è un settore cardine nell'economia europea. Fornisce infrastrutture necessarie allo sviluppo di numerosi altri settori produttivi ed è significativa sia per l'occupazione che per la creazione di valore aggiunto. Tuttavia, l'industria delle costruzioni resta strutturalmente debole in quanto caratterizzata dalla presenza della piccola impresa, da un basso contenuto tecnologico e da una elevata intensità di manodopera rispetto al capitale. Ciò ha condotto nel tempo ad una produttività del lavoro inferiore alla media, nazionale ed europea, ed a una ridotta capacità innovativa, sia di prodotto che di processo. In questo lavoro utilizziamo i dati macroeconomici Eurostat di EU 28 per documentare queste dinamiche. Dall'analisi emerge il ritardo competitivo dell'industria delle costruzioni italiana rispetto alla analoga dinamica europea. Inoltre, utilizziamo i dati di bilancio Amadeus Bureau van Dijk per calcolare la produttività, il markup e una misura appropriata del progresso tecnologico, stimando la così detta produttività totale dei fattori (TFP) del settore, in sei paesi europei per il periodo 2011-2019. La TFP è una misura complessiva della produttività tecnologica, fattore chiave per la crescita economica nel lungo termine. Il markup fornisce informazioni sul grado di competitività del settore. Dall'analisi emerge la necessità di accrescere il contenuto tecnologico e innovativo del settore costruzioni per sostenere sia la produttività e la competitività che i salari. Non ultima, emerge la necessità di disegnare nuove regole e forme di relazioni industriali, a livello nazionale ed europeo, per facilitare la ripartenza del settore costruzioni. È determinante ridurre il gap tecnologico che separa questa industria da quelle a maggiore produttività, e contenuto tecnologico-digitale, senza però danneggiare i livelli occupazionali.

Classificazione: JEL D24, L74.

Parole chiave: Economia, Costruzioni, Produttività totale dei fattori, Markup; Occupazione; Funzione di produzione translog.

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[1] This paper is part of the project "Discus - Digital Transformation in the Construction Sector: challenges and opportunities", a European Union co-funded research project (DG Employment, Social Affairs and Inclusion, VS/2019/0078). Partners: Fondazione Di Vittorio (Italy, project coordinator); Fundacion 1° de Mayo (Spain), Association travail emploi Europe société-ASTREES (France), Arbeitsforschung und Transfer e.V. (Germany), Laboratoire d'Etudes sur les Nouvelles formes de Travail, l'Innovation et le Changement, LENTIC, Université de Liège (Belgium), Workers Educations and Training College, WETCO (Bulgaria). Supporters: CGIL (Italy), FNV (Netherlands), EFBWW (EU). Website: https://discusproject.eu.

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A quantitative analysis of the European Construction sector: Productivity, investment and competitiveness. [1]

Abstract in English

The construction industry is a key sector in the European economy. It provides infrastructure necessary for the development of numerous other productive sectors, and it is significant both in terms of employment and value added. However, the construction industry remains structurally weak as it is characterized by the presence of small firms, low technology content and a high intensity of labor relative to capital. Over time, this has led to a labor productivity below the national and European average, and to a limited capacity for innovation, both in terms of products and processes. In this paper, we use Eurostat macroeconomic data for the EU 28 to document these asymmetric dynamics. From the analysis, it emerges the competitive gap of the Italian construction industry compared to the similar European dynamics. In addition, we use Amadeus Bureau van Dijk balance sheet data to calculate productivity, markup and an appropriate measure of technology progress, estimating the so-called total factor productivity (TFP) for the industry, in six European countries for the period 2011-2019. TFP is an overall measure of technology productivity, a key driver of long-term economic growth. The markup provides information on the degree of competitiveness of the sector. The analysis reveals the need to increase the technology and innovation content of the construction industry in order to sustain productivity, competitiveness and wages. Finally, it emerges the need to design new rules and industrial relations, at national and European level, to facilitate the recovery of the construction sector. It is crucial to reduce the technological gap that separates this industry from those with higher productivity and technological-digital content, without, however, compromising employment levels.

Classificazione: JEL D24, L74.

Keywords: Economics, Construction, Total factor productivity, Markup; Translog production function.

1. Introduction

In this paper, we present some stylized facts related to the "Construction sector" for EU 28 and the main European countries. Our aim is to provide a quantitative analysis of the sector, focusing on labor productivity, technological progress and competitiveness. We start our investigation from macro data of national account to descend towards the micro data using the balance sheets and the book values of the main European companies operating in the sector.

Among countries, particular attention will be given to Belgium, Bulgaria, France, Germany, Italy and Spain that make up the network of the research project. Macro data are taken from the *Eurostat database* and range from 1995 to 2018.[3] Micro data, on the other hand, are from the *Amedeus - Bureau Van Dijk* database and concern corporate and financial data, covering the period 2011-2019.

The aim is consistent with the DISCUS project, namely we manage (1) to provide new information to support "industrial relations in particular those designed to develop expertise and the exchange of EU-relevant information, as well as actions to improve knowledge on industrial relations institutions and practices across the EU and the dissemination of results"; (2) to collect and "and use of (comparative) information on industrial relations systems in EU Member States and on their development at European level", and (3) to develop "research activities including preparatory studies, surveys and other forms of data collection, monitoring exercises and studies" useful to focus on the major changes taking place in the Construction sector, and to identify the economic and institutional policies that allow a balanced and sustainable development - between capital, labor and technology - of the Construction sector.

On the empirical ground, we are interested in four main features:

- defining the dimension of the European Construction sector;
- measuring labor productivity;
- offering a measure of the degree of competitiveness of the sector in any individual countries;
- measuring through the Total Factor Productivity (the so-called Solow residual) the content and dynamics of the technology advancement in this sector.

To this end, we start our analysis collecting statistical data to fuel our dataset. Then, we present an econometric procedure to estimate technological progress (i.e. Total Factor Productivity TFP) in specific sub sectors and firms. We employ a *translog production function* to estimate these components and the corresponding indexes.

[3] More exactly, we refer to: [nama_10_a10] - Gross value added and income by A*10 industry breakdowns and [nama_10_a10_e] - Employment by A*10 industry breakdowns.

2. Some stylized facts

In Figure 1, we report the Nace classification of industrial sectors of the European Union (EU). Specifically, we focus on Divisions 10-33 for Manufacturing, and Divisions 41-43 for Construction. As said, Construction is the economic industry that includes all construction firms. There is no common definition of whether it is an industry or a sector. However, the mix of this macro sectors allow to take a picture of this aggregate sector and to describe the contribution and impact of the Construction sector on the economy, the environment and society as a whole.

Figure 1. Statistical Classification of Economic Activities (Nace)

Note: Industry standard classification system used by the European Union

Broad Structure of NACE Rev. 2

Section	Title	Divisions
A	Agriculture, forestry and fishing	01-03
B	Mining and quarrying	05-09
C	Manufacturing	10-33
D	Electricity, gas, steam and air conditioning supply	35
E	Water supply; sewerage, waste management and remediation activities	36-39
F	Construction	41-43
G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45-47
H	Transportation and storage	49-53
I	Accommodation and food service activities	55-56
J	Information and communication	58-63
K	Financial and insurance activities	64-66
L	Real estate activities	68
M	Professional, scientific and technical activities	69-75
N	Administrative and support service activities	77-82
O	Public administration and defence; compulsory social security	84
P	Education	85
Q	Human health and social work activities	86-88
R	Arts, entertainment and recreation	90-93
S	Other service activities	94-96
T	Activities of households as employers; undifferentiated goods and services producing activities of households for own use	97-98
U	Activities of extraterritorial organisations and bodies	99

Source: Ramon - Reference and management of nomenclatures (Eurostat)

It should be noted (Figures 2 and 3) that while the Construction division identifies a delimitated aggregate of production activities, in the Manufacturing division the set is broader, and therefore we select the sub-sector 23, which includes those production activities that must be brought back to the Construction sector even though they are not taxonomically classified in it.

Figure 2. The Construction sector

SECTION F - CONSTRUCTION				
Division	*Group*	*Class*		*ISIC Rev. 4*
41			Construction of buildings	
	41.1		Development of building projects	
		41.10	Development of building projects	4100*
	41.2		Construction of residential and non-residential buildings	
		41.20	Construction of residential and non-residential buildings	4100*
42			Civil engineering	
	42.1		Construction of roads and railways	
		41.11	Construction of roads and motorways	4210*
		41.12	Construction of railways and underground railways	4210*
		41.13	Construction of bridges and tunnels	4210*
	42.2		Construction of utility projects	
		42.21	Construction of utility projects for fluids	4220*
		42.22	Construction of utility projects for electricity and telecommunications	4220*
	42.9		Construction of other civil engineering projects	
		42.91	Construction of water projects	4290*
		42.99	Construction of other civil engineering projects n.e.c.	4290*
			Specialised construction activities	
43	43.1		Demolition and site preparation	
		43.11	Demolition	4311
		43.12	Site preparation	4312*
		43.13	Test drilling and boring	4312*
	43.2		Electrical, plumbing and other construction installation activities	
		43.21	Electrical installation	4321
		43.22	Plumbing, heat and air conditioning installation	4322
		43.29	Other construction installation	4329
	43.3		Building completion and finishing	
		43.31	Plastering	4330*
		43.32	Joinery installation	4330*
		43.33	Floor and wall covering	4330*
		43.34	Painting and glazing	4330*
		43.39	Other building completion and finishing	4330*
	43.9		Other specialised construction activities	
		43.91	Roofing activities	4390*
		43.99	Other specialised construction activities n.e.c.	4390*

Source: RAMON - Reference and management of nomenclatures (Eurostat)

According to Eurostat database, the Construction sector in EU28 is characterized by the presence of a large **number of firms**. Overall, more than 3.5 million firms (Table 1) operate in the sector. It should be noted that among the European countries, Italy is the one with the highest number of construction firms (502.775) followed by France, Spain and Germany. Belgium does not reach 115.000 firms, and Bulgaria is even further behind (19.000). In the sub sectors, Spain emerges in that of "Construction of buildings", the United Kingdom in "Civil Engineering", followed by Germany and Italy while in "Specialized construction activities" the leading position is held by France, followed by Italy and Germany.

Eurostat statistics provide additional information that helps to profile the sector. The average **size of the firms** is an important feature. Here, the previous ranking is reversed (Table 2). The Italian economy is among those with the smallest average firm size in terms of employees (2.6 employees per enterprise), very close to Belgium, Spain and France. The case of Germany stands out from data where the average size is much greater (6.8) and even Bulgaria where the size rises to 7.4. This characteristic is also found in the sub-sectors where the average size of the "Civil engineering" sector is much higher than the other sectors. These elements affect both the aggregate production, and the overall added value and labor productivity.

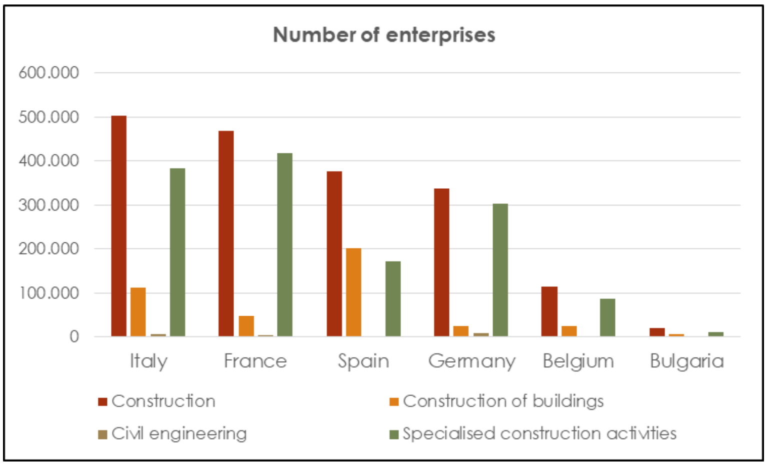
Figure 3. The sub-sectors of Manufacturing to be traced back to Construction

SECTION C - MANUFACTURING				
Division	*Group*	*Class*		*ISIC Rev. 4*
23			Manufacture of other non-metallic mineral products	
	23.1		Manufacture of glass and glass products	
		23.11	Manufacture of flat glass	2310*
		23.12	Shaping and processing of flat glass	2310*
		23.13	Manufacture of hollow glass	2310*
		23.14	Manufacture of glass fibres	2310*
		23.19	Manufacture and processing of other glass, including technical glassware	2310*
	23.2		Manufacture of refractoryproducts	
		23.20	Manufacture of refractoryproducts	2391
	23.3		Manufacture of clay building materials	
		23.31	Manufacture of ceramic tiles and flags	2392*
		23.32	Manufacture of bricks, tiles and construction products, in baked clay	2392*
	23.4		Manufacture of other porcelain and ceramic products	
		23.41	Manufacture of ceramic household and ornamental articles	2393*
		23.42	Manufacture of ceramic sanitary fixtures	2393*
		23.43	Manufacture of ceramic insulators and insulating fittings	2393*
		23.44	Manufacture of other technical ceramic products	2393*
		23.49	Manufacture of other ceramic products	2393*
	23.5		Manufacture of cement, lime and plaster	
		23.51	Manufacture of cement	2394*
		23.52	Manufacture of lime and plaster	2394*
	23.6		Manufacture of articles of concrete, cement and plaster	
		23.61	Manufacture of concrete products for construction purposes	2395*
		23.62	Manufacture of plaster products for construction purposes	2395*
		23.63	Manufacture of ready-mixed concrete	2395*
		23.64	Manufacture of mortars	2395*
		23.65	Manufacture of fibre cement	2395*
		23.69	Manufacture of other articles of concrete, plaster and cement	2395*
	23.7		Cutting, shaping and finishing of stone	
		23.70	Cutting, shaping and finishing of stone	2396
	23.9		Manufacture of abrasive products and non-metallic mineral products n.e.c.	
		23.91	Production of abrasive products	2399*
		23.99	Manufacture of other non-metallic mineral products n.e.c.	2399*

Source: Ramon - Reference and management of nomenclatures (Eurostat)

Table 1. The number of firms - Construction sector (2019)

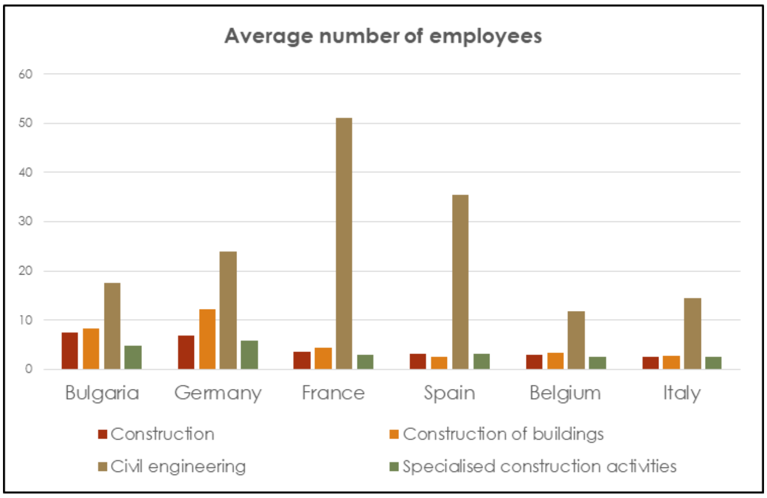
GEO/TIME	Construction	Construction of buildings	Civil engineering	Specialised construction activities
EU28	3,523,557	896,383	109,524	2,517,652
Italy	502,775	112,125	6,208	384,442
France	468,974	48,020	4,003	416,952
Spain	376,235	202,002	2,943	171,291
Germany	338,475	24,870	9,765	303,840
United Kingdom	330,545	96,578	24,476	209,491
Poland	281,953	72,598	18,383	190,972
Czechia	177,390	30,762	1,725	144,903
Netherlands	173,775	73,164	8,316	92,295
Belgium	114,645	25,123	3,021	86,501
Sweden	104,097	23,915	2,622	77,560
Slovakia	95,114	14,069	1,012	80,033
Portugal	81,629	38,984	2,893	39,752
Hungary	69,658	15,119	4,360	50,179
Greece	61,833	15,878	5,059	40,896
Ireland	57,255	15,573	1,560	40,122
Romania	52,792	27,681	3,355	21,756
Finland	41,110	17,857	1,452	21,801
Austria	36,157	4,698	1,146	30,313
Lithuania	31,708	4,068	511	27,129
Bulgaria	19,889	7,607	1,980	10,302
Slovenia	18,668	2,909	605	15,154
Croatia	17,994	6,860	878	10,256
Latvia	11,590	3,690	1,040	6,860
Estonia	10,931	3,943	852	6,136
Luxembourg	3,930	1,524	71	2,335



Source: Authors' calculation on Eurostat data

Table 2. Average number of employees - Construction sector (2019)

GEO/TIME	Construction	Construction of buildings	Civil engineering	Specialised construction activities
EU28	3.7	3.7	14.6	3.2
Luxembourg	11.5	8.5	66.3	11.7
Austria	8.3	14.4	26.2	6.7
Bulgaria	7.4	8.2	17.5	4.8
Romania	6.9	6.2	20.7	5.6
Germany	6.8	12.1	24	5.8
Croatia	5.7	5.5	25.4	4.1
Latvia	5.7	6.3	14.1	4.1
Finland	4.9	4.3	13.7	4.9
United Kingdom	4.6	4.6	9.9	4
Estonia	4.4	4.4	9.7	3.6
Sweden	4	4.7	10.5	3.5
Portugal	3.8	3.8	16.1	3
France	3.6	4.3	51	3
Lithuania	3.4	10.3	36.3	1.7
Slovenia	3.3	4.7	13	2.7
Poland	3.2	3.9	9.1	2.4
Hungary	3.1	4.1	8.5	2.3
Spain	3.1	2.4	35.5	3.2
Belgium	2.9	3.3	11.8	2.5
Italy	2.6	2.7	14.4	2.4
Netherlands	2.6	1.9	6.7	2.8
Ireland	2.4	2.3	6	2.3
Czechia	2.1	2.9	33.3	1.5
Greece	2	2	4.9	1.7
Slovakia	1.7	2.5	16.1	1.4



Source: Authors' calculation on Eurostat data

Between 2000 and 2018, the trend of the **production volume** (index) is particularly indicative to describe the relative and absolute changes in this industry in EU 28, and to capture the great variability between countries, with the basic heterogeneity that characterize the major traditional European economies, but also those of the new EU members, such as Bulgaria.

Table 3. Volume index of Production - Construction sector

Note: Seasonally and calendar adjusted data. Cumulative growth from 2000

	Total cumulative growth				
	2000M01	2005M1	2008M1	2013M1	2019M8
Austria		22,40%	44,79%	40,10%	58,00%
Belgium		2,90%	13,02%	21,10%	20,70%
Bulgaria		74,10%	148,54%	99,70%	118,90%
Croatia		19,70%	59,47%	9,40%	17,90%
Czechia		34,90%	64,84%	35,60%	60,30%
Denmark		22,90%	39,33%	20,20%	49,70%
European Union 28		3,10%	17,48%	-5,70%	10,20%
Finland		14,50%	43,68%	46,20%	62,90%
France		8,00%	20,68%	5,00%	6,90%
Germany		-33,40%	-2,63%	-6,50%	12,90%
Hungary		58,20%	50,52%	26,20%	116,70%
Italy		20,60%	39,27%	-5,60%	-8,90%
Luxembourg		-0,50%	25,93%	20,90%	49,60%
Netherlands		-3,90%	11,58%	-16,60%	23,70%
Poland		-34,30%	26,64%	27,10%	58,90%
Portugal		-10,90%	-23,97%	-93,60%	-106,10%
Romania		35,40%	109,97%	108,60%	137,20%
Slovakia		22,60%	64,23%	39,80%	57,20%
Slovenia		18,50%	107,57%	8,50%	70,60%
Spain		20,90%	14,97%	-31,40%	-5,90%
Sweden		15,90%	49,41%	51,30%	67,40%
United Kingdom		26,50%	37,91%	24,30%	52,20%

Source: Authors' calculation on Eurostat data

Starting from the cumulative data, over the period 2000-2005, the **production index** (see Table 3), provides a leading indicator of recession and recovery, and of relative fluctuations. For example, Bulgaria, starting from a delayed position, records an impressive acceleration with an overall production index that grows up to 148% in 2008, and does not suffer the impact of the debt crisis that broke out that year, with a further acceleration that lasts until the end of 2019.

This is not the case in other European countries. As known, in the last two decades, Italy has slowed down with a cumulative fall in this sector of -5.6% until 2013, and a further recession (-8.95) until 2019. Analogously, and even larger, is the recession of the Construction sector in Spain (-31.4% until 2013 and -5.9% until 2019). Germany and France, on the other hand, are disengaged from this negative pattern and, after the recession of 2008-2013, are back in growth, widening the gap with the main European countries. Analogously, it is the dynamics of the sub-sectors as shown by the data in Table 4.

Table 4. Volume index of Production - sub-sectors

Note: Seasonally and calendar adjusted data. Cumulative growth from 2000

	2000-2008			2008-2019		
	Construction	Buildings	Civil engineering	Construction	Buildings	Civil engineering
EU28	17,08%	17,41%	11,86%	-9,73%	-9,44%	-9,38%
EA19	13,71%	13,62%	10,67%	-17,89%	-17,25%	-18,32%
Belgium	12,98%	12,88%	18,00%	-4,91%	-11,68%	8,20%
Bulgaria	312,72%	333,81%	272,02%	-32,62%	-42,02%	-11,28%
Czechia	80,68%	70,52%	112,80%	-16,00%	-14,16%	-20,75%
Denmark	34,38%	32,58%	53,92%	NA	NA	NA
Germany	-10,27%	-13,17%	-4,64%	5,87%	4,51%	20,28%
Spain	15,29%	19,84%	0,79%	-38,96%	-38,63%	-45,15%
France	20,25%	18,96%	25,82%	-20,08%	-19,42%	-23,33%
Croatia	74,08%	84,58%	63,82%	-37,80%	-32,99%	-43,14%
Italy	41,47%	21,62%	2.34%	-42,59%	-36,64%	-31,62%
Luxembourg	16,86%	NA	NA	-1,67%	NA	NA
Hungary	37,53%	44,80%	17,67%	52,11%	39,07%	80,52%
Netherlands	11,53%	NA	NA	8,31%	NA	NA
Austria	50,61%	47,46%	49,45%	11,32%	13,51%	1,93%
Poland	10,85%	-7,19%	38,20%	-22,70%	-9,64%	-35,24%
Portugal	-22,36%	-23,46%	-20,45%	-57,10%	-58,43%	-54,99%
Romania	109,22%	90,86%	112,19%	-7,46%	5,02%	-21,06%
Slovenia	122,70%	116,62%	131,00%	-56,28%	-66,44%	-50,97%
Slovakia	80,54%	115,09%	47,20%	-22,34%	-37,58%	-0,56%
Finland	53,00%	62,37%	21,01%	16,60%	20,19%	-8,73%
Sweden	50,89%	61,67%	-6,15%	20,09%	28,06%	-47,30%
United Kingdom	16,73%	19,19%	-10,00%	10,70%	5,56%	73,16%

Source: Authors' calculation on Eurostat data

The current Covid-19 crisis has also reflected on the relative weight of the Construction sector compared to the **added value** of the global economy. Between 1995 and 2018, according to Eurostat, there was a fall in the EU of 2.18% (Table 5). Among the main EU economies, the major fall was in Spain, Germany and Italy. This is the result of two effects: the weak growth of the added value inside the sector, and the evolution of the added value in whole economy. Thus, while in the German economy the recovery in the Construction sector was accompanied by a large recovery of the aggregate economy, in Italy and Spain two recessions add up.

This negative pattern has dragged with it that of **employment**. According to the Eurostat data, in EU 28, between 2008 and 2017 there was a loss of employment of 18.3% in the Construction sector. The largest was in Spain (-54.3%) and Italy (-28%). Then, negative but more limited in France (-9.7%) and in Germany (+9.7%), after an initial recessionary turn.

The absolute numbers are impressive. In Italy, slightly less than 600 thousand jobs were lost, in Spain 1.3 million, in France 186 thousand employees. Globally, in EU 28 almost 3.5 million jobs were lost, with a positive net contribution only in Germany. These features and the relative gaps are confirmed by the update to 2018 reported in Table 6. Overall, there has been a great change in the size and composition of the sector with negative impact on production, employment and productivity. We will return to these points later, focusing on the role of technological progress and competitiveness in shaping the evolution of productivity.

Table 5. Share of added value 1995-2018 in the Construction sector

GEO/TIME	1995	2018	Change (1995-2018)
Australia	6,49%	8,34%	1,85%
Austria	10,03%	6,33%	-3,70%
Belgium	4,76%	5,26%	0,50%
Denmark	5,33%	5,67%	0,35%
Estonia	5,39%	7,93%	2,54%
Euro area - 19	6,99%	4,45%	-2,54%
European Union -	7,03%	4,85%	-2,18%
Finland	6,70%	6,34%	-0,36%
France	8,04%	5,49%	-2,55%
Germany	8,23%	4,51%	-3,72%
Greece	4,45%	3,12%	-1,32%
Hungary	4,78%	4,64%	-0,14%
Ireland	4,86%	2,79%	-2,07%
Italy	6,46%	4,30%	-2,16%
Japan	9,25%	5,64%	-3,60%
Norway	5,28%	6,59%	1,31%
Poland	9,99%	8,49%	-1,50%
Portugal	8,68%	4,14%	-4,53%
Romania	6,28%	5,75%	-0,53%
Slovenia	6,99%	4,95%	-2,04%
Spain	10,50%	6,13%	-4,37%
Sweden	6,94%	6,33%	-0,61%
United Kingdom	6,88%	5,96%	-0,92%
United States	6,11%	3,61%	-2,51%

Source: Authors' calculation on Eurostat data

Table 6. Change in Employment 2008-2018 in the Construction sector

GEO/TIME	2008	2018	Abs. (2008-2018)	Tot change (%)
Austria	277.16	301.24	24.08	8.69%
Belgium	272.80	279.30	6.50	2.38%
Bulgaria	297.71	184.54	-113.17	-38.01%
Czechia	444.27	405.82	-38.45	-8.65%
Denmark	205.60	188.74	-16.86	-8.20%
Estonia	72.20	49.60	-22.60	-31.30%
Finland	198.60	216.30	17.70	8.91%
France	1,874.00	1,753.00	-121.00	-6.46%
Germany	2,295.00	2,515.00	220.00	9.59%
Greece	386.32	204.30	-182.02	-47.12%
Hungary	316.68	337.85	21.17	6.68%
Ireland	240.93	153.39	-87.54	-36.33%
Italy	1,956.80	1,531.60	-425.20	-21.73%
Latvia	108.65	69.45	-39.20	-36.08%
Lithuania	154.24	103.50	-50.74	-32.90%
Luxembourg	39.16	45.93	6.77	17.29%
Netherlands	543.00	475.00	-68.00	-12.52%
Poland	1,212.30	1,198.10	-14.20	-1.17%
Portugal	501.05	298.84	-202.21	-40.36%
Romania	731.80	676.30	-55.50	-7.58%
Slovenia	92.14	67.65	-24.49	-26.58%
Spain	2,438.30	1,224.30	-1,214.00	-49.79%
Sweden	295.50	386.40	90.90	30.76%
United Kingdom	2,261.39	2,309.56	48.17	2.13%

Source: Authors' calculation on Eurostat data

As mentioned, changes in value added and employment, measured in total worked hours, have affected the **"labor productivity"** in the Construction sector. Data in Table 7 summarize Eurostat information for the whole economy, the industry in the narrow sense, the manufacturing and the aggregate Construction sector. For this latter, a significant slowdown in hourly productivity, measured in real terms, is recorded, between 2000 and 2018. Italy, France and Spain show a downturn that in Italy shows a magnitude that brings productivity well below 17 euros per hour. Germany shows a more favorable trend, and productivity per hour worked, in the period 2009-2018, remains stable and close to the average value of the period 2000-2008. Noteworthy is the advancement in Bulgaria whose productivity remains however one fifth of that of Germany, or at best a quarter of that of Italy.

Overall, labor productivity for EU 28 records a negative trend with an overall average loss, although in some countries, such as Belgium, there is a significant improvement in the labor productivity of this sector.

Finally, it should be noted that the Construction sector shows the lowest labor productivity in each country, compared to other sectors where the average level of it is at least twice as high. As known, this is due to the specific features of the sector such as the low level of technological progress, the small size of the firms and the degree of competition whose role will be studied in more detail in the next section.

Table 7. Labor productivity per hour worked

	2000 - 2008				2009 - 2018			
	Tot	Ind	Man	Cons	Tot	Ind	Man	Cons
European Union 28	NA	NA	NA	NA	31,42	38,46	36,95	21,76
Euro area 19	NA	NA	NA	NA	35,43	48,20	46,24	23,78
Austria	27,90	32,59	30,01	30,70	37,62	59,36	57,50	27,59
Belgium	36,05	37,72	34,51	27,83	44,11	66,90	63,55	36,70
Bulgaria	3,01	2,02	1,50	1,34	4,96	5,45	4,85	4,83
Denmark	39,78	47,70	35,88	31,92	50,18	74,42	68,26	38,08
Germany	30,97	33,93	32,10	21,07	40,82	56,03	53,33	21,83
Ireland	30,81	30,18	28,47	29,06	62,35	155,51	166,46	37,29
Greece	14,21	14,89	13,00	11,99	17,18	20,42	17,54	14,27
Spain	24,42	25,25	22,70	31,00	28,40	38,62	34,69	28,10
France	33,35	32,61	29,20	29,44	43,10	59,04	57,03	26,24
Croatia	6,89	6,12	6,04	4,92	11,08	10,77	10,24	7,93
Italy	28,64	27,93	25,48	24,51	30,99	34,30	33,49	17,71
Netherlands	34,59	43,24	33,61	27,72	44,39	69,28	61,92	33,67
Poland	4,75	5,33	4,27	9,77	10,34	12,30	12,46	9,92
Portugal	12,79	9,63	8,66	10,23	16,18	17,20	15,70	9,81
Romania	2,67	2,84	2,54	3,44	6,83	8,26	8,42	5,32
Slovenia	10,84	9,05	8,06	11,96	19,70	24,51	23,44	13,67
Finland	27,82	30,76	28,61	25,99	38,65	69,20	66,86	24,54
Sweden	29,86	29,54	25,12	27,01	43,64	60,97	56,71	27,92
United Kingdom	30,33	35,15	27,85	25,12	40,61	NA	NA	NA
Norway	53,72	133,22	39,09	44,32	67,82	167,12	65,50	41,48

Source: Authors' calculation on Eurostat data

The dynamics of labor productivity is closely linked to the nature of the sector itself. Indeed, from an historical perspective, the construction sector has always been characterized by a limited effort in formal research activities compared to other industries (for instance the automotive, electronics, or the pharmaceutical one). Usually, companies in the private business sector, but not construction firms, have been investing in **research and development** (R&D), which is a well-known indicator of the degree of innovativeness in the industry. This is due to the fact that many industries are obliged to invest in R&D in order to maintain their competitiveness, especially those operating in sectors where the pace of technological advancement is rapid, and the product life cycle is reduced over time. The Construction sector on the other hand differs from technology-intensive industries in some crucial ways. In many cases, technology employed in construction is not perceived as a major factor of competitiveness because it does not directly affect the attractiveness of the final product. Secondly, the development cycle is much longer than in other industries, and product life cycle is much longer as well. Finally, any produced real asset is unique, based on the orders placed by customers. This results in very little economies of scale, made exception for material suppliers or the housing market (Someya, 1992). Adding the inevitable uncertainty at the basis of R&D expenditure, these intrinsic characteristics are the main factors that prevent the Construction sector from conducting R&D and applying innovative technologies. This is shown in Table 8, which highlights how R&D in the sector is on average 14 times lower than the average for the overall economy.

Table 8. R&D intensity in Construction and the whole economy (2018)

GEO/TIME	R&D intensity (1995)	R&D intensity (2018)	Growth (% points)
Austria	0.07%	0.34%	0.26%
Belgium	0.30%	0.30%	0.00%
Finland	0.22%	0.83%	0.61%
France	NA	0.11%	NA
Germany	0.06%	0.06%	-0.01%
Hungary	0.01%	0.13%	0.12%
Italy	0.03%	0.14%	0.11%
Japan	0.40%	0.41%	0.01%
Korea	0.49%	NA	NA
Lithuania	NA	0.02%	NA
Mexico	0.01%	0.01%	0.00%
Norway	0.04%	0.12%	0.08%
Poland	NA	0.06%	NA
Portugal	0,00%	0,09%	0,09%
Romania	0.09%	0.00%	-0.09%
Spain	NA	0.15%	NA
Sweden	NA	0.12%	NA
Turkey	0.00%	0.02%	0.02%
United Kingdom	NA	0.10%	NA

Source: Authors' calculation on Eurostat data

Previous research on individual countries confirms this view and show that the Construction sector is lagging behind when it comes to R&D investment (see Fairclough, 2002; Hampson et al., 2014; Kraatz et al., 2014).

3. A microdata analysis for some European countries

Now, we present a microdata analysis of the European Construction sector. To this aim, we employ the data provided by the *Amadeus-Bureau Van DijK database of Moody's Analytics*. The analysis focuses mainly on Bulgaria, Belgium, France, Germany, Italy and Spain.

Amadeus contains comprehensive information on around 21 million companies across Europe. Such data can be used to research individual companies, search for companies with specific profiles and for analysis. It is a database of comparable financial and business information on Europe's largest 550,000 public and private companies by total assets. Forty-three countries are covered. Amadeus provides standardized annual accounts (consolidated and unconsolidated), financial ratios, sectoral activities and ownership data. The database is suitable for research on competitiveness, economic integration, applied microeconomics, business cycles, economic geography and corporate finance. Specifically, it provides the following data:

- Company information for both Western and Eastern Europe, with a focus on private company information;
- Company financials in a standard format so you can compare companies across borders;

- Financial strength indicators;
- Directors;
- Images of reports and accounts for listed companies;
- Stock prices for listed companies;
- Detailed corporate structures;
- Market research;
- Business and company-related news;
- M&A deals and rumours;
- Maps.

In what follows we focus on the Construction sector starting from companies with a turnover in excess of €1 million over the period 2011-2019. For these firms we initially focus on variables that can be observed or obtained directly, thus estimating, by means of the microeconomic data, the productivity of labor. As a second step, we employ an econometric algorithm that relies on a *translog production function* to estimate, in a statistically robust way, the contribution of technological progress and the degree of competitiveness in determining the evolution of labor productivity. Technological progress is proxied by TFP. The competition of the market from the markup on the labor cost - i.e. the difference between the selling price of a good or service and its cost.

Let us start from the description of the sample in Amadeus. Table 9 shows the number of firms for each country under consideration. It emerges the huge number of firms for Italy, Spain and France in comparison to others, including Germany. For this country, the figure is influenced by the fact that it is not mandatory for German companies to publish their balance sheet data.[4] For the remaining two countries, the actual number of companies operating in the Constructive sector, (defined statistically by codes F41, F42, F43 and F23) is smaller. Then, from Amadeus we compute the labor productivity per hour worked based on the micro data. This is shown in Table 10.

Table 9. Number of firms in the Construction sector by country, 2018

Note: F41: Construction of buildings, F42 Civil Engineering, F43: Specialized construction activities, F23: Manufacture of other non-metallic mineral products

nace_2digit	cod_country						
	BE	BG	DE	ES	FR	IT	tot.
23	1077	1755	865	7410	2840	18578	32525
41	2435	5981	1788	25351	4715	61662	101932
42	989	2468	848	4621	3777	10205	22908
43	2689	3423	2059	30658	26667	57445	122941
tot.	7190	13627	5560	68040	37999	147890	280306

Source: Authors' calculation on Amadeus data

[4] Actually, the coverage of small businesses and balance sheet variables vary from country to country, following the filing requirements by the business registries of each country. Although most countries require limited liability companies to register once only are formed, requirements in terms of who reports (in terms of company size) and what to report from balance sheet items is extremely variable even within European countries.

Table 10. Labor productivity in the Construction sector by country, 2018

Note: F41: Construction of buildings, F42 Civil Engineering, F43: Specialized construction activities, F23: Manufacture of other non-metallic mineral products

nace_2dig	cod_country						
it	BE	BG	DE	ES	FR	IT	Total
23	102,4922	21,3581	73,1516	75,62	76,0075	66,5793	71,3596
41	73,89	11,1477	69,7429	53,5956	69,0482	52,4815	55,187
42	70,1895	14,9923	60,4967	61,5183	59,9551	62,9006	59,0026
43	66,816	11,7275	57,9354	46,3269	53,2178	49,1591	50,0581
	76,9799	14,0148	68,9306	58,3395	59,786	55,6484	57,8916

Source: Authors' calculation on Amadeus data

The second information obtained from Amadeus database is related to the measure of labor productivity. In this case, the data refers to the productivity of an average working day of eight hours. From the micro data, it is possible to compute an average value for each country. As expected, the highest labor productivity in the Construction sector is recorded in Germany and Belgium, well above the European average. Note the low level of labor productivity in Bulgaria, equal to one fifth of the European average, and the delay of Italy compared to the European average value of the most economically advanced countries.

Therefore, the micro data are consistent with the features of the macro data, confirming once again the heterogeneity of the Construction production system in the EU 28, and the need to pursue different labor, industrial and innovation policies from country to country, or at least between groups of countries. In the following, we will use the micro data on employment and labor productivity, computed from balance sheet data, to estimate the contribution of investment, technological progress, and the degree of competition (in each individual countries) in determining the pattern of employment and productivity.

4. A translog transformation (technical section)

The *translog production functions* occurred in the context of researches related to the discovery and definition of new flexible forms of production functions. In fact, the first form of a *translog* production may be considered the proposal made in 1967 by J. Kmenta for the approximation of the CES production function with a second order Taylor series, when the elasticity of substitution is very close to the unitary value, which is the case of Cobb-Douglas production function. The form of the above-mentioned production function is:

$$lnY = ln\,A3 + \alpha 3 \cdot ln\,K + \beta 3 \cdot ln\,L + \chi 3 \cdot ln\,(K\,/\,L) \tag{1}$$

Where: ln is the natural logarithm, Y is output, K capital stock, L is labor, K/L in capital intensity and the remaining letters represent coefficients to be estimated.

The second form of production function was defined in conditions of relaxing the constraints imposed to the parameters in the previous Kmenta function, in order to test the homotheticity assumptions. This new and more general form was called *log-quadratic*. It is important to mention that the term "translog production function", abridged from "transcendental logarithmic production function" was proposed by Christiansen, Jorgensn and Lau in two papers published in 1971 and 1973, which dealt with the problems of strong separability (additivity) and homogeneity of Cobb-Douglas and CES production functions and their implications for the production frontier. The generalized form of translog production function, which considers a number of *n* inputs (production factors), can be expressed as:

$$lnY = lnA + \sum_{i=1}^{n} \alpha_i lnx_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} lnx_i * ln\, x_j \qquad (2)$$

The modern *translog production functions* represent in fact a class of flexible functional forms for the production functions (Allen and Hall, 1997). One of the main advantages of the respective production function is that, unlike in case of Cobb-Douglas production function, it does not assume rigid premises such as perfect or "smooth" substitution between production factors or perfect competition on the production factors market (Klacek, et al., 2007).

In addition, the concept of the translog production function permits to pass from a linear relationship between the output and the production factors, which are considered, to a nonlinear one. Due to its properties, the translog production function can be used for the second order approximation of a linear-homogenous production, the estimation of the Allen elasticities of substitution, the estimation of the production frontier or the measurement of the total factor productivity dynamics.

We use this elastic formulation (2) to estimate the contribution of TFP in affecting labor productivity in the Construction sector. Further, using this same function we can get a robust estimation of the markup on labor cost. This standard approach to the estimation of markups, which combines insights from Hall (1988) with proxy variable production function methods, is well established in economic literature.

5. How to estimate the markup

The markup is commonly defined as the price of output divided by the marginal cost (i.e. the ability of a firm to set a price that is above its marginal costs). Measuring markups is notoriously a hard task for economists since marginal cost data is not readily available. There were developed three distinct approaches to measure markups. (i) The first approach, the so called "accounting approach" relies on directly observable gross (or net) margins of profits. (ii) The second approach developed within the boundaries of the Industrial organization literature relies on the specification of a specific demand system, which delivers price-elasticities of demand. Then, putting together the information retrieved with assumptions on firm's competition, markups can be estimated through the first order condition associated with optimal pricing (Berry et al., 1995). (iii) Here, following De Loecker et al. (2019) we rely on a third approach, the production approach. This approach is based on the insight of Hall (1988) to estimate markups from the firm's cost minimization decision. Hall (1988) used industry aggregates, De Loecker and Warzynski (2012) recently proposes to estimate firm level markups. The method uses information from the firm's financial statements and the advantage is that it does not require any assumptions on demand and on competition patterns of firms. Here, markups are obtained by exploiting cost minimization of a variable input of production.

Consider an economy with N firms, indexed by $i = 1, \dots, N$. Firms are heterogeneous in terms of their productivity (A_{it}) and production technology $Y_{it}(\cdot)$.[5] In each period t, firm i minimizes the contemporaneous cost of production given the production function:

$$Y_{it} = Y_{it}(A_{it}, V_{it}, K_{it}) \tag{3}$$

Where: $V = (V^1, \dots, V^j)$ is a vector which contains all the variable inputs of production (including labor, intermediate inputs and raw materials)[6]; $K_{it}$is the capital stock and A_{it} is productivity. The key assumption is that within one period (a year in our data), variable inputs adjust without friction, whereas the fixed input (i.e. capital) is subject to adjustment costs and other additional frictions.[7] We can write the Lagrangian objective function associated with the firm's cost minimization problem:

$$\mathrm{L}(V_{it}, K_{it}, \lambda_{it}) = {P^{VI}}_{it} V_{it} + r_{it} K_{it} + F_{it} - \lambda_{it}(Y(\cdot) - \bar{Y}_{it}) \tag{4}$$

Where:

- P^{VI} is the price of the variable input;
- r_{it} is the user cost of capital;
- F_{it} is the fixed cost;
- $Y(\cdot)$ is the general technology of production;
- $\bar{Y}_{it}$ is a scalar and λ is the Lagrange multiplier.

[5] The expression to compute markups is derived from a general firm-specific production technology. The only requirement is the production function to be twice differentiable.

[6] In the implementation, we employ information on a bundle of variable inputs - and not the individual inputs – however, in the exposition we treat the vector L as a scalar L.

[7] The conditional statement refers to the fact that we condition on the factors of production that are chosen dynamically. E.g. if capital faces adjustment costs or simply time to build, the firm chooses variable inputs to minimize cost, given the level of capital that was set in the previous period.

If variable input prices are given to the firm, then the first order condition with respect to the variable input V can be written as:

$$\frac{\partial L_{it}}{\partial V_{it}} = P^{VI}{}_{it} - \lambda_{it}\frac{\partial Y(\cdot)}{\partial V_{it}} = 0 \tag{5}$$

Multiplying all terms in (5) by $\left(\frac{V_{it}}{Y_{it}}\right)$, and rearranging yields an expression for the output elasticity of input V:

$$\frac{\partial L_{it}}{\partial V_{it}} = \frac{P^{VI}{}_{it}V_{it}}{Y_{it}} - \lambda_{it}\frac{\partial Y(\cdot)}{\partial V_{it}}\frac{V_{it}}{Y_{it}} = 0$$

$$\frac{P^{VI}{}_{it}V_{it}}{Y_{it}} - \lambda_{it}\frac{\partial Y(\cdot)}{\partial V_{it}}\frac{V_{it}}{Y_{it}} = \frac{P^{VI}{}_{it}V_{it}}{Y_{it}} - \lambda_{it}\theta^{v}{}_{it} = 0$$

$$\frac{P^{VI}{}_{it}V_{it}}{Y_{it}} = \lambda_{it}\alpha^{V}{}_{it}$$

$$\alpha^{V}{}_{it} = \frac{1}{\lambda_{it}}\frac{P^{VI}{}_{it}V_{it}}{Y_{it}} \tag{6}$$

i.e. the Lagrange multiplier λ is itself a direct measure of marginal cost. Therefore, since we define the markup as price marginal cost ratio $\mu_{it} = \frac{P_{it}}{\lambda_{it}}$, where P is the output price. Substituting this expression for the markup into(6), we obtain a simple expression for the markup:

$$\lambda_{it} = \frac{P_{it}}{\mu_{it}}$$

$$\alpha^{V}{}_{it} = \frac{\mu_{it}}{P_{it}}\frac{P^{VI}{}_{it}V_{it}}{Y_{it}}$$

$$\mu_{it} = \alpha^{V}{}_{it}\frac{P_{it}Y_{it}}{P^{VI}{}_{it}V_{it}} = \alpha^{V}{}_{it}\left(\frac{P^{V}{}_{it}V_{it}}{P_{it}Y_{it}}\right)^{-1} \tag{7}$$

The markup derived in this way does not rely on the specification of any particular demand system. Note that with this approach to markup estimation, there are in principle multiple first order conditions (one for each of the variable input in production) that yield to an expression for the markup. However, regardless of which variable input of production is used, there are two key ingredients needed in order to measure the markup: (i) the revenue share of the variable input, $\frac{P^{V}{}_{it}V_{it}}{P_{it}Q_{it}}$, and (ii) the output elasticity of the variable input, $\alpha^{V}{}_{it}$. Therefore, the marginal cost of production is derived from a single variable input in production, without imposing any particular substitution elasticity with respect to other inputs in production (variable or fixed) or returns to scale. The only crucial component that we need for the estimation is the output elasticity of a variable input of production (${\alpha^V}_{it}$). Actually, while the production approach to markup estimation, described in De Loecker and Warzynski (2012) does not restrict the output elasticity, when implementing this procedure the estimation of this latter parameter is dependent on a specific production function, and assumptions of underlying producer behavior, which are all necessary in order to identify and estimate the elasticity from the data.

To this purpose, we estimate a parametric *translog* production function for each firm-year using the most recent techniques that consider the well-known potential biases discussed in the literature. This implies that $f(\cdot)$ is approximated by a second-order polynomial where all (logged) inputs, (logged) inputs squared, and interaction terms between all (logged) inputs are included. More specifically the *translog* production technology with Hicks-neutral productivity employed as a production function on the value added takes the following form:

$$y_{it} = \beta_l l_{it} + \beta_k k_{it} + \beta_{ll} {l^2}_{it} + \beta_{kk} {k^2}_{it} + \beta_{lk} l_{it} k_{it} + TFP_{it} + \varepsilon_{it} \tag{8}$$

Where: all variables are in logs, y_{it} is value added of production, l_{it} and k_{it} denote labor and capital, respectively, and the βs are parameters. Total factor productivity is captured by TFP and ε is the error term containing unanticipated shocks to the producer and measurement error.

We measure value added with firm revenue less expenditures on material inputs, labor with the number of employees, and capital with the book value of tangible assets. Unfortunately, we observe neither physical quantities nor firm-level prices. Therefore, we deflate all variables with available industry specific price indices.[8] For robustness, we experimented also alternative specifications of the production function, including a Cobb-Douglas specification.

6. What is Total Factor Productivity

Generally speaking, "productivity" measures the efficiency of a production activity. Traditionally, there are two kind of indexes used in economic analysis to quantify productivity: namely single factor productivity (i.e. labor, capital or energy productivity) and **total factor productivity (TFP)**, a measure of the technology content of any production. Labor productivity is usually computed as value-added per worker and represents the amount of real gross domestic product (GDP) produced by an hour worked. It provides information about the efficiency and quality of labor used in the production process, in a specific economic and social context. However, this measure of productivity may be misleading when applied to measure the Construction sector performance, because materials and role of techniques in productivity improvement are largely neglected (Zhi et al., 2003). For these reasons, TFP has been preferred as a more comprehensive indicator to assess efficiency in the use of resources, thus becoming a standard measure to catch

[8] While the use of deflation is clearly inferior, De Loecker and Warzynski (2012) show that it affects only the level of the markup estimates, and not the correlation between markups and firm-level characteristics.

the major determinants of long-run economic growth (Krugman, 1996). In other words, single factor productivities provide only a partial picture of technological progress, and TFP growth measurement is important to understand the full picture underlying the production activities. Assuming a traditional production function - i.e. a mathematical relationship, which specify how much output it is possible to obtain by employing a determined amount of capital and labor - TFP is formally given by the share of the output growth not explained by the direct contributions of both capital and labor. In other words, TFP growth is the rate at which the production frontier expands over time, due to advances in technology, innovation, knowledge as well as improvements in the organization of production. The basic idea behind TFP is to provide an aggregate index that combines the quantity and quality of all factors used in the process. Therefore, TFP growth is measured as the difference between the output growth and that of total inputs (Jorgenson et al., 2016). Notably, it captures the effects of qualitative improvements that allow output to increase without using additional inputs (Appendix B for details on growth accounting).

Economists usually agree that when measuring industry-level productivity, all the inputs should be considered as they are employed together to produce a common output. However, a relatively small number of studies has been done focusing on factors influencing industry-level TFP growth in the Construction sector. As TFP growth is a relevant measure of technological change, it is necessary to review factors identified as "technological progress" in growth accounting studies. There are three main sources of productivity growth: economies of scale, resources allocation and the expansion of knowledge and technology. In the Construction sector, factors that fall into these categories include the capital-labor ratio, the composition of output, the increase in the corporate share in contract construction, the quality of labor, the soft skills, the economies of scale, the introduction of innovations in building (BIM), the replacement of labor-saving building materials for others and the share of unionized workers (Sveikauskas et al., 2016).

Technology, capital and the educational level of the workforce interact together determining the rate of productivity growth. Indeed, technological progress must often be incorporated into new tangible capital goods and used by trained employees to be effective (Timmer et al., 2014). Meanwhile, through learning by doing, workers introduce themselves new misleading when we are interested in computing the contribution of technology and innovation in determining economic growth (Bygballe and Ingemansson, 2014). Accordingly, R&D expenditure is a more qualified index, since it captures some crucial dimensions of innovations and educational factors (of workers) affecting the productivity pattern. Many endogenous models of economic growth (Lucas, 1988; Romer, 1994) have incorporated a large set of technology determinants into structural models in order to estimate a non-distorted measure of productivity. As said, total factor productivity, TFP, is the aggregate index, which captures all these dimensions.

In the Construction industry, an extensive literature has shown that TFP is affected by:

(i) *The composition of output* in terms of different construction products. The potential economic growth in various sub-sectors is different. Moreover, the composition and interaction between products and sectors, through reallocations of resources and complementarity effects, generate often improvements in the productivity of the sector (Bartelsman, 2013);

(ii) *Technological progress* that is advances in knowledge and rate of innovations. Advances in knowledge come from either organized or informal R&D activities (Kraatz and Sanchez, 2014). In addition, technological progress in Construction sector is affected by the technological advancement in the country, as a whole. At the same time, significant endogenous innovation comes from job practice and learning by doing (Thompson, 2010). Further, new knowledge can be disseminated through the modernization of capital equipment or international technological transfer.

(iii) *The quality of labor and materials* that is new materials and inputs of better quality used in productions. The use of prefabricated components made it possible to move transfer some labor off-site. The concepts of prefabrication and ready buildable design have been promoted in the Construction sector since the early 90s to enhance productivity (Shahzad et al., 2015; Jang and Lee, 2018).

(iv) *Returns to scale* that is a positive relationship between average hours worked and the share of capital per worker. Returns to scale in the Construction sector are however limited by labor-intensive characteristics and non-standard products of the Construction sector (Ofori, 1990).

(v) *Government regulations.* By promoting changes in the legal, institutional and social environment, government may play either a positive or a negative role in determining the pace of productivity growth (Dubois and Gadde, 2002).

(vi) *Cyclical factors* which include energy prices and the inflation rate. A sharp increase in the energy price has a negative impact on productivity growth since it makes some energy intensive capital goods economically unattractive, leading to a slowdown in the rate of capital accumulation. Inflation can also hamper productivity growth, as it discourages capital formation by increasing uncertainty, and thus pushing firms to postpone innovative investment (Dhawan et al.,2010; Punzi, 2019).

(vii) *Industrial relation and labor market policies.* In Construction sector, labor costs affect crucially profitability and competitiveness; then, labor regulations affect labor productivity in many ways. Precisely, in the short run, labor regulation may raise firms' labor and investment adjustment costs, with a negative impact on innovation and investment. However, a stricter labor regulation may stimulate firms to invest and innovate as time passes to recover rents, so positively affecting productivity and TFP in the long run (Bellocchi et al., 2020). Some of the indexes traditionally used to capture these complex dimensions include the percentage of unionized workers and the percentage of contracts that favor the creation of labor-management committees, allow for incentive wage payment and for subcontracting. Notably, according to Allen (1985), decline in percentage of union will cause a decline in labor productivity.

The measurement of TFP, and its growth, has been subject to several approaches over time: from the use of index computed from the "growth accounting" (Appendix B), to linear and quadratic programming techniques for econometric estimation (Appendix C). Although new ways of estimation are still being researched, combining the available methods on a dataset is the most effective way to increase the accuracy of the results. This is due to the compelling advantages and disadvantages of each method over the others. There are two main approaches by which TFP growth can be estimated: *frontier* and *non-frontier* approaches. Each of them can then be sub-classified into its parametric and non-parametric form. The main difference the two approaches lies in the definition of the efficient frontier. While in the former the output frontier corresponds to the set of maximum achievable output levels for a given combination of inputs, the latter constructs only a mean line using ordinary least square regression.

In the next Section, we estimate TFP at the firm level by means of a non-frontier production function semiparametric approach. In addition, we will estimate the markup of industries in the construction industries. From a practical point of view, we follow De Loecker and Warzynski (2012), who in turn build on the pioneering work of Hall (1986). Hall (1986, 1988) was estimating industry-level markups when noticed that the conventional measure of TFP growth under imperfect competition is biased by a factor proportional to the markup. Therefore, the method of estimating TFP relies on structural production function estimation. The idea is that, for a cost-minimizing producer, markup equals the ratio of the output elasticity of a variable input free of adjustment costs (labor or materials) to the input's revenue share. Hall's method has recently been used to estimate firm-level markups by De Loecker et al. (2020) and many others. As said above, the justification for the choice of these methods in explained in Appendix B and C.

7. TFP growth in the Construction sector

Figure 4 shows the evolution of labor productivity for the Construction sector over the period 2011-2018. The time series are computed from the Amadeus database for the six countries under analysis. An overall stable productivity trend emerges, with a common growth phase until 2016-2017 and a subsequent slowdown. Very interesting is the acceleration in Bulgaria which shows an initial comparative gap, compared to the EU average, and a "catching-up" in labor productivity afterwards. Also significant is the recovery of productivity in Italy, the Spanish slowdown and German volatility.

How much of this dynamic is caused by technological progress and competitiveness in the Construction sector? The breakdown of labor productivity in the sources underlying the process of growth allows to provide answers to this question. More precisely, by reversing the generalized translog function we can calculate the contribution of technological progress A as a residual, i.e.

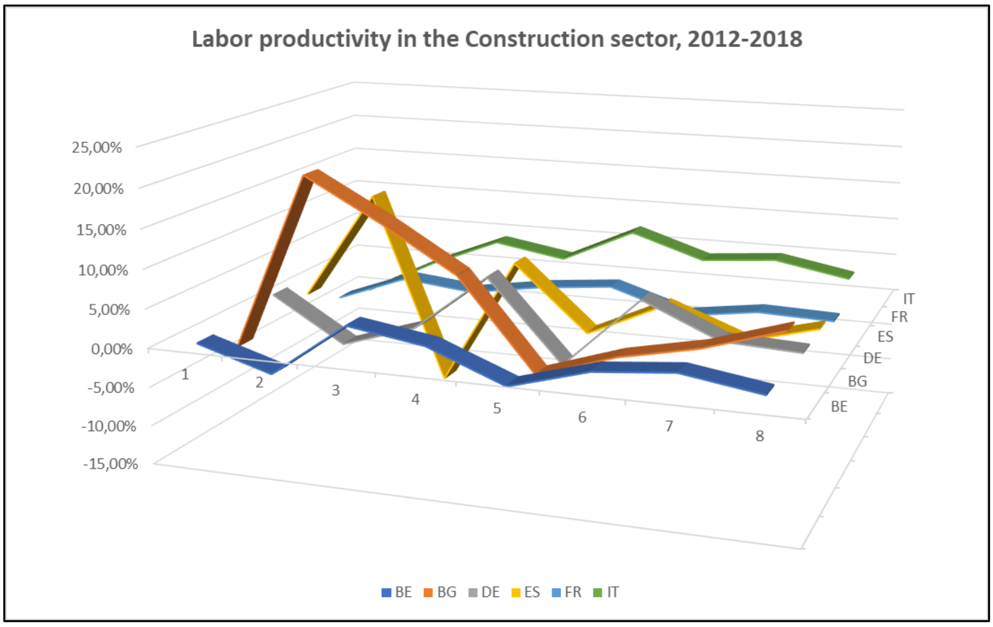
$$lnA = lnY - \sum_{i=1}^{n} \alpha_i lnx_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij} lnx_i * ln\, x_j \qquad (9)$$

Then, the linearized form of equation (8) is:

$$TFP_{it} = y_{it} - (\beta_l l_{it} + \beta_k k_{it} + \beta_{ll} l^2{}_{it} + \beta_{kk} k^2{}_{it} + \beta_{lk} l_{it} k_{it} + \varepsilon_{it}) \quad (10)$$

Where: Total Factor Productivity (TFP_{it}) is a measure of technological progress A. We use this relationship to compute the value of the TFP, and Figure 4 illustrates its pattern for the diverse countries estimated using the micro data, over the period 2012-2018.

Figure 4. A microdata analysis of the European Construction sector

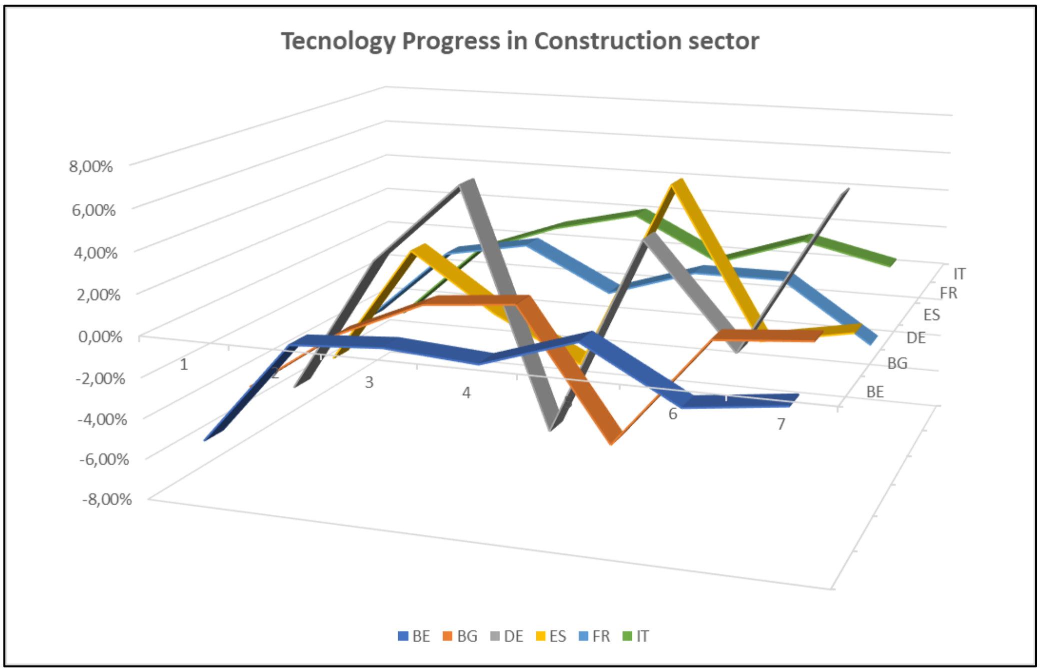


Source: Author's calculation on Amadeus data (Bureau Van Dijck)

For all countries, the contribution of TFP tends to vary over time, with even negative variations that slow down the growth process. It should be noted that countries like Bulgaria records an overall positive impact, with a negative variation only over the period 2015-2016. Belgium and Germany are similar, with high volatility, but an average positive contribution. The impact of TFP for the remaining countries, on the other hand, is negligible.

As known, TFP is an aggregate proxy of technological progress to productivity. Traditionally, a number of factors are found to be significantly related to TFP growth in the Construction sector, among them: economies of scale, R&D, investment allowance granted, and labor unions are leading contributors (Zhi et al., 2003). In the Construction sector, the impact of R&D spending and innovation are historically low. Eurostat macro data give some indication of the R&D share on total investment expenditure. Comparing 1998 and 2017 (Table 10) a stable situation emerges with a slight acceleration of the average R&D intensity for Belgium and Italy, among European countries. Unfortunately, data are not available for Bulgaria and they are incomplete for Spain and France. Moreover, R&D expenditure does not always translate into an improvement of observed TFP as R&D may require time and further technology application phases, or possibly process failures in the transition from the discovery to its actual implementation.

Figure 5. TFP in the Construction sector



Source: Author's calculation on Amadeus data (Bureau Van Dijck)

Building Information Modeling (BIM) represents the main technological innovation in the Construction sector, over the last two decades. BIM is mainly an intelligent 3D model-based process that gives architecture, engineering, and construction professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure. BIM can help to optimize work and company processes. For example, in Architecture it makes better design decisions, improve building performance, and collaborate more effectively throughout the project lifecycle. In Construction, it helps to digitize construction site and connect project information from design through construction and handover. In the field of Civil engineering it allows to use intelligent, connected workflows to help improve predictability, productivity and profitability.

All these BIM innovations, which are primarily digital in nature, influence the aggregate technological progress, labor productivity, but also employment. Further, this process is particularly crucial when BIMs are computer files, which can be extracted, exchanged or networked to support decision-making regarding a built asset. BIM software is used by individuals, firms and government agencies which plan, design, construct, operate and maintain buildings and diverse physical infrastructures, such as water, refuse, electricity, gas, communication utilities, roads, railways, bridges, ports and tunnels.

Table 11. R&D intensity growth

GEO/TIME	R&D intensity (1995)	R&D intensity (2018)	Growth (% points)
Austria	0.07%	0.34%	0.26%
Belgium	0.30%	0.30%	0.00%
Finland	0.22%	0.83%	0.61%
France	NA	0.11%	NA
Germany	0.06%	0.06%	-0.01%
Hungary	0.01%	0.13%	0.12%
Italy	0.03%	0.14%	0.11%
Japan	0.40%	0.41%	0.01%
Korea	0.49%	NA	NA
Lithuania	NA	0.02%	NA
Mexico	0.01%	0.01%	0.00%
Norway	0.04%	0.12%	0.08%
Poland	NA	0.06%	NA
Portugal	0,00%	0,09%	0,09%
Romania	0.09%	0.00%	-0.09%
Spain	NA	0.15%	NA
Sweden	NA	0.12%	NA
Turkey	0.00%	0.02%	0.02%
United Kingdom	NA	0.10%	NA
United States	0.08%	0.04%	-0.04%

Source: Author's calculation on Amadeus data (Bureau Van Dijck)

However, the impact of technology and digital innovation on productivity and employment can be controversial in the short run. From Amadeus micro data it is possible to get useful information on R&D expenditure, even if indirectly, through the accounting of Intangible Investments. As reported in Figure 6 (see also Appendix A), the Panel of the six countries reveals an overall negative impact of Intangible Investment on employment and labor productivity and positive on the technological process. In short, it highlights a trade-off between technological progress and employment that "crowds out" labor with respect to innovation in the short term. This fact has important economic and institutional implications in the labor market, and for labor policies, that must be seriously considered to allow a balanced transformation of the Construction sector towards BIM.

Figure 6. Impact of investment, Tecnological progress and Intangible assets on Employment, Labor productivity and Tecnological progress

	Employment	Labor Productivity	Tecnology Progress
Investment	+	+	+
Innovation	+	+	
Intangible asset per worker	-	+	+

Source: Author's own elaboration

8. Changes in markup and competitiveness

As said in Section 4, the *translog production function* allows to estimate the markup on labor cost, which is a measure of the degree of market competition. If the markup is equal to 1, labor productivity is equal to its (real) marginal cost, and any productive factor is repaid to marginal productivity as it should be in a perfect competitive market. When we move away from this competitive configuration, labor productivity can be greater than marginal cost, and the difference between the two quantities is a measure of the market power of firms caused by the elasticity of the demand curve, technological progress and competitive configuration in the market. For clarity, it is useful to re-write the formula of markup:

$$\mu_{it} = \alpha^{V}{}_{it} \frac{P_{it}Y_{it}}{P^{VI}{}_{it}V_{it}} = \alpha^{V}{}_{it} \left(\frac{P^{V}{}_{it}V_{it}}{P_{it}Y_{it}}\right)^{-1}$$

Therefore, in our analysis the marginal cost of production is computed from a single variable input in production, without imposing any particular substitution elasticity with respect to other inputs in production or returns to scale. The only crucial component that we need for the estimation is the output elasticity of a variable input of production ($\alpha^{V}{}_{it}$). As regards the factors that guide firms in setting their markups in the Construction sector, the literature has identified many of them, finding that contractor size has a significant impact on their attitude towards markup decision-making process. More precisely, when deciding on the size of markup, large contractors tend to be more concerned about the nature of construction work, while medium-sized contractors are more concerned about the state of their companies' finance (Dulaimi and Shan, 2002).

Table 12 and 13 summarize the computation of this index of market competitiveness. Precisely, we provide the estimate, in historical time series, for the aggregate Construction sector, over the period 2012-2018; and the average value of markup estimated in the sub-sectors, over the same period under observation.

Table 12. The estimation of markup (time series)

year	BE	BG	DE	ES	FR	IT
2012	1,31	1,42	1,50	1,26	1,22	1,26
2013	1,33	1,40	1,53	1,19	1,24	1,22
2014	1,33	1,42	1,37	1,20	1,20	1,28
2015	1,33	1,43	1,51	1,34	1,23	1,32
2016	1,35	1,39	1,41	1,34	1,23	1,23
2017	1,35	1,39	1,53	1,38	1,25	1,23
2018	1,37	1,41	1,49	1,28	1,39	1,24
Total	1,34	1,41	1,49	1,29	1,26	1,26

Source: Author's calculation on Amadeus data (Bureau Van Dijck)

Table 13. The estimation of average markup - subsectors

it	BE	BG	DE	ES	FR	IT
23	1,19	1,31	1,51	1,38	1,30	1,16
41	1,53	1,37	1,62	1,39	1,45	1,37
42	1,42	1,45	1,47	1,35	1,35	1,32
43	1,17	1,55	1,20	1,07	1,10	1,21

Source: Author's calculation on Amadeus data (Bureau Van Dijck)

The result is remarkable. A crucial considerable heterogeneity emerges in the EU Construction market. Germany has the highest level of concentration, both in the historical perspective and as average value of the sub-sectors, followed by Bulgaria and Belgium. The Construction market appears to be more competitive in the remaining countries where the index is close to the threshold value 1 that identifies the perfect competition. Still to be noted is that the markup is high and stable over time in all six countries, even if with some fluctuation, not very significant, in the sub-periods.

What is the main economic implication of this configuration about competitiveness on employment and wages in Construction sector? The variation of the markup changes the average level of prices and consequently the real labor costs. Thus, an increase in markup decreases the real wage and leads to an increase in the natural rate of unemployment. By letting firms increase their prices, given the nominal wage, less stringent enforcement of antitrust legislation leads to a decrease in the real wage. Higher unemployment is required to make workers accept this lower real wage, leading to an increase in the natural rate of unemployment.

9. Conclusions

In this paper, we used macro and micro data to analyze, on a quantitative perspective the structure and composition of the Construction sector, in EU 28 and in the six countries targeted by the research project. The data are from the Eurostat database and Amadeus Bureau Van Dijck. In short, our empirical results provide new information "to improve knowledge on industrial relations institutions and practices across the EU and the dissemination of results".

From the statistical and quantitative analysis, a heterogeneous market emerges, with a low contribution of technological progress. This is due to the size of the firms, which are small on average, to a low level of technology and required working skills, and to a still poor innovation rate. However, *Building Information Modeling* is changing the Construction sector with a significant impact on technology content, labor organization and skills, productivity and digitalization. It is an ongoing process that, although in its first steps, tends to transform the entire sector rising productivity.

Data presented capture this change. In particular, the analysis of the balance sheet data shows the significant changes in the European construction market, with the acceleration of TFP, estimated at company and sector level, and the degree of concentration of the market that moves the Construction sector away from the configuration of more competitive market.

Technology and competitiveness affect not only profits, but also employment, labor productivity and (real) wages. Often, as the quantitative analyses presented in this paper show, in a negative sense at least in the short term. Therefore, this pattern and risk requires considerable attention in terms of new regulations and industrial relations to enable a transformation of the Construction sector into a positive one. It is advisable to reduce the technology gap that separates this sector from those with higher productivity and technology-digital content, without, however, threatening employment for a traditionally labor-intensive sector.

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Appendix A

The panel data analysis

Panel (data) analysis is a statistical method, widely used in social science, economics and econometrics to analyze two-dimensional (typically cross sectional and longitudinal) panel data. The data are usually collected over time and over the same variables (individuals, countries, sectors …) and then a regression is run over these dimensions. Multidimensional analysis is an econometric method in which data are collected over more than two dimensions. A common panel data regression model looks like $y_{it} = a + bx_{it} + u_{iy}$, where y is the dependent variable, x is the independent variable, a and b are coefficients, i and t are indices for subjects and time. The error u is very important in this analysis. Assumptions about the error term determine whether we speak of fixed effects or random effects. In a fixed effect model, it is assumed u to vary non-stochastically over i or t making the fixed effects model analogous to a dummy variable model in one dimension. In a random effects model, u is assumed to vary stochastically over i or t requiring special treatment of the error variance matrix. In the present analysis we assume fixed effects; in other words, we assume that there are unique attributes of countries that do not vary across time. These attributes may or may not be correlated with the individual dependent variables.

Here below, we report the main econometric results of our investigation for the six countries under analysis. The period is from 2012 to 2019. See also Table 12 in the main text.

Figure A1. Intangible per worker over Employment (-)

Intangible per worker -> Employment **PANEL**						year	
Fixed-effects (within) re		Number o	198.089			2013	0,002147
Group variable: id		Number o	50.588				(0.262)
						2014	0,023141
R-sq:		Obs per group:					(0.000)
within	0,0064	min	1			2015	0,042606
between	0,0305	avg	3,9				(0.000)
overall	0,0105	max	7			2016	0,023229
							(0.000)
F(7,50587)	122,00					2017	0,03586
corr(u_i, Xb)	0,0498						(0.000)
Prob > F	0,00					2018	0,033233
(Std. Err. adjusted for 50,588 clusters in id)							(0.000)
dE	Coef.					intan_pc1	
						D1.	-0,13008
							(0.094)
						_cons	-0,00055
							(0.704)

Source: Author's calculation on Amadeus data (Bureau Van Dijck)

Figure A2. Intangible per worker over Labor productivity (-)

Intangible per worker -> dlabprod			**panel**				
Number of obs	201.438						
F(15, 50729)	66,78						
Prob > F	0						
R-squared	0,0036					year	
Root MSE	0,2913					2013	0,022727
(Std.Err.adjusted for 50,730clustersin id)							(0.000)
						2014	0,025859
dlabprod	Coef.						(0.000)
						2015	0,033538
cod_country			nace_2digit				(0.000)
BG	0,037696		41	-0,0031		2016	0,025742
	(0.000)			(0.058)			(0.000)
DE	-0,01403		42	-0,00299		2017	0,036626
	(0.000)			(0.144)			(0.000)
ES	0,009653		43	0,004623		2018	0,050035
	(0.000)			(0.001)			(0.000)
FR	-0,01149					intan_pc1	0,165158
	(0.000)						(0.046)
IT	0,005962					_cons	-0,02309
	(0.004)						(0.000)

Source: Author's calculation on Amadeus data (Bureau Van Dijck).

Figure A3. Intangible per worker over technological progress (+)

Intang per worker -> TFP PANEL						
Fixed-effects (within) regression		Number of obs	201.585		Robust	
Group variable: id		Number of groups	50.566		TFP	Coef.
R-sq:		Obs per group:			year	
within	0,0549	min	1		2013	0,013187
between	0,0719	avg	4			(0.000)
overall	0,0573	max	7		2014	0,035268
						(0.000)
F(7,50565)	1255,04				2015	0,045291
corr(u_i, Xb)	0,0214					(0.000)
Prob > F	0				2016	0,025283
(Std. Err. adjusted for 50,566 clusters in id)						(0.000)
					2017	0,040476
						(0.000)
					2018	0,041521
						(0.000)
					intan_pc1	
					D1.	0,019158
						(0.212)
					_cons	-0,02653

Source: Author's calculation on Amadeus data (Bureau Van Dijck)

Appendix B

Growth accounting. The standard approach

In its basic version, "growth accounting" is developed using rather simple principles (Solow, 1956). It starts from the mathematical description of the production process, namely the production function. According to this framework, inputs are combined together in the production process to generate a certain amount of output. Let's assume that only two factors are employed in production, namely capital and labor, without further distinctions (such as between skilled and unskilled labor, tangible and intangible capital), as well as technical progress (i.e. the organization of production).

In this basic case, using one of the most widely employed production function in both theoretical and empirical studies (the so-called Cobb-Douglas) we can write:

$$Y = AK^{\alpha}L^{1-\alpha}$$

Where: K denotes capital, L denotes labor, A is the TFP which measures technological progress and Y denotes output. In addition, the capital exponent (α) represents the capital income share while the labor exponent $(1-\alpha)$, represents the corresponding labor income share. These two shares measure the importance that capital and labor inputs have in production. Dividing, side by side, by labor, the production function can be written as:

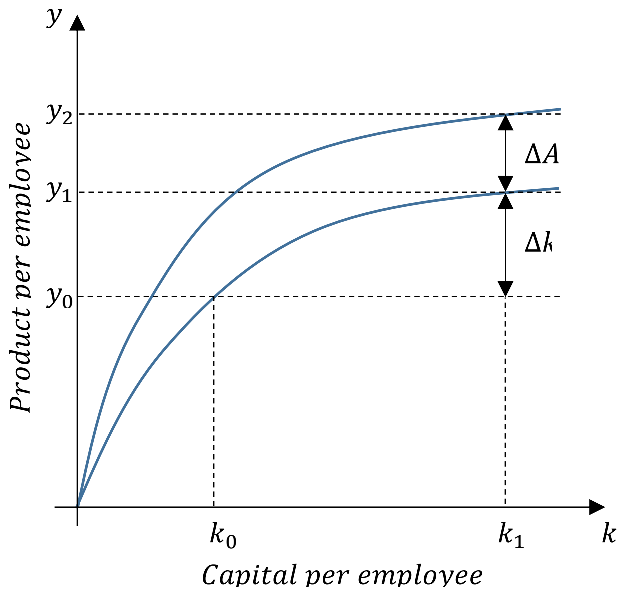
$$\frac{Y}{L} = A\left(\frac{K}{L}\right)^{\alpha}$$

Where: Y/L is output per person employed, i.e., labor productivity, and K/L is capital per person employed, i.e. the capital-labor ratio. We denote the ratios by lowercase, placing $y = Y/L$ and $k = K/L$. The production function becomes:

$$y = Ak^{\alpha}$$

Figure 1a illustrates how the increase in capital, denoted by k, and the growth in technical progress, denoted by A, contribute to the increase in labor productivity y.

Figure 1a. Production function in its intensive form



Source: Author's own elaboration

The graphical representation of the production function in figure 1a provides useful information on the role of capital accumulation (*k*) and technological progress (A) in determining labor productivity *y* in the long run. Precisely:

- Labor productivity *y* raises as capital per person *k* increases. Figure 1a illustrates this point through a shift along the production function. Indeed, when k increases, shifting to the right, the output per worker also raises from y_0 to y_1. Note however that, given the assumption of decreasing returns to scale, the capacity of *k* to positively affect *y* decreases along time as k becomes larger and larger.
- Hence, the second factor determining labor productivity in the long run is technological progress A. Technological progress (what we call TFP) acts in such a way to increase labor productivity *y* given the amount of capital per worker *k*. In Figure 1a, technological progress causes an upward shift in the production function, rising productivity given the level of capital intensity *k*. In other words, capital intensity can remain fixed, but the technological content of capital and labor must raise to push up labor productivity *y* in the long run.

Given this simple representation of the production function, the contribution of TFP to productivity is computed, using "growth accounting". In a first stage the contribution of labor and capital is deducted from the output, each weighted according to the weight these factors have in the production process. Therefore, what remains from this calculation is nothing but a measure of technological change, called **total factor productivity** (TFP). The idea is that technological progress leads in the long run to an increase in production holding inputs quantities constant.

Hence, growth accounting states that the growth rate of labor productivity is equal to the sum of the growth rate of capital endowment per worker, weighted by the share of capital income that measures its weight in the production process, and the growth rate of total factor productivity. Note that here we are facing an accounting identity that as such is unable to offer us a clear explanation of the dynamics of labor productivity. Hence, to derive an interpretation, we must impose a causal link between exogenous and endogenous variables. Exogeneity is sometimes established in emphatic form by arguing that TFP determines the evolution of capital accumulation per worker and labor productivity.

How can we measure the contribution of these two factors to productivity growth? Let us start with the production function written earlier:

$$y = Ak^{\alpha}$$

If we calculate the growth rates, we get:

$$\left(1 + g_y\right) = (1 + g_A)(1 + g_k)^{\alpha}$$

By applying logarithm, this latter expression can be further simplified in the following way:

$$g_y = g_A + \alpha g_k$$

Thus, to determine the growth rate of total factor productivity (TFP) we must subtract from the productivity growth rate g_y the growth rate of capital per employee g_k weighted by the share of capital income:

$$g_A = g_y - \alpha g_k$$

In terms of growth accounting, this implies that in the long run the growth rate of labor productivity and the growth rate of capital accumulation per worker will adjust to the growth rate of total factor productivity.

Appendix C

Our empirical estimation of TFP and markups

Usually, firm-level productivity studies assume output (either measured in terms of sales or value added) as a function of inputs the firm employs and its productivity level. TFP is then measured as a residual of this functional relationship. Nevertheless, there are a number of methodological issues connected to the estimation of markups and TFP by applying standard OLS to a balanced panel of firms. First and foremost, productivity and inputs of production are likely to be correlated and hence the estimation introduces both simultaneity and endogeneity problems. Second, the entry and exit of firms from the panel is not considered, thus resulting in an additional selection bias. Although the simultaneity and selection bias are well-known by the literature, other methodological issues have emerged recently. Specifically, the use of industry-wide deflators to proxy prices at the firm level was challenged and it was also pointed out that firms' product choices are likely to be linked to their productivity (Katayama et al., 2009; Bernard et al., 2009). In order to address these methodological problems, several parametric and semiparametric estimators have been developed in applied econometric studies. However, traditional estimators used to overcome endogeneity issues (i.e. fixed effects panel regression, instrumental variables and Generalized Method of Moments - GMM) yielded to poor result for what concerns the estimation of production function, probably because of the strong underlying assumptions. Thus, a number of alternative semiparametric methods have been introduced. Here, the pioneering work are those of Olley and Pakes (1992) and Levinsohn and Petrin (2004) which have developed a semiparametric estimator that addresses the simultaneity bias (and also the selection bias in the former case). Several extensions to their model have subsequently come to light (De Loecker and Warzynski, 2012). Estimation of firm-level markups and TFPs based on the production function approach employs the ratio of the output elasticity of a variable input to the same input cost share in revenue as relevant estimator for the markup. The production function approach was pioneered by Hall (1986), in estimating of industry-level markups. The ratio estimator builds on Hall's original ideas and has recently been used to estimate firm-level markups by De Loecker and Warzynski (2012), De Loecker et al. (2020) and many others. The resulting estimates have received wide attention and many potential problems in interpreting these estimates have been discussed (see Traina 2018; Basu, 2019; Syverson 2019; De Loecker and Eeckhout 2018).