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Measuring International Technology Spillovers and Progress Towards the European Research Area

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Abstract: The objective of this paper is to contribute to the development of an evidence-based system to monitor progress towards the European Research Area (ERA) and a knowledge-based economy. We start with an overview of existing theory and empirical evidence on the role of international technology spillovers on economic growth. Further, we discuss the transmission channels of international technology spillovers and barriers to international technology diffusion. Next we turn to measuring specialisation in knowledge-based sectors and geographical concentration patterns of these sectors. The remainder of this paper proposes three sets of indicators to monitor progress towards the ERA and a knowledge-based economy in relation to international technology diffusion.

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Key words: International technology spillovers; Knowledge-intensive economy; Absorptive capacity; European Research Area.

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Executive Summary

The objective of this paper is to contribute to the development of an evidence-based system to monitor progress towards the European Research Area (ERA) and a knowledge-based economy. We start with an overview of existing theory and empirical evidence on the role of international technology spillovers on economic growth. Further, we discuss the transmission channels of international technology spillovers and barriers to international technology diffusion. Next we turn to measuring specialisation in knowledge-based sectors and geographical concentration patterns of these sectors. The remainder of this paper proposes three sets of indicators to monitor progress towards the ERA and a knowledge-based economy in relation to international technology diffusion.

Modern growth theory has established the importance of knowledge and international knowledge spillovers as sources of economic growth. Existing empirical evidence at firm and industry levels suggests that social rates of return to R&D/technology investment are higher than the private rates of return. In many countries foreign sources of technology account to a large extent for technology adoption.

International technology spillovers can take place through a number of channels: *embodied technology* can be transmitted through international trade with goods and services; capital flows; and mobility of scientists; *disembodied technology* is diffused via international trade of technology.

Barriers to international technology diffusion. However, international technology diffusion is neither inevitable nor automatic. Empirical evidence suggests that international technology spillovers are conditioned by domestic R&D expenditure, human capital and the quality of institutions. Thus, domestic R&D expenditure has the potential to generate total factor productivity growth from both innovation and technology transfer. This effect is different for laggard countries and technology leaders.

Measuring and monitoring specialisation in R&D intensive industries is important and policy relevant. Country rankings of R&D intensity might be misleading if account is not made of their industrial structure.

R&D intensive industries and knowledge-intensive services tend to concentrate in space reflecting the geographical concentration of investment, infrastructure, physical and human capital.

Multinational enterprises are the main drivers of the growing internationalisation of business R&D. Recent research suggests that on average, the probability of the location of a representative R&D foreign affiliate in an EU region increases with market potential, agglomeration economies, business and government R&D intensity and proximity to centres of research excellence. The determinants of the location choice of R&D foreign affiliates vary depending on the country of origin of the foreign investor.

The remainder of this paper proposes **three sets of indicators to monitor progress towards the ERA and a knowledge-based economy in relation to international technology diffusion**: Lisbon-Oriented Indicators, ERA Headline Indicators and a Comprehensive Set of Indicators for the analysis of developments in science, technology and competitiveness in the ERA.

1 CONCEPTUAL FRAMEWORK

1.1 International technology spillovers

In the context of increased global competition, research and development (R&D), innovation, as well as science, technology and human resources have become increasingly international. European Commission (2008) and OECD (2008) discuss related recent evidence and policy implications. This increased internationalisation requires international co-operation and co-ordination of national science, technology and innovation policies. The European Research Area (ERA) is aimed to contribute to this purpose.

The importance of international R&D and technology spillovers is well established in modern (endogeneous) growth theory and documented by empirical evidence. Keller (2004) provides a review of theory and empirical findings on international technology diffusion..

As pointed out by Keller (2004), the point of departure of the theories of endogeneous growth (Aghion and Howitt, 1992; Grossman and Helpman 1991; Romer 1990) are two related characteristics of knowledge/technology: (i) knowledge/ technology is non-rival (the marginal costs for an additional technology user is negligible); (ii) knowledge is partially non-excludable due to imperfect intellectual property protection which implies that the return to investments in technology is partly private and partly public (social).

Existing empirical evidence at firm and industry levels suggests that social rates of return to R&D/technology investment are higher than the private rates of return (Griliches, 1992). Jones and Williams (1998) relate the theoretical models of new growth theory to empirical results of the productivity literature and show that these results can be taken as lower bounds for the social rate of return to R&D.

Given that new technologies are created in a small number of industrialised countries[1], in many countries foreign sources of technology account to a large extent for technology adoption (Keller, 2004). It has been argued that the bigger the technology gap the larger the potential to benefit from international technology spillovers (Gerschenkron, 1962). However, international technology spillovers are neither inevitable nor automatic (Keller, 2004). While firms, industries

[1] For example Eaton and Kortum (1999) show that in the late 1980s, 80 percent of research scientists and engineers in industrialized countries were employed in five countries: US, UK, Germany, Japan, and France)

and countries below the frontier are more likely to benefit from international technology diffusion they need to have the capability to internalise the external knowledge available in the frontier technology.

It has been shown that international technology spillovers are conditioned and enhanced by prior R&D investment (Cohen and Levinthal, 1989; Geroski et al., 1993; Mancusi, 2008). Existing empirical evidence indicates that domestic expenditure on R&D and innovation improves the capacity to absorb foreign country technology (Fagerberg, 1994; Verspagen, 1991; Griffith et al 2004; Cameron et al 2005; Kneller, 2005).

There is also evidence showing that technology spillovers are limited in space suggesting a distance effect (Jaffe, 1986, 1989, Audretsch and Feldman, 1996). A number of contributions have suggested that technology externalities are mainly intra-national (Jaffe et al. 1993; Branstetter, 2001; Maurseth and Verspagen, 2002; Peri, 2005).

1.2 Channels of international technology spillovers

International technology spillovers can take place through a number of channels: international trade, foreign direct investment, mobility of scientists. Earlier empirical studies have focused on international trade as a significant source of technology diffusion. Coe and Helpman (1995) find evidence of trade related international knowledge spillovers on growth rates of total factor productivity (TFP) in 22 OECD countries over the period 1971-1990. They built on Grossman and Helpman (1990) who argued that the stock of knowledge is the result of both domestic and foreign R&D spending and constructed for each country "knowledge stocks" with spillovers measured as stocks weighted by trade flows. In particular Coe and Helpman (1995) focus on imports of manufactured goods as the channel of knowledge spillovers. Additional evidence on international knowledge spillovers through imports include Coe, Helpman and Hoffmaister (1997, 2009), Keller (1998), and Madsen (2007).

Another strand of literature suggests "learning by exporting" as a possible channel for knowledge spillovers, through contact with more advanced foreign competitors in international export markets. However empirical evidence on this channel is inconclusive (Bernard and Jensen, 1999; Clerides et al., 1998).

Foreign direct investment (FDI) is often associated with technology advantage in order to overcome the lack of knowledge of local markets. Evidence about knowledge spillovers from foreign direct investmet is provided by Aitken and Harrison (1999), Keller and Yeaple (2003), Javorcik (2004), Brandstetter (2006), and Haskel et. al. (2007).

In contrast to previous studies which have focused on a particular channel of international knowledge spillovers, Lee (2006) examines the relative effectiveness of several channels including inward and outward FDI, imports of intermediate goods, and a disembodied direct channel measured by technological proximity and patent citations between countries. By using data from OECD countries over the period 1981-2000 he finds that, while international knowledge spillovers through inward FDI and the disembodied direct channel were significant and robust, outward FDI and imports of intermediate goods do not appear effective as channels for in the international transmission of knowledge.

1.3 Barriers to international technology spillovers

Domestic absorption capacity

Griffith et al (2004) provide empirical evidence that the size of international technology spillovers depends on domestic R&D expenditure. They suggest that in non-frontier countries (US is taken as the technology leader), domestic R&D expenditure has the potential to generate TFP growth from both innovation and technology transfer. Their conclusion is supported by Eaton et al (1998) who found that with the exception of Portugal, social rates of return to R&D were higher in OECD countries than in the US.

Mancusi (2008) analyses the role of international technology spillovers and domestic absorptive capacity on innovation in a large group of OECD countries using data on patents over the period 1978-2003. She finds that international technology spillovers (international patent citations) from technology leaders (US, Japan, Germany) had a positive effect on innovation (patent applications at the European Patent Office) in countries below the technology frontier. Further, while prior R&D experience (self-citations to previous patents) increased the elasticity of innovation capacity to international technology spillovers in laggard countries, its marginal effect was negligible in countries at the technological frontier. Finally, the analysis decomposes international spillovers in their intra-industry and inter-industry components and finds that only intra-industry international technology spillover had a strong positive effect on the innovation output.

The role of institutions

Parente and Prescott (1994, 1999) focus on institutions as a determinant of domestic absorptive capacity and barriers to foreign technology adoption such as monopoly rights. Crespo-Cuaresma et al. (2008) show that countries with lower levels of product market regulation, employment protection and lower barriers to entrepreneurship benefit most from foreign R&D. Further, the relationship between international knowledge spillovers and wage bargaining is found to be non-monotonic, with positive effects in the case of low and high co-ordination and insignificant for intermediate levels. Their results suggest that absorptive capacity increases with competitive products and labour markets.

Additional empirical evidence on the role of institutions on the impact of R&D spillovers on TFP is provided by Coe, Helpman and Hoffmeister (2009). They show that benefits from own R&D, from international R&D spillovers and from human capital formation are relatively high in countries where the ease of doing business and the quality of tertiary education systems are relatively high. Further, strong patent protection is associated with higher levels of TFP, higher returns to domestic R&D and larger international R&D spillovers. Finally, countries whose legal origins are based on English or German law tend to benefit more from their own and foreign R&D capital than countries whose legal origins are based on French and to a lesser extent on Scandinavian law.

1.4 Knowledge-based sectors: Specialisation and spatial patterns

Specialisation in knowledge-based sectors

Country rankings of R&D intensity might be misleading if account is not made of their industrial structure. For example, R&D intensity (measured as gross domestic expenditure on R&D as percentage of GDP) is the highest in Sweden, Finland, Japan and South Korea (OECD, 2008). Mathieu and van Pottelsberghe de la Potterie (2008) suggest that business R&D intensity at country level is likely to be influenced by technology specialisation. Their econometric analysis finds that after accounting for their industrial structure, Sweden, USA, France and to a lower extent Japan invest more in R&D in comparison with other countries. However, Finland and South Korea appear to have R&D intensities similar to Germany after accounting for their specialisation in ICT industries.

This result suggests that measuring and monitoring specialisation in R&D intensive industries is important and policy relevant.

Specialisation in R&D intensive industries ($SPEC_i^{R\&D}$) can be measured by an index constructed following Balassa (1965):

$$SPEC_i^{R\&D} = \frac{X_i^{R\&D} / \sum_k X_{i,k}}{X_{world}^{R\&D} / \sum_k X_{world,k}}$$

The numerator of the index represents the share of the R&D intensive industries in country i in total economic activity (measured by gross value added, or employment or exports in all sectors k). The denominator of the index corresponds to the share of R&D intensive industries in total economic activity in the world economy (gross value added, or employment, or exports). Values of the index greater than 1 for country i suggest that country i is specialised in R&D intensive industries relative to the world average.

R&D intensive industries include the following (high-tech) industries (OECD, 2007):

	ISIC Rev. 3
- Aircraft and spacecraft	353
- Pharmaceuticals	2423
- Office, accounting and computing machinery	30
- Radio, TV and communications equipment	32
- Medical, precision and optical instruments	33

The scope of the index can be extended to measure specialisation in knowledge–based sectors including the high-tech industries as defined above and the following knowledge-intensive services (OECD, 2009):

	ISIC Rev. 3
- Water transport	61
- Air transport	62
- Post and telecommunications	64
- Financial intermediation, except insurance and pension funding	65
- Insurance and pension funding, except compulsory social security	66
- Activities auxiliary to financial intermediation	67
- Real estate activities	70
- Renting of machinery and equipment	71
- Computer and related activities	72

- Research and development	73
- Other business activities	74
- Education	80
- Health and social work	85
- Recreational, cultural and sporting activities	92

A narrower index measuring specialisation in knowledge-intensive sectors will include the following high-tech manufacturing and high-tech knowledge-intensive services:

	ISIC Rev. 3
High-tech manufacturing	
- Aircraft and spacecraft	353
- Pharmaceuticals	2423
- Office, accounting and computing machinery	30
- Radio, TV and communications equipment	32
- Medical, precision and optical instruments	33
High-tech knowledge-intensive services	
- Post and telecommunications	64
- Computer and related activities	72
- Research and development	73

An index of technology specialisation can be constructed in a similar way by using the share of patents in a particular field (for example ICT, biotechnology) in total patents for each country i normalised by the world share of patents in that filed.

The index can be constructed using an alternative benchmark, for example the ERA. In this case, values greater than 1 would indicate country specialisation relative to the ERA average.

The specialisation index can be normalised to obtain values between -1 and +1 as follows:

$$SPEC_i^{*R\&D} = \frac{SPEC_i^{R\&D} - 1}{SPEC_i^{R\&D} + 1}$$

The greater the value of the index, the higher the specialisation in R&D is.

Geographic concentration of knowledge-based sectors

R&D intensive industries and knowledge-intensive services tend to concentrate in space reflecting the geographical concentration of investment, infrastructure, physical and human capital.

The geographic concentration of R&D intensive industries (knowledge-based sectors) can be measured by an index which compares the spatial distribution of R&D intensive industries (knowledge-based sectors) and the spatial distribution of the whole manufacturing (economic activity). Measures of geographical concentration of industries are described in Iara and Traistaru (2003); Traistaru-Siedschlag and Volpe Martincus (2006).

We define the following measures of employment shares[2] (E = employment) to be used in the calculation of concentration measures for European Union's countries:

$$s_j^{R\&D} = \frac{E_j^{R\&D}}{E^{R\&D}} = \frac{E_j^{R\&D}}{\sum_j E_j^{R\&D}}$$

$$s_j = \frac{E_j}{E}$$

$s_j^{R\&D}$ = the share of employment in R&D intensive industries (knowledge-based sectors) in country j in total employment in R&D intensive industries (knowledge-based sectors) in the European Union

s_j = the share of total employment in country j in total employment in the European Union

Herfindahl index of geographical concentration

[2] Other measures of economic activity that can be used are gross value added and exports

This is a measure of absolute concentration of R&D activity in the European Union. It is calculated as follows:

$$H^{R\&D} = \sum_j (s_j^{R\&D})^2$$

The index is positively related to geographical concentration.

Index of relative geographical concentration

This index measures the spatial distribution of R&D activity relative to the spatial distribution of total employment in the European Union.

It is calculated as follows:

$$RC^{R\&D} = \sum_j \left| s_j^{R\&D} - s_j \right|$$

It takes values between 0 and 2. The higher the value, the higher is the degree of relative concentration of R&D (knowledge-based) activity. The index is equal to 0 when there is perfect dispersion of R&D activity. It is equal to 2 when there is maximum concentration of R&D activity.

1.5 What determines the attractiveness of the EU to R&D foreign investment?

R&D activity has become increasingly international. In many countries the share of foreign affiliates in R&D activity is higher than the share of foreign affiliates in manufacturing and it is increasing. This suggests that research is now more internationalised than production (OECD, 2007). Multinational enterprises (MNEs) are the main drivers of this growing internationalisation of enterprise R&D and in many countries foreign affiliates carry out more R&D than domestic firms. While traditional cross-border R&D enterprise activities have tended to locate in developed economies, an increasing amount of R&D outward investment in recent years has gone to emerging economies.

While internationalisation of R&D is not new the speed and extent have increased in recent years. In addition to the traditional role of R&D foreign investment in diffusing technology (demand-driven) related to adapting products and services to local market conditions and supporting MNEs local manufacturing operations, R&D foreign investment is being increasingly motivated by tapping into worldwide centres of knowledge (supply-driven) as part of firms strategies to source innovation globally (OECD, 2008).

Siedschlag et al (2009) examine determinants of the attractiveness of EU regions to R&D foreign investment. Specifically, the paper analyses the location choice of 446 new foreign affiliates incorporated in the European Union over the 1999-2006 period. United Kingdom and Germany accounted for over 70% of the number of R&D foreign affiliates. Central and Eastern European countries (EU10) accounted for 6% of the number of R&D foreign affiliates. Most R&D foreign affiliates located in the UK have headquarters in North America (US and Canada). Most R&D foreign affiliates located in Germany originate in Western Europe. US investors accounted for 30% of the number of R&D foreign affiliates. Switzerland accounts for the biggest number of R&D affiliates from Western Europe.

The econometric analysis suggests that on average, the probability of the location of a representative R&D foreign affiliate in an EU region increases with market potential, agglomeration economies, business and government R&D intensity and proximity to centres of research excellence. The determinants of the location choice of R&D foreign affiliates vary depending on the country of origin of the foreign investor. Thus, agglomeration externalities and business R&D intensity had a higher positive effect on the propensity to locate in an EU region in the case of multinationals from North America in comparison to European based multinationals. The presence of a ranked university had a significant effect on the location choice for North American R&D multinationals but no significant effect in the case of European R&D multinationals.

Our research results suggest a number of policy implications. First, policy aiming to increase the R&D intensity of regions are likely to foster the attractiveness of regions to R&D foreign investment. Second, positive externalities from clustering of R&D foreign affiliates outweigh competition effects. Third, given the heterogeneous behaviour of foreign investors, differentiated policy depending on target partner countries can increase the success of such policies.

2 LISBON-ORIENTED INDICATORS

2.1 Headline indicator for international technology spillovers

- A *composite index* obtained as an average of the following summary indicators:
  - summary indicator of international mobility of researchers
  - summary indicator of international diffusion of technology embodied in goods and services
  - summary indicator of international diffusion of technology embodied in capital flows
  - summary indicator of international diffusion of disembodied technology

The above summary indicators can be estimated by using a factor analysis and the detailed indicators presented in Section 4. 3

2.2 Specialisation index in knowledge-based sectors

The specialisation index can be obtained using data on employment, exports or gross value added. It can be calculated as shown in Section 1.4.

2.3 Geographic concentration of knowledge-based sectors

The geographic concentration index can be obtained using data on employment, exports or gross value added. It can be calculated as shown in Section 1.4.

3 ERA HEADLINE INDICATORS

3.1 ERA policy

- GERD financed by government as a percentage of GDP and/or per capita
- BERD financed by government as a percentage of GDP and/or per capita
- Government expenditure on R&D (GOVERD) as a percentage of GDP
- Government total R&D personnel as a percentage of national total
- Product market regulation

3.2 ERA making

- Share of high- and medium-high technology industries in total exports of manufactured goods in the ERA
- Share of R&D expenditure of affiliates under foreign control in total R&D expenditure from ERA countries
- Share of foreign doctoral students from ERA countries
- Share of employed scientists migrants from ERA countries in total employed scientists
- Percentage of GERD financed by abroad, from ERA countries
- Percentage of BERD financed by abroad, from ERA countries
- Patents with foreign co-investors from ERA countries
- Number of patent applications to the EPO per million population
- Patent citations from ERA countries

4 COMPREHENSIVE (STC) INDICATORS

4.1 Indicators related to knowledge-based activities in the EU and attractiveness to R&D investment

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	R&D intensity				
	GERD as a percentage of GDP	C	High	EU27, US, Japan: 1995-2006	Eurostat
	Percentage of GERD financed by industry	C	High	EU27, US, Japan: 1995-2006	Eurostat
	Percentage of GERD financed by government	A1	High	EU27, US, Japan: 1995-2006	Eurostat
	BERD as a percentage of GDP	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Main Science and Technology Indicators (MSTI)
	HERD as a percentage of GDP	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	GOVERD as a percentage of GDP	C	High	EU 15, CZ, PL, HU, SK, US, Japan: 1995-2006	OECD MSTI
	Percentage of BERD performed in the aerospace industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of BERD performed in the electronics industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of BERD performed in the office machinery and computer industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	Percentage of BERD performed in the pharmaceutical industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of BERD performed in the instruments industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of BERD performed in service industries	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of HERD financed by industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Specialisation index in knowledge-based sectors				
	Specialisation of countries in knowledge-based sectors relative to the world average	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD
	Specialisation of countries in knowledge-based sectors relative to the ERA average	C	High	EU 15, CZ, PL, HU, SK, US, Japan: 1995-2006	OECD
	Concentration index of employment in knowledge-based sectors				
	Concentration of employment in knowledge-based sectors relative to the world average	C	High	EU 15, CZ, PL, HU, SK, US, Japan: 1995-2006	OECD
	Concentration of employment in knowledge-based sectors relative to the ERA average	C3	High	EU 15, CZ, PL, HU, SK, US, Japan: 1995-2006	OECD
	Human capital				
	New university graduates	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	Science and engineering degrees	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database
	Graduation rates at doctoral levels	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database
	Share of tertiary-level graduates in total employment	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Educational attainment database
	Total R&D personnel per thousand total employed	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Total business enterprise R&D personnel per thousand employed in industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Higher education R&D personnel as a percentage of national total	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Government total researchers as a percentage of national total	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Framework conditions				
	Product market regulation (index)[c]	A1	Satisfactory	EU15, PL, CZ, HU, SK US Japan:1998, 2003	OECD Product market regulations
	Employment protection regulation (index)[d]	A1	Satisfactory	EU15, US Japan: 1990, 1998, 2003; PL, CZ, HU, SK:1998, 2003	OECD Employment Outlook

[c] The index was estimated using a factor analysis in which each component of the regulatory framework is weighted according to its contribution to the overall variance in the data. The methodology is described in Nicoletti, Scarpetta and Boylaud (2000).

[d] Estimated using the factor analysis applied to regulations referring to regular contracts and those referring to fixed-term contracts or contracts under temporary work agencies. The methodology is described in Nicoletti, Scarpetta and Boylaud (2000).

4.2 Indicators related to the knowledge triangle

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	Human capital				
	New university graduates	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database
	Science and engineering degrees	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database
	Graduation rates at doctoral levels	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Education database
	Share of tertiary-level graduates in total employment	C	High	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD Educational attainment database
	Total R&D personnel per thousand total employed	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Total business enterprise R&D personnel per thousand employed in industry	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Higher education R&D personnel as a percentage of national total	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Government total researchers as a percentage of national total	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Percentage of firms with new-to-market product innovations	C	Satisfactory	EU27:2002-2004;2004-2006	Eurostat CIS
	Percentage of firms undertaking non-technological innovation	C	Satisfactory	EU27:2002-2004;2004-2006	Eurostat CIS

4.3 Indicators related to the 5th Freedom across the ERA: free circulation of researchers, knowledge and technology

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	International mobility of researchers				
	Share of foreign doctoral students from EU countries	B	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Education data base
	Share of employed professionals and technicians from abroad in total employed	B	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD database on Immigrants and Expatriates
	International diffusion of technology embodied in goods and services				
	Share of highly R&D intensive industries - in total exports of manufactured goods	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Share of imports of highly R&D intensive - in total imports of manufacture goods	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Export market share in the aerospace industry	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Export market share in the electronics industry	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Export market share in the office machinery and computer industry	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Export market share in the pharmaceuticals industry	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	Export market share in the instruments industry	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	Export market share in knowledge intensive services	C	High	EU15, EU 15, CZ, PL, HU, SK, US, Japan 1993-2006	OECD MSTI
	International diffusion of technology embodied in capital flows				
	Share of R&D expenditure of foreign affiliates in total R&D expenditure	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation
	Share of turnover of foreign affiliates in total turnover	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation
	Share of R&D foreign affiliates in value added	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation
	Share of R&D foreign affiliates in employment	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation
	Share of foreign affiliates in high technology exports	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation
	Share of foreign affiliates in high technology imports	C	Satisfactory	EU15, EU 15, CZ, PL, HU, SK, US, Japan	OECD Statistics on Measuring Globalisation

No	Proposed Indicators	Type of Indicator	Quality	Availability	Source
	International diffusion of disembodied technology				
	Technology payments as a percentage of GDP	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	Main Science and Technology Indicators (MSTI)
	Technology payments as a percentage of GERD	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Technology receipts as a percentage of GDP	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI
	Technology receipts as percentage of GERD	C	Satisfactory	EU 15, CZ, PL, HU, SK, US, Japan:1995-2006	OECD MSTI

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