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Technological Capabilities in Central and Eastern Europe: An Analysis Based on Priority Patents

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Abstract

This contribution studies the technological capabilities of Central and Eastern European (CEE) economies based on priority filings for the period of 1980-2009. From a global perspective, the indicators suggest a division of labour in technological activities among world regions whereby Europe, Latin America and the former USSR are specializing in sectors losing technological dynamism (Chemicals and Mechanical Engineering) while North America, the Middle East (especially Israel) and Asia Pacific are increasingly specializing in Electrical Engineering, a sector with significant technological opportunities. Regarding priority filings, CEE reduced its technological activities drastically after 1990. The recovery of CEE economies regarding technological capabilities is unfolding very slowly. The results speak for the ability of CEE countries in contributing to a limited number of fields with growing technological opportunities. The technological profile of the CEE region will more likely than not complicate the technology upgrading process towards activities at the technological frontier.

Keywords: technological capabilities, patent indicators, priority patents, Central and Eastern Europe, country comparisons

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Introduction

This contribution studies the evolution of the technological capabilities of CEE economies in the period 1980-2009.A number of empirical studies have explored how the legacy of a central planning system has influenced the functioning of Central and Eastern European (CEE) innovation systems in market economies (Meske, 2004; Kravtsova and Radosevic, 2012; EBRD, 2014) These contributions stress that, considering the systemic character of technological change and innovation, the path of technological development of CEE economies draws to a large extent on the technological capabilities accumulated in past, on the integration of these economies in global markets and on the changes in the institutional structures shaping innovation related activities. Other research has provided empirical evidence for the increasing integration of CEE economies into the world markets and the institutional restructuring of innovation related activities towards research and development models of market-based economies (Radosevic and Auriol 1999, Landesmann and Szekeley 1995). Given these findings. The challenge is now twofold. Firstly, as for other catching up economies, in the case of CEE countries, there is a need for capturing the incremental technological advance that is relevant to their productivity growth. Secondly, the assessment of technological capabilities needs to consider global trends in technological development and the position of CEE economies in a dynamic technological landscape. To explore these issues we use patent indicators based on so-called "priority filings" and derive specialisation indicators.

Patent indicators have a long tradition in the analysis of innovation and technological activities (Archibugi 1988; Grilliches, 1990; Grupp, 1998). The strengths and weaknesses of patents for these purposes have been discussed extensively (see for example Archibugi 1992 for an overview). A weak point of patents as an indicator is that not all technological inventions are patentable. Moreover, there exist a different propensity to patent across technologies and sectors. Accordingly, patent indicators measuring technological specialisation and its changes across time are biased towards those technological activities that can be captured by patents (Archibugi 1992, Pavitt 1988). Archibugi (1992) points out that patents capture a technological capability but are most appropriate to trace technological capabilities with a business potential. From this perspective, in the context of technological catching-up, patent indicators show a further weakness: they underestimate imitative and incremental type of technological activities (Puga and Trefler 2010). The underestimation is even larger if indicators use foreign patent applications only (counts of patents or patent applications in foreign countries from the perspective of the inventor). In the case of CEE economies, there has been a significant disparity between domestic patenting and patenting abroad (Archibugi 1992). By being focused only on technology effort at the world frontier indicators based on foreign patenting are misleading indicators for the domestic technological capabilities in this region (Marinova 2001).

Despite these limitations, there is an extensive body of empirical research based on patents comparing technological development across countries and sectors (Nagaoka et al., 2010; Nesta and Patel 2013; OECD 2009; Nagaoka, Motohashi and Goto 2010). However, the existing studies on CEE economies use mainly US patent data to analyse technological development before and during the transition period from planned to market economies. Radosevic and Kutlaca (1999) analyse the patenting activity of CEE in the United States (US) for the period 1969-1994. Their data suggest that, regarding US patents, in the 1970s technological activities of CEE economies increased compared to the less developed EU countries and other economies with comparable income. In the 1990s technological activities fell sharply. Only in Hungary and in the ex-Yugoslavia

(Croatia and Slovenia) technological activity remained above the levels of the 1970s. The technological specialisation analysis by Radosevic and Kutlaca (1999) suggests that the technological advantages of CEE economies were based on metallurgical and mechanical technologies as well as in chemicals/drugs. Marinova (2001) compares the technological activities of formerly planned economies with OECD countries for the period 1976-1999. Again, her analysis suggests that, regarding US patents, CEE economies experienced a decrease in their technological activities in the 1990s. The gap between CEE economies and developed market economies was relatively significant. Regarding technological specialisation, CEE countries had a technological strength in the fields of "petroleum, coal and chemicals". More recently, also drawing on US patents, Lengyel et al. (2015) have studied the geographical distribution of technological activities in CEE economies. Their analysis suggests that CEE inventors tend to agglomerate in selected regions as is the case in western economies. Moreover, by identifying cross-border interactions in patent applications (considering different national locations of patent assignees and inventors), the results suggest a strong role played by foreign multinationals in the domestic technological activities of CEE economies.

By using US patent data, these contributions capture the technological activities being carried out in CEE with higher market value. However, to obtain a full picture of technological capabilities in CEE, incremental technological improvements and technological activities with lower international business potential should also be considered. For this purpose, we have developed patent indicators based on the worldwide count of priority filings (de Rassenfosse et al. 2013) for the period 1980-2009. By using priority filings, the results capture a more in-depth view of the development of the technological capabilities of CEE economies before and after the transition period. The next section describes the data used and the methodology applied for deriving indicators and the limitations. Section 3 presents the analysis of patent activities of CEE economies from a comparative perspective. Different world regions are considered and compared to CEE. The presentation of indicators at the national level for CEE countries follows in section 4. The discussion of the main findings closes the paper in section 5.

Data and Methods

To capture technological capabilities of CEE economies in a more comprehensive way than research contributions have done so far, we develop patent indicators based on counts of priority patent applications filed by a country's inventors. A priority filing is the first patent application filed to protect an invention. Accordingly, to capture the technological capabilities of a country we count the priority filings of the inventors located in the correspondent country independently of the location of the patent office where the filing has taken place. The geographical dimension of the priority filing is determined hence by the place of the inventor. This seems more appropriate for our purposes since the location of the inventor indicates most likely where the technological capabilities have been accumulated (or where the inventive activity takes place). Unlike US patent counts or, transnational patent counts or triadic patent families which capture "inventive performance" the methodology developed by de Rassenfosse et al. (2013)captures "the (overall) inventiveness of countries'"". In their view, "inventive performance" involves the assessment of patenting activities regarding high-value patent indicators while "inventiveness" shows to the success of countries engaged in technological activities and applying for patents to protect their inventions independently of the value of the invention. Using data from the Worldwide Patent

Statistical Database (PATSTAT, October 2012) and using the search algorithm developed by de Rassenfosse et al. (2013) we derive indicators for CEE countries and selected world regions.[1] To cope with the missing information in the database regarding the location of inventors we use the search algorithm provided by de Rassenfosse et al. (2013). The algorithm estimates the missing information by using available information in the family of the priority filing.

Another potential bias of our data is that the patent counts include filings from different patent offices which operate under different regulatory regimes (de Rassenfosse et al. 2013). Especially in the case of Japan, the Japanese IP framework seems to inflate the counts of priority patents of Japanese inventors. Recently changes in the US patent system have led to bias towards trivial patents which transformed the patent system 'from a shield that innovators could use to protect themselves, to a grenade that firms lob indiscriminately at their competitors, thereby increasing the cost and risk of innovation rather than decreasing it' (Jaffe and Lerner, 2006, p. 2). As they point out 'the weakening of examination standards and the increase in patent applications has led to a dramatic increase in the number of patents granted in the U.S' (ibid, p.3). However, as the overall effects of this bias are not yet clear we interpret US patents data at their face value. Also, our time horizon of analysis extends well before these changes. Overall, an institutional bias needs to be taken into account when making cross-country comparisons between countries with radically different Intellectual

[1] The world regions and countries included are listed in the annex. In the data collection the countries considered in the world regions change according to the respective political transition. In the case of Central and Eastern Europe (CEE), after 1990 Czechoslovakia and Yugoslavia do not appear in the patent statistics. Data for CEE region after 1990 include Croatia, Slovakia Slovenia. Czech Republic, Hungary, Poland, Romania, Bulgaria Latvia, Lithuania, Estonia.

Property frameworks or various national propensities to use of patents as an instrument of IPRs.

To study the changes in technological specialisation of world regions and countries we draw on the technological classification developed by Schmoch (2008, revised in 2013) to define 35 technological fields that can be grouped in 5 technological sectors (Chemicals, Electrical Engineering, Mechanical Engineering, Instruments, Others) based on the International Patent Classification (IPC). If a priority patent application includes patent classes that belong to different technological fields or sectors, the classification follows a fractional counting methodology.

The specialisation analysis develops first the RTA – Revealed Technological Advantage Index (Frietsch and Schmoch, 2010; Zheng et al., 2011). This indicator allows the analysis of the technological specialisation of a country or world region vis-à-vis the specialisation of the world in a given period. For a specific country and technology, if the indicator is 1 the share of the technology in the total patent output of the country equals the share of that technology in the world patent output. If the indicator is greater than 1, the country is relatively more specialised in the technology compared to the world output in the selected period and less specialised if the indicators are lower than one. Secondly, to account for changes in the specialisation profiles we draw on the approach put forward by Kropacheva and Molero (2013). Considering the Revealed Technological Advantage (RTA) of each world region or country in the respective technological sector/field and the shifts in the RTA values over two periods, technological sectors/fields are classified as being:

- "Continuous Advantages" if they display a RTA>1 in both periods under consideration,

- “Newly Gained Advantages” if they display a RTA>1 in the recent period and RTA < 1 in the oldest period,
- “Lost Advantages” if they display a RTA<1 in the recent period and RTA > 1 in the oldest period and
- “Continuous Disadvantages” if RTA <1 in both periods.

The aim of this classification is to differentiate between the technological sectors where regions and countries have been traditionally engaged in accumulating capabilities from sectors where regions are starting to specialize and to create absorptive capacity in novel technologies for the region.

Finally, the analysis considers the directions of technological change from a global perspective. For this purpose an indicator of technological dynamisms is derived for each technology and sector (see Table 1). In line with Radosevic and Yoruk (2014) we use the difference between the shares that each technological sector holds in the total patent output in the period 2000-2009 and in the period 1980-1989. Changes in the shares in each period reflect whether the respective technologies are gaining importance in relative terms or are stagnant. Drawing on Radosevic and Yoruk (2014) we interpret this dynamic as changes in the opportunities for technological change (technological opportunities) in the respective field/sector (i.e. sectors with larger potential for implementation and commercialization).

Table 1. Priority filings in 35 technology fields and 5 technological sectors 1980-2009 (world)

		Technology Field	**1980 - 1989**		**1990 - 1999**		**2000 - 2009**		**Techn. dynamism***
			Filings	**Share**	**Filings**	**Share**	**Filings**	**Share**	
Electrical engineering	1	Electrical machinery, apparatus, energy	321367	7	331416	7	473834	7	-0,63
	2	Audio-visual technology	241570	6	306932	6	391624	6	0,03
	3	Telecommunications	124966	3	190361	4	298378	4	1,38
	4	Digital communication	30387	1	65634	1	201726	3	2,17
	5	Basic communication processes	86754	2	68877	1	69614	1	-1,00
	6	Computer technology	201165	5	282465	6	511835	7	2,66
	7	IT methods for management	4489	0	15084	0	109046	2	1,45
	8	Semiconductors	159451	4	218792	4	332142	5	1,07
		Total	**1170148**	**27**	**1479561**	**29**	**2388199**	**34**	**7,13**
Instruments	9	Optics	207141	5	271024	5	341942	5	0,12
	10	Measurement	277080	6	240621	5	302920	4	-2,04
	11	Analysis of biological	16260	0	17258	0	27691	0	0,02

		materials							
	12	Control	91598	2	98902	2	134153	2	-0,19
	13	Medical technology	94290	2	137713	3	216675	3	0,92
		Total	**686369**	**16**	**765518**	**15**	**1023382**	**15**	**-1,18**
Chemistry	14	Organic fine chemistry	87404	2	79898	2	107746	2	-0,47
	15	Biotechnology	29931	1	37311	1	75065	1	0,38
	16	Pharmaceuticals	35413	1	55454	1	138321	2	1,15
	17	Macromolecular chemistry, polymers	81738	2	90764	2	94513	1	-0,53
	18	Food chemistry	47868	1	63980	1	130129	2	0,75
	19	Basic materials chemistry	97531	2	108092	2	139877	2	-0,25
	20	Materials, metallurgy	165411	4	135506	3	153182	2	-1,61
	21	Surface technology, coating	90285	2	96825	2	116281	2	-0,42
	22	Micro-structural and nano-technology	54	0	1380	0	10101	0	0,14
	23	Chemical engineering	129185	3	119713	2	136990	2	-1,01
	24	Environmental technology	59623	1	88530	2	119325	2	0,33
		Total	**824443**	**19**	**877452**	**17**	**1221530**	**17**	**-1,52**
Mechanical Engineering	25	Handling	168746	4	193069	4	207125	3	-0,92
	26	Machine tools	226146	5	176592	4	189466	3	-2,49
	27	Engines, pumps, turbines	159187	4	149469	3	204180	3	-0,74
	28	Textile and paper machines	141870	3	152841	3	167281	2	-0,87
	29	Other special machines	198077	5	207533	4	229916	3	-1,27
	30	Thermal processes and apparatus	120637	3	117976	2	146668	2	-0,68
	31	Mechanical elements	144562	3	161542	3	211150	3	-0,31
	32	Transport	162553	4	230544	5	341477	5	1,13
		Total	**1321779**	**30**	**1389567**	**28**	**1697264**	**24**	**-6,15**
Other fields	33	Furniture, games	80453	2	145690	3	245556	3	1,65
	34	Other consumer goods	79937	2	117266	2	166223	2	0,53
	35	Civil engineering	205662	5	257179	5	298929	4	-0,46
		Total	**366052**	**8**	**520135**	**10**	**710707**	**10**	**1,71**

* Difference between the shares in the first and last period (1980-1989 and 2000-2009).

Source: PATSTAT, October 2012. Authors' calculations.

Table 1 gives the data for the number of priority filings in each technological field and sector and the respective share in the total output. Also, the table includes the indicator for technological dynamism for each field and sector. The sector “Electrical Engineering” has experienced a strong relative growth in the overall patenting activities suggesting the presence of technological opportunities (especially in the fields of “computer technology” and “digital telecommunication”). The sector “Other fields” (which includes consumer goods and civil engineering) has also gained relative importance especially in the field “Furniture and Games”. Interestingly, the sector “Mechanical Engineering” has reduced its share of priority patents in the overall patenting activities which can be interpreted as a relative decline of technological opportunities. The same holds for the sectors “Chemicals” and “Instruments”. Apart from some exceptions (such as “Pharmaceuticals”, “Food Chemistry”, “Nano-technology” and “Medical Technology”), the technological fields in these sectors are stagnating in terms of technological opportunities compared to other fields. These indicators of technological dynamism will be considered in the technological specialisation analysis.

CEE in the global technological landscape

The study of technological capabilities of CEE starts with a short overview of how technological capabilities have developed globally in terms of priority filings. As explained in the introduction these indicators are most suitable for capturing indigenous incremental technological capabilities relevant for the home economies. The location of the inventor determines the origin of the patent. Figures 1 and 2 give time series for the period 1980-2009 of absolute and per capita number of priority filings in 9 world regions.

In absolute terms the number of priority patents assigned to inventors from Asia Pacific is by far the largest and about 6 times larger than the next larger region, the EU15, in the year 2009. Due to the institutional bias in the data for Japan pointed out in the previous section, the data for Asia Pacific has been given with and without Japan[2]. Asia Pacific is in absolute terms the strongest region in the number of priority patents. In the 1990s, China and Korea have increased their technological activities notably compared to the countries in the other world regions. The former USSR experiences a strong decrease in the number of priority patent applications after 1990 and recovers only slightly at the end of 1990s. Their level of patenting activities stays above the CEE achievements. CEE experiences a decrease in patent activities at the end of the 1980s and do not recover. These trends hold as well for the per capita indicators. In line with previous research (Marinova, 2001; Radosevic and Kutlaca 1999) the novel indicators based on counts of priority filings suggest a drastic slowdown of the accumulation technological capabilities in CEE countries after 1990[3]. The recovery of the former USSR after 1998 is quite clear (Figure 2).

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[2] The values for Asia Pacific including Japan are given in the right hand axis. In the period 1980-1989, 98% of the patents appointed to the region Asia Pacific belong to Japan. China and Korea are the follower economies in this region holding 2% of the region's priority patents. In the period 2000-2009 Japan holds 58.3% of the regional share in Asia Pacific followed by China (18%) and Korea (17,9%).

[3] One of reviewers to this paper wonders whether the sharp drop after 1990 could be attributed to the higher propensity to patent in the socialist system. In the fUSSR only there was a system of 'authors certificates' which were considered a lower form of IPR and were usually awarded to employees as a recognition for their technical improvements. However, data on priority patents for fUSSR do not include this form of IPR. Also, 'authors' certificates' did not exist in CEE. Finally, drop in patenting after 1990 was also very sharp

Regarding priority patents, EU15 is the second strongest world region followed quite closely by North America in absolute number of priority patents in the period 1980-1999. However, EU15 seems to be able to maintain the level of patent applications after 2005 while North America's annual level decreases slightly.

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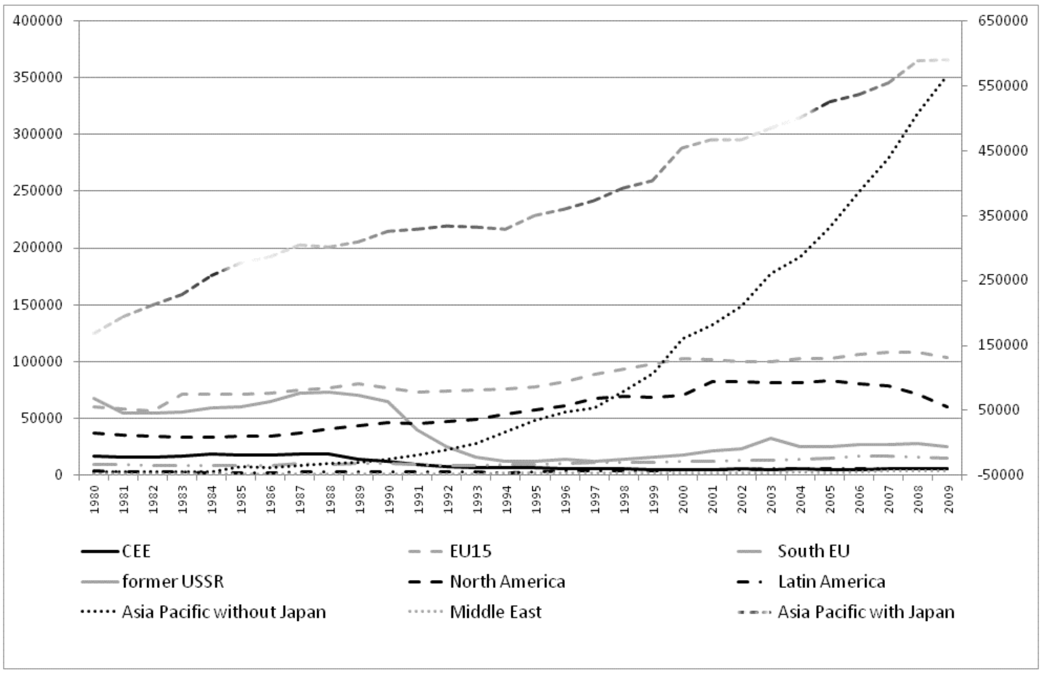
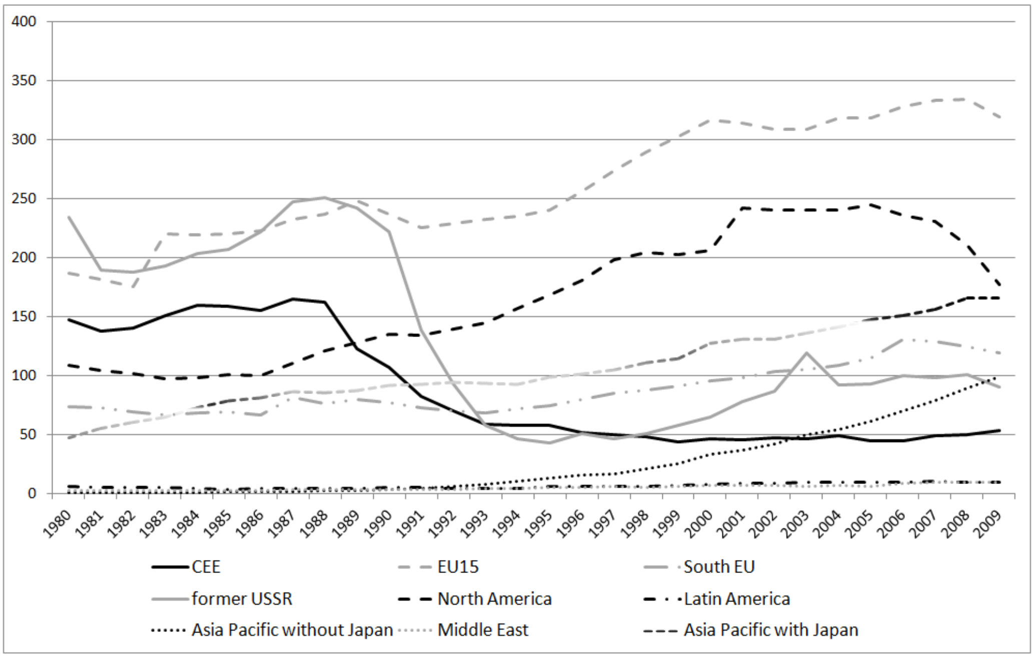
for US patents from CEE/fUSSR were there was not possible institutional bias (for details see Radosevic and Kutlaca, 1998). We explain a sharp drop in patenting as the outcome of transition from closed to open economy which leads to reduction of 'reinventing the wheel' technology effort into which economy was forced due to its closed nature or excessive import substitution. An example of inverse transition from relatively open to economy isolated under international sanctions which has induced 'reinventing the wheel' technology effort confirms the relevance of this hypothesis (see Radosevic, 1999 who analyses also innovation activities of FR Yugoslavia (Serbia) in the period of international sanctions).

Figure 1. Priority patents in world regions (1980-2009)*



* Only the values for Asia Pacific with Japan are given in the right hand axis.
Source: PATSTAT October 2012. Authors' calculations

Figure 2. Patent intensity (priority patents per capita) 1980-2009



Source: PATSTAT October 2012. Authors' calculations

To account for the heterogeneity in Central and Eastern European economies in the accumulation of technological capabilities the analysis focuses next on patent intensity at the country level. Table 2 gives the cumulative patent intensity in three periods for the CEE economies and selected economies for comparison

In the period 1980-1990 CEE countries maintain a relatively high level of priority patents per capita compared to Germany, the UK or Russia. Czechoslovakia was clearly the leading CEE country regarding patent intensity followed by Hungary and Bulgaria. After 1990 the patent intensity of all CEECs (except ex-Yugoslavia) falls dramatically. CEE countries fall clearly behind Asian economies, other European countries, the USA and Russia. The overall patent activity in the fUSSR and Russia dropped at rate similar to CEE countries. However, as suggested in the analysis of the world regions in the previous section, Russian patent activity has fully recovered and is at a level well above the CEECs.

Tabel 2. Cumulative Patent Intensity (cumulative priority patent applications per 1 mio inhabitants per period) in CEE and benchmark countries (1980-1989, 1990-99, 2000-09)*

	1980-1989	1990-1999	2000-2009
Slovenia (4)	-	815	1422
Hungary	1956	1266	833
Czech Republic (4)	-	642	606
Poland	1304	655	576
Latvia (4)	-	573	524
Croatia (4)	-	269	489
Slovakia (4)	-	317	337
Estonia* (3)	-	1479	305
Lithuania (4)	-	271	241
Bulgaria	1763	368	236
Romania	987	445	202
Yugoslavia	244	11	19
Czechoslovakia	3594	248	1
South Korea	375	5268	20169
Taiwan	175	1674	8802
Germany	3272	3631	4889
United Kingdom	2390	3056	3104
Israel	2215	2608	2758
USA	1339	1852	2259
Russia (1)	3810	787	1603
Denmark**	n.a.	n.a.	1422
Ireland**	n.a.	n.a.	1013
fUSSR (2)	2322	818	912
China	18	77	691
Spain	396	398	573
Ukraine (1)**	10	149	410
Portugal	90	99	209
Brazil	148	145	194
Turkey	10	13	70
Chile	5	6	27
India	8	9	9

*Per capita data based on last years' population in each period

** Coverage problems for Denmark (before 1993), Ireland (before 1989) and Ukraine (in 2003)

(1) Data for the periods 1980-1989 and 1990-1999 have been estimated based on the total priority applications in the fUSSR region in the respective periods and the share of the country in the fUSSR priority patent output in the period 2000-2009
(2) fUSSR includes national data for the former USSR countries excluding the Baltic countries.
(3) Data for Estonia between 1990 and 1996 are above average reaching over 300 priority patents per Mio inhabitant in 1992 and 1993. In 1996 the patent intensity reduces drastically to 20 patents per Mio inhabitant.
(4) Before 1990 the country does not appear in PATSTAT as a location of inventors.

Source: PATSTAT October 2012. Authors' Calculations

Despite this sharp decrease in the level of patent intensity of CEE economies in the most recent period, the region witnesses diverging national performances. Slovenia becomes the economy with largest levels of patent intensity in the latest period reaching the level of Denmark. Hungary and Czech Republic are able to maintain only half of their patent intensity before 1990. Bulgaria and Romania are the countries of countries with the sharpest decrease after 1990. They hold lowest patent intensity below 40 patents per million inhabitants per year in the period 2000-2009.

Technological specialisation in the global technological landscape

The specialization analysis considers firstly RTA indicators for 5 technological sectors (Chemicals. Electrical Engineering, Mechanical Engineering, Instruments and Other fields). These are calculated for each world region in two periods: 1980-89 and 2000-09. Considering the variation in the RTA indicators for each region, the sectors are classified as “Sectors of Continuous Advantages”, “Sectors of Newly Gained Advantages”, “Sectors of Lost Advantages” and “Sectors of Continuous Disadvantages” as given in Table 3.

Table 3: Shifting Revealed
Technology Advantage RTA of World Regions (5 technological sectors)
1980-89/2000-09

	RTA >1 (1980-89)	**RTA <1 (1980-1989)**
RTA >1 (2000-09)	***CEE:*** chemicals, mechanical eng. ***EU15:*** mechanical eng., other fields* ***South EU:*** chemicals, mechanical eng., other fields* ***Former USSR:*** instruments, mechanical eng. ***North America:*** instruments ***Asia Pacific:*** electrical eng.* ***Latin America:*** mechanical eng., other fields* ***Middle East:*** instruments **Sectors of continuous advantages**	***CEE:*** other fields* ***EU15:*** - ***South EU:*** - ***Former USSR:*** chemicals ***North America:*** electrical eng.* ***Asia Pacific:*** - ***Latin America:*** chemicals ***Middle East:*** electrical eng.* **Newly gained advantages**
RTA <1 (2000-09)	***CEE:*** - ***EU15:*** chemicals ***South EU:*** - ***Former USSR:*** other fields* ***North America:*** chemicals, other fields* ***Asia Pacific:*** - ***Latin America:*** - ***Middle East:*** chemicals, other fields* **Sectors of lost advantages**	***CEE:*** electrical eng.*, instruments ***EU15:*** electrical eng.*, instruments ***South EU:*** electrical eng.*, instruments ***Former USSR:*** electrical eng.* ***North America:*** mechanical eng. ***Asia Pacific:*** instruments, chemicals, mechanical eng., other fields* ***Latin America:*** electrical eng.*, instruments **Middle East:** mechanical eng. **Sectors of continuous disadvantages**

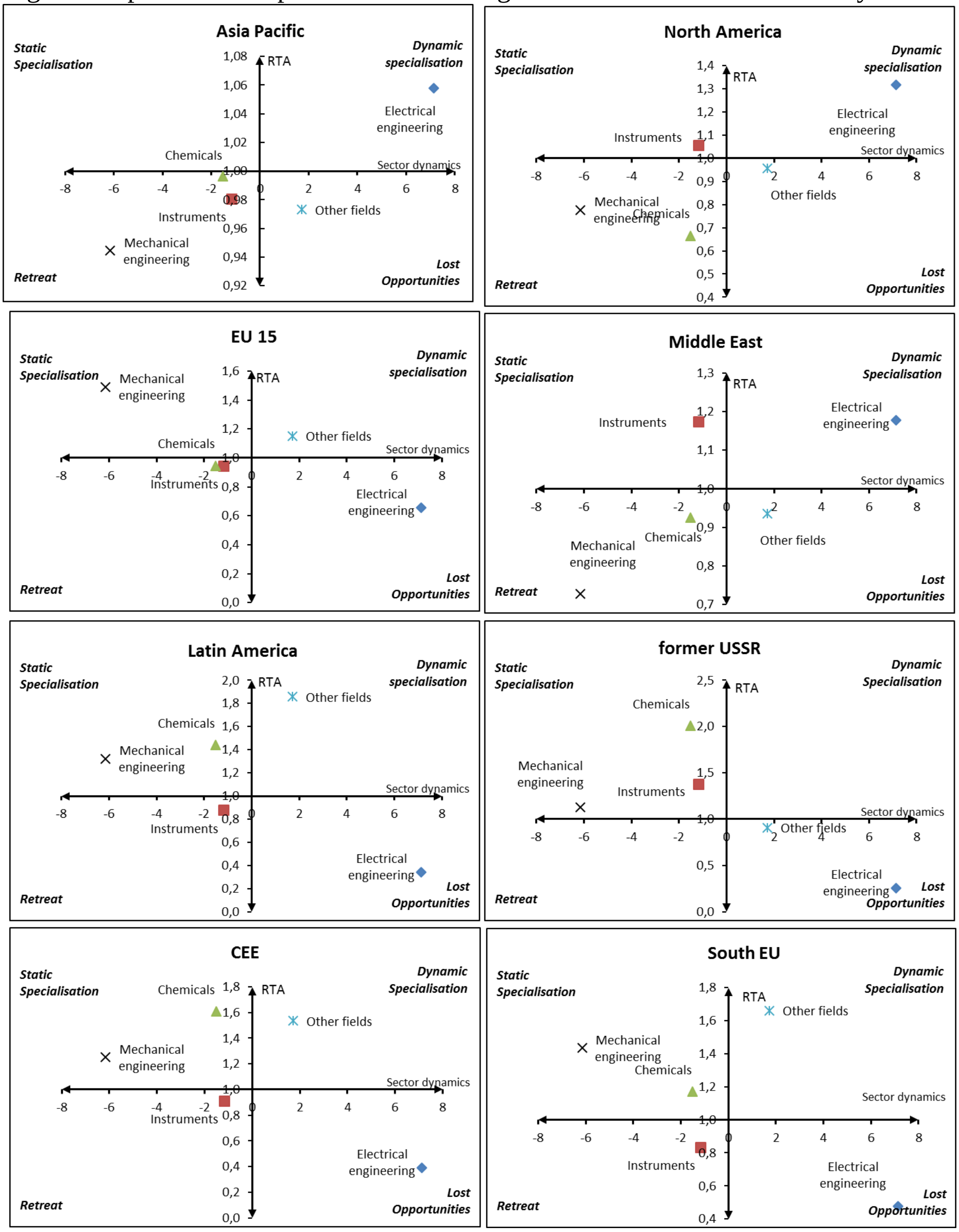
*Indicator for technological dynamism >0 (See Table 1)
Source: PATSTAT October 2012. Authors' calculations

For most regions technological sectors can be classified either as sectors of "Continuous Advantages" or as sectors of "Continuous Disadvantages", which means that changes in the technological specializations of regions at the level of the 5 technological sectors considered are minor. Especially the profiles of South EU and Asia Pacific remain rigid in terms of specialization. On the one hand, "Chemicals" and "Mechanical Engineering" are traditional sectors of technological activities in CEE, EU15 and South EU. On the other hand, "Electrical Engineering" is a sector of continuous disadvantages in Europe as well as in the former USSR and Latin America. The indicators suggest that specialization is persistent and historically rooted. The few shifts in the specialization profiles can be observed in the former USSR and Latin America (increasingly specializing in “Chemicals”), in North America and Middle East (increasingly specializing in “Electrical Engineering”) and in CEE (increasingly specializing in “Other fields” which includes “Consumer Goods” and “Civil Engineering” technologies).

This specialization analysis is extended to the technological dynamism of the different sectors. For this purpose the graphs in Figure 3 combine the specialization rates in 2000-2009 (y axis) with the technological dynamism of the sectors between 1980-1989 and 2000-2009 (x axis) as given by the indicator presented in Table 1. This combination allows us to classify the sectors for each region as:

- “sectors of static specialization”: sectors the region is specializing in (RTA>1) that report decreasing technological dynamism;
- “sectors of dynamic specialization”: sectors the region is specializing in (RTA>1) that report increasing technological dynamism;
- “retreat sectors”: sectors with RTA<1 in the corr4espong region that experience decreasing technological dynamism;
- “sectors of lost opportunities”: sectors with RTA<1 in the corresponding region that report increasing technological dynamism.

Figure 3: Specialization patterns of world regions in 2000-2009 and sector dynamics.



Source: PATSTAT October 2012. Authors' calculations

The sectors “Electrical Engineering” and “Other fields” (which covers the technological fields “Consumer Goods and “Civil Engineering”) are the two sectors with increasing technological opportunities (Table 1). Considering the technological dynamism of the sectors the results suggest that North America, the Middle East (especially Israel) and Asia Pacific are increasingly specializing in “Electrical Engineering” and exploiting a “dynamic specialization” in this sector (see the graphs for the respective regions in Figure 3). On the other hand, Europe, Latin America and the former USSR are losing technological opportunities in “Electrical Engineering”. These regions are maintaining a specialization mainly in stagnant sectors with declining technological dynamism in the global patent activities (Chemicals and/or Mechanical Engineering). The focus of European regions (South EU and EU 15) and Latin America on “Other fields” over the whole period seems to be the only path towards the accumulation of technological capabilities in fields of increasing technological opportunities. CEE is also newly diversifying towards this sector (see Table 3 and Figure 3).

The technological specialization of CEE countries

The comparison of the specialization profile of CEE with other world regions suggests a moderate ability of the region to contribute to the development of technological sectors with increasing technological opportunities. Next, the analysis will take a closer look at the technological specialization considering changes in the national technological specialization profiles across 35 technology fields. The analysis allows to account for heterogeneity across CEE countries and technology fields. Table 4 provides a classification of the specialization of CEE countries in 35 technological fields considering the shifts in their specialization indicators over time.

Table 4. Shifting areas of RTA (35 technologies) in patents in CEE countries

⇧ Continuous Advantage ⇩ Continuous Disadvantage ⇘ Lost Advantage ⇗ New Advantage

Technological Sector	Technology Field	Field Dynamics*	Country											Number of countries where technology experinces a			
			BG	HU	PL	RO	HR	CZ	EE	LT	LV	SK	SI	⇩	⇘	⇗	⇧
Chemicals	Pharmaceuticals	1,15	⇧	⇧	⇗	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	0	0	1	10
Chemicals	Food chemicals	0,75	⇧	⇧	⇧	⇘	⇗	⇧	⇘	⇧	⇧	⇧	⇘	0	3	1	7
Chemicals	Biotechnology	0,38	⇧	⇧	⇧	⇘	⇘	⇧	⇗	⇧	⇧	⇧	⇧	0	2	1	8
Chemicals	Environmental technology	0,33	⇗	⇧	⇧	⇗	⇧	⇧	⇧	⇧	⇧	⇧	⇧	0	0	2	9
Chemicals	Micro-structural and nano-technology	0,14	⇗	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇗	⇩	⇗	7	0	4	0
Chemicals	Basic materials chemicals	-0,25	⇧	⇧	⇧	⇧	⇘	⇧	⇧	⇧	⇧	⇧	⇩	1	1	0	9
Chemicals	Surface technology, coating	-0,42	⇘	⇩	⇘	⇗	⇩	⇩	⇩	⇧	⇩	⇩	⇩	7	2	1	1
Chemicals	Organic fine chemicals	-0,47	⇘	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	⇧	0	1	0	10
Chemicals	Macromolecular chemicals, polymers	-0,53	⇘	⇩	⇧	⇧	⇩	⇩	⇧	⇩	⇩	⇧	⇩	6	1	0	4
Chemicals	Chemical engineering	-1,01	⇧	⇧	⇧	⇧	⇩	⇧	⇧	⇧	⇗	⇧	⇧	1	0	1	9
Chemicals	Materials, metallurgy	-1,61	⇧	⇩	⇧	⇧	⇩	⇧	⇧	⇧	⇧	⇧	⇩	3	0	0	8
Electrical engineering	Computer technology	2,66	⇗	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	10	0	1	0
Electrical engineering	Digital communication	2,17	⇩	⇗	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	9	0	2	0
Electrical engineering	IT methods for management	1,45	⇩	⇩	⇩	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	10	0	1	0
Electrical engineering	Telecommunications	1,38	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
Electrical engineering	Semiconductors	1,07	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
Electrical engineering	Audio-visual technology	0,03	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
Electrical engineering	Electrical machinery, apparatus, energy	-0,63	⇩	⇩	⇩	⇗	⇩	⇩	⇩	⇩	⇘	⇩	⇧	8	1	1	1
Electrical engineering	Basic communication processes	-1,00	⇩	⇩	⇘	⇩	⇩	⇩	⇩	⇩	⇗	⇘	⇩	8	2	1	0
Instruments	Medical technology	0,92	⇧	⇧	⇗	⇗	⇧	⇧	⇧	⇧	⇧	⇩	⇘	1	1	2	7
Instruments	Optics	0,12	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	⇩	11	0	0	0
Instruments	Analysis of biological materials	0,02	⇧	⇧	⇧	⇧	⇩	⇧	⇧	⇧	⇧	⇧	⇩	2	0	0	9
Instruments	Control	-0,19	⇩	⇧	⇩	⇩	⇧	⇗	⇗	⇩	⇗	⇩	⇗	5	0	4	2
Instruments	Measurement	-2,04	⇧	⇘	⇧	⇧	⇩	⇗	⇧	⇧	⇘	⇘	⇗	1	3	2	5
Mechanical engineering	Transport	1,13	⇗	⇗	⇗	⇩	⇧	⇧	⇘	⇩	⇩	⇧	⇧	3	1	3	4
Mechanical engineering	Mechanical elements	-0,31	⇩	⇘	⇧	⇧	⇘	⇧	⇩	⇩	⇩	⇧	⇧	4	2	0	5
Mechanical engineering	Thermal processes and apparatus	-0,68	⇗	⇧	⇗	⇗	⇧	⇧	⇗	⇧	⇘	⇗	⇧	0	1	5	5
Mechanical engineering	Engines, pumps, turbines	-0,74	⇗	⇗	⇗	⇗	⇧	⇧	⇧	⇧	⇧	⇧	⇩	1	0	4	6
Mechanical engineering	Textile and paper machines	-0,87	⇩	⇩	⇩	⇘	⇩	⇧	⇩	⇩	⇩	⇩	⇩	9	1	0	1
Mechanical engineering	Handling	-0,92	⇗	⇩	⇧	⇩	⇗	⇩	⇗	⇗	⇩	⇩	⇧	5	0	4	2
Mechanical engineering	Other special machines	-1,27	⇧	⇧	⇗	⇗	⇧	⇧	⇧	⇧	⇧	⇧	⇧	0	0	2	9
Mechanical engineering	Machine tools	-2,49	⇘	⇩	⇧	⇧	⇗	⇧	⇘	⇩	⇘	⇩	⇧	3	3	1	4
Other fields	Furniture, games	1,65	⇩	⇧	⇩	⇩	⇧	⇩	⇩	⇩	⇗	⇧	⇧	6	0	1	4
Other fields	Other consumer goods	0,53	⇩	⇩	⇩	⇩	⇧	⇩	⇩	⇗	⇩	⇩	⇧	8	0	1	2
Other fields	Civil engineering	-0,46	⇗	⇧	⇧	⇗	⇧	⇧	⇧	⇧	⇧	⇧	⇧	0	0	2	9

*See Table 1.

Source: PATSTAT October 2012. Authors' calculations

For CEE, our analysis shows that as already discussed, “Chemicals” and “Mechanical Engineering” are traditional sectors of revealed technological advantage in CEE.

The results presented in Table 4 suggest that the focus on the sector “Chemicals” is persistent over time in all CEE countries. Even though “Chemicals” is a stagnant sector in terms of technological dynamism, a closer look at technology fields within “Chemicals” shows that in the most dynamic fields in Chemicals (“Pharmaceuticals”, “Environmental Technology”, “Biotechnology” and “Food Technology”) CEE countries show either a “continuous advantage” or a “New advantage”. The results in Table 4 show that all CEE countries are specializing in “Pharmaceuticals” and in “Environmental Technology”. Moreover, most CEE countries (except for Romania and Hungary) are specializing in “Biotechnology”. The indicators suggest that CEE economies have strengthened their focus on their traditional technological fields in Chemicals nonetheless, at least for some countries, they have focused on chemical technologies with increasing technological opportunities. Exceptions to this development are Romania and Croatia that seem to be losing technological advantage in the field of “Biotechnology”. A further exception is that most CEE economies have lost advantage in the field of “Micro-Structural and Nano-technologies”, which displays as well increasing technological opportunities within Chemicals. Only Bulgaria, Czech Republic, Latvia and Slovenia are newly specializing in this dynamic field.

So far as “Mechanical Engineering” is concerned, Table 5 gives data on Priority Patent Applications in CEE countries for two periods. The patent output in the region is mainly sustained by Poland and Czech Republic that hold together more than 50% of the priority filings counted in the region in this sector.

Table 5. Priority Patent Applications in Mechanical Engineering in CEE countries. Total Number and National Shares.

Country	1990-1999	2000-2009
Bulgaria (BG)	5194 (4,0%)	3542 (3,4%)
Hungary (HU)	11893 (9,2%)	11368 (10,9%)
Poland (PL)	51873 (39,9%)	45640 (43,9%)
Romania (RO)	19698 (15,2%)	8887 (8,6%)
Czech Republic (CZ)	19946 (15,4%)	16499 (15,9%)
Estonia (EE)	5071 (3,9%)	382 (0,4%)
Croatia (HR)	3593 (2,8%)	5229 (5,0%)
Lithuania (LT)	1522 (1,2%)	1371 (1,3%)
Latvia (LV)	2501 (1,9%)	651 (0,6%)
Slovenia (SI)	4470 (3,4%)	5739 (5,5%)
Slovakia (SK)	4168 (3,2%)	4624 (4,4%)
	129929 (100%)	103931 (100%)

Source: PATSTAT October 2012. Authors' calculations

According to the information presented in table 4, the revealed technological advantage over time of CEE in "Mechanical Engineering" is mainly driven by the continuous specialization on the fields "Other special Machines", "Engines, Pumps and Turbines" and "Thermal Processes and Apparatus". CEE countries either have continuously focus on these fields since the 1980s or started to focus on the fields more recently. These three sectors account for a negative indicator of technological dynamism. However, CEE economies are increasingly concentrating in "Transport"-technologies, the only field within "Mechanical Engineering" with increasing technological opportunities. Hungary, Czech Republic, Slovakia and Slovenia have hold a "Continuous Advantage " in "Transport" technologies over time andBulgaria, Hungary and Poland have started to focus on the field in the period 2000-2009. Despite the accumulation of capabilities in mature technological fields of "Mechanical Engineering", CEE countries except for Romania, Estonia and Latvia are specializing in the "Transport" (a field opening up technological opportunities in "Mechanical

Engineering")which reflects integration of Eastern Europe in the European industrial networks in this sector (IMF, 2013).

As to the sector "Instruments", despite the relatively weak focus of CEE economies on this sector compared to other world regions, two Instrument-technologies have strong weight in the national technological profiles: "Analysis of biological materials" and "medical technology". These are complementary technologies to technologies in Chemicals and, moreover, show positive indicators of technological dynamism. Only Slovakia and Slovenia are not focusing on "medical technology", which accounts for the stronger indicator of technological dynamism in the sector (see Table 1).

With respect to "Electrical Engineering", CEE holds a "Continuous Technological Disadvantage" in this sector. The relatively weak patenting activities in "Semiconductors", "Audio-visual technology", and "Telecommunication technologies" are persistent in all CEE countries. Estonia, Hungary and Latvia are a few exceptions to the overall relative disregard of "Electrical Engineering" by CEE. Estonia maintains a newly gained advantage in "Digital Communication" and "IT methods for management". In Hungary, "Digital Communication" is also a "newly gained technological advantage". Latvia has recently specialized in "Basic Communication Processes".

Finally, in the sector "Other fields", CEE countries have a "Continuous Technological Advantage" in technologies for "Civil Engineering" except Bulgaria and Romania. Remarkably, Latvia experiences a "Newly Gained Revealed Technology Advantage" in technologies for "Furniture and Games", a field with strong increase in technological opportunities.

Conclusions

The paper is the first comparative analysis of technology accumulation of the CEE economies and fUSSR area using priority patents. The advantage of using priority patents for regions like former socialist countries which by and large belong to middle- and lower-high income economies is that priority patents can proxy much better their overall technology effort. Foreign patents (like USPTO data) by inventors from these economies are only about world technology frontier activities of these economies which gives very partial picture given that the majority of their technology effort is about incremental technology improvements and behind the technology frontier activities.

The results that emerge from our analysis should be interpreted in the light of two key stylized facts from innovation and development literature (Freeman and Soete, 1997; Kornai, 2010, Fagerberg, Mowery and Nelson, 2005). First, technology accumulation represents the basis for the long-term productivity growth. In short and medium-term countries can grow based on non-technology factors but in the long-term they grow either based on imitation or technology accumulation at the world frontier (Aghion, Akcigit, and Peter Howitt, 2015). Second, technology accumulation is the country specific process and is the outcome of interaction of technology import and endogenous technology efforts. In a short and medium term countries can growth either on mere openness or being closed but being active in terms of endogenous technological efforts. However, catching-up requires coupling between import of technology and endogenous technological activities (Radosevic, 1999; Freeman, 2006).

Based on this perspective we focus on CEE but from a broad comparative angle. The overall picture that emerges is characterized by simultaneous persistence and path dependence of technology accumulation specialization patterns among world regions and by dramatic shifts among country groups in terms of catching up, falling behind and forging ahead.

First, there is dramatic falling behind of the CEE in between socialist period (1980-89) and the last decade (2000-2009). In per capita terms the cumulative patent intensity of CEE in the socialist period was clearly behind the UK and Germany but equal to or higher than the US and several times higher than the intensity of Korea and Taiwan. However, this picture has dramatically reversed during transition period of the 1990s as Korea and Taiwan not only caught up but forged ahead in terms of patent intensity. A very high patent intensity of the CEE in the socialist period shows the dominance of behind technology frontier technology efforts which on average have significantly declined afterwards as they have opened themselves to foreign technology inflows after 1990.

Second, during the post-socialist period the patent intensity of the CEECs (except Slovenia) has fallen further behind. So, economic recovery and catch-up during the 2000-09 period has not been followed by increasing patent intensity. This is corroborated by Kravtsova and Radosevic (2011) who show that increases of productivity in post-socialist countries are closely related to increases in production capability, not to technology intensity. A decline in incremental technology activities as proxied by priority patents was especially severe in fUSSR as these economies were more closed during the socialist period and thus suffered bigger transition shock[4].

However, there is also a visible recovery of technological activities in Russia as well as increased divergence among the CEECs. The former USSR (fUSSR) recovered

[4] See footnote 3

slightly at the end of the 1990s to reach a level above CEE. Russia has fully recovered in terms of domestic technological activities and our estimates suggest that its patent intensity is well above the CEE. CEE countries have either slowed down the accumulation of technological capabilities in the period 2000-2009 or have revived technological activities. Only Slovenia, Poland and the Czech Republic (together Estonia and Latvia) are triggering the accumulation of technological capabilities in the most recent period. The other CEE countries have very stagnant levels of patenting activities. A higher technology intensity of Russia in the recent period demonstrates the revival of incremental technology activities which are not at technology frontier but are the reflection of domestic led technology modernization. A persistent lack of recovery in priority patenting of CEE is the outcome of much bigger openness of these economies and intensive technology inflows through their very high FDI dependence.

In terms of technological specialization, the analysis based on RTA indicators and their changes between the periods of 1980-1989 and 2000-2009 points out a strong persistency in the specialization of world regions since 1980. This finding is not surprising if we consider the cumulative and path dependent nature of technological development. “Chemicals” and “Mechanical Engineering” are traditional sectors of specialization in Europe and Latin America. On the other hand, “Electrical Engineering” and “Instruments” are sectors of specialization in Asia Pacific, North America and Middle East (largely Israel). A weak shift in the specialization profiles can be observed in certain regions towards Chemicals (former USSR and Latin America). A “Continuous Advantage” in “Electrical Engineering” is clear in Asia Pacific. The specialization indicators for this region are recently very strongly and narrowly confined on “Telecommunication”, “Audio visual Technologies” and “Electrical machinery, apparatuses and Energy”.

In a nutshell, the specialization analysis points out at a global division of labor whereby EU and fUSSR together with Latin America are more specialized in "Chemicals" and "Mechanical engineering" (sectors losing technological dynamisms) while Pacific (North America and Asia Pacific) and Middle East (especially Israel) are triggering activities in the most dynamic sector ("Electrical Engineering"). These regions are hence broadening their technological capabilities and are increasing absorptive capacity in the more dynamic technological fields while Europe and fUSSR) are accumulating knowledge in, on average, less dynamic technological sectors. It is interesting that at the high level of aggregation (5 sectors) the technology knowledge specialization patterns of the former socialist world is quite close to the EU specialization pattern which again reiterates the historically rooted nature of technological trajectories. In that respect, the wider Europe share as its common feature strong specialization in much less dynamic areas ('Chemicals and 'Mechanical Engineering') and de-specialization in much more technology dynamic area of 'Electrical engineering'.

Technology specialization patterns of CEE remain strongly focused on “Chemicals”. The data indicate a recent diversification towards chemical fields with technological dynamism in areas such as “Pharmaceuticals”, “Biotechnology” and “Environmental Technology”. This indicates the ability of some of the CEECs to accumulate knowledge in the most dynamic of chemical fields. Several CEE countries (Croatia, Slovenia, Slovakia, Czech Republic and Romania) continue to exhibit continue technological advantage in “Mechanical Engineering”. However,given the stagnant developments in this sector the results are discouraging for the accumulation of technological capabilities. The same holds for the relatively weak engagement of all CEE countries in dynamic fields such as “Semiconductors”, “Audio-visual technology”, and “Telecommunication technologies”. Hungary, Estonia, and Latvia are the only CEE economies which have gained RTA in some fields of “Electrical Engineering”. Nonetheless, CEE countries are exceptionally focusing also in technological fields beyond the core sectors such as in the fields of “medical technologies” (in the sector “Instruments”) or in “furniture and games” (in the sector “Other fields”). Again, ”medical technologies”, “furniture and games” show a very dynamic trend in the technological landscape which confirms the potential of CEE to accumulate technological capabilities in fields with increasing technological opportunities.

CEE shares fully structural features of the technology specialization of the wider Europe i.e of the EU15 and fUSSR. This last conclusion raises the important policy issue: should Europe specialize in ‘Electrical engineering’ technology area where ICT producing sectors play prominent role? This issue is reflection of the prevailing view that the EU productivity weaknesses is structural in nature ie. it is concentrated in a narrow set of ICT producing industries (van Ark, O’Mahony and Timmer, 2008). In the light of our evidence on the persistence of patterns of technology accumulation and specialization it seems more appropriate to build on its strengths in chemicals and mechanical engineering areas by fusion with electrical engineering knowledge rather than try to change at large specialization pattern.

The analysis based on counts of priority filings complements existing evidence based on US patent statistics and confirms that CEE experienced a strong drop in the accumulation of technological capabilities after 1990. The recovery is unfolding very slowly. The paths of technological development do not differ greatly across CEE countries in terms of specialization so there is strong regional pattern which reflects historically rooted paths of technology accumulation of the wider Europe. In general terms, CEE countries are not accumulating technological capabilities in fields with technological opportunities. In a nutshell, technological activities focus on traditional technological fields which are comparatively stagnant. Specialization in dynamic technology fields beyond the core sectors “Chemicals” and “Mechanical Engineering” remain an exception.. The technological profile of the CEE region can make the technology upgrading process difficult. The challenge is to develop strategies to effectively utilize their acquired science and technology capabilities but also to embark into new technologically dynamic areas.

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Annex

Definition of world regions

CEE
Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Czechoslovakia, Yugoslavia.

EU15
Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK.

EU27
EU15, CEE (excluding Croatia, Czechoslovakia and Yugoslavia), Malta, Cyprus.

Former USSR (excluding EU members)
Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, Uzbekistan.

North America
Canada, USA.

Latin America
Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Columbia, Costa Rica, Cuba, Dominican Republic, Equador, EL Salvador, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Mexico, Nicaragua, Panama, Paraguay, Peru, Surinam, Trinidad & Tobago, Uruguay, Venezuela.

Asia Pacific
Australia, Bahamas, Brunei, China, Hong King, India, Indonesia, Japan, Laos, Macau, Malaysia, Micronesia, Mongolia, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Vietnam.

Middle East
Bahrain, Egypt, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, Turkey, United Arab Emirates, Yemen.