Intangible Capital and Labour Productivity Growth: Panel Evidence for the EU from 1995-2015*

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Artificial intelligence and the next generation of competences :
How Digital – and Artificial Intelligence will impact jobs and competences profiles?

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1. Introduction and Motivation

Intellectual Capital for Communities In the Knowledge Economy

- Recent research findings indicate a disappointing growth performance among European Union (EU) and Euro Area (EA) countries since the start of the crisis in 2008 (van Ark 2015, van Ark and Jäger 2017).
- By utilizing a *growth accounting methodology*, this literature proves that a significant proportion for the slowdown of the EU/EA growth performance is due to a lack of investments in intangible capital by businesses (van Ark 2015, Corrado et al. 2016).
- However, there exists only scarce econometric studies (*cross-country growth accounting*) concerning the relationship between business intangible capital and labour productivity growth at the country-level. Moreover, such studies have only studied a pre-crisis period (Roth and Thum 2013).
- To overcome the research gap this paper utilizes a *cross-country growth accounting estimation approach* upon a largely extended database matching INTAN-Invest with EUKLEMS data consisting of 16 EU countries from 1995-2015 with an overall amount of 243 (instead of 98) observations. The paper is thereby able to i) corroborate earlier econometric findings (Roth and Thum 2013), ii) analyse/compare the pre-crisis period to a crisis period (Piekkola 2017) and iii) compare novel econometric findings to the existing growth accounting results (van Ark 2015, Corrado et al. 2016).

2. Links between Intangible Capital and Labour Productivity Growth

- In times of knowledge economy investments of intangible capital become the dominant source of growth (CHS 2005, 2009, Van Ark 2015, Piekkola 2017, Bounfour and Miyagawa 2015).
- Prior studies have identified the positive relationship between software and organizational capital (Brynjolfson et al. 2002).
- Prior studies have underlined the importance of R&D (Guellec and van Pottelsberghe de la Potterie 2001).
- More recent studies have underlined the importance of economic competencies (Roth and Thum 2013; Piekkola 2014, 2017).
- The complementarity of investments is of major importance (Bounfour and Miyagawa 2015).

3. Previous Empirical Results

- There exists a range of previous empirical results using a *growth accounting* framework for pre-crisis and times of crisis (the latest are Van Ark 2015, Corrado et al. 2013, 2016).
- Such results indicate that the incorporation of intangible assets into the boundary of the national accounts have three effects: i) a significant investment (in GDP) in %, ii) a sizeable positive contribution to labour productivity growth and iii) a growth acceleration effect.
- However, econometric results using a *cross-country growth accounting* approach, however, are still scarce.

Intellectual Capital for Communities In the Knowledge Economy

Table 1
Previous Empirical Results, 2005-2015 (1/3)

Article	Country	Investment (in GDP) in %	Contribution to LPG in %†	Growth acceleration in %
CHS (2005)	US	10-12 (98-00)	/	/
CHS (2009)	US	~ 13 (03)	27 (95-03)	11.2 (95-03)
Jalava et al. (2007)	FI	9.1 (05)	16, 30 (95-00), (00-05)	13.2, 2.1 (95-00), (00-05)
Van Rooijen et al. (2008)	NL	8.3* (01-04)	/	/
Baldwin et al. (2009)	CA	~19 (01)	/	/
Barnes and McClure (2009)	AU	9.6 ± (05/06)	20 (94/95-05/06)	4,5 (94/95-05/06)
Fukao et al. (2009)	JAP	11.1** (00-05)	27, 16 (95-00), (00-05)	17.3, -1.4 (95-00), (00-05)

Table 1
Previous Empirical Results, 2005-2015 (2/3)

Article	Country	Investment (in GDP) in %	Contribution to LPG in %†	Growth acceleration in %
Hao et al. (2009)	DE, FR, IT, ES	7.1, 8.8, 5.2, 5.2 (04)	31, 37, 59, 64 (95-03)	10.5, 13.8, 37.2, 40 (95-03)
Marrano et al. (2009)	UK	13± (04)	20 (95-03)	13.1 (95-03)
Van Ark et al. (2009)	DE, FR, IT, ES, AT, CZ, DK	7.2, 7.9, 5.0, 5.5, 6.5, 6.5, 7.9 (06)	21, 24, 41, 26, 23, 15, 34 (95-06) ‡	11.2, 9.3, 11.5, 30.6, 18.6, 2.2, 37.0 (95-06) ‡
Nakamura (2010)	US	Intangible=Tangible (00-07)	/	/
Edquist (2011)	SE	10/~16** (04)	41, 24 (95-00), (00-06)	16 , -2.3 (95-00), (00-06)
Baldwin et al. (2012)	CA	13.2 (08)	29, 75 (76-00), (00-08)	13.3, 14.3**** (76-00), (00-08)
Hulten and Hao (2012)	CN	7.1 (06)	15 (00-08)	0.7 (00-08)

Intellectual Capital for Communities In the Knowledge Economy

Table 1
Previous Empirical Results, 2005-2015 (3/3)

Article	Country	Investment (in GDP) in %	Contribution to LPG in %†	Growth acceleration in %
*Roth and Thum (2013)****	13 EU countries	9.9** (98-05)	50 (98-05)	4.4 (98-05)
Corrado et al. (2013)	EU-15, JP, US	6.6, /, 10.6 (95-09)	24, 11, 28 (1995-2007)	/
Muntean (2014)	ON (CA)	10.4 (08)	26, (98-08)	/
Van Ark (2015)	EU-15	10[a] (95-10)	/	/
Corrado et al. (2016)	EU-14, New Mem. States, US	7.2, 6.4, 8.8 (00-13)	19, 8, 33 (00-07) 43, 17, 42 (07-13)	/

Notes: Table 1 is an updated version of Table 1 in Roth and Thum (2013). †LPG= Labor Productivity Growth, ± Measure here is adjusted MGVA; ‡ Only for Czech the period ranges from 1997 to 2006; [a] Measure here is market sector GDP; * Measure here is intangible capital spending excluding general government industry; ** Measure here is GVA; *** Cross-Country Growth Accounting, **** Compared to the Intangibles already included in the National Accounts US= United States, UK= United Kingdom, FI= Finland, JAP= Japan, IT= Italy, ES= Spain, DE= Germany, FR= France, NL= Netherlands, AT= Austria, CZ= Czech Republic, DK= Denmark, SE= Sweden; The numbers in brackets refer to the relevant time periods.

4. Estimation Approach, Model Specification, Research Design and Data

4.1 Estimation Approach

- Following Roth and Thum (2013) a *cross-country growth accounting* approach is utilized.
- This approach differs in two important respects from the traditional methodological framework of single growth accounting (CHS 2009, Van Ark 2015, Corrado et al, 2013, 2016).
- First, the output elasticities are estimated, rather than imposed. Secondly, part of the model can be designed to explain the international variance in TFP (total factor productivity) growth.

4.2 Model Specification

Following the theoretical framework of CHS (2009), a slightly revised specification as developed by Roth and Thum (2013) is expressed in equation (1) below:

$$\left(\mathbf{lnq_{i,t}} - \mathbf{lnq_{i,t-1}}\right) = \mathbf{c} + \mathbf{gH_{i,t}} + \mathbf{mH_{i,t}}\frac{\left(\mathbf{Q_{max,\,t}} - \mathbf{Q_{i,t}}\right)}{\mathbf{Q_{i,t}}} + \mathbf{n}\left(\mathbf{1} - \mathbf{ur_{i,t}}\right) + \mathbf{p}\sum_{\mathbf{j=1}}^{\mathbf{k}}\mathbf{X_{j,i,t}} + \mathbf{yd_{i,t}} + \boldsymbol{\alpha}\left(\mathbf{lnk_{i,t}} - \mathbf{lnk_{i,t-1}}\right) + \boldsymbol{\beta}\left(\mathbf{lnr_{i,t}} - \mathbf{lnr_{i,t-1}}\right) + \mathbf{u_{i,t}} \quad \textbf{(1)}$$

Where:

$\left(\boldsymbol{lnq_{i,t}} - \boldsymbol{lnq_{i,t-1}}\right)$ is labour productivity growth (GVA for the non-farm business sectors in country $\boldsymbol{i}$ and period $\boldsymbol{t}$. The constant **c** is exogenous technological progress. The level of human capital $\boldsymbol{(gH_{it})}$ reflects the capacity to innovate domestically. The term $\boldsymbol{mH_{it}}\frac{\left(\boldsymbol{Q_{max,\,t}} - \boldsymbol{Q_{i,t}}\right)}{\boldsymbol{Q_{i,t}}}$ proxies a catch-up process. The term $\boldsymbol{n}(\mathbf{1} - \boldsymbol{ur_{it}})$ accounts for business cycle effect. The term $\boldsymbol{p}\sum_{\boldsymbol{j=1}}^{\boldsymbol{k}}\boldsymbol{X_{jit}}$ is a sum of k extra policy variables. $\boldsymbol{yd_{it}}$ are year dummies to control, amongst others, for the economic downturn in 2001 (IT-Bubble, 9/11 attack) as well as the economic downturn since the year 2007. $\left(\boldsymbol{lnk_{i,t}} - \boldsymbol{lnk_{i,t-1}}\right)$ and $\left(\boldsymbol{lnr_{i,t}} - \boldsymbol{lnr_{i,t-1}}\right)$ represent the growth of tangible and intangible capital services. $\boldsymbol{u_{i,t}}$ represents the error term.

4.3 Research Design

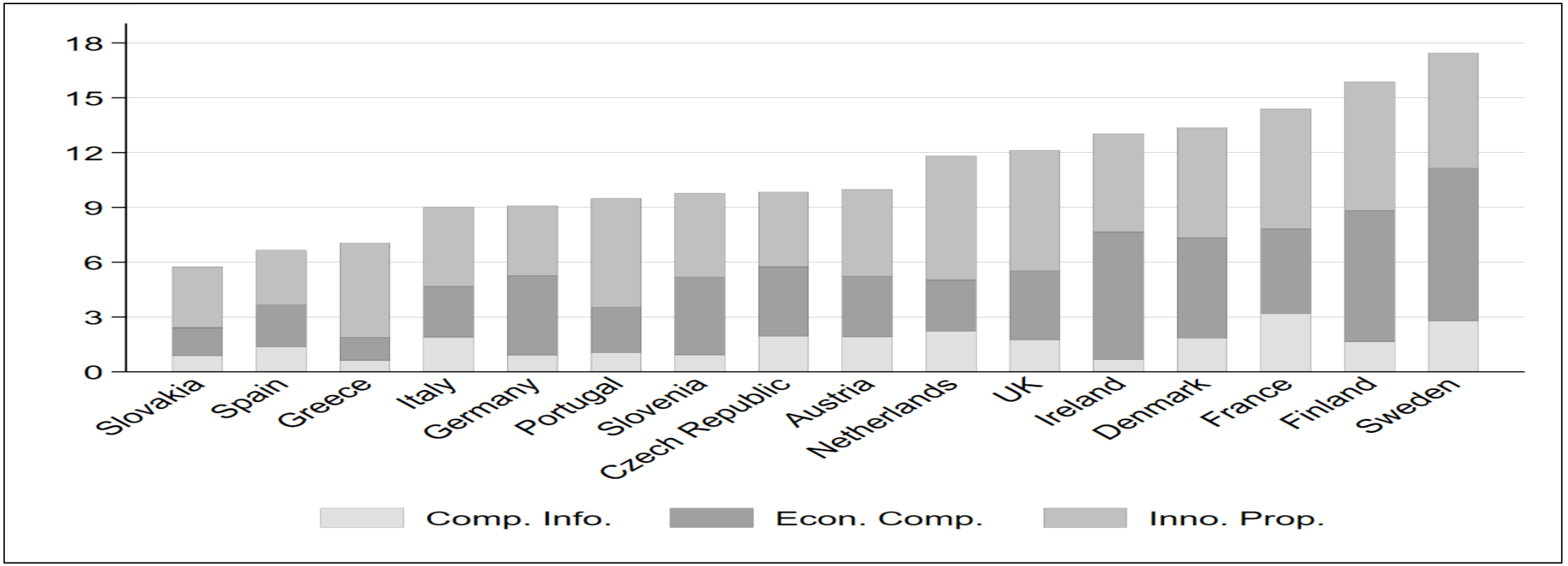
- The econometric analysis covers 16 out of the EU-28 countries from 1995 to 2015. The countries included are Austria, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, the Netherlands, Portugal, Spain, Slovakia, Slovenia, Sweden and the United Kingdom.
- Belgium, Portugal and Hungary and Luxemburg were excluded due to data availability and time series inconsistency.
- By utilizing updated EUKLEMS and updated INTAN-INVEST data, equation (1) is estimated on a sample of 243 observations, instead of 98 observations as prior research studies at country level.
- Initial intangible capital stocks are constructed according to the INNODRIVE approach by Roth and Thum (2005) and Niebel et al. (2017).
- Tangible and Intangible Capital Services were constructed according to Roth and Thum (2013) following Oulton and Srinivasan (2003) and Timmer et al. (2007).

4.4 Data

- Data on the single components of intangible capital were taken from the latest INTAN-Invest dataset – until 2015.
- Data on GVA, tangible capital stocks, capital compensation, gross fixed tangible capital investments, tangible investment price indices, labor input (number of hours worked per persons engaged) and depreciation rates for tangible capital were calculated from the latest EUKLEMS database – until 2015.
- Human capital is measured as the “percentage of population who attained at least upper secondary education,” which is taken as a proxy for the inherent stock of human capital. These data are provided by Eurostat.
- The variables rule of law and trust are taken from the Worldwide Governance Indicators project and the World Value Survey.
- Other relevant policy variables are either taken from the Penn World Table or form Eurostat.

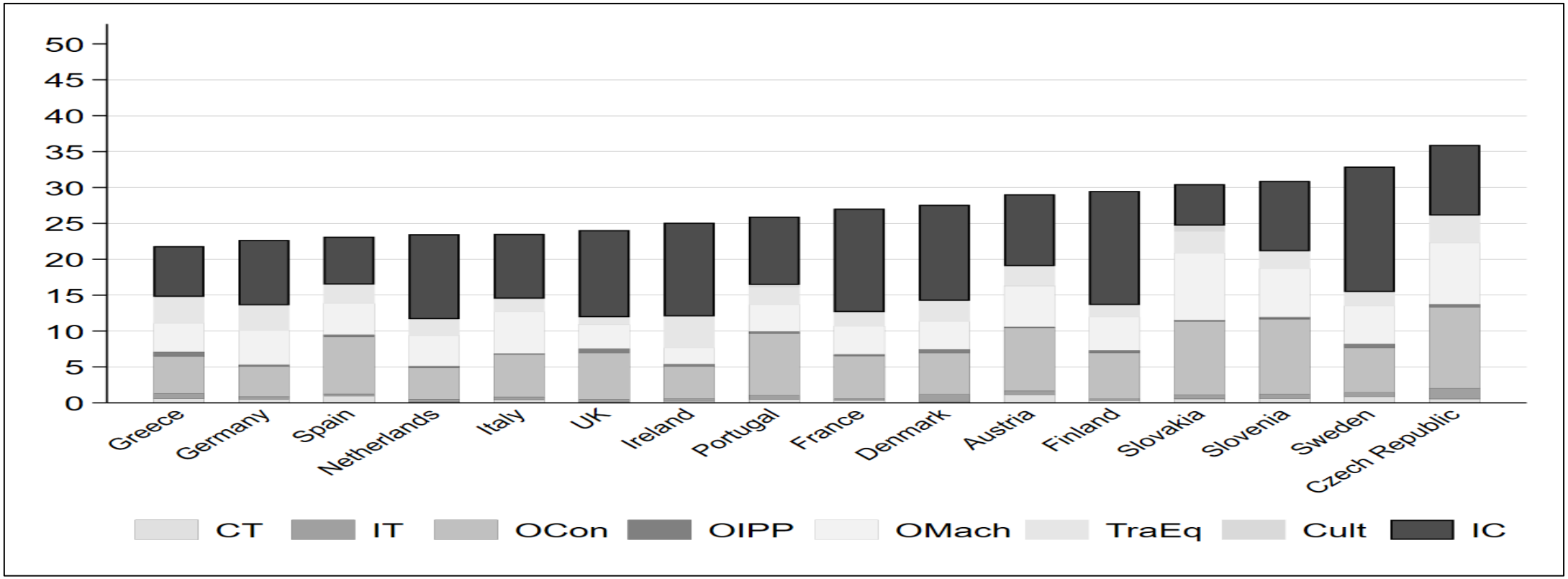
5. Descriptive Statistics

Figure 1.
Business Intangible Capital (as a percentage of Adjusted VA), EU16, 1995-2015.



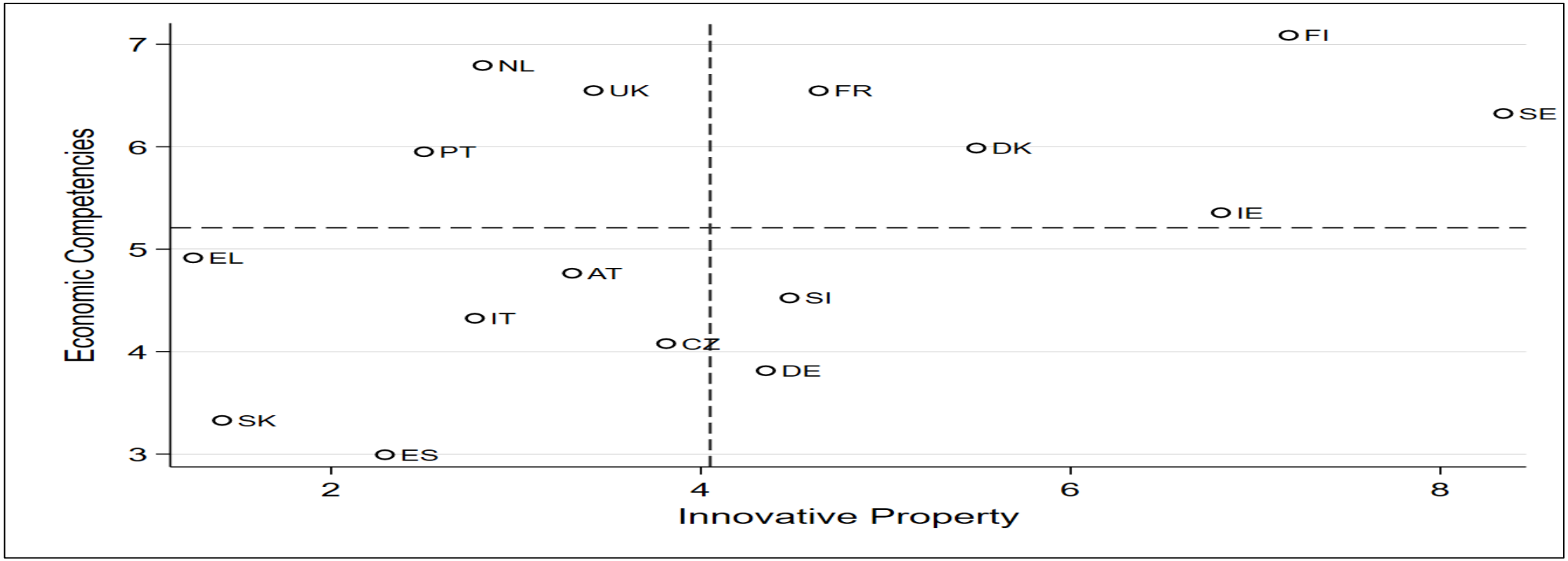
Note: Updated and modified Figure 1 in Roth and Thum (2013). Comp. Info=Computerized Information, Econ. Comp=Economic Competencies, Inno. Prop. = Innovative Property Source: Own estimations using INTAN-Invest data

Figure 2.
Business Tangible and Intangible Capital Investments (% VA), EU16, 1995-2015.



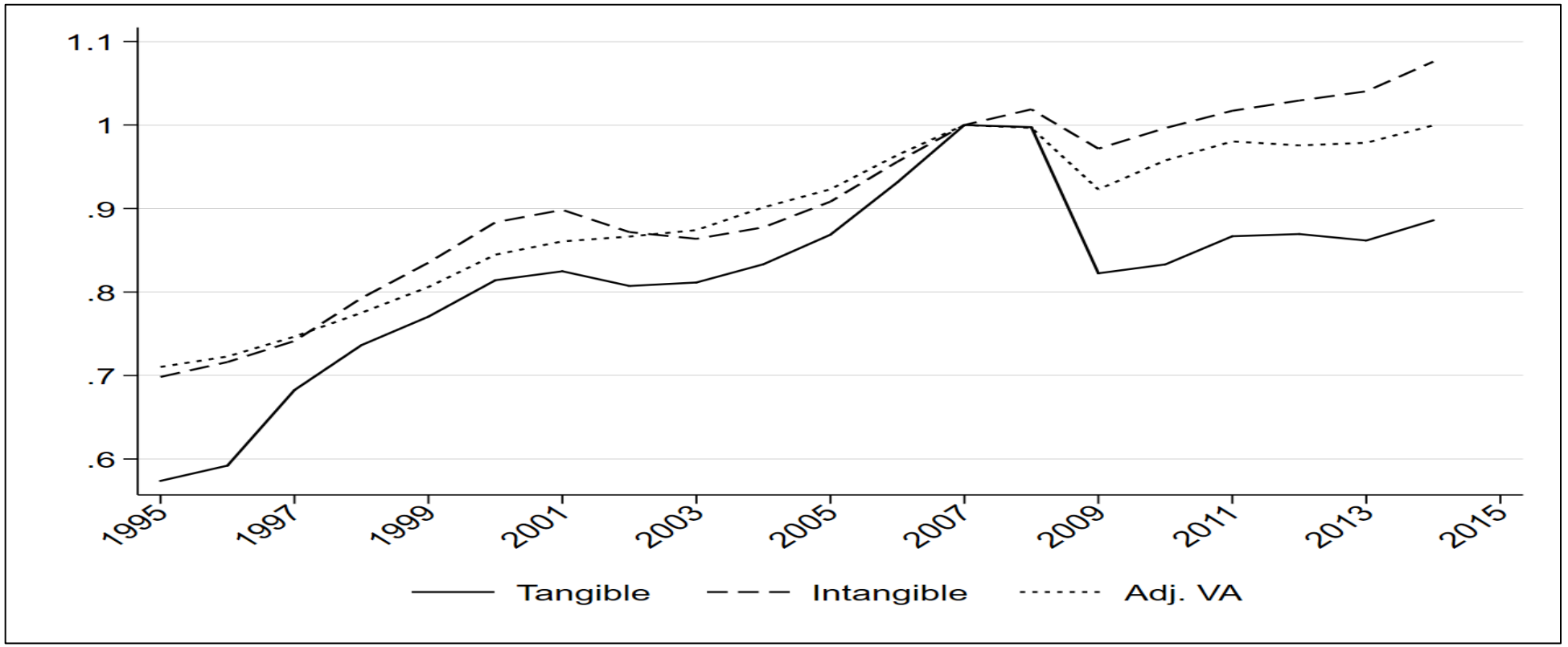
Note: Updated and modified Figure 2 in Roth and Thum (2013). CT= Communications equipment, IT = Computing equipment, OCon = Total non-residential capital investment, OIPP = Other intellectual property products, OMach = Other machinery and equipment, TraEq = Transport equipment, IC = Intangible capital. Residential Structure has been excluded.
Source: own calculations on INTAN-Invest and EUKLEMS databases.

Figure 3.
Scatterplot between Innovative Property and Economic Competencies (as a percentage of Adjusted VA), 1995–2015.



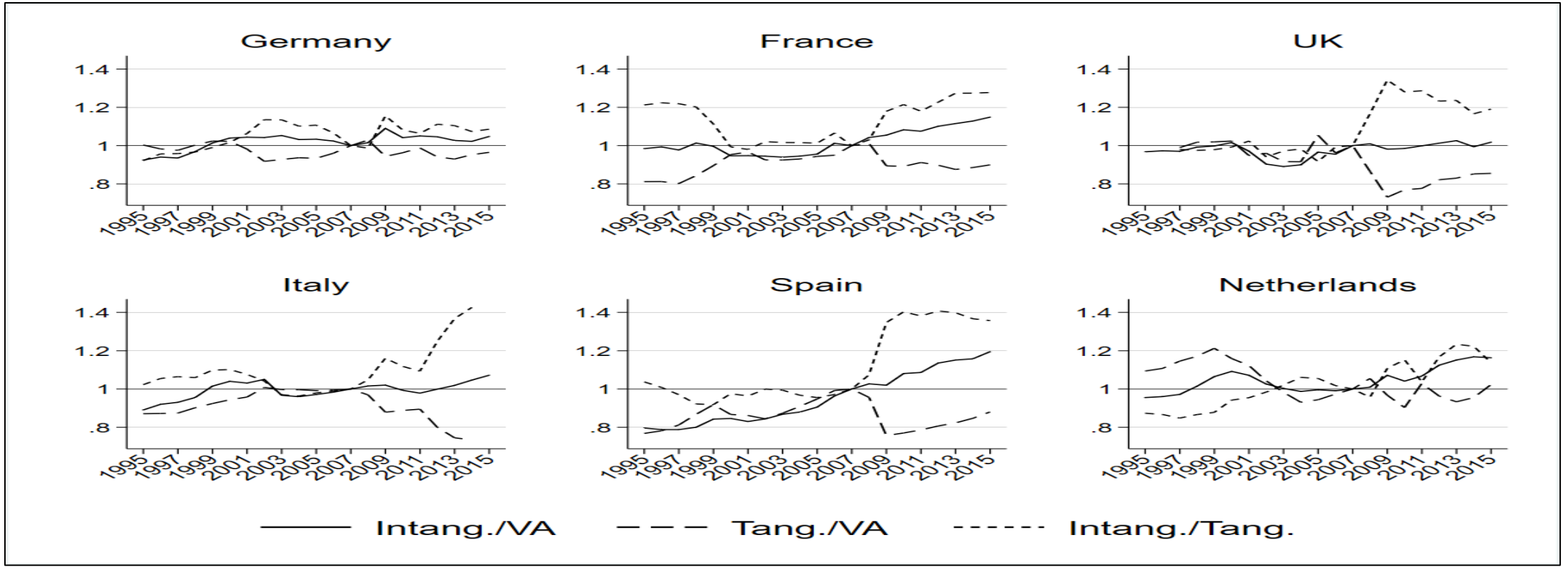
Notes: Updated and modified Figure 3 in Roth and Thum (2013). The dashed lines indicate the EU16 average values. AT = Austria, CZ = Czech Republic, DE = Germany, DK = Denmark, EL = Greece, ES = Spain, FI = Finland, FR = France, IE = Ireland, IT = Italy, NL = the Netherlands, PT = Portugal, SE = Sweden, SI = Slovenia, SK = Slovakia, UK = United Kingdom. Source: Own estimations using INTAN-Invest data

Figure 4.
Time series of Tangible and Intangible investments (2007=1), EU15, 1995–2014.



Notes: Standardized for 2007 =1. Residential Structures are excluded.
Source: Own estimations using INTAN-Invest and EUKLEMS data.

Figure 5.
Time series of Tangible and Intangible investments and Value Added, 6 largest EU Economies, 1995–2015.



Notes: Standardized for 2007 =1. Residential Structures are excluded. Value Added is adjusted Value Added from INTAN-Invest. Source: Own estimations using INTAN-Invest and EUKLEMS data.

6. Econometric estimation

Table 2. Intangibles and labor productivity growth. Random effects estimation.

Dep. Var.: Adj. VA Growth Random effects model	(1) 2000-2015	(2) 2000-2007	(3) 2008-2015
Tangible Capital Service Growth	0.05	0.16**	-0.11
	(0.55)	(0.05)	(0.48)
Intangible Capital Service Growth	0.22***	0.11	0.23***
	(0.00)	(0.28)	(0.00)
Business Cycle	yes	yes	yes
Catch-up	yes	yes	yes
Upper Secondary Education	yes	yes	yes
Year dummies	yes	yes	yes
Observations	243	120	123
Countries	16	16	16
R-square overall	0.74	0.58	0.72
R-square between	0.77	0.82	0.88
R-square within	0.74	0.5	0.69

Robust pval in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Intangible Capital Service Growth explains around 35% of LPG.

Note: Adjusted VA is non-farm business sectors value added.

7. Conclusion

- This paper has analysed the relationship between intangible capital investment and labour productivity growth by businesses by analysing an EU-16 country sample over the time-period 1995-2015 with the help of a *cross-country growth accounting* estimation approach.
- The paper corroborates earlier findings (Roth and Thum 2013) and finds a positive relationship between intangible capital investments by businesses and labour productivity growth for the full sample from 2000-2015. Intangible capital services is able to explain 35% of labour productivity growth.
- The paper detects that when differentiating a pre-crisis sample from a crisis-recovery sample the positive relationship between intangible capital and labour productivity growth is more pronounced in times of crisis-recovery.
- A contrasting finding holds for the relationship between tangible capital and labour productivity growth.
- Similar to earlier results (Corrado et al. 2016) the paper finds that whereas intangible capital investment have swiftly recovered from the crisis, tangible capital investments have still not recovered to pre-crisis levels.