WP3: Education, health and R&D: Impacts on smart growth

Task 5. THE RESEARCH OUTPUT OF UNIVERSITIES AND ITS DETERMINANTS: INTANGIBLE INVESTMENTS, SPECIALIZATION AND INEFFICIENCIES IN THE EU

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SPINTAN – Final Conference

Rome, September 12 - 13th, 2016

SPINTAN smartpublicintangibles

SEVENTH FRAMEWORK PROGRAMME

Ivie

INTRODUCTION

- The activities of the universities are mainly devoted to the generation of intangible assets/outputs.

- Researchers face three types of problems:

① The HEIs develop **several activities simultaneously**: teaching, research, knowledge transfer, etc.

② The productive processes of the activities are **multi-product → produce several outputs**

- Teaching outputs: graduates and postgraduates, etc.
- Research outputs: publications, patents, PhDs, etc.
- Knowledge transfer outputs: contracts with firms, technological assistance, etc.

③ It is necessary to take into account not only the **quantity** but also the **quality**

OUR PREVIOUS WORK

- Our previous work in the INDICSER project (Pastor, Serrano and Zaera, 2012) has proposed a university research output indicator (publications-based) that considers not only the quantity of publications but also their quality.

  - Pastor, J.M., L. Serrano and I. Zaera (2015): "The research output of European higher education institutions", Scientometrics, 102, 3, pp. 1867-1893.

- Results have shown **significant differences in research output quantity as well as in quality** of the EU countries.

- Part of this heterogeneity can be explained by the quantity of R&D devoted to research. However there are important differences in output per capita.

- In order to obtain a rigorous assessment of the performance of HEIs, we need to **explain the heterogeneity of the research output that still remains unexplained**

THE OBJETIVES

- The heterogeneity of the aggregated research output could be explained in terms of the following determinants:

  - **Differences of intangible assets** (R&D expenditure)
  - **Differences in the quality of the research output** and
  - **Inefficiencies of the research institutions** themselves.
    - Inside the specific Fields of Science (FOS)
    - Specialization (composition) of the specific fields

- Our task is to answer the following questions :

  - Which are the determinants of the research output of the HEI?
  - To what extent do differences in terms of intangible investments, quality, specialization of scientific fields and inefficiencies explain the differences in the research output among HEIs?

THE METHODOLOGY

To answer these questions we have used **shift-share analysis** and **a five-step approach based on the non-parametric methodology (DEA)**:

1. **Shift-share analysis** allows us to decompose the differences in the research output rate of growth into differences in research output growth of each specific field and differences of composition of the specific fields.

2. **Five-step methodology DEA-based*** allows us the decompose the differences in the research output of universities in terms of **Intra-field inefficiency** (inefficiencies of the HEIs inside each specific field) and **specialization inefficiency** (inefficiencies of the HEIs due the composition or specialization).

    - This approach allows also to control for the quality and the R&D investments

THE shift-share analysis

The differences in the scientific production growth for each country (P) against the EU during the period 2008-2012 will be broken down as follows:

$$D^P - D^{EU} = \underbrace{\sum_{j=1}^{7}\frac{1}{2}(\theta_j^P + \theta_j^{EU})(D_j^P - D_j^{EU})}_{\text{Intra-field effect}} + \underbrace{\sum_{j=1}^{7}\frac{1}{2}(D_j^P + D_j^{EU})(\theta_j^P - \theta_j^{EU})}_{\text{Composition effect}}$$

D_j^{EU} and D_j^P represent, respectively, the growth rate in 2008-2012 of scientific knowledge production area *j* to EU for each country *P*.

θ_j^{EU} and θ_j^P are the weight of scientific production area *j* in total scientific production of the EU and in each country respectively.

The **composition effect** is the result of being more (or less) specialized in the FOS with higher (or lower) rate of growth.

The **intra-field effect** is the result of having a higher (or lower) rate of growth in FOS

THE FIVE-STEP METHODOLOGY (I)

STEP 1: Research output inefficiency by scientific field

Using DEA, we calculate the **research output inefficiency** of the HEIs of each country **by scientific field** θ_i^n

$$Max\ \theta_i^n$$

s.t.

$$\sum_{r=1}^{R} \lambda_r Y_r^n \geq Y_i^n \theta_i^n$$

$$\sum_{r=1}^{R} \lambda_r X_{rm}^n \leq X_{im}^n \quad m = 1, \dots, M$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

θ_i^n is the efficiency score of HEI of country *i* in the scientific field *n*, and represents the potential increase that HEI of country *i* could achieve in the output of the scientific field *n* without increasing the input vector (in our case R&D expenses and R&D personnel).

THE FIVE-STEP METHODOLOGY (II)

STEP 2: Research output inefficiency by scientific field including the quality of the output (pure inefficiency) (I)

The previous research output inefficiency of HEI of country *i* in FO S *n* θ_i^n does not consider the quality of the output (publications).

The number of citations per document (CD) is the most commonly used indicator by researchers in order to take into account the quality of research.

The use of citations as an indicator of research quality and impact is based on the assumption that the citation of a document represents recognition of its interest and usefulness in the construction of new knowledge (González-Albo 2012).

THE FIVE-STEP METHODOLOGY (II)

STEP 2: Research output inefficiency by scientific field including the quality of the output (pure inefficiency) (II)

The research output inefficiency of the HEIs of country i in FOS n that controls for the quality of output θ_{Qi}^{n} will be obtained by including an additional restriction.

$$Max\ \theta_{Qi}^{n}$$

$$\text{s.t. And}$$

$$\sum_{r=1}^{R} \lambda_r Y_r^n \geq Y_i^n \theta_{Qi}^{n}$$

$$\sum_{r=1}^{R} \lambda_r X_{rm}^n \leq X_{im}^n \quad m = 1, \ldots, M$$

$$\sum_{r=1}^{R} \lambda_r CD_r^n \geq CD_i^n$$

$$\lambda_r \geq 0 \quad r = 1, \ldots, R$$

θ_{Qi}^{n} represents the potential increase that the HEIs of country *i* could achieve in the output of the FOS *n* without increasing the input vector and **maintaining the same quality** of the production research (citations per document).

THE FIVE-STEP METHODOLOGY (III)

STEP 3: Scientific field efficient aggregate research output

We can estimate the efficient aggregate research output of the HEIs of each country (i.e., assuming that all HEIs are efficient in each scientific field). We will calculate both the aggregated output in terms of the number of documents $(\hat{Y}_i)$ and the aggregate output controlling for quality $(\hat{Y}_{Qi})$

$$\hat{Y}_i = \sum_{n=1}^{N} \hat{Y}_i^n = \sum_{n=1}^{N} Y_i^n \, \theta_i^n$$

$$\hat{Y}_{Qi} = \sum_{n=1}^{N} \hat{Y}_{Qi}^n = \sum_{n=1}^{N} Y_i^n \, \theta_{Qi}^n$$

However, being efficient in each scientific field does not guarantee being efficient in the aggregated scientific output. Being efficient in aggregated production necessarily implies:

① being efficient in each scientific field (intra-field efficiency) and

② having a correct scientific field specialization of the output (composition efficiency).

THE FIVE-STEP METHODOLOGY (IV)

STEP 4: Composition effect

In this step we estimate the composition effect (θ_i^{CE}) that would exist even with no technical inefficiency within any scientific

$$Max\ \theta_i^{CE}$$

s.t.

$$\sum_{r=1}^{R} \lambda_r \hat{Y}_r \geq \hat{Y}_i \theta_i^{CE}$$

$$\sum_{r=1}^{R} \lambda_r X_{rm} \leq X_{im} \quad m = 1, \ldots, M$$

$$\lambda_r \geq 0 \quad r = 1, \ldots, R$$

θ_i^{CE} represents the potential increase that the HEIs of country i could achieve in their aggregate research output without increasing the input vector and assuming that they are also achieving the maximum output (given the quantity of inputs) in each scientific field. It captures the impact on output associated with the particular scientific composition/specialisation of the HEIs of each country.

THE FIVE-STEP METHODOLOGY (IV)

STEP 5: Global research output inefficiency (I)

The **global research inefficiency** score (θ_i) in terms of quantity of documents without adjusting by quality is It can be obtained as

1) The ratio between the maximum attainable output $\hat{Y}_i^*$ and actual output Y_i:

$$\theta_i = \frac{\hat{Y}_i \theta_i^{CE}}{Y_i} = \frac{\hat{Y}_i^*}{Y_i}$$

2) The solution of this problem:

$$Max\ \theta_i$$

s.t.

$$\sum_{r=1}^{R} \lambda_r \hat{Y}_r \geq \hat{Y}_i \theta_i$$

$$\sum_{r=1}^{R} \lambda_r X_{rm} \leq X_{im} \quad m = 1, \dots, M$$

$$\lambda_r \geq 0 \quad r = 1, \dots, R$$

THE FIVE-STEP METHODOLOGY (IV)

STEP 5: Global research output inefficiency (II)

We can express this global quantitative inefficiency score *(θ_i)* as the product of two factors:

$$\theta_i = \frac{\hat{Y}_i^*}{Y_i} = \frac{\hat{Y}_i^*}{\hat{Y}_{Qi}^*} \cdot \frac{\hat{Y}_{Qi}^*}{Y_i} = QE_i \cdot \theta_i^{PE}$$

The first factor is the **quality effect** $(QE_i = \hat{Y}_i^* / \hat{Y}_{Qi}^*)$ and represents the quality bias in the global quantitative inefficiency indicator due to considering only the quantity of documents and not their quality. If $QE_i < 1$, it means that the quantitative indicator is penalizing that country because it has a higher quality output that is not taken into account. The second factor is the global pure inefficiency score (θ_i^{PE}). This indicator, when controlled for quality, is a more suitable indicator of efficiency because it measures how much the scientific output of HEIs in each country can increase without raising inputs or reducing quality.

THE FIVE-STEP METHODOLOGY (V)

STEP 5: Global research output inefficiency (III)

In turn, we can decompose the global pure inefficiency score into two additional components according to the following expression:

$$\theta_i = \frac{Y_i^*}{Y_i} = \frac{Y_i^*}{Y_{Qi}^*} \cdot \frac{Y_{Qi}^*}{Y_i} = \frac{Y_i^*}{Y_{Qi}^*} \cdot \frac{Y_{Qi}^*}{Y_{Qi}} \cdot \frac{Y_{Qi}}{Y_i} = QE_i \cdot \theta_i^{PE} = QE_i \cdot \theta_i^{CE} \cdot \theta_i^{IE}$$

The **composition effect** (θ_i^{CE}) represents the impact of the field of science composition/specialisation on the measured global pure inefficiency score.

The **intra-field inefficiency** (θ_i^{IE}) indicates the aggregate intra-field inefficiency. This intra-field inefficiency has the advantage of controlling by the particular specialization by FOS, making feasible comparisons across countries without penalizing those more oriented to FOS with lower publication rates. Those FOS mixes may be still considered appropriate by each country in spite of those lower publication rates compared to the amount of inputs used.

DATA

- **28 European countries** for the period **2008-2012**
- **OUTPUTS**: PUBLICATIONS BY FIELDS OF SCIENCE
  - **Citable documents** per country/year by field of science (FOS):
  - Source: ¿SCImago or Web of Science?

	SCIMAGO Scopus	WEB OF SCIENCE
Source database	Scopus (Elsevier B.V)	Inst. for Scientific Information
Indexed documents	55 millions	23 millions
Number of journals	22.000	12.000
Publishers	5.000	3.300
Countries of journals	97	71
Categories	304	220
Access	Open	Restricted

→

SCIMAGO (Scopus)

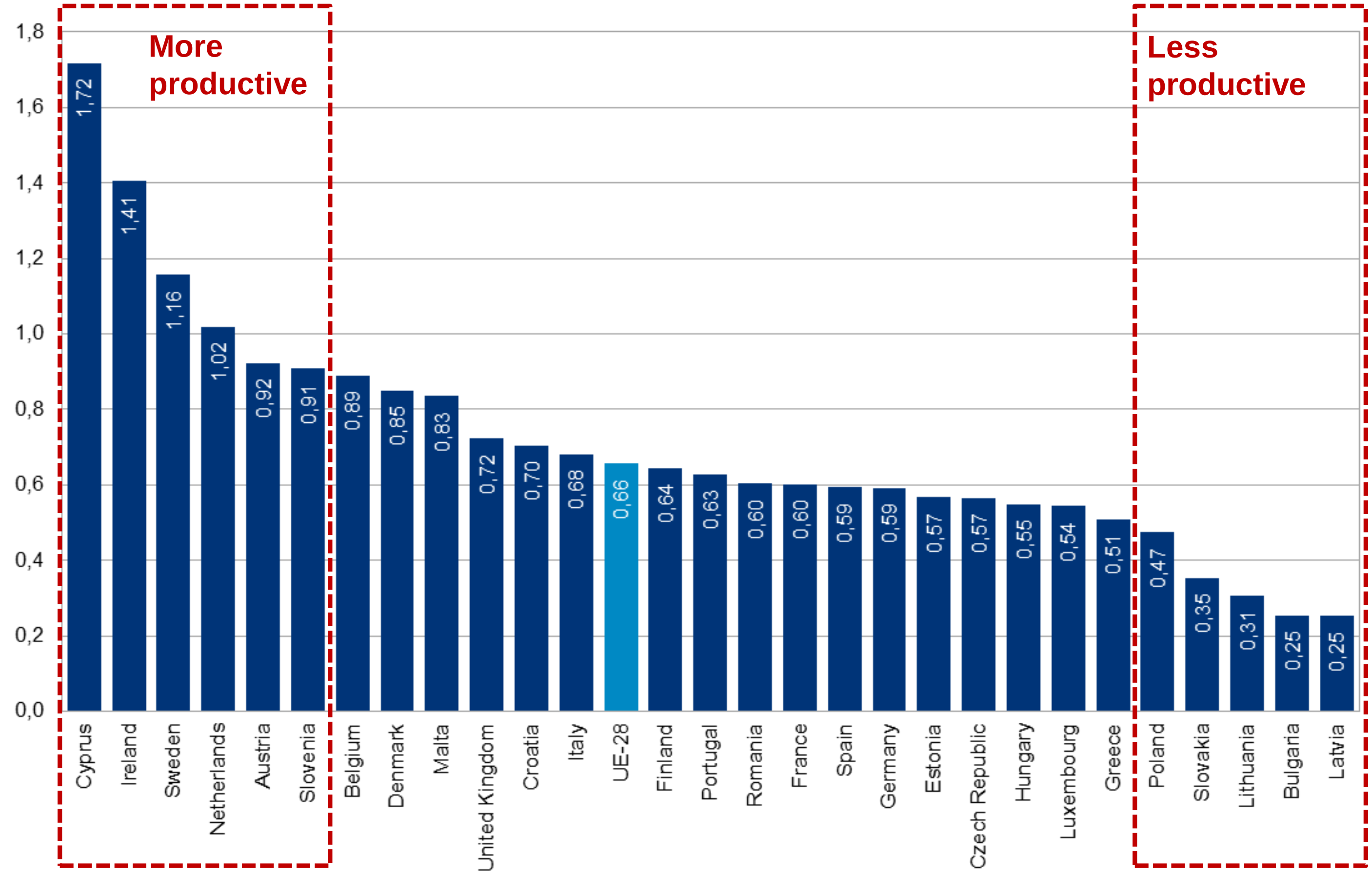
- More documents
- More journals
- More categories (social sciences are better represented)
- More geographical coverage

DATA

- **INPUTS**: R&D DATA by scientific field
  - Intramural **R&D expenditure**: current and capital expenditure
  - **R&D personnel** (full-time equivalent): researchers and other
  - **Sectors** covered:
    - Higher education: universities
    - Government: public research organizations
  - Data per country/year by **scientific field**
    - FOS1. Natural sciences
    - FOS2. Engineering and technology
    - FOS3. Medical and health sciences
    - FOS4. Agricultural sciences
    - FOS5. Social sciences
    - FOS6. Humanities
  - Source: Statistics on research and development (**Eurostat**)

THE FACTS

Figure 1. Scientific output related to R&D personnel in Government and Higher Education. EU countries. 2012
Citable documents per R&D personnel

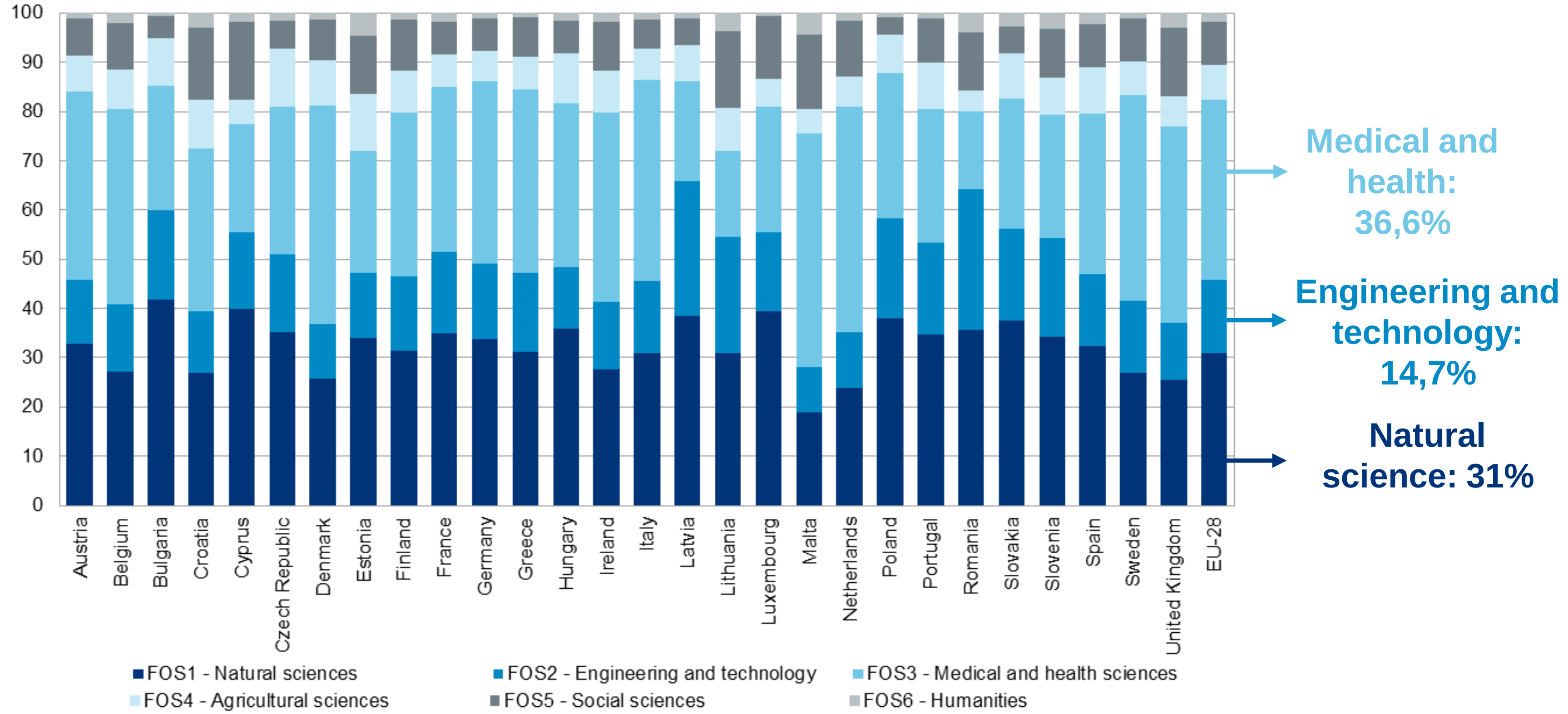


Source: SCImago Journal & Country Rank and Eurostat.

FACT 1: There are important differences in output per capita among the EU countries. (i.e. The scientific output per capita in Cyprus is 6.8 times more than the output of Latvia.)

Figure 2. Distribution of scientific output by field of science. EU countries. 2012

Percentage



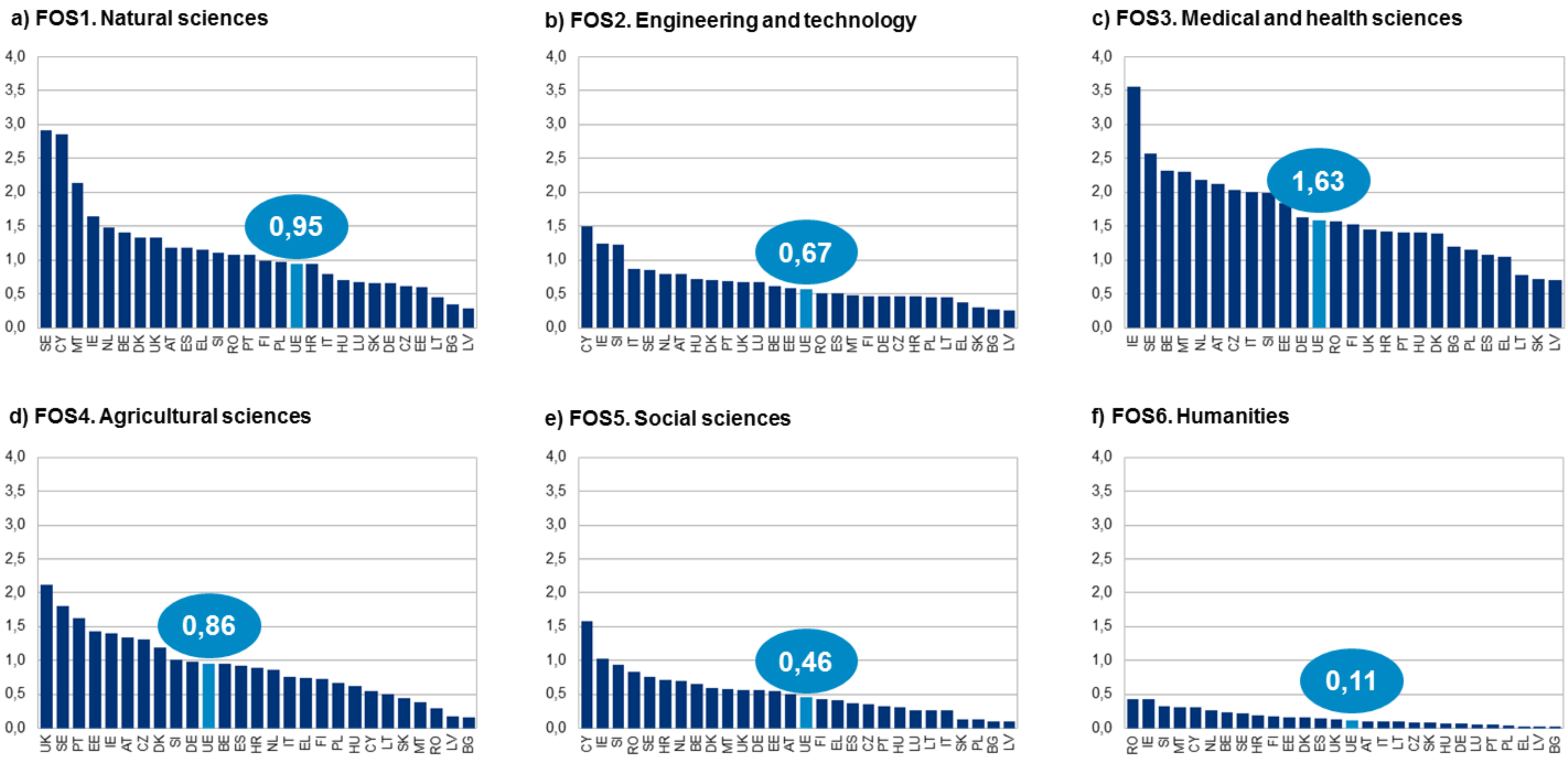
Source: SCImago Journal & Country Rank and own elaboration.

FACT 2: There are important differences in specialization in the fields of science (FOS). (i.e. the specialization of Estonia in Humanities is 2.6 times the EU average. UK is overspecialized in Social Sciences (60% higher than the EU average) and Humanities (70% higher than the EU average). Germany is under specialized in Humanities (40% lower than the EU average), etc.

THE FACTS

Figure 3. Scientific output related to R&D personnel in Government and Higher Education by field of science. EU countries. 2012

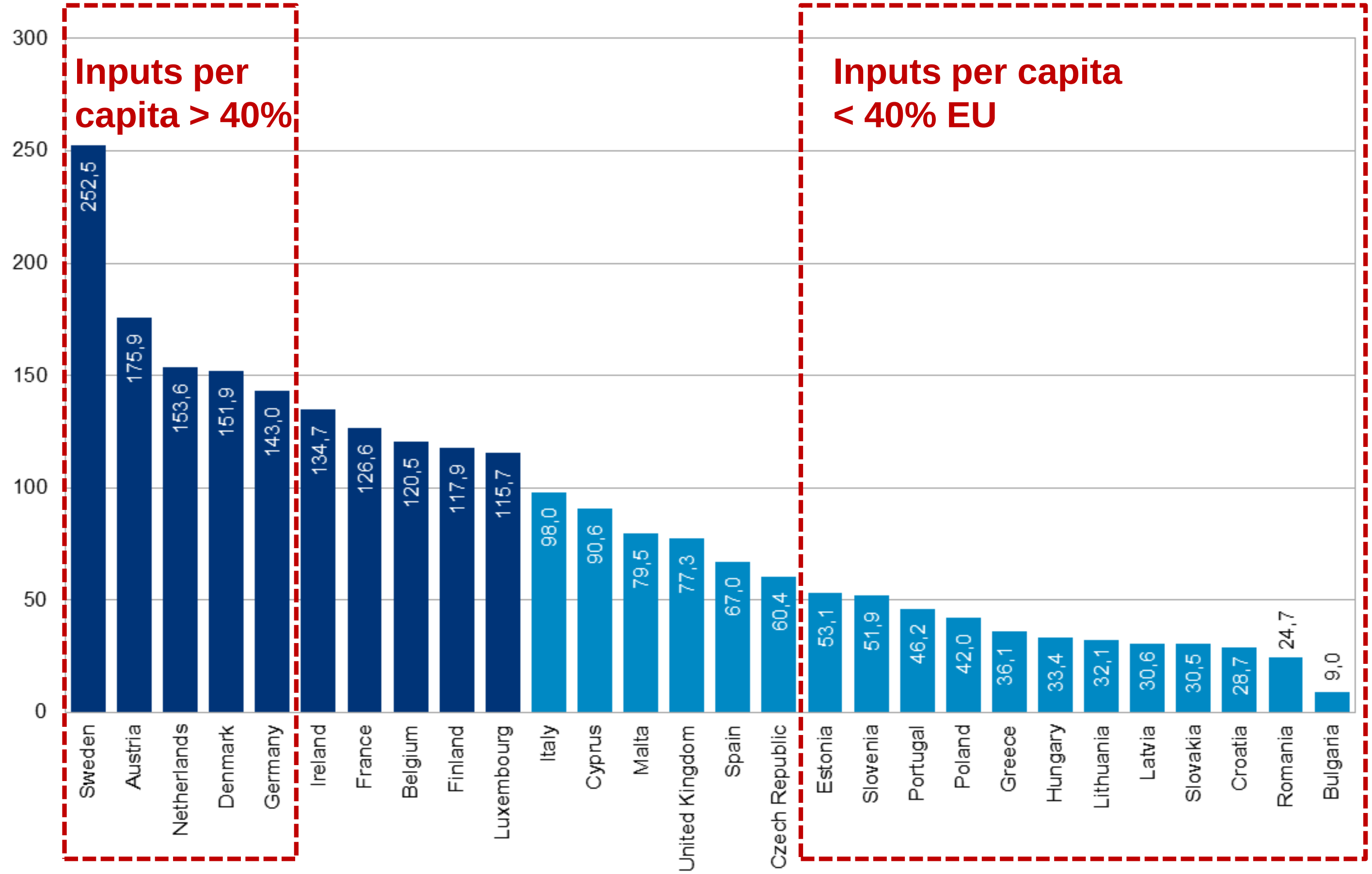
Citable documents per R&D personnel



Source: SCImago Journal & Contry Rank and own elaboration.

FACT 3: There are important differences in productivity among the FOS. The productivity of FOS3 (Medical sciences) is 14 times higher than FOS6 (Humanities). The productivity of FOS1 (Natural sciences) is 8.6 times higher than FOS6

Figure 4. R&D expenditure per R&D personnel. Government and Higher Education. EU countries. 2012
EU-28=100



Source: SCImago Journal & Country Rank and Eurostat.

FACT 4: There are important differences in R&D expenditure per capita (i.e. R&D pc in Sweden is 2.2 times the EU average and 25 times higher than in Bulgaria).

CONCLUSIONS:

FACT 1: There are important differences in output per capita among the countries.

There are **3 possible factors causing** these differences:

FACT 2: Differences in specialization among the countries
FACT 3: Differences in output per capita among the FOS.
FACT 4: Differences in R&D expenditure per capita among the countries.

We will calculate to what extent do differences in terms of specialization, differences in efficiency inside the scientific fields and differences in R&D per capita explain the differences in the research output among HEIs of the EU countries.

RESULTS: shift-share analysis

Shift-share of citable documents

Differences in the scientific output growth of the countries against the EU. 2008-2012

	INTRA-FIELD EFFECT	COMPOSITION EFFECT	TOTAL	INTRA-FIELD EFFECT	COMPOSITION EFFECT	TOTAL
Austria	3,2%	-0,7%	2,4%	129,8%	-29,8%	100,0%
Belgium	2,4%	0,0%	2,4%	100,2%	-0,2%	100,0%
Bulgaria	-14,6%	2,2%	-12,4%	118,0%	-18,0%	100,0%
Croatia	6,9%	-0,4%	6,5%	105,8%	-5,8%	100,0%
Cyprus	53,9%	-9,6%	44,3%	121,8%	-21,8%	100,0%
Czech Republic	12,2%	-2,7%	9,5%	128,0%	-28,0%	100,0%
Denmark	16,1%	-0,6%	15,5%	104,2%	-4,2%	100,0%
Estonia	20,1%	2,7%	22,8%	88,3%	11,7%	100,0%
Finland	-3,5%	-0,1%	-3,5%	98,2%	1,8%	100,0%
France	-7,6%	0,0%	-7,6%	99,4%	0,6%	100,0%
Germany	-3,5%	-0,7%	-4,2%	83,4%	16,6%	100,0%
Greece	-12,3%	-1,2%	-13,5%	91,0%	9,0%	100,0%
Hungary	-15,0%	-0,6%	-15,6%	95,9%	4,1%	100,0%
Ireland	9,3%	-0,1%	9,2%	100,6%	-0,6%	100,0%
Italy	0,3%	-2,2%	-1,9%	-16,1%	116,1%	100,0%
Latvia	34,0%	-4,9%	29,1%	116,8%	-16,8%	100,0%
Lithuania	-9,9%	-3,7%	-13,6%	73,0%	27,0%	100,0%
Luxembourg	88,5%	2,4%	90,9%	97,4%	2,6%	100,0%
Malta	31,4%	3,8%	35,1%	89,3%	10,7%	100,0%
Netherlands	5,3%	1,2%	6,5%	81,7%	18,3%	100,0%
Poland	5,7%	-3,8%	1,9%	298,2%	-198,2%	100,0%
Portugal	29,5%	-2,2%	27,3%	108,2%	-8,2%	100,0%
Romania	46,2%	-11,8%	34,4%	134,2%	-34,2%	100,0%
Slovakia	-5,2%	-1,1%	-6,2%	82,6%	17,4%	100,0%
Slovenia	7,4%	0,1%	7,5%	98,1%	1,9%	100,0%
Spain	10,7%	-0,6%	10,1%	106,0%	-6,0%	100,0%
Sweden	3,8%	-0,2%	3,6%	105,5%	-5,5%	100,0%
United Kingdom	-6,6%	2,6%	-4,0%	164,0%	-64,0%	100,0%
EU28	-	-	-	**107,3%**	**-7,3%**	**100,0%**

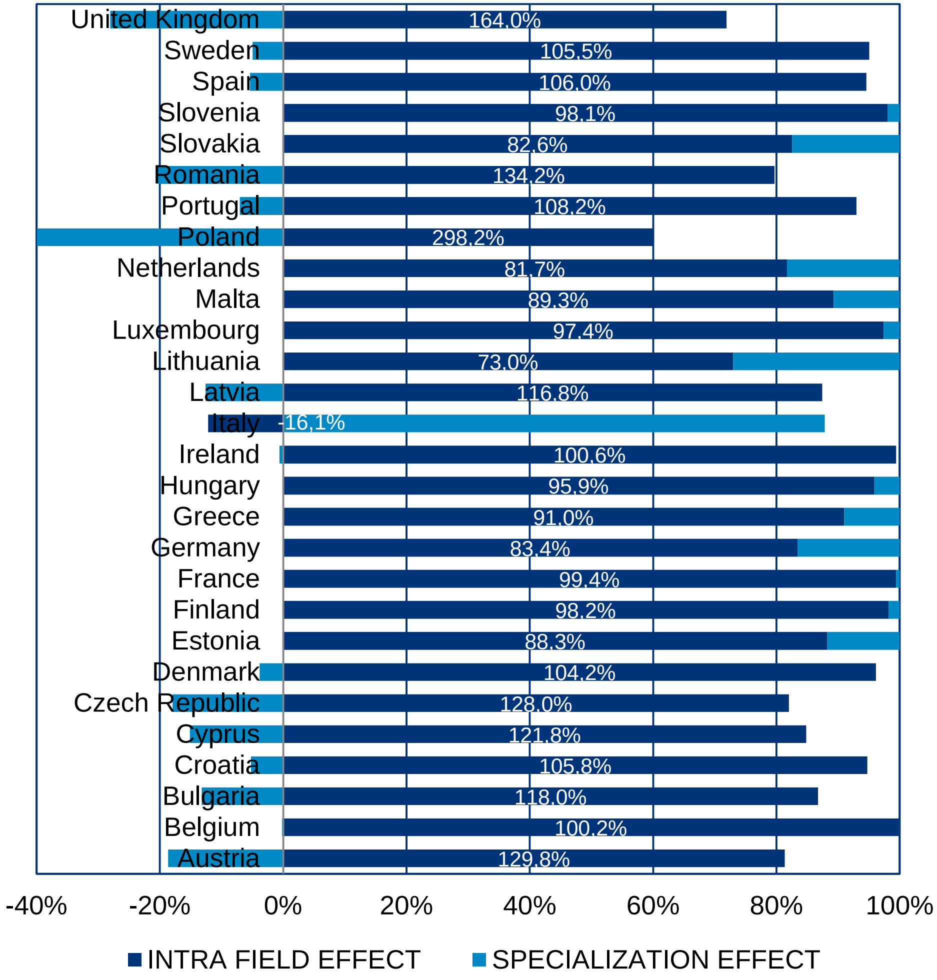
Most of the differences in the scientific output growth of the countries are due to differences in the output growth of each scientific fields.

The **intra-field effect** is higher than the **composition effect** in all the countries (with the only exception of Italy).

So, in most of the countries the differences in the composition against the EU only explain a small proportion of the output growth differences. The **composition effect** is not important.

RESULTS: shift-share analysis

Shift-share of citable documents
Differences in the scientific output of the countries against the EU countries. 2008-2012



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RESULTS: shift-share analysis

Shift-share of citable documents

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Bulgaria	-14,6%	2,2%	-12,4%	118,0%	-18,0%	100,0%
Croatia	6,9%	-0,4%	6,5%	105,8%	-5,8%	100,0%
Cyprus	53,9%	-9,6%	44,3%	121,8%	-21,8%	100,0%
Czech Republic	12,2%	-2,7%	9,5%	128,0%	-28,0%	100,0%
Denmark	16,1%	-0,6%	15,5%	104,2%	-4,2%	100,0%
Estonia	20,1%	2,7%	22,8%	88,3%	11,7%	100,0%
Finland	-3,5%	-0,1%	-3,5%	98,2%	1,8%	100,0%
France	-7,6%	0,0%	-7,6%	99,4%	0,6%	100,0%
Germany	-3,5%	-0,7%	-4,2%	83,4%	16,6%	100,0%
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EU28	-	-	-	**107,3%**	**-7,3%**	**100,0%**

In some countries, the **composition effect** is relatively significant and **positive**. That's the case of Estonia or Netherlands. These countries are specialized in those scientific fields with higher scientific output growth.

In other countries, the **composition effect** is relatively significant and **negative**. That's the case of Germany and specially Italy. These countries are specialized in those scientific fields with lower scientific output growth.

RESULTS: shift-share analysis

Shift-share of citable documents

Differences in the scientific output growth of the countries against the EU. 2008-2012

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Spain	10,7%	-0,6%	10,1%	106,0%	-6,0%	100,0%
Sweden	3,8%	-0,2%	3,6%	105,5%	-5,5%	100,0%
United Kingdom	-6,6%	2,6%	-4,0%	164,0%	-64,0%	100,0%
EU28	-	-	-	**107,3%**	**-7,3%**	**100,0%**

In other countries, the **intra-field effect** is relatively significant. That's the case of Austria, Czech Republic, Romania and specially UK and Poland.

The scientific output growth of these countries are mainly explained by the scientific output growth in each scientific field.

Table 3. Global inefficiency and its components

	Global quantitative inefficiency $(\theta_i = \hat{Y}_i^*/Y_i)$	Quality effect $(QE_i = \hat{Y}_i^*/\hat{Y}_{Qi}^*)$	Decomposition of Global pure inefficiency: Global pure inefficiency $(\theta_i^{PE} = \hat{Y}_{Qi}^*/Y_i)$	Composition effect $(\theta_i^{CE} = \hat{Y}_{Qi}^*/\hat{Y}_{Qi}^{\square})$	Intra-field inefficiency $(\theta_i^{IE} = \hat{Y}_{Qi}^{\square}/Y_i)$
Belgium	1.20	1.04	1.15	1.00	1.15
Bulgaria	1.14	1.00	1.13	1.00	1.13
Czech Rep.	1.40	1.01	1.39	1.00	1.39
Denmark	1.57	1.11	1.42	1.09	1.30
Germany	1.05	1.00	1.05	1.03	1.02
Estonia	1.74	1.00	1.75	1.14	1.53
Ireland	1.11	1.00	1.11	1.00	1.11
Greece	1.32	1.06	1.25	1.07	1.16
Spain	1.35	1.00	1.35	1.00	1.35
Croatia	1.18	1.00	1.18	1.00	1.18
Italy	1.29	1.00	1.29	1.00	1.29
Cyprus	1.15	1.00	1.15	1.00	1.15
Latvia	3.26	1.03	3.15	1.07	2.95
Lithuania	2.06	1.01	2.04	1.04	1.96
Luxembourg	2.81	1.00	2.81	1.44	1.95
Hungary	1.35	1.03	1.32	1.02	1.29
Malta	2.12	1.00	2.12	1.00	2.12
Netherlands	1.25	1.14	1.09	1.07	1.02
Austria	1.49	1.06	1.40	1.00	1.40
Poland	1.13	1.01	1.13	1.00	1.13
Portugal	1.48	1.01	1.46	1.12	1.31
Romania	1.11	1.00	1.11	1.00	1.11
Slovenia	1.11	1.00	1.11	1.00	1.11
Slovakia	1.71	1.04	1.65	1.00	1.65
Finland	1.81	1.05	1.73	1.12	1.54
Sweden	1.01	1.00	1.01	1.00	1.01
U.K.	1.00	1.00	1.00	1.00	1.00
W Average	**1.20**	**1.02**	**1.18**	**1.02**	**1.15**

Source: Own elaboration.

GLOBAL INEFFICIENCY:

Given the actual use of inputs and without taking into account quality, **the research output** of the HEI in the EU **could increase by around 20%** if the inefficiencies were removed.

Most inefficient: In some countries output could be increased by a factor of 2 or more (Latvia, Luxembourg, Lithuania, Malta, Slovakia).

Most efficient: UK is the only efficient country. Sweden (1.01) and Germany (1.05) are in most efficient countries.

Table 3. Global inefficiency and its components

	Global quantitative inefficiency ($\theta_i = \hat{Y}_i^*/Y_i$)	Quality effect ($QE_i = \hat{Y}_i^*/\hat{Y}_{Oi}^*$)	Decomposition of Global pure inefficiency: Global pure inefficiency ($\theta_i^{PE} = \hat{Y}_{Oi}^*/Y_i$)	Composition effect ($\theta_i^{CE} = \hat{Y}_{Oi}^*/\hat{Y}_{Oi}^{\square}$)	Intra-field inefficiency ($\theta_i^{IE} = \hat{Y}_{Oi}^{\square}/Y_i$)
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Finland	1.81	1.05	1.73	1.12	1.54
Sweden	1.01	1.00	1.01	1.00	1.01
U.K.	1.00	1.00	1.00	1.00	1.00
W Average	**1.20**	**1.02**	**1.18**	**1.02**	**1.15**

Source: Own elaboration.

GLOBAL PURE INEFF. :

The output (number of publications controlled by quality) **could increase by 18%** for the EU countries as a whole and if all inefficiencies were removed.

Control for quality **does not significantly alter the results** in most countries.

The quality effect is very limited except in cases like the **Netherlands and Denmark**, where control for quality significantly improves their performances.

Table 3. Global inefficiency and its components

	Global quantitative inefficiency $(\theta_i = \hat{Y}_i^* / Y_i)$	Quality effect $(QE_i = \hat{Y}_i^* / \hat{Y}_{Oi}^*)$	Decomposition of Global pure inefficiency		
			Global pure inefficiency $(\theta_i^{PE} = \hat{Y}_{Oi}^* / Y_i)$	Composition effect $(\theta_i^{CE} = \hat{Y}_{Oi}^* / \hat{Y}_{Oi}^{\square})$	Intra-field inefficiency $(\theta_i^{IE} = \hat{Y}_{Oi}^{\square} / Y_i)$
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Sweden	1.01	1.00	1.01	1.00	1.01
U.K.	1.00	1.00	1.00	1.00	1.00
W Average	**1.20**	**1.02**	**1.18**	**1.02**	**1.15**

Source: Own elaboration.

DECOMPOSITION GLOBAL PURE INEFF. :

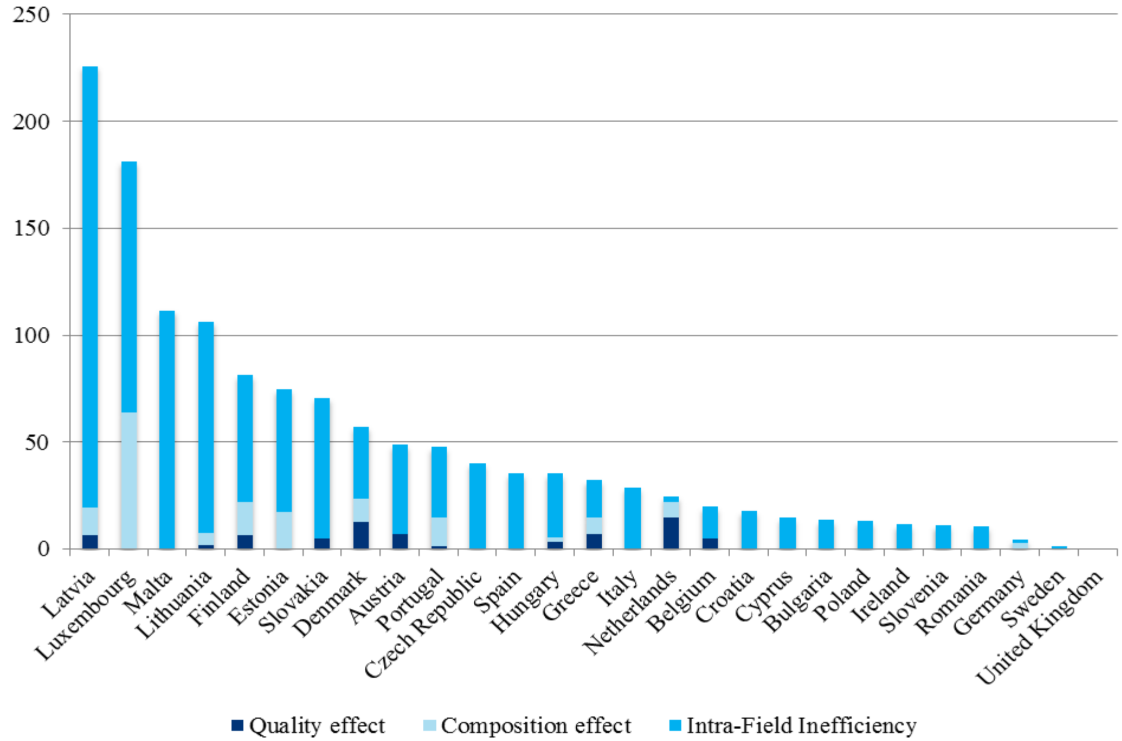
Most of the inefficiency comes from inefficiencies within each specific field. The composition effect is much less significant.

The CE is only 2.2%, whereas intra-field inefficiency is 15.4%. The CE represents 12.3% of global pure inefficiency while intra-field inefficiencies represent the remaining 87.6%.

Taking into account quality and allowing for differences in specialization across fields of science reduce the measured global inefficiency (from 20% to 15.4%).

RESULTS: The five-step methodology

Figure 10. Scientific research inefficiencies: quality effect, composition effect and intra-field inefficiency.
Percentages



Latvia is the most inefficient country. Its research output could be increased 225,9%.

UK is the most efficient country. Its research output is the maximum attainable. It has the most suitable specialization and it is efficient in all the FOS.

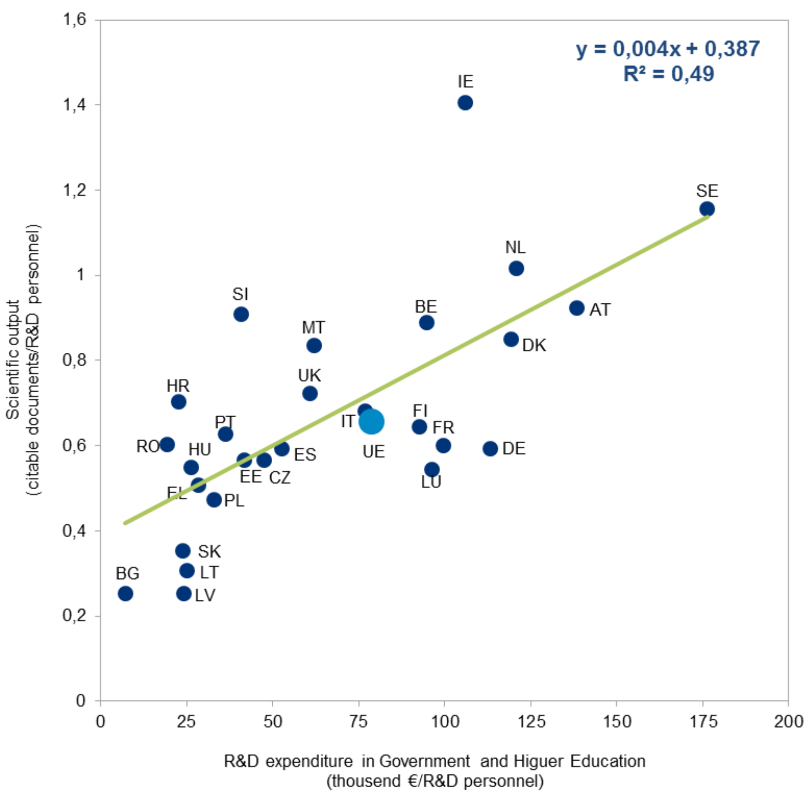
Although the **quality effect** tends to be small for most of the countries, it is relevant in some countries with high quality output such as Denmark and the Netherlands. The composition effect of most of the countries is fairly moderate in general (except Luxembourg, the Baltic republics, Finland, etc.)

RESULTS: The five-step methodology

- We reported **important differences in output per capita** of HEIs
- Which is the origin of these differences
  - different type of specialization across FOS?
  - differences in intra-field inefficiencies?
  - differences in output quality?
  - differences in the quantity of resources per capita?

RESULTS: The five-step methodology

Scientific output vs. R&D expenditure. EU countries. 2012



We observe a positive relationship between R&D (intangibles) per capita and research output per capita. The higher the R&D per capita, the higher the research output per capita.

On the other hand, the figure shows that the widespread heterogeneity in output per capita is not only explained by the amount of resources used, since some countries obtain a much higher output per capita with the same resources per capita than others.

So are the huge differences in efficiency levels underlying the differences in output per capita?

What happens when we remove the effect of specialization and the effect of inefficiencies?

RESULTS: The five-step methodology

Figure 11. Maximum scientific output vs. R&D expenditure. EU countries.

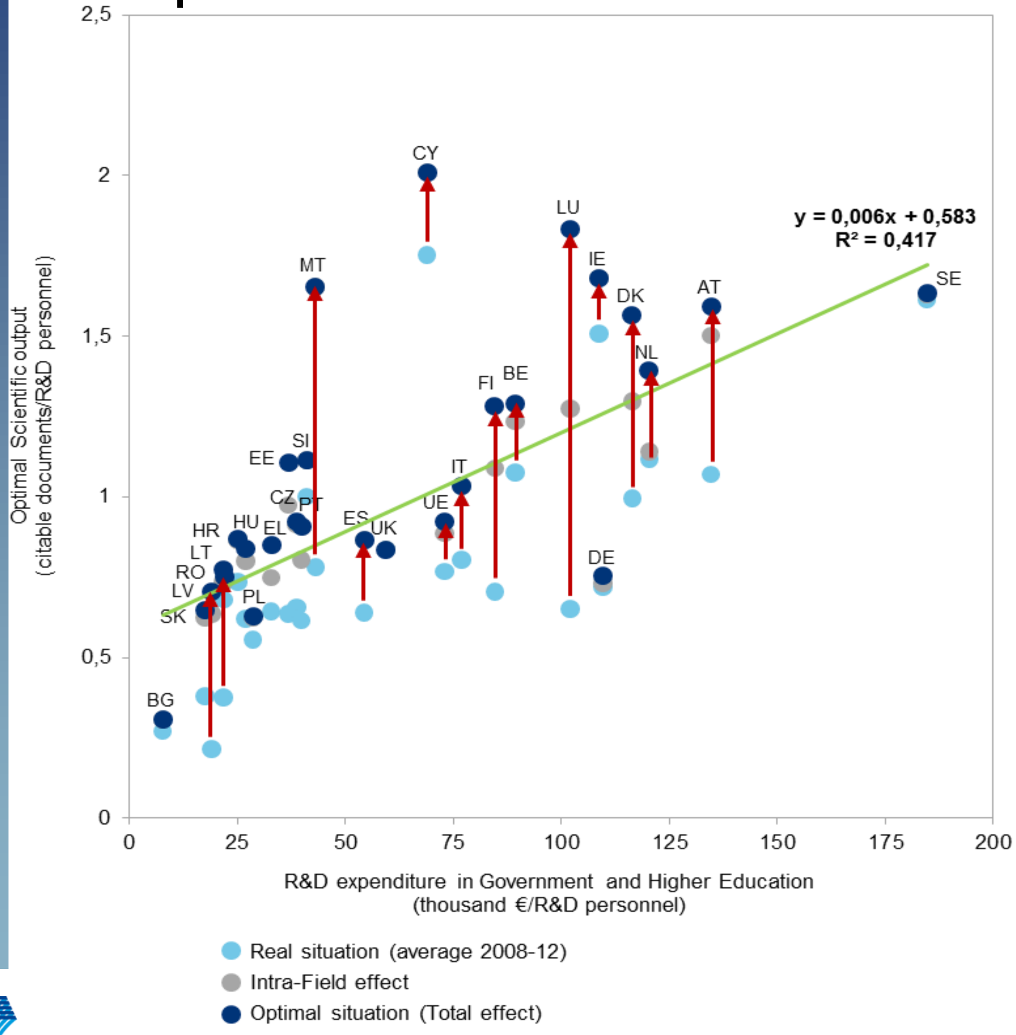


Figure shows the effect that removing all inefficiencies would have, also considering the quality effect and the specialisation effect on output per capita (optimal situation).

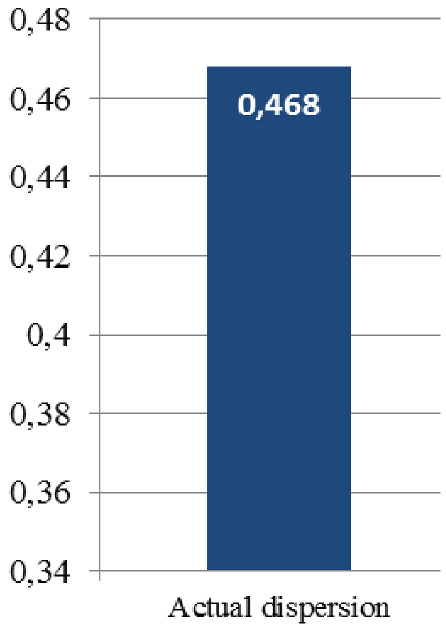
The **light blue dots represent actual output,** the **dark blue dots represent maximum output** per capita corrected for quality once inefficiencies have been removed.

All the countries improve, particularly the most inefficient ones.

When we remove the effect of the quality, specialization and inefficiencies, still there are a high level of heterogeneity in output per capita. Thus, differences in quality, specialization and inefficiencies are not the main origin of the heterogeneity in research output per capita → most of the origin of the heterogeneity is due to heterogeneity in the amount of resources per capita.

RESULTS: The five-step methodology

Figure 12. Dispersion of the research output per capita
Deviation coefficient EU28

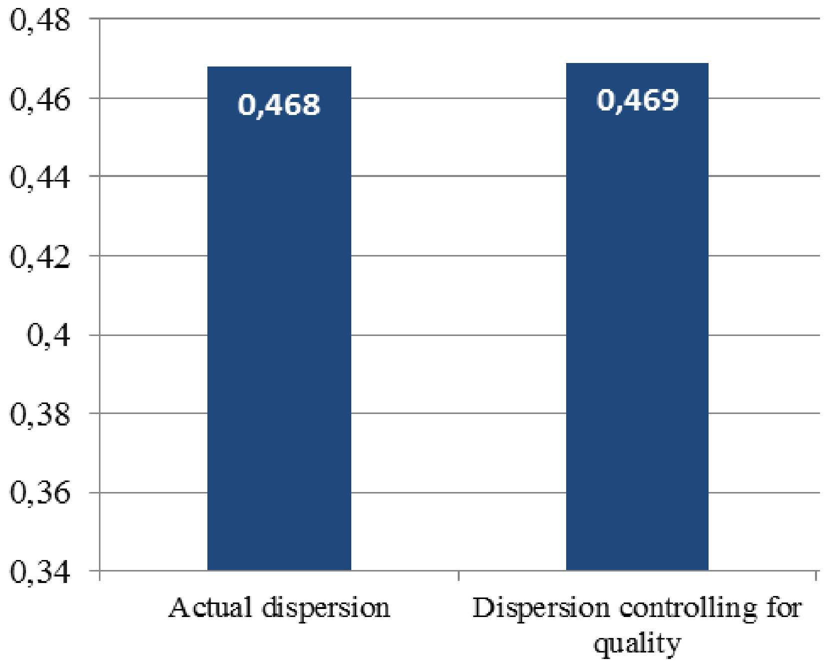


The heterogeneity of the output per R&D personnel is very high. The deviation coefficient is 46.8%

¿What happens to the heterogeneity if we control for **quality**?

RESULTS: The five-step methodology

Figure 12. Dispersion of the research output per capita
Deviation coefficient EU28

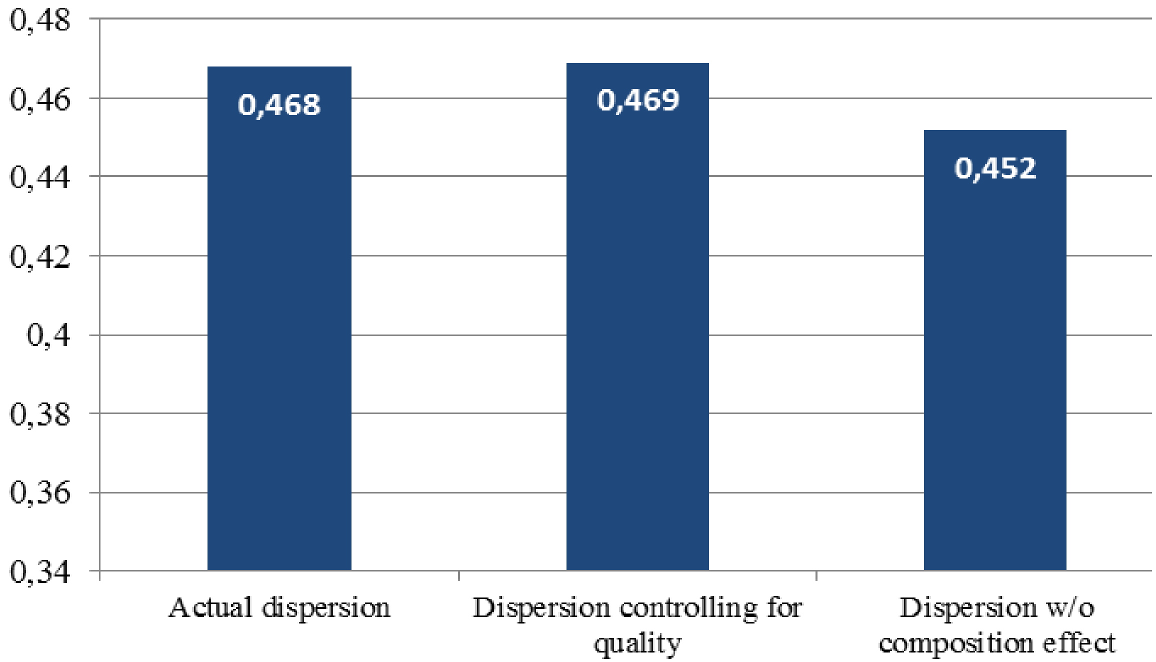


When we control for quality the effect still there is a high level of heterogeneity in output per capita. The deviation coefficient is almost the same 46.9%.

¿What happens to the heterogeneity if we control for **specialization**?

RESULTS: The five-step methodology

Figure 12. Dispersion of the research output per capita
Deviation coefficient EU28

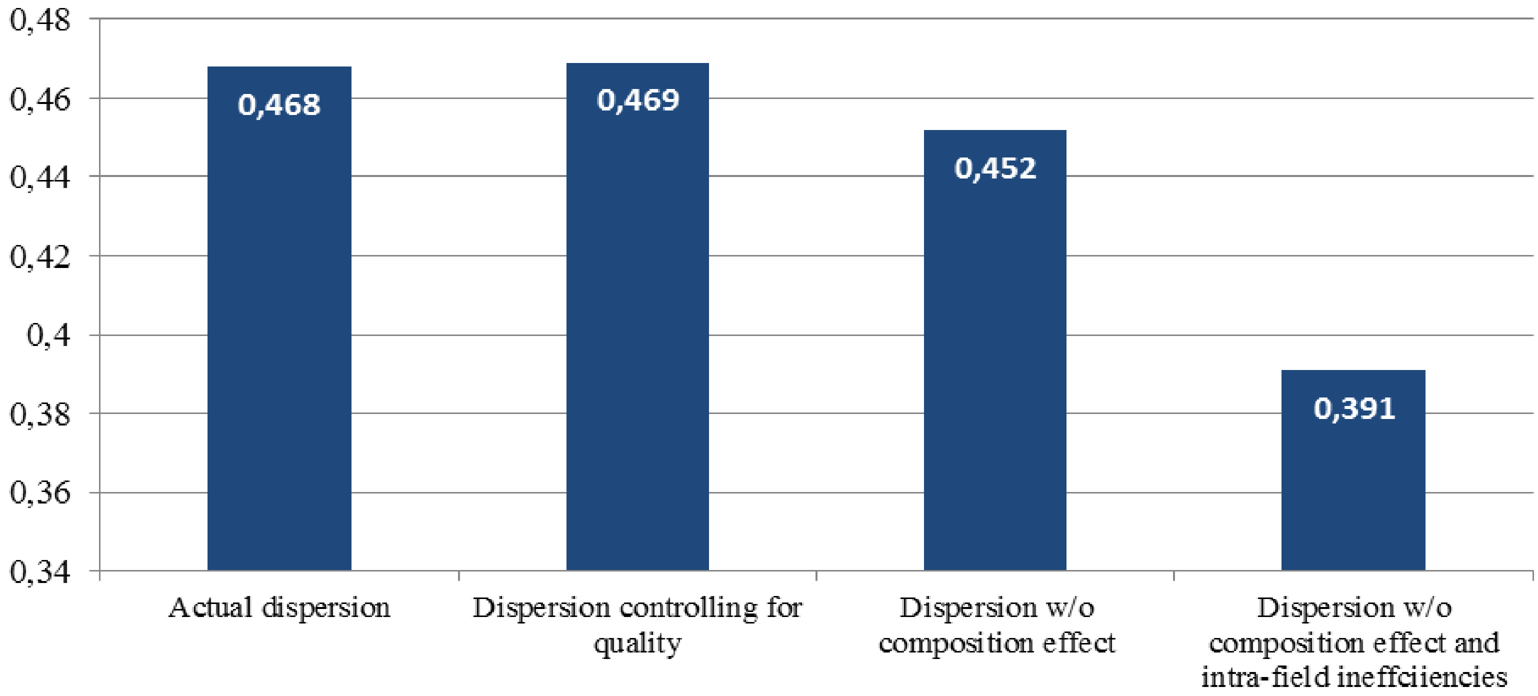


When we control for specialization still there is a high level of heterogeneity in output per capita. The deviation coefficient only decreases from 46.9% to 45.2%.

¿What happens to the heterogeneity if we also remove the **intra-field efficiencies**?

RESULTS: The five-step methodology

Figure 12. Dispersion of the research output per capita
Deviation coefficient EU28



When we control for specialization still there is a high level of heterogeneity in output per capita. The deviation coefficient only decreases from 45.2% to 0.391.

When we remove the effect of the quality, specialization and the intra-field inefficiencies, still there is a high level of heterogeneity in output per capita. → **most of the origin of the heterogeneity is due to heterogeneity in the amount of resources per capita.**

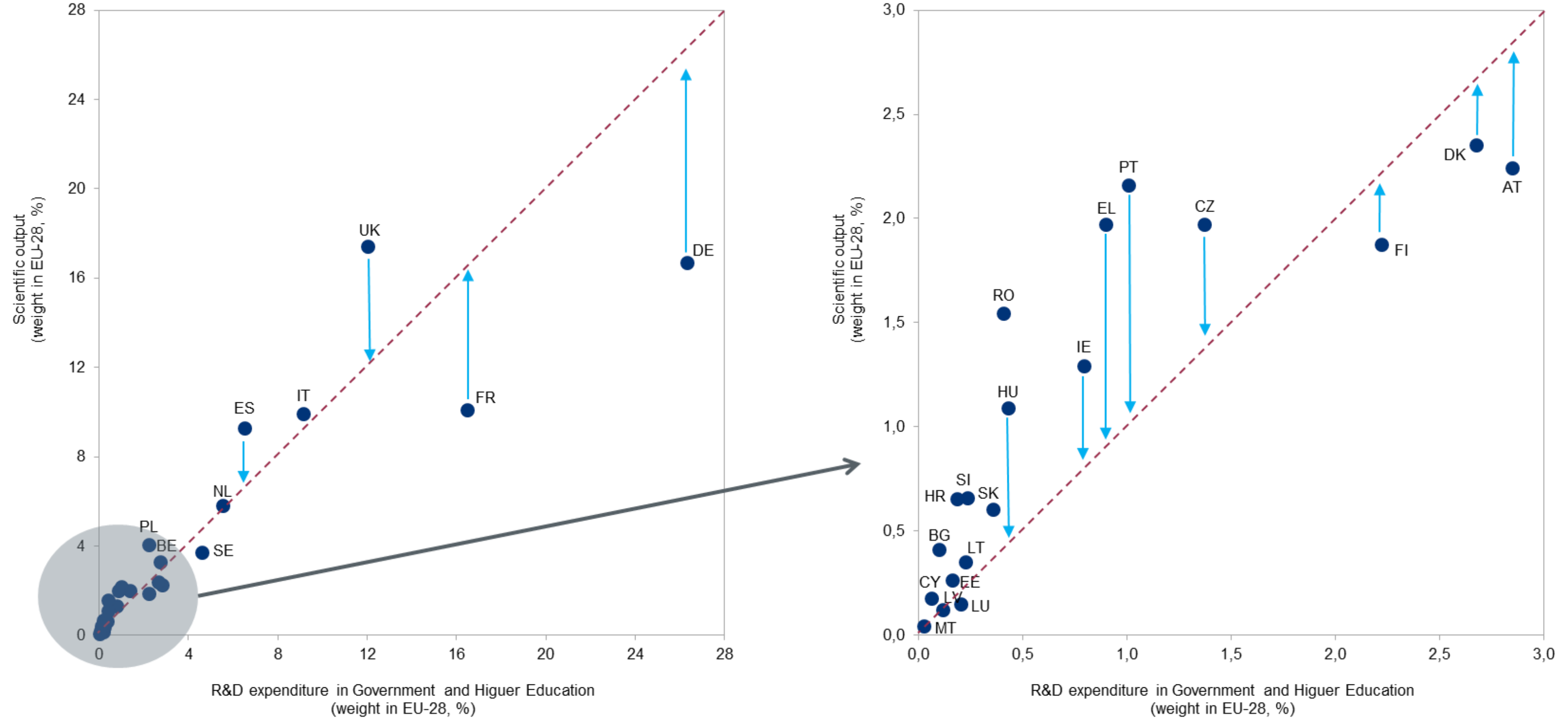
CONCLUSIONS

- We have analyzed the determinants of the research output of the HEI
  - Quality
  - Specialization
  - Inefficiencies inside scientific fields
  - Inputs (R&D expenses and R&D personnel)
- Shift-share analysis has shown that **most of the research output growth has been due to other factors than specialization.**
- DEA methodology has been used to explain the differences in research output. Results have shown that **most of the inefficiencies** come from inefficiencies **inside each specific fields**, on the contrary, quality and **inefficiencies associated with the specialization are much less significant**.
- If we remove the effect of quality, specialization and intra field inefficiencies output would increase 18% and heterogeneity would decrease 17% → This means that 83% of the **inequality/heterogeneity of the research output per capita is due to the heterogeneity of the used inputs** (R&D – intangibles per capita).

POLICY IMPLICATIONS (I)

But…. Is it only a matter of more financial resources?

YES: Those countries that invest more money in R&D obtain more research output.



NO: Some countries are getting more value for the money allocated to R&D than others (small countries like Bulgaria, Croatia, Romania or large countries like UK, Spain or Italy). The weight of these countries in terms of publications is larger that their weights in terms of R&D expenditure. On the opposite side the largest EU countries (Germany or France) : % publications < % R&D expenditure

POLICY IMPLICATIONS (II)

- These results should encourage **policy makers to design policies** that improve the research output of those countries which, given the amount of resources that they devote, obtain poorer results (**efficiency):**

① **EUROPE 2020** has already designed some actions to promote research (train enough researchers to meet their national R&D targets and to promote attractive employment conditions in public research institutions, creation of knowledge alliances between universities and business, etc.).

② **Regarding the increase in the efficiency** appropriate incentives for HEIs and researchers should be designed to promote the efficient use of financial and human resources

WP3: Education, health and R&D: Impacts on smart growth

Task 5. THE RESEARCH OUTPUT OF UNIVERSITIES AND ITS DETERMINANTS: INTANGIBLE INVESTMENTS, SPECIALIZATION AND INEFFICIENCIES IN THE EU

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Lorenzo Serrano

Ivie and Universitat de València

SPINTAN – Final Conference

Rome, September 12 - 13th, 2016

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SEVENTH FRAMEWORK PROGRAMME

Ivie