Knowledge accounting:
an economic approach

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Motivation

How can we measure the *knowledge intensity of economies*?

Despite this term being frequently used, there is no metric that measures it accurately…

- **Industry classification** according to technology intensity, on the basis of R&D expenditure and the use of high-skilled labor.

  Limitations: - It focuses on the **current creation of knowledge** rather than **how the productive system uses it.**
  - Normally based on a single factor: R&D expenditure in the case of manufacturing and human capital in services.
  - It doesn't take into account intra-industry heterogeneity among countries.

- **Synthetic indices** that group multiple variables or indicators.

  Limitations: -They are usually partial and have ambiguous meaning, because aggregation criteria are not economically clearly founded.

- Knowledge Satellite Accounts

  Limitations: - Complexity and data requirements.

Motivation

How can we measure the *knowledge intensity of economies*?

Our proposal:

- **Knowledge accounting** seems viable on account of the theoretical and empirical advances achieved in the measurement of physical and human capital.

- **Focus**: to measure the weight of knowledge in GVA, by calculating the market value of a set of inputs which are knowledge-based and incorporate knowledge into the production processes.

- **Application**: the methodology can be applied to economies whose national accounts systems offer industry data on various types of labor and capital services and their corresponding compensation (**EU KLEMS database**).

Methodology

- L_{ij} is the amount of labor of type *i* used in sector *j*
- K_{hj} is the amount of capital of type *h* used in sector *j*
- P_{ij}^{L} is the unitary wage paid for labor of type *i* in sector *j*
- P_{hj}^{K} is the user cost of type *h* capital in sector *j*
- V_j is the quantity of sector *j* value added
- P_j^{V} is the price of sector *j* value added

The value added (GVA) of sector *j* is distributed among the different inputs included in the production process so that,

$$V_j P_j^V = \sum_{i=1}^{m} L_{ij} \cdot P_{ij}^L + \sum_{h=1}^{n} K_{hj} \cdot P_{hj}^K$$

We decompose the value of labor and capital services into two parts, one that incorporates knowledge and another one that does not:

$$\sum_{i=1}^{m} L_{ij} \cdot P_{ij}^L = \sum_{i=1}^{f} L_{ij} \cdot P_{ij}^L + \sum_{i=f+1}^{m} L_{ij} \cdot P_{ij}^L \qquad \sum_{h=1}^{n} K_{hj} \cdot P_{hj}^K = \sum_{h=1}^{g} K_{hj} \cdot P_{hj}^K + \sum_{h=g+1}^{n} K_{hj} \cdot P_{hj}^K$$

assuming that there are *f* types of low-skilled labor and *g* assets that don't incorporate knowledge significantly.

Methodology

Assumption of **non-separability**: the knowledge of a qualified worker is a contribution to the production process non-separable from the contribution of unqualified labor by the same worker (similarly, in knowledge intensive capital the contribution of non knowledge components of this capital, like the iron of the machine, is not separable from the contribution of knowledge-intensive capital).

Value of knowledge intensive labor (KIL)

$$KIL_j^{ns} = \sum_{i=f+1}^{m} L_{ij} \cdot P_{ij}^{L}$$

Value of knowledge intensive capital (KIK)

$$KIK_j^{ns} = \sum_{h=g+1}^{n} K_{hj} \cdot P_{hj}^{K}$$

Knowledge-intensive value added (KIV): $KIV_j^{ns} = KIL_j^{ns} + KIK_j^{ns}$

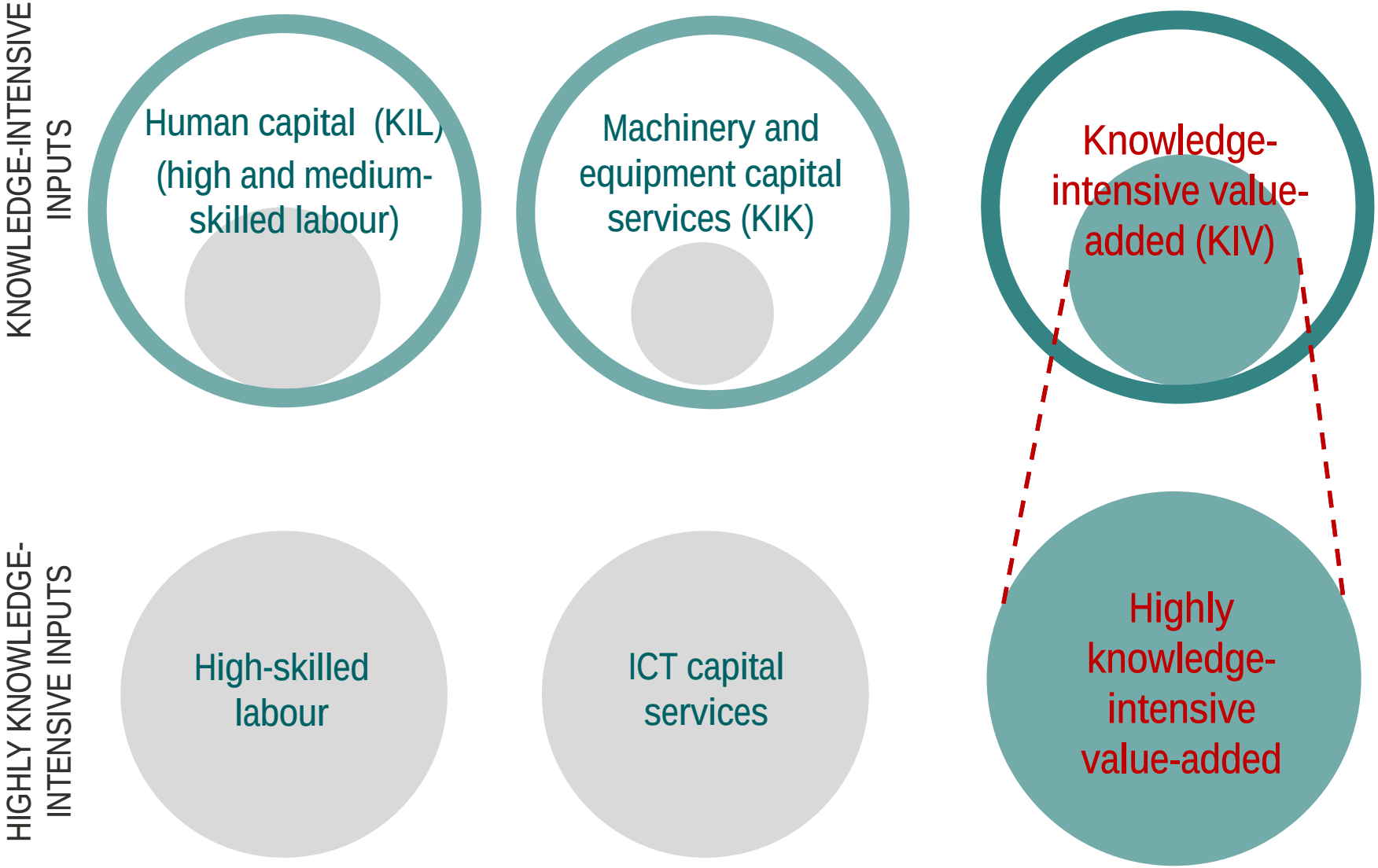
Knowledge intensity (ç) of an activity *j*: $\varsigma_j^{ns} = KIV_j^{ns} / (V_j P_j^{V})$

Knowledge intensity (Ç) of the economy depends on the weight of the various industries in the aggregate, on the basis of the value-added generated:

$$Ç = \sum_{j=1}^{q} \varsigma_j^{ns} \cdot \left(\frac{V_j P_j^{V}}{\sum_{j=1}^{q} V_j P_j^{V}}\right)$$

Methodology

2 x 2 categories of knowledge inputs used in productive activities



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Data

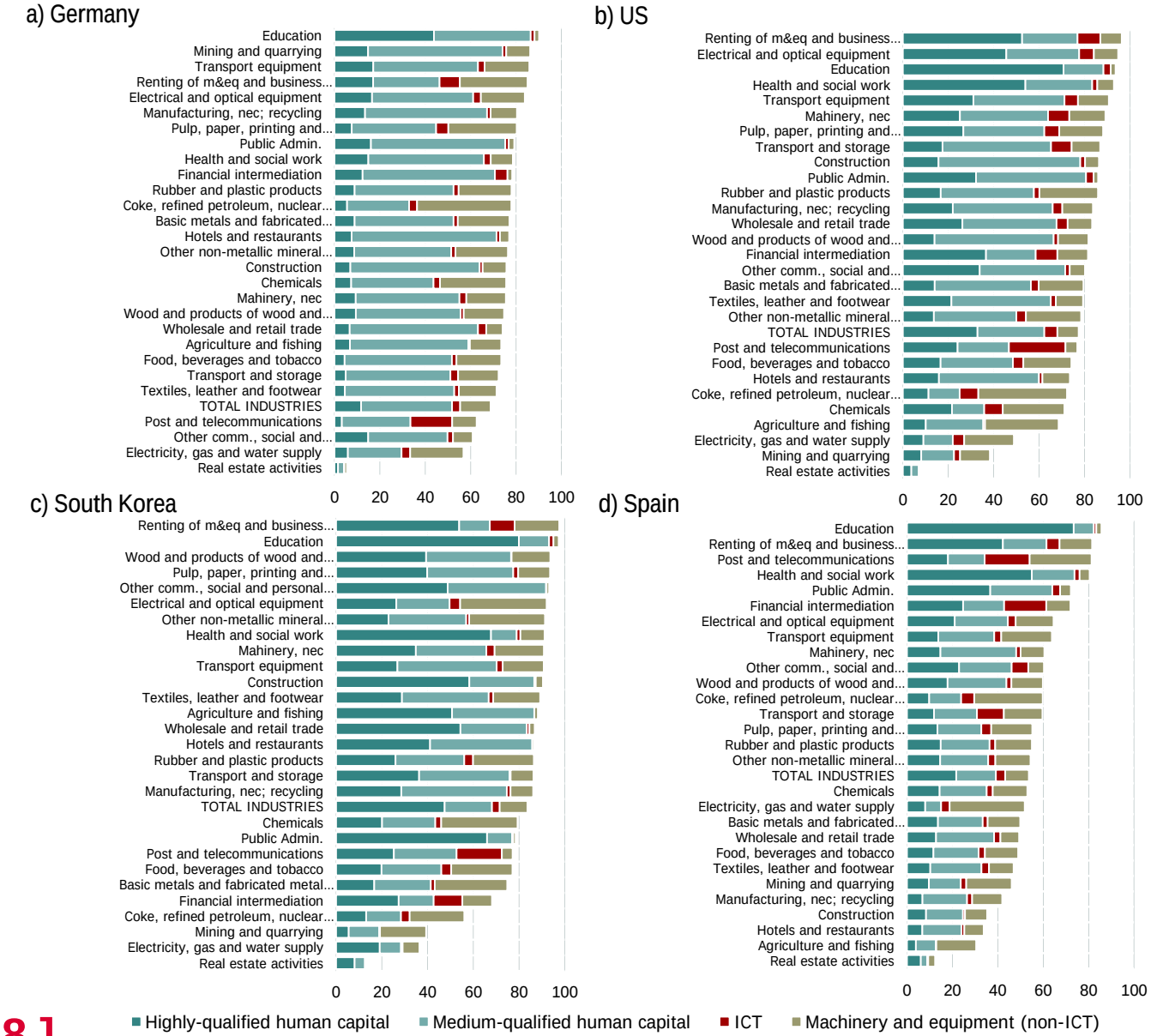
- EU KLEMS database
- 18 countries
- 28 industries
- 1980-2007

Table 3. Countries and period coverage

Countries	Period covered
Germany	1980-2007
Australia	1980-2007
Austria	1980-2007
Korea	1977-2005
Denmark	1980-2007
United States	1970-2007
Slovenia	1995-2006
Spain	1980-2007
Finland	1970-2007
France	1980-2007
Ireland	1995-2005
Italy	1970-2007
Japan	1970-2006
The Netherlands	1979-2007
Portugal	1995-2005
United Kingdom	1970-2007
Czech Republic	1995-2007
Sweden	1993-2007

Industry results: knowledge intensity by industries and countries

FIGURE 1. GVA knowledge intensity by industries, 2007. (percentage)



Note: 2005 for South Korea. Source: EU KLEMS and own calculations.

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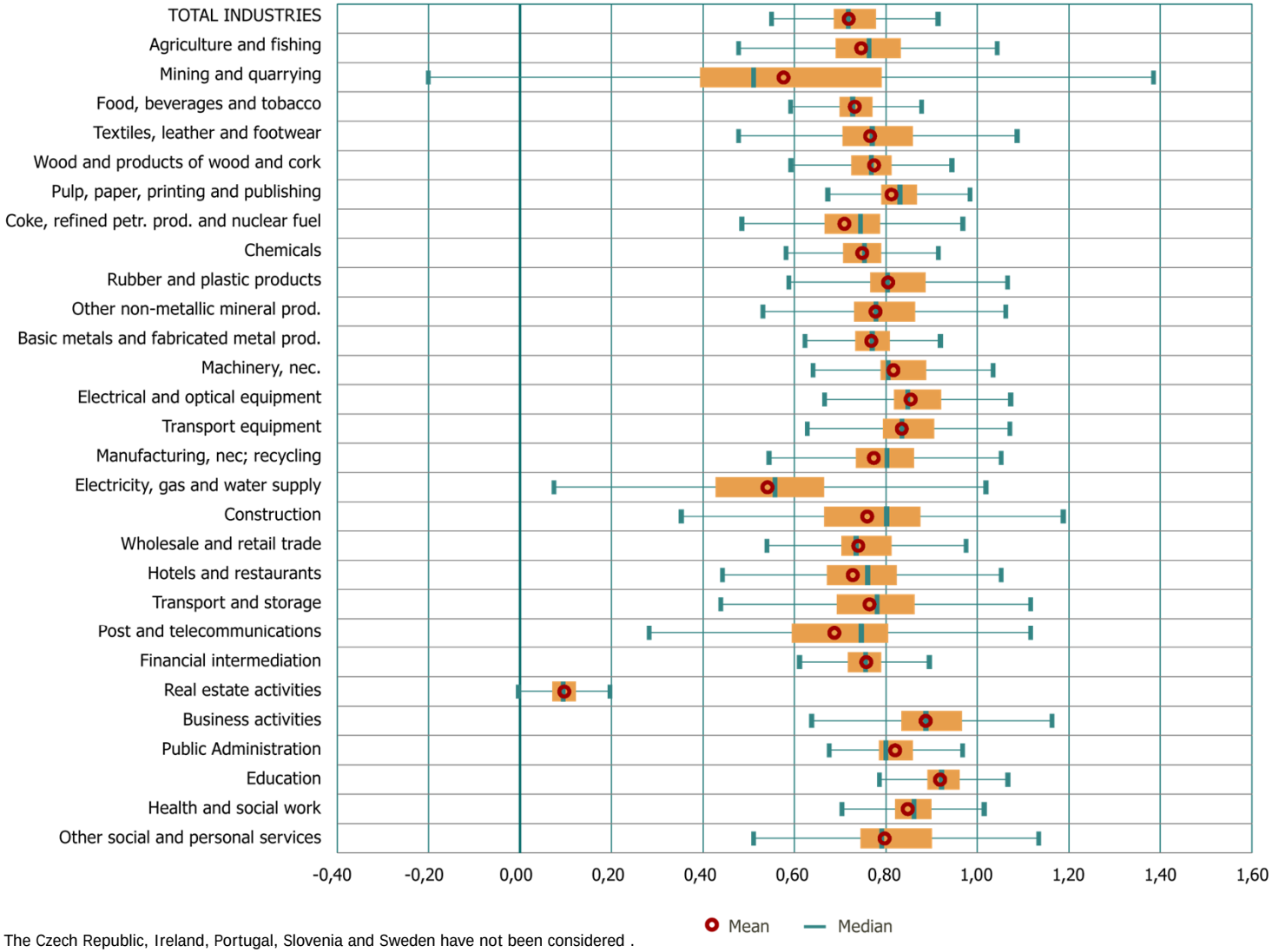
Industry results: dispersion of knowledge intensity

FIGURE 2. Boxplot of GVA knowledge intensity by industries, 2005



Note: The Czech Republic, Ireland, Portugal, Slovenia and Sweden have not been considered .
Source: EU KLEMS and own calculations.

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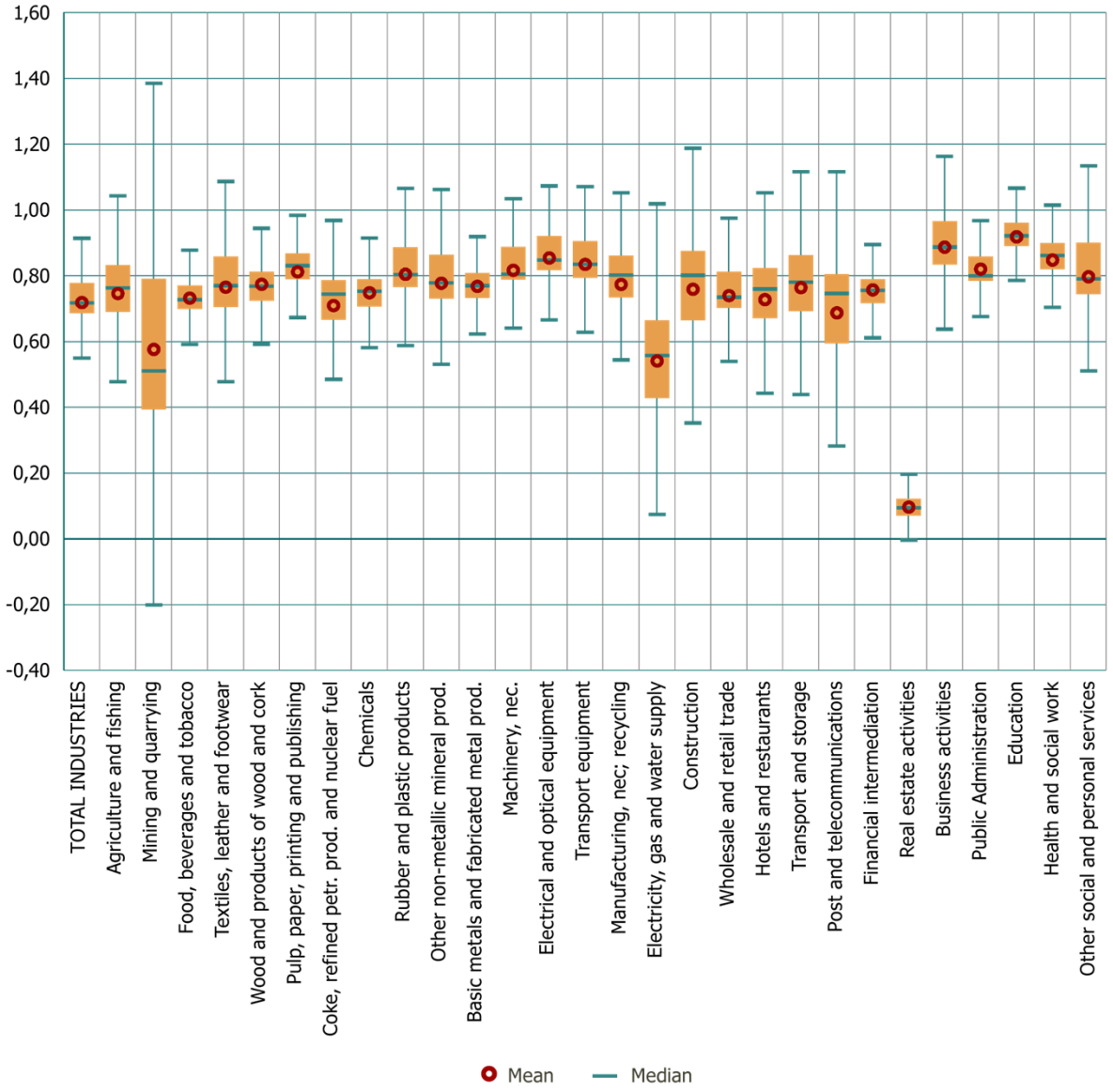
Industry results: dispersion of knowledge intensity

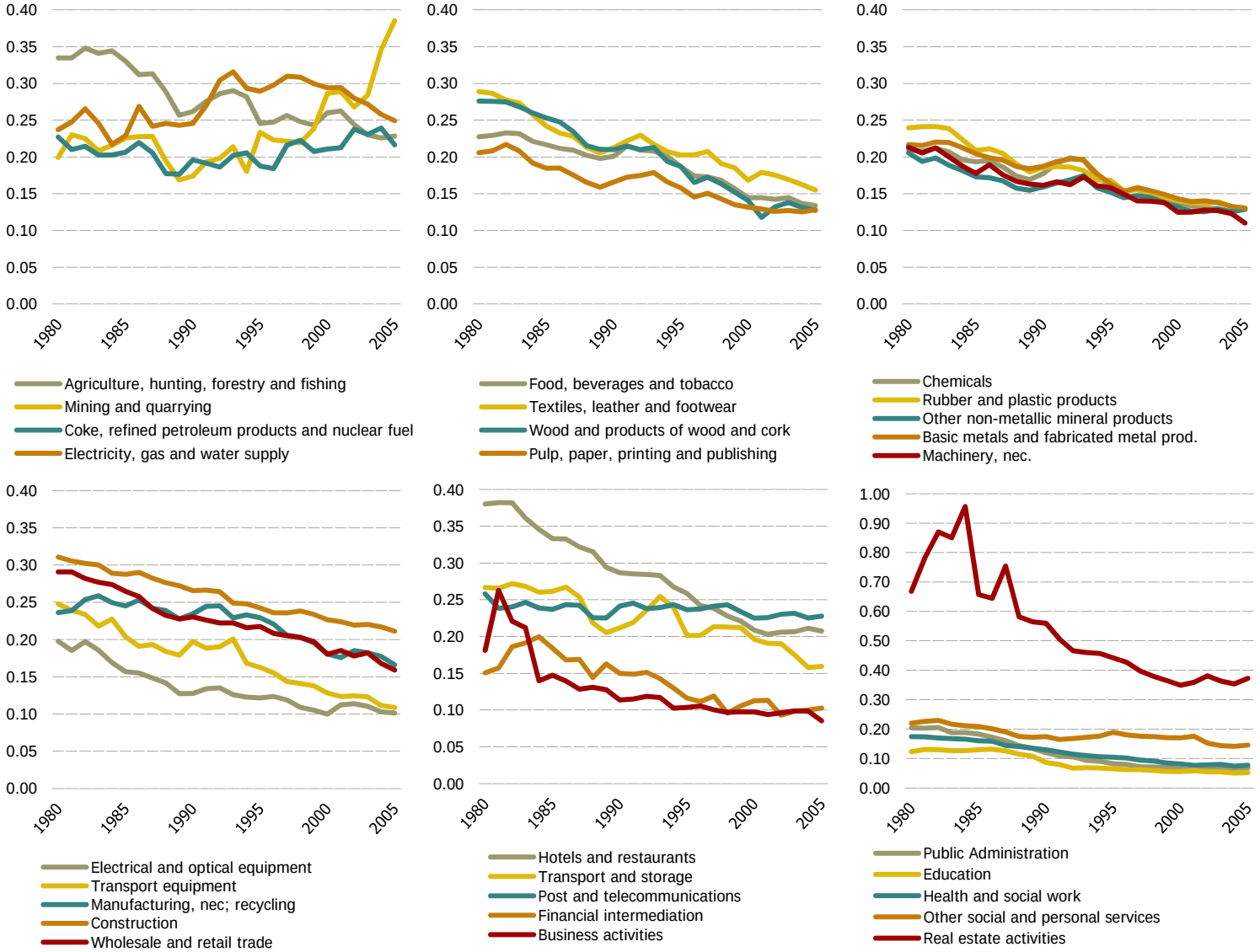
FIGURE 2. Boxplot of GVA knowledge intensity by industries, 2005



Note: The Czech Republic, Ireland, Portugal, Slovenia and Sweden have not been considered .
Source: EU KLEMS and own calculations.

Industry results: temporal evolution of dispersion

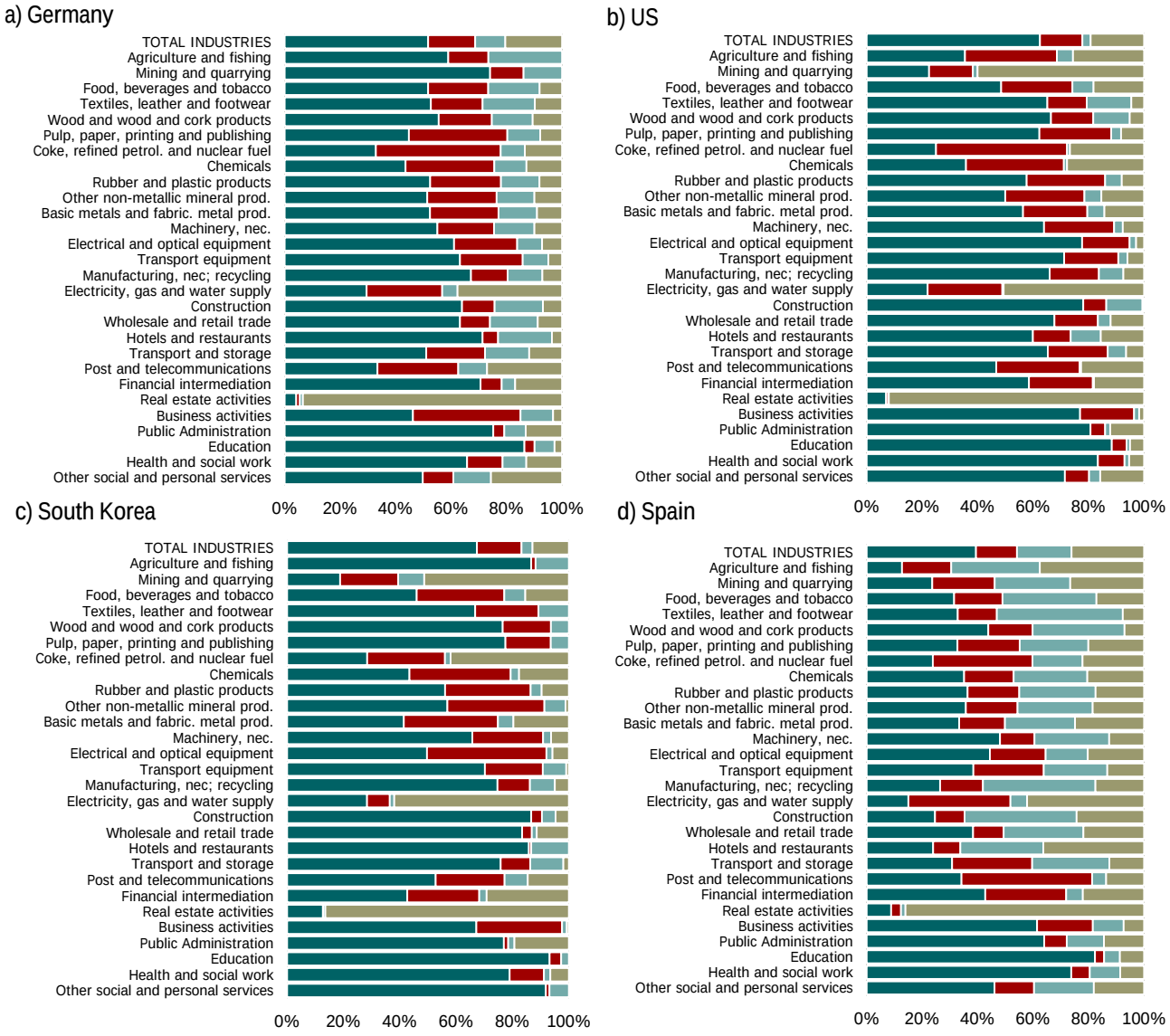
FIGURE 3. σ-convergence in GVA knowledge intensity by industries,1980-2005.
(coefficient of variation)



Note: The Czech Republic, Ireland, Portugal, Slovenia and Sweden have not been considered .
Source: EU KLEMS and own calculations.

Industry results: knowledge contribution to productivity

FIGURE 4. Labour productivity by components and indutries, 2007.
(percentage)



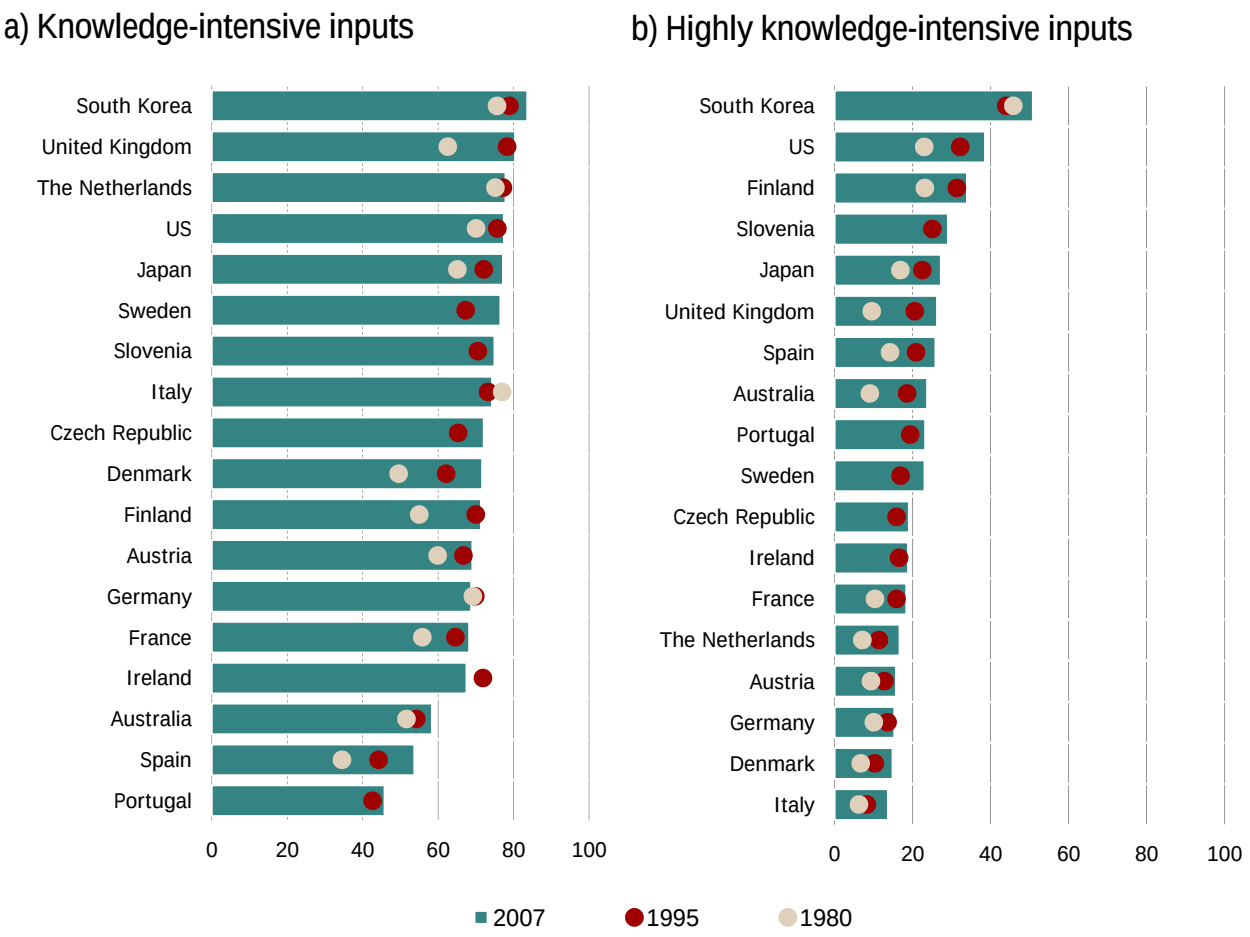
Note: 2005 for South Korea. *Source:* EU KLEMS and own calculations.

Industry results: summary

- Knowledge intensity in the same industry varies notably among countries and warns us of the risk of classifying industries in categories by technological intensity.
- Human capital is more determinant in establishing differences in knowledge intensity than machinery, among sectors and within sectors.
- Data of activities specialized in the production of human capital and machinery and equipment confirm that inputs which incorporate knowledge are also produced with knowledge.
- The time series show that the use of knowledge is an increasingly common feature of the countries in the sample.
- Differences among countries in labor productivity for each sector are primarily associated with the contribution of highly qualified labor.

Aggregate results: knowledge intensity by countries

FIGURE 5. GVA knowledge intensity by countries, 1980, 1995 y 2007.
(percentage)



Note: 2005 for Ireland, Portugal and South Korea and 2006 for Japan and Slovenia.
Source: EU KLEMS and own calculations.

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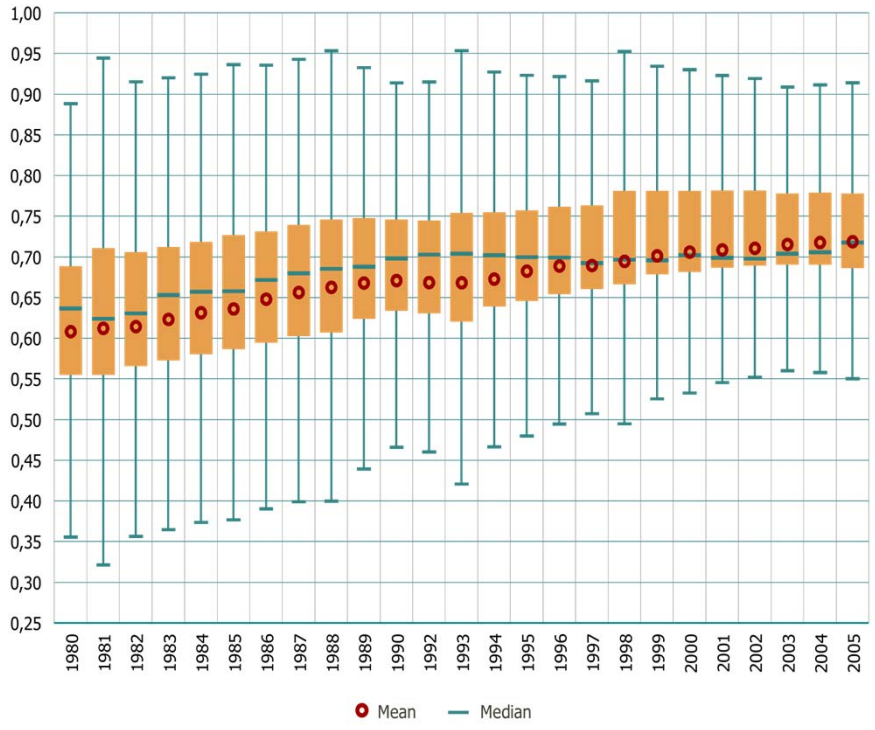
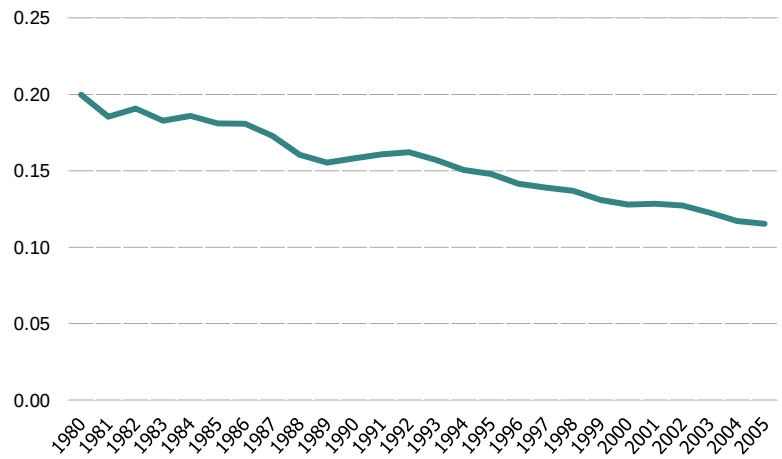
Aggregate results: dispersion and convergence

FIGURE 6. Boxplot of GVA knowledge intensity by countries, 1985-2005



Note: The Czech Republic, Ireland, Portugal, Slovenia and Sweden have not been considered .
Source: EU KLEMS and own calculations.

FIGURE 7. -convergence in GVA knowledge intensity. Total industries, 1980-2005.
(coefficient of variation)



Note: The Czech Republic, Ireland, Portugal, Slovenia and Sweden have not been considered .
Source: EU KLEMS and own calculations.

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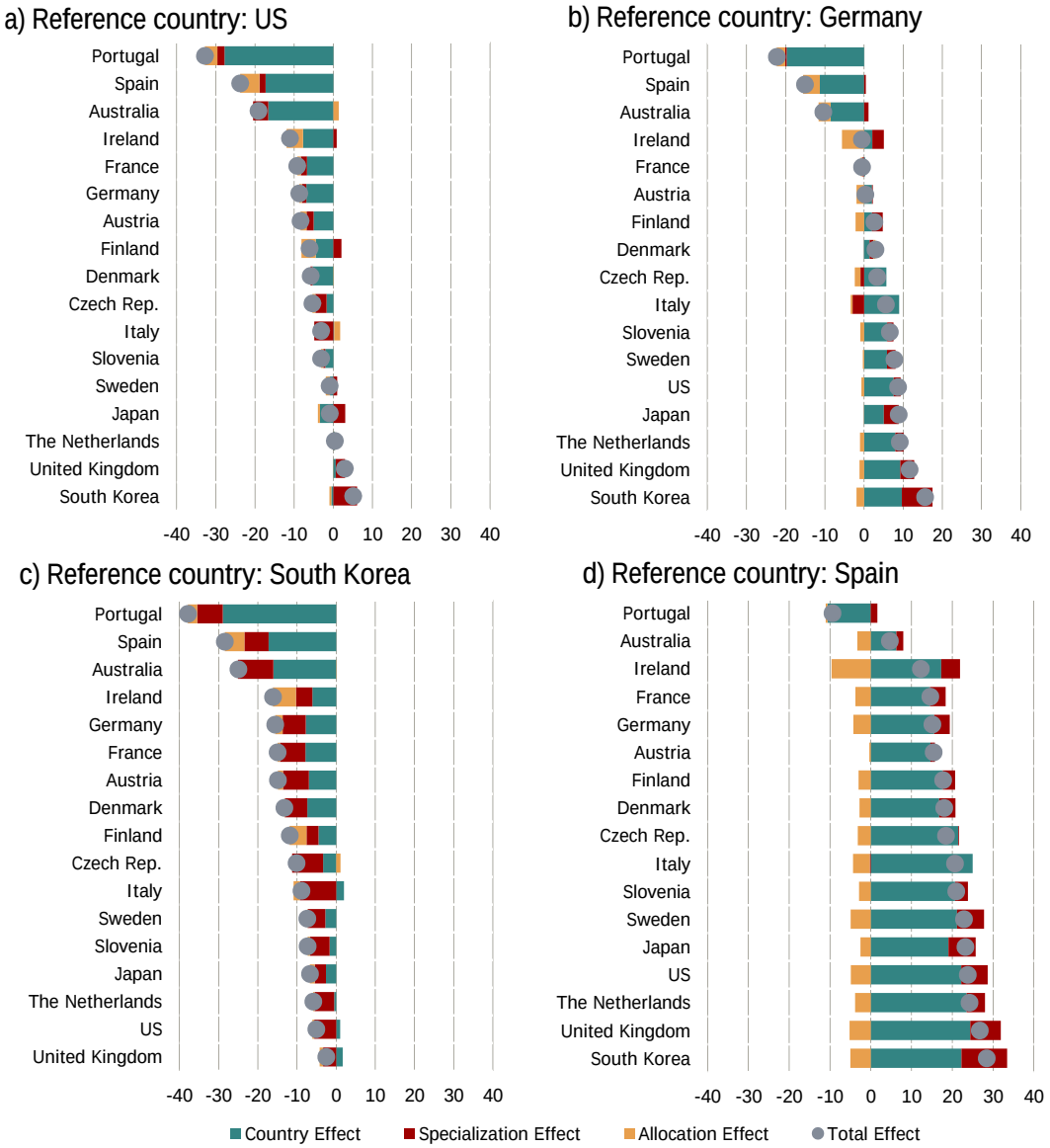
Aggregate results: determinants of differences

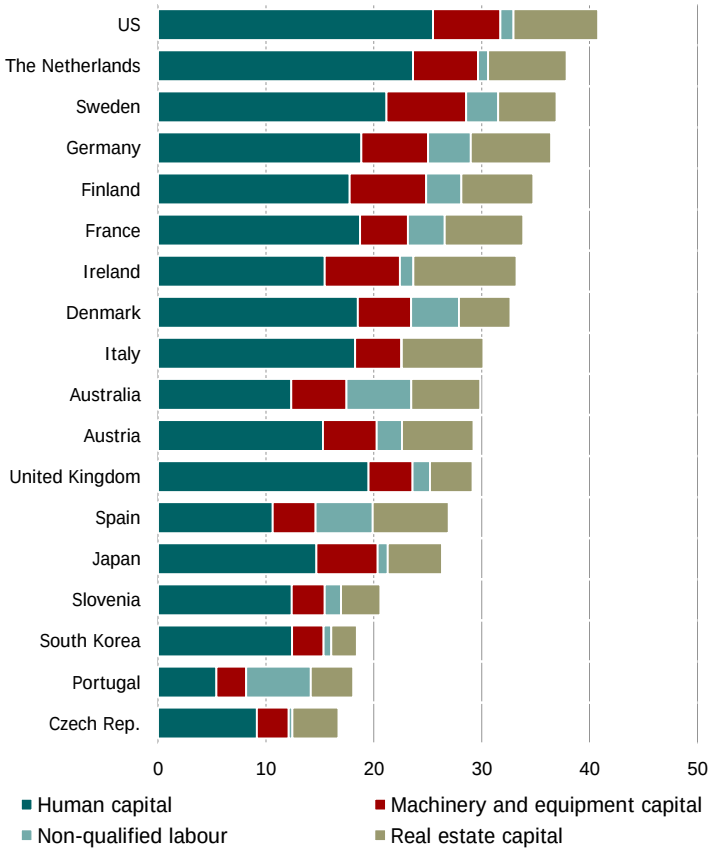
FIGURE 8. Knowledge-intensity shif-share analysis. 2007
(absolute differences in percentage points on GVA)



Note: 2006 for Japan and Slovenia and 2005 for Ireland, Portugal and South Korea. 2005 for Figure 3c.
Source: EU KLEMS and own calculations.

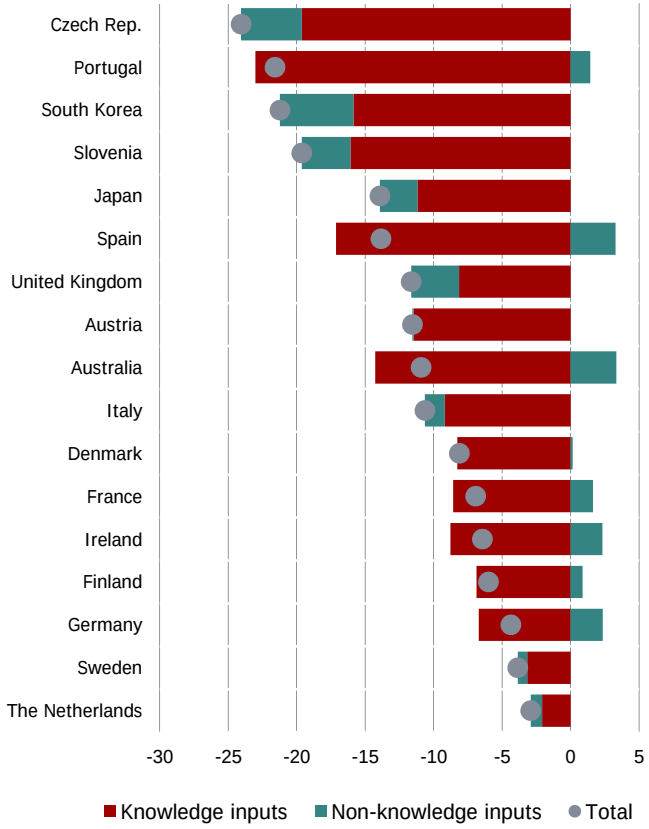
Aggregate results: knowledge and productivity

FIGURE 10. Labour productivity by components, 2007.
(2000 PPS euros per hour worked)



Note: 2006 for Japan and Slovenia and 2005 for Ireland, Portugal and South Korea.
Source: EU KLEMS and own calculations.

FIGURE 11. Decomposition of the differences in labour productivity. Reference country: US, 2007
(absolute differences in percentage points on GVA)



Note: 2006 for Japan and Slovenia and 2005 for Ireland, Portugal and South Korea.
Source: EU KLEMS and own calculations.

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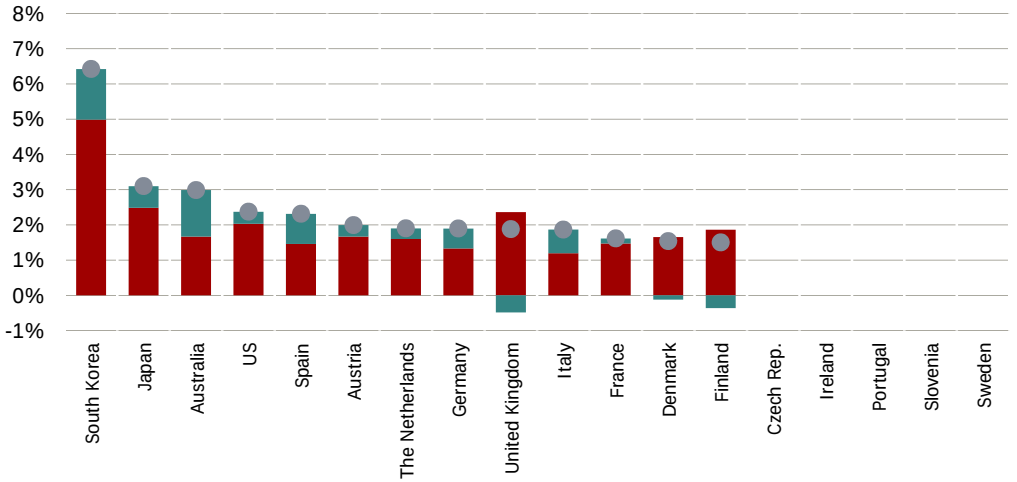
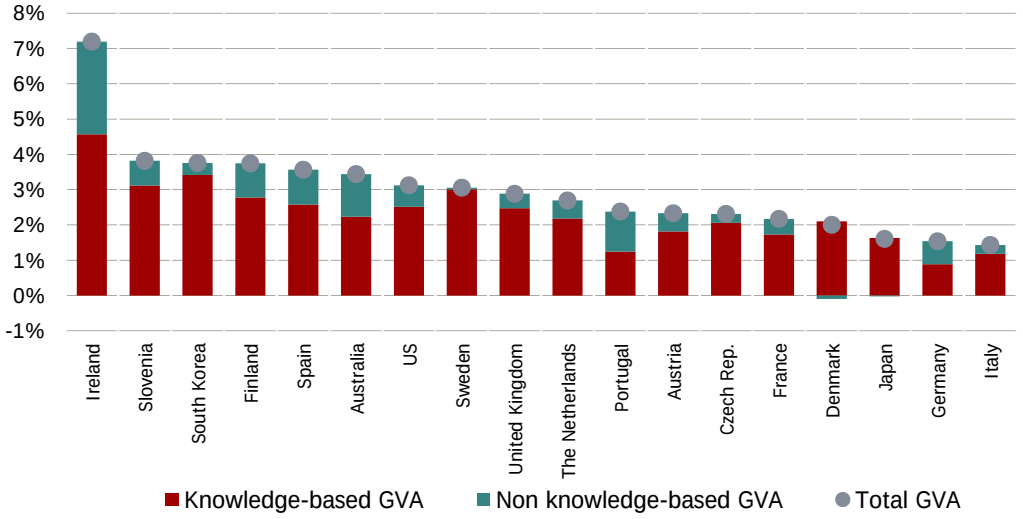
Aggregate results: knowledge and GVA growth

FIGURE 13. Knowledge contribution to the annual growth of GVA. 1980-1995 and 1995-2007 (percentage points)

a) 1980-1995



b) 1995-2007



Note: 1990-2006 for Japan and Slovenia and 1990-2006 for Ireland, Portugal and South Korea in figure 10b.
Source: EU KLEMS and own calculations.

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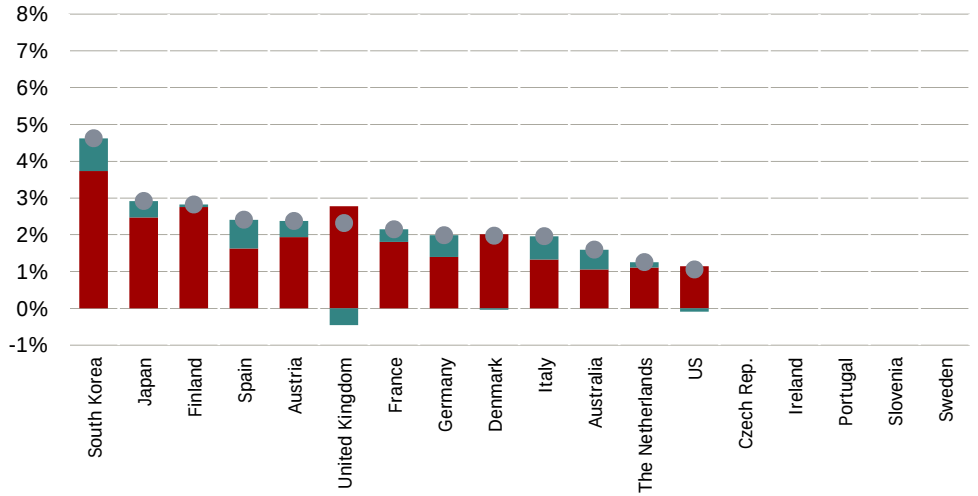
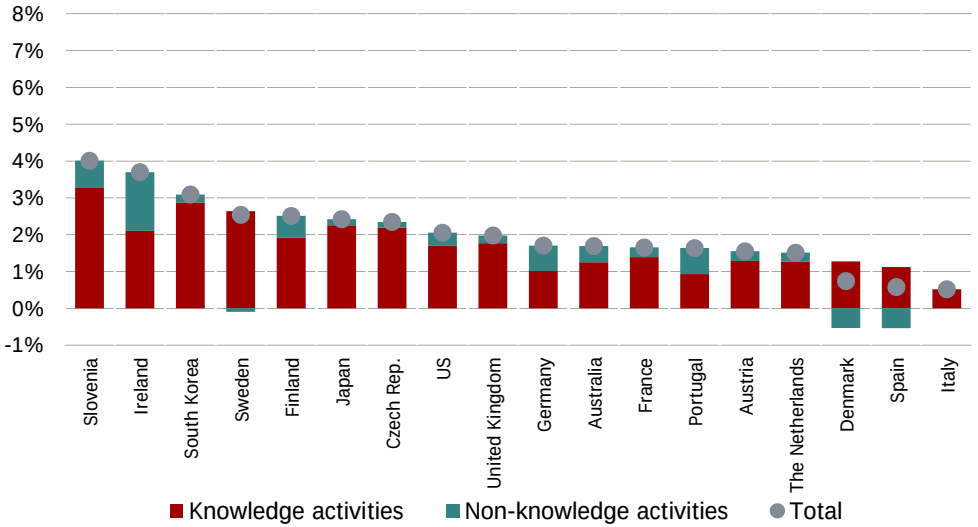
Aggregate results: knowledge and productivity growth

FIGURE 14. Knowledge contribution to the annual growth of labour productivity. 1980-1995 and 1995-2007 (percentage points)

a) 1980-1995



b) 1995-2007



Note: 1990-2006 for Japan and Slovenia and 1990-2006 for Ireland, Portugal and South Korea in figure 14b.
Source: EU KLEMS and own calculations.

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Aggregate results

- Recently, in several advanced economies the intensity of the use of knowledge has been higher than 75%. The increasing intensity is associated primarily with higher education and ICT.
- Country differences in knowledge intensity decrease, due to the positive evolution of less developed countries.
- The main differences among countries are based on intra-industry specialization, rather than inter-industry specialization.
- The disadvantages in country productivities in comparison with the US stem from the high use of knowledge-intensive factors in the American economy.
- From 1980 to 2007 knowledge has played a crucial role in the growth of GVA and productivity in almost all developed countries.

Knowledge accounting: conclusions

The results of applying the proposed metric of the use of knowledge-based factors in productive activities show that:

- Today advanced economies are extensively based on knowledge: more than half of the GVA remunerates human capital and machinery, factors which incorporate knowledge to the production processes.

- Knowledge is an increasingly common feature of all industries: the factors which incorporate it are the basis for competitiveness and growth.

- The differences among countries in knowledge intensity stem primarily from intra-industry differences: due to the very different activities being carried out within them and to their different weight in each economy.

Knowledge accounting: policy implications

- The conventional country classification by categories of technological intensity prevents us from showing that the same industry can differ in the intensity of knowledge among countries → what is critical for promoting the use of knowledge is the renewal of the productive structure in each industry.

- The differences among industries in the intensity of use of human capital and machinery do not respond to the dichotomy manufacturing *vs.* services → manufacturing is not superior in the use of knowledge.

- The highest contributions of knowledge to productivity lie on a better use of human capital, particularly, of the workers with higher education → if education does not meet the needs of industry or if employment offered by firms does not exploit the potential of education, more value added will not be generated nor wages will be able to increase.

Extensions

- Case study: Spain
  - Pérez y Benages (2012): “El PIB basado en el conocimiento: importancia y contribución al crecimiento”, Ivie, forthcoming.
- GVA vs Total Production *knowledge intensity*
  - Knowledge intensity of intermediate inputs
  - Knowledge intensity of imports
- Knowledge intensity as determinant of productivity and growth: the role of different components

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