Determinants of Productivity Gap in the European Union: A Multilevel Perspective

Randolph Bruno Elodie Douarin Julia Korosteleva Slavo Radosevic

University College London

School of Slavonic and East European Studies

Centre for Comparative Studies of Emerging Economies

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Faltering EU28 ‘convergence machine’: competing interpretations

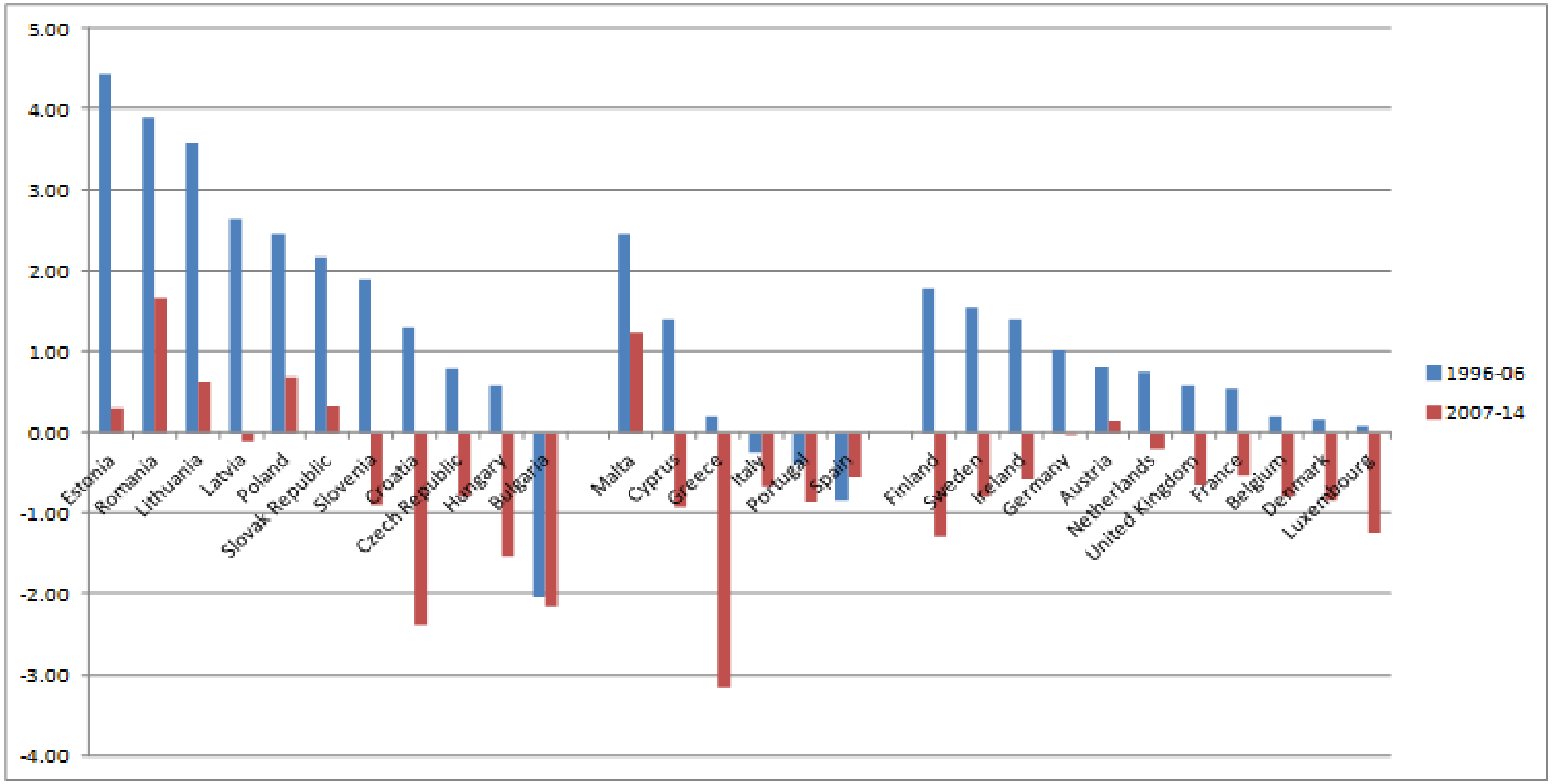
- Macroeconomic *cum* institutional interpretation: *EMU built in defects*
- Structural reforms *cum* supply side policies: *Doing business*
- Structuralist *cum* Schumpeterian interpretation: *Technology gap*

Our three contributions and preview of findings

1. An analysis of productivity growth in the EU with a focus on **firm data** at a very disaggregated level, namely setting one common EU-wide frontier to allow for a cross-country comparison
2. A multilevel model to control for sector-specific and country-specific clustering effects
3. Explore the interplay between *in-house R&D and embedded R&D* and extends our understanding of the Schumpeterian growth process.

The most significant factors that determine productivity gap across EU are related to **technology gap variables** - own R&D intensity of firms and countries as well as R&D embedded in purchased equipment and machinery - and how they **interact**

Growth of Total Factor Productivity in EU28 economies - an average of two periods: divergence in the CEE Decline in South and North



Source: The Conference Board Total Economy Database™, May 2015, http://www.conference-board.org/data/economydatabase/

Our exploration of the determinants of productivity gap in Europe is informed by three types of literature

- The literature on the determinants of productivity
- The literature on the technology gap and why growth rates differ
- The literature on multilevel modelling of growth

Productivity studies

- There exist significant and persistent differences in productivity across countries (Bartelsmann et al, 2013) and large and persistent productivity differences across producers within even ***very narrowly*** defined industries (Syverson 2011)

Firm level determinants:

- Firm level heterogeneity accounts for substantial differences in aggregate performance
- Examples of firm level determinants of productivity (Syverson 2011, JEL):
  - Competition; Sunk costs; Innovation, technology spill-overs; organisational structures/managerial skills, intangibles; human capital, managerial practices etc.
  - There is increasing evidence that *within* industry reallocations are shaping changes in industry average aggregates.

Productivity studies (c. ed)

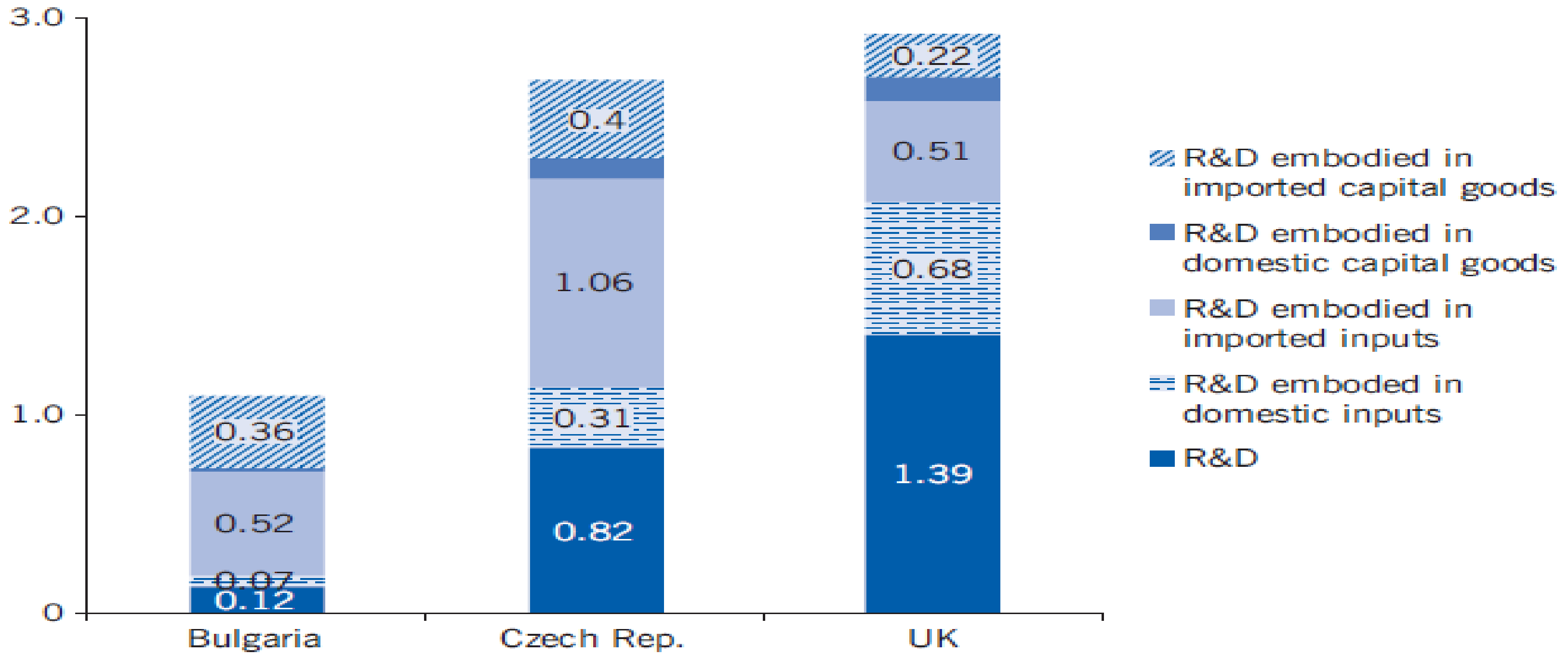
- **Sector level determinants**
  - Lee (2013) shows that catch-up is more likely in sectors with short technology cycles as measured by patent citations;
  - Jung and Lee (2010) show that international catch up (Korea vis-à-vis Japan) is more likely to occur in sectors where technologies are more explicit (e.g. electronics) and more easily **embodied** in imported machinery and equipment than in sectors with more tacit knowledge regime (e.g. automotive, fashion, design);
  - They also find that the absolute bulk of productivity gap is due to the sector level catch up whereas the firm level catch up is minimal;
  - However, firm level variables are important in explaining intra-national catch up (and not only!).
- **Country level determinants**
  - The critical factor are differences in TFP
  - Determinants of TFP: education, health, infrastructure, institutions, openness, competition, financial development, geographical predicaments and absorptive capacity (including capital intensity) appear to be the most critical determinants of TFP (Isaksson (2007)

Exploring multilevel determinants of productivity gap: Research Questions

- Multi-level determinants
  - Firm-level determinants:
    - Technology transfer (via FDI)
    - Multi-plant firms
    - Size, age
  - Industry determinants:
    - Industry concentration (within sector-year-country vs. within sector-year-EU);
  - Macro regional determinants: Europe North, East and South
  - Technology gap determinants
    - Own disembodied and external embodied technology: Direct and 'indirect' R&D investments
- *Research Question:* Which of these determinants play a more important role in explaining the productivity gap?

Direct and ‘indirect’ (embedded) R&D intensity varies across different income levels

Figure 4. R&D intensities in value-added in 2000 (shares in %)



Source: Radosevic, S. (ed.). *Synthesis Report: WP3. Innovation, Entrepreneurship and Industrial Dynamics. Technology Upgrading and Innovation Policy in Central and Eastern Europe*. GRINCOH Working Paper Series No. 3, 2015. Online at: http://www.grincoh.eu/media/syhtnesis_reports/grincoh_wp3_synthesis_report_radosevic.pdf [9]; Author's own calculations based on Knell, M. *Embodied Technology Diffusion and Intersectoral Linkages in Europe*. Europe Innova Sectoral Innovation Watch Deliverable WP4, 2008. Online at: https://www.researchgate.net/profile/Mark_Knell/publication/265369750_Product-embodied_technological_diffusion_and_intersectoral_linkages_in_Europe/links/5409c8550cf2d8daaabf3431.pdf?origin=publication_detail

I Z A
World of Labor

Sample

- 124,862 firms spanning 90 4-digit NACE sectors located in 15 EU countries in 2004-2013 (549,317 total obs.) from Amadeus:
  - Firm size (proxied by employment/fixed assets)
  - Foreign ownership (time-invariant)
  - Number of subsidiaries overseas (time-invariant)
  - Firm age (& age^2)
- Merged with other industry-level data sourced form World Input-Output Tables and National Statistical offices/Eurostat:
  - Embodied vs. disembodied R&D
  - Industry concentration within domestic and EU market (separately)
- Able to distinguish between EU North (Core) and EU East and South (Periphery)

1^{st} Step: Total Factor Productivity estimation

Total Factor productivity at 4-digit (see Foster, Haltiwanger Syverson 2008):

$$\ln[\text{Value Added}_{(firm,year)}] = a^{L}[\text{Labour}_{(firm,year)}] - a^{FA}[\text{Fixed Assets}_{(firm,year)}] + \xi$$

$$\ln[\text{TPF}_{(firm,year)}] = \ln[\text{Value Added}_{(firm,year)}] - \hat{a}^{L}[\text{Labour}_{(firm,year)}] - \hat{a}^{FA}[\text{Fixed Assets}_{(firm,year)}]$$

TFP as ***residual*** of a four digit regression at the firm level for 4 separate manufacturing sectors;

1. Computing (NACE 26): High-technology
2. Chemical (NACE 20): Medium-high-technology
3. Basic Metals (NACE 25): Medium-Low-technology
4. Food (NACE 10): Low-technology

Example: TFP regression for Manufacture of electronic components (NACE code 2611)

```
Linear regression                               Number of obs =     11590
                                                F( 11,   2309) =   854.97
                                                Prob > F      =    0.0000
                                                R-squared     =    0.7962
                                                Root MSE      =    .97579

                              (Std. Err. adjusted for 2310 clusters in bvdidnumber)
------------------------------------------------------------------------------------
                     |               Robust
LN_r_valueadded_con~d |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
---------------------+--------------------------------------------------------------
LN_r_fixedassetstheur |   .2817864   .0122892    22.93   0.000     .2576874    .3058855
 LN_numberofemployees |   .6763992   .0187599    36.06   0.000     .6396112    .7131872
                     |
                year |
                2005 |   .0198958   .0309501     0.64   0.520    -.0407972    .0805887
                2006 |   .0873545   .0343056     2.55   0.011     .0200814    .1546275
                2007 |   .0711793    .034922     2.04   0.042     .0026974    .1396611
                2008 |   .0301764   .0366955     0.82   0.411    -.0417831    .1021359
                2009 |  -.1702227   .0364772    -4.67   0.000    -.2417542   -.0986911
                2010 |  -.0757905   .0380357    -1.99   0.046    -.1503781   -.0012029
                2011 |  -.0354986   .0379826    -0.93   0.350    -.1099823     .038985
                2012 |  -.0688868   .0381614    -1.81   0.071     -.143721    .0059473
                2013 |    -.22269    .061596    -3.62   0.000    -.3434792   -.1019008
                     |
               _cons |   3.346874   .0583546    57.35   0.000     3.232441    3.461307
------------------------------------------------------------------------------------
```

2^{nd} Step: TFP gap computation

Following Jung Lee (*Industrial and Corporate Change* 2010):

$$\text{Total Gap} = TFP_{firm,sector,time} - [MaxEU_{sector}(\sum 1/n_s (TFP_{sector,country})]$$

Total productivity gap is difference between TFP of individual firms and **the highest level of TFP among countries averages**

Multilevel Methodology

- We employ **Multilevel modelling** to address the issue of data clustering bias given a hierarchical structure of our data in which **years** represent ***Level One***; **firms** represent ***Level Two;*** ***sectors (4-digits)*** represent ***Level Three;*** *and* ***countries*** represent ***Level Four.***
- Failure to account for a nested structure of data (dependence of observation due to clustering of data) will lead to biased results, especially for coefficients of predictors that are measured at the group level (Rabe-Hesketh *et al*. 2005).
  - For example, firms within an industry-country sample are more alike than a random sample of firms. This is the '***clustering***' effect of industry-country groups.
- With a nested structure of data we control for unobserved heterogeneity within different cluster groups (e.g. sector/country);
- However, we undertake thorough robustness checks by using a pure fixed effects model (with *firms* and *time fixed* effects) vis-à-vis a mixed model (lower bound effects).

Exploring multilevel determinants of productivity gap: model specification

- **Total productivity gap (4-level model)**

$$Total\_GAP_{tikl} = \beta_0 + \beta_1 X_{tikl} + \beta_2 X_{tkl} + u_l + v_{kl} + \varphi_{ikl} + \varepsilon_{tikl} \quad (1)$$

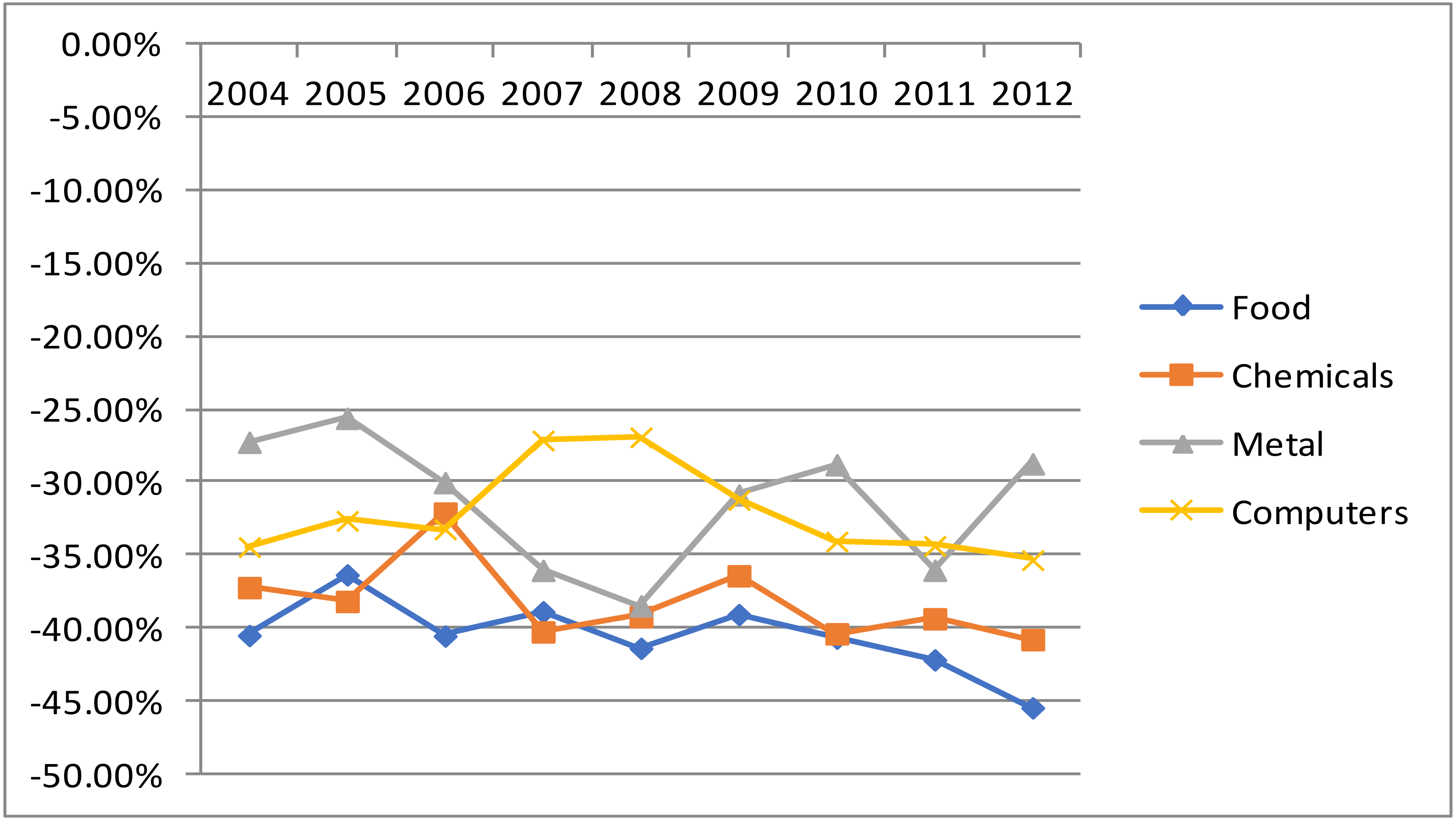
To denote 4 levels we have subscript t_{ikl} above, where t represent years, *i* represents firms, k - industrial sectors, and l - countries. X_{tkl} denote firm-level time-variant covariates, and X_{tikl} - sector-level covariates

$u_l + v_{kl} + \varphi_{ikl} + \varepsilon_{tikl}$

is the random part of the equation , where u_l are the country level residuals, v_{kl} - sector within country level residuals, and φ_{ikl} - firm within sector-country level residuals; ε_{tikl} show the completely idiosyncratic effect of years within firms-sectors-countries.

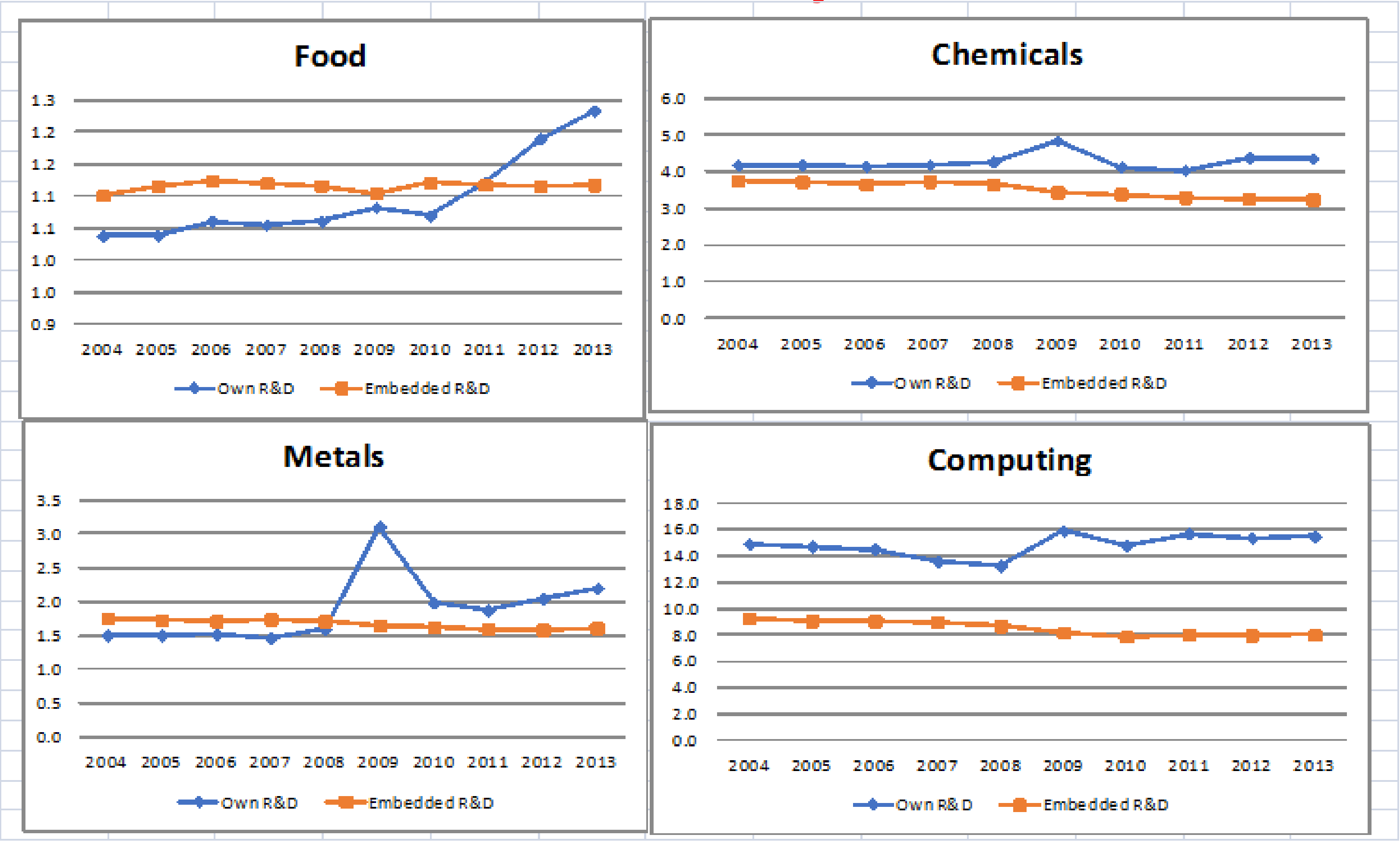
Average Gap Firm - Max TFP:

weighted by shares of countries in the sample



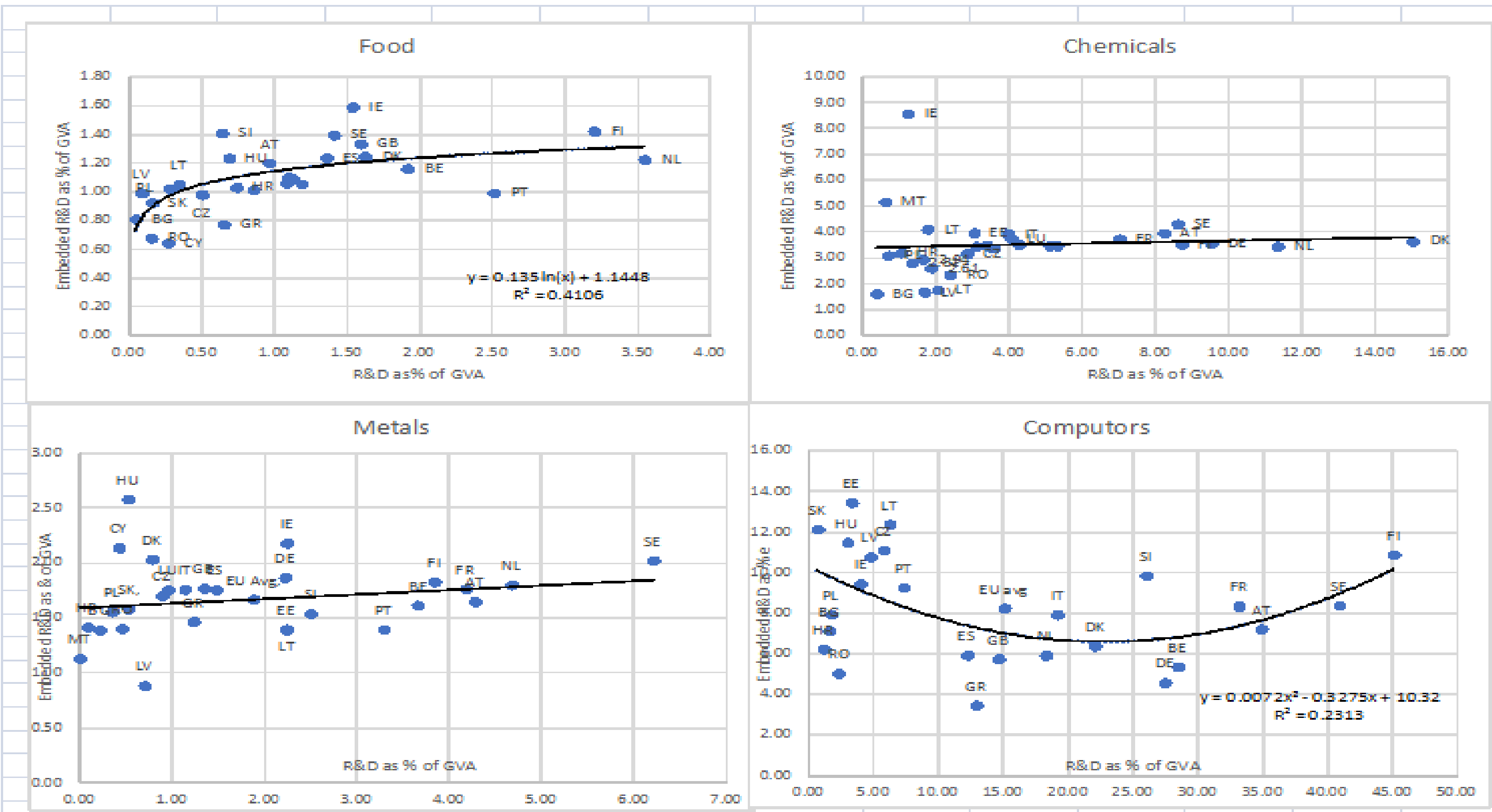
R&D and embedded R&D intensity in four sectors, 2004-13 (based on country sector averages)

Exist significant sector differences in both R&D and embedded R&D intensity



R&D and embedded R&D intensity in four sectors across EU28 countries (average 2004-2013)

Variance in R&D intensity across countries is more significant than variance in embedded R&D (vertical axis)



Multilevel model results (non-weighted sample)

	(1)	(2)	(3)	(4)
Dep: TFP GAP	NACE 26 Computing	NACE 20 Chemicals	NACE 24 Basic Metal	NACE 10 Food
L.LN_number ofemployees	0.00957*	-0.00425	-0.00793^{+}	0.0334***
	(0.00403)	(0.00389)	(0.00468)	(0.00231)
L.LN_noofrec ordedsubsidiar ies	-0.00633	-0.00674	0.00919	-0.0586***
	(0.0109)	(0.00922)	(0.0118)	(0.00724)
EU_D_south_ east	-0.352***	-0.299***	-0.482***	-0.0323
	(0.0962)	(0.0696)	(0.0900)	(0.110)
RESCALED_ age	0.000958^{+}	0.000231	0.000179	-0.000339
	(0.000493)	(0.000555)	(0.000536)	(0.000256)
RESCALED_ age_sq	-0.000000988	-0.00000117	-0.00000186	-0.000000199
	(0.000000690)	(0.00000469)	(0.00000306)	(0.00000108)
foreign_owner	0.00266	0.00104	-0.0228	-0.000673
	(0.0163)	(0.0136)	(0.0185)	(0.00985)
L.LN_concent ration_index_ 4dig	-0.642***	-0.181*	-0.489***	0.527***
	(0.0625)	(0.0738)	(0.0942)	(0.0451)
L.LN_concent ration_index_ EU_4dig	1.119***	0.0620	0.729***	0.795***
	(0.0857)	(0.0603)	(0.104)	(0.0477)
L1_Spike_adj 4O_26	-0.00772			
	(0.00589)			
L1_Spike_adj 4O_20		0.000983		
		(0.00644)		
L1_Spike_adj 4O_24			0.00644	
			(0.00802)	

Multilevel model results (non-weighted sample)(cont)

Dep: TFP GAP	NACE 26 Computing	NACE 20 Chemicals	NACE 24 Basic Metal	NACE 10 Food
L1_Spike_adj4O_10				0.00958*
				-0.00397
L1_LNown_rnd_perc_prod	0.586***	1.086***	0.970***	10.12***
	-0.0756	-0.114	-0.29	-0.307
L1_LNembedded_sector_EU_gross	0.646***	0.818***	-0.0258	2.532***
	-0.0926	-0.101	-0.102	-0.0922
c.L1_LNown_rnd_perc_prod#c.L1_LNembedded_sector_EU_gross	-0.259***	-0.728***	-0.844**	-11.66***
	-0.0377	-0.0836	-0.296	-0.381

Results

- While firm-level variables and idiosyncratic firm factors play major role in explaining productivity differences within industries, in multi-level setting, these differences do not seem to be significant
- There is not a simple one to one relationship between industry structure, innovation and productivity growth (Aghion et al., 2005)
- Dummy for 'South-East' is significantly negative for three sectors (except food industry) which show that being periphery represents an additional liability in the closure of the productivity gap
- Factors which are consistently positively and significantly correlated to productivity gap are those related to the technology gap explanatory framework: (R&D expenditures) and R&D embedded in machinery & equipment.
- However, the interaction between its own R&D and embedded R&D does **not** generate positive effects but consistently significantly negative coefficients across all three out of four sectors.

Robustness Checks

- Fixed Effects Model (non-weighted sample):
  - Fully accounting for any residual (time-invariant) un-observed heterogeneity (see also Bruno et al. Economics Letter 2019) due to location, sector, distance, etc.
- Fixed Effects Model (weighted sample)
  - Fully accounting for any residual (time-invariant) un-observed heterogeneity (see also Bruno et al. Economics Letter 2019) due to location, sector, distance, etc.
  - European firms' demography (from Eurostat sampling accounting)

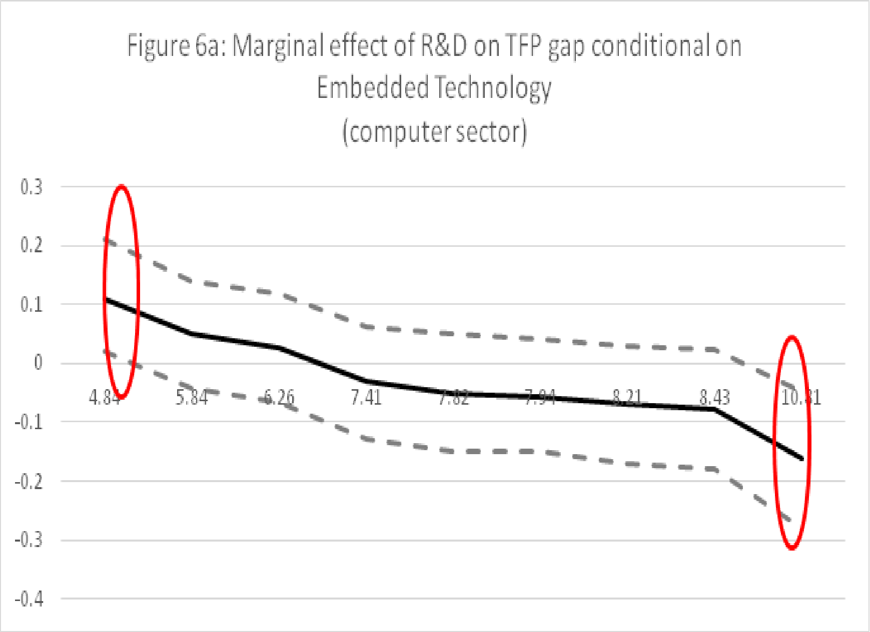
Endogeneity

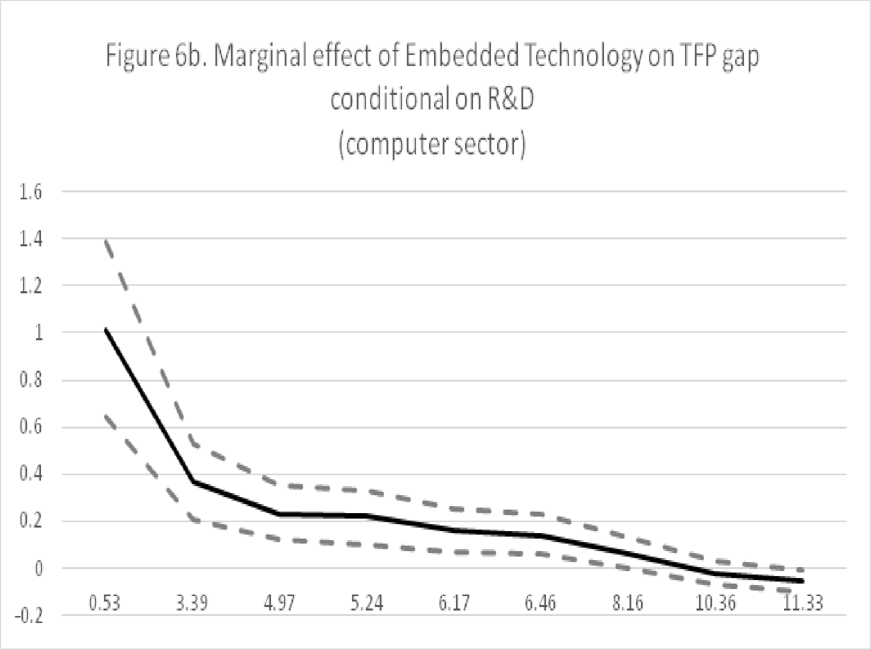
- It is reasonable to assume that the role of R&D (read firm-level R&D), in its two forms (own vs. embodied) might be in turn driven by productivity improvements (e.g. “best” firms do more R&D)
- However, we have three mitigating factors:
  1. The RHS R&D measures are a 2-digit industry variables scarcely affected by “single” firm level productivity measures
  2. On the LHS we do not have productivity *per se* but productivity gap vis-à-vis a 4-digit specific frontier, so the reverse causality channel is highly reduced
  3. The usual lagged one year LHS variables are adopted.

How the negative and significant average coefficient on the interaction term between R&D and embedded R&D changes along the distribution of own and embedded R&D?

- The negative and significant coefficient on the interaction term between R&D and embedded R&D are averages, and they may hide changes along the distribution of own and embedded R&D in our sample
- The coefficients estimated reflect whether firms operating in sub-sectors with more investment in R&D given the level of embedded R&D are further away from the overall sector frontier (and vice versa).
- In all cases, the marginal effects are shown to be downward sloping, consistently with the negative sign we reported for the interaction terms.
- This indicates that in all sectors, firms operating in subsectors with a high level of investment in R&D or embedded R&D are less and less likely to be associated with closing the gap

Firms operating in subsectors with a high level of investment in R&D or embedded R&D are less and less likely to be associated with closing the gap (example below)





Mismatches between R&D and embedded R&D

- The marginal effects of embedded technology on productivity gap are **significant and consistently falling** with increased R&D intensity across all three sectors for which this relationship is significant > mismatches between R&D and embedded R&D are a broad feature of the EU innovation landscape, which deserves further public scrutiny
- On the other hand, the marginal effects of R&D on TFP conditional on embedded technology are **less consistent across three sectors**. They vary in computers and chemicals, and are consistently significant and falling for the food sector > the mismatches between R&D and embedded R&D are sector specific.

Results: Total Gap

Firms are more likely to catch-up to the EU-frontier if they :

1. Are larger
2. Operating in more concentrated sector in the EU > the sector is not concentrated domestically but is at the EU level
3. Are located in EU North
4. They have higher own as well as embedded technology
5. If they can strategically combine interaction between own and embedded R&D
6. Age, foreign owner, multiplant organisation do not matter for closing productivity gap

Conclusions (1)

1. Multilevel perspective offers new and robust important insights into the nature of catching up in the European Union.
2. A limited role for firm level determinants once we control for firm heterogeneity via fixed effects
3. A clear difference in dynamics in the EU north (core) versus EU South and East (periphery)
4. Endogenous nature of market structure (concentration) (negative on domestic market, positive at EU markets)
5. By and large our results support ‘modified’ technology gap interpretation of the productivity gap in the EU
6. Own R&D at the sectoral level is a significant determinant of closing productivity gap and *embodied R&D* (domestic and imported) also plays an important role in closing the gap

Conclusions (2)

7. But negative interaction between endogenous technology effort and technology transfer shows lack of complementarities (mismatches) in interaction between R&D and technology transfer (FDI/GVC) Policies

This confirms the importance of coupling of own R&D effort with the inward and international technology transfer!

8 What lies behind these mismatches would require further in-depth research. (cf.

- ✓ wrong sequencing between R&D investments and investment in imported M&E
- ✓ due to varied significance of these two forms of investments in different sectors
- ✓ mismatches between R&D and forms of imported technology which can be as in our case in the form of M&E or imported know-how or patented licences)

The bottom line: these mismatches are actively contributing to increases in productivity gaps within the EU28

THANK YOU

Appendix: R&D Embedded computation

- From the World Input-Output Database (http://www.wiod.org/home) we collected the value of transactions from one industry of a country to another industry of the same or another country year by year between 2000 and 2014 (Input-Output matrix).
- Next, we collected data on EU-28 countries and particularly the value of transactions in four manufacturing sectors: computing, chemicals, basic metal and food.
- For each combination of receiving sector, country and year (e.g. "computing" Germany in 2005) we computed the relative weight of the transactions from all sectors (two-digit codes) in the total transaction value. This shows the relative importance of the transaction values from different sectors into four "target" sectors.
- Finally, we multiplied each relative weight (specific to each sector, country and year) by R&D intensity, as a percentage of gross value added (GVA), according to the OECD's scale as shown in the table below. See Galindo-Rueda and Verger (2016), see table 1 page 10.
- The result is the R&D to GVA ratio imported from other technology-weighted sectors within the European Union (including domestic).

Stata Variables	Variable Name	Description	Source
gap_TFP_firm_max	TFP GAP /Ln(Firm_TFP)-Ln(EU_frontier)-4Digit(t)/	Three Steps procedure: 1) Collection of Residuals of a TFP 4-digit regression on the whole sample; 2) Computation of EU Frontier TFP level within each 4-digit; 3) Firm-level TFP minus EU frontier. Positive values indicate firms above the frontier, negative values below.	Authors computations using Amadeus BvD ©
numberofemployees	Number of Employees(t)	Number of firm's employees	Amadeus BvD ©
noofrecordedsubsidiaries	Number of Recorded Subsidiaries(last available year)	Number of the firm's subsidiaries	Amadeus BvD ©
RESCALED_age	Age(t)	Age represents the number of years that the firm operates calculated as the current year of the observation minus the foundation year.	Authors computations using Amadeus BvD © information on "year of incorporation."
concentration_index_4dig	Concentration Index(t)	Market Share of top 4 firms (turnover) within each sector (based on 4difit Nace rev.2) & within each country	Amadeus BvD ©
concentration_index_EU_4dig	Concentration Index EU(t)	Market Share of top 4 firms (turnover) within each sector (based on 4difit Nace rev.2) across the whole European Union	Amadeus BvD ©
own_rnd_perc_prod	Own R&D (t)	Percentage of Business production value spend on R&D. Calculated as Business Expenditure on R&D in millions of EUR divided by production value in millions of EUR multiplied by 100	BERD (NACE2)
embedded_T_sector_EU_gross	Embedded R&D(t)	Percentage of R&D imported from other technology-weighted-sectors within the European Union (including domestic) as a percentage of GVA	BERD (NACE2) Eurostat combined with WIOD
Dummy Variables			
Spike_adj40_26	Spike dummy(t)	1 if the previous year ratio of investment in capital is higher than 20%. This variable capture the so-called "investment lumpiness" phenomenon. Companies with "lumpy investment", i.e. volatile capital "shifts" might experience more erratic performance patterns.	Authors computations using Amadeus BvD © information on "ratio of investment on capital."
EU_D_south_east	EU dummy(fixed)	Dummy variable that is equal to 1 if the country is located in East or South of Europe, 0 otherwise	Authors computation using Eurostat
foreign_owner	Foreign Owner dummy(last available year)	Dummy Variable that is equal to 1 if the firm has a foreign owner, 0 otherwise	Authors computations using Amadeus BvD © information on "foreign ownership."