# Mapping Inventors' Networks to Trace Knowledge Flows Among EU Regions

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**Abstract**
Recent literature on technological changes has highlighted the role of knowledge recombination in innovation. Evidence suggests that the production of scientific and technological knowledge is becoming an increasingly collective phenomenon. Thus, in rapidly developing industries, it is almost inevitable to develop inter-organizational collaborations to identify new opportunities for new technologies. The aim of this chapter was to explore the innovative activities and networks in European regions (EU 27 plus Norway and Switzerland) from 1980 to 2010. Specifically, we analysed the most innovative sectors: environmental (green), biotechnology (biotech), laser and optic technology and nanotechnology (nanotech). This longitudinal study relies on European Patent Office (EPO) patents and inventors' data by year and region, as provided by OECD-Regpat database. Our main findings emphasize the rise of co-inventions in intra-regional and inter-regional inventive networks, the concentration of innovations in centralregions and peripheral regions' reliance on external knowledge flows tocompensate for their technological weaknesses.

## 1. Introduction[1]

Conventional theories on innovation have tried to explain the technological trajectory of firms stressing the discontinuities existing in the firm innovation process (D'Aveni, 1994; Tushmann and Anderson, 1986). As highlighted over the years by the Schumpeterian tradition, radical innovations emerge erratically by chance, when dynamic entrepreneurs, exploring new market opportunities, introduce "new combinations" moving the entire economic system far from equilibrium (Schumpeter, 1934, 1947). However, a great deal of technological change and product improvements consist of marginal and incremental innovations (Arrow, 1962; Freeman, 1994; Malerba, 1992). This was not acknowledged in the innovation literature during 1980s and 1990s, where the focus was prevalently on basic radical inventions and innovations (Clark et al., 1984, Jewkes et al., 1958). After the end of the 1970s the economic importance of marginal technical improvements for sustaining innovation in firms becomes largely acknowledged (Basalla, 1988; Dosi, 1982; Rosenberg, 1976; 1982). As argued by Mokyr (2000): "Much if not most creativity comes from the manipulation of what is already known, rather than in addition of totally new knowledge" (p. 18).

Often innovations are only fed by a continuous re-combination of flows of pre-existing knowledge, coming from different sectors or firms through cumulative learning processes, as Pavitt

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(1984, 1999) authoritatively showed. A critical aspect is how old and new knowledge is integrated by firms, and applied to new domains. Within the economic system there is an overwhelming amount of old knowledge that firms reuse and re-combine for new needs.

Old knowledge might be recombined to new uses in other domains, or the firms might acquire existing knowledge from outside to feed their internal innovation activities, along with an open innovation strategy (Asheim and Isaksen, 2002; Chesbrough, 2003a and b).

Generative collaborations within an innovative ecosystem or regional innovation system (Asheim et al., 2011) may enlarge the space of possibilities and identify new systems of use alongside the discovery of new functionalities and the recombination of new and old knowledge within a process of innovation cascades (Bonaccorsi, 2011; Lane 2011). The new literature about technological change has emphasized the role of knowledge recombination as one of the most important sources of technological novelty and invention (Weitzman, 1998; Strumsky et al., 2012 and 2012; Youn et al., 2014). Youn et al. (2014), for instance, showed that after a huge creation of new patent codes (indicating the introduction of novel technologies) occurred between 1800-1850, the subsequent pattern of inventions was mainly based on the recombination of existing codes, occupying a practically infinite space of technological configuration. Patents (Jaffe et al., 1993) are the main expression of this technology novelty and, in fact, new patents nowadays are typically associated with old existing technological codes.

As Fleming (2001) affirms, “the source of technological novelty and uncertainty lies within the combination of new components and new configurations of previously combined components” (pg. 130), while in the history of patent analysis there is a very limited role for the development of original technologies (Strumsky et al., 2012). In literature, there is considerable evidence that the production of scientific and technological knowledge is becoming more and more a collective phenomenon (Allen, 1983; Freeman, 1991; Gay et al., 2008). As Powell and Giannella (2010, p. 4) define collective invention as a “technological advance driven by knowledge sharing among a community of inventors who are often employed by organizations with competing intellectual property interests”. Collaborations enable organizations and regions to share, transfer, and assimilate knowledge by supporting knowledge creation and recombination process, reduce the costs of innovation, extent the depth and breadth of local knowledge base by facilitating the access to diversified knowledge, and foster externalities and knowledge spillover. This study investigates the extension of collaborative invention processes across time and geographical boundaries. Our first research question was to investigate in EU the relative decline of individual patents and the emergence of co-patenting activity (Hall et al, 2001; Fleming and Frenken, 2007).

Economic geography and regional science have an established tradition of studying the importance of geographical proximity for innovation and the formation of networks (Rallet and Torre, 1999; Boschma and Frenken, 2010; Cassi and Plunket, 2015). In the example of the collaboration networks of inventors in German biotechnology, Ter Wal (2013) has demonstrated that the role of geographic distance as mechanisms of tie formation and network evolution shifts over time as the technological regime of the industry changes. Several studies have stressed the spatial dependence of invention process and the critical role of spatial proximity even though other forms of proximity (such as cognitive, cultural, organizational, and institutional) have been recognized as important (Marrocu et al., 2013). However, collaborations over long-distance remain a critical driver for accelerating knowledge creation (Wilhelmsson, 2009). Our second research question explores the innovation performance of inventors considering their scalar geographical localization (intra-regional, inter-regional, extra-EU). In this light, our analysis confirms the patenting distribution across European regions within a strong innovative area, commonly named "blue banana" (Foddi and Usai, 2013).

Our third research question explores the inter-regional collaboration in EU lagging-behind regions, which is expected to balance the local lack of resources and structures for innovation. The need for co-invention opportunities drives the consideration of a higher collaboration propensity of peripheral regions.

Finally, in rapidly developing industries, the development of collaboration strategies to identify new opportunities and learn about new technology (Powell, 1998) is almost inevitable. In this study, the increasing relevance of innovative industries such as bio, nano, green, laser and optical technologies is analyzed.

## 2. Methodology

This study explores the innovation activity and innovation networks in European regions (EU28 plus Norway and Switzerland), considering the period from 1980 to 2010. The study is based on data about EPO patents and inventors per year and region as provided by *OECD-Regpat database* (release version February 2015). EPO patents are all patents granted by the European Patent Office (EPO). Priority year is used to define a thirty years range from 1980 to 2010. Firstly, a general cleaning process is applied to make the dataset effective. Patent data concerning "not classified" regions are also deleted. Since the same *patent id* is replicated in the database on multiple lines in relation to the number of involved inventors and the number of regions to which each inventor is assigned. Inventor's share (*Inv_share*) is measured as the share the inventor is involved into the patent creation, whilst regional share ($Reg\_share$) is defined as based on the number of regions where the inventor is registered[2]. Therefore, the number of patents per region is operationalized as a fractionalized counting based on the sum of inventors' shares weighted for regional share ($\sum Reg\_share * Inv\_share$).

The final dataset involves 284 European regions which are defined by using the NUTS2 classification at EU28 countries (plus Switzerland and Norway) level and 2,493,658 EPO patents. However, since this study focuses on knowledge flows across European regions by exploring the inventors network and EPO patents may involve no European inventors, EU patents are identified as the EPO patents involving at least one European inventor. The EU patents dataset is reduced to 1,228,481 EU patents.

In addition, a further classification is taken out in order to make a distinction between individual patents (which involve a unique inventor) and co-invented patents (which involve more than one inventor). Then, co-invented patents are classified as intra-region (the patent involves more inventors belonging the same European region), inter-regions (the patent involves more inventors belonging to different European region) and with extra- European regions (the patent involves more inventors and some of them belonging to extra- European regions). The last group specifically focuses on inventors from developed countries (such as US, Canada and Japan), and from emerging countries (such as BRICS) and other countries.

Below, data are organized for exploring the transformation path of the European regions over time by depicting the trend, the technological specialization, the role of collaborative innovations and the interregional flows of knowledge focusing on inventor networks. In addition, based on technological classes defined by International Patent Classification (IPC), we study the innovation process focusing on the investigation of the pattern of geographical localization of some new industries such as bio, nano, green, laser and optical technologies.

The relationship between patents and sectors relies on the international patent classification (IPC) mapped as provided by the Van Looy et al. (2014). We focus on the Statistical Classification of Economic Activities in the European Community (NACE) at 2-digit level (Eurostat, 2014). IPC v.8 - NACE rev.2 concordance table (see Table 2 in Appendix A) allows to associate the patents to 26 different sectors (i.e., the patent with a NACE corresponding to C08B is associate to the Manufacture of Chemicals and Chemical Product sector, sector 20).

[2] *Reg_share* is less than 1in the case of multiple registration or when the system is unable to uniquely assign the inventor at one region. *Inv_share* is less than 1 when patent is co-invented.

The large number of patents existing in our database are within the “high” and “medium-high” tech group (respectively, from 1980 to 2010, we found 1,061,319 and 1,350,486 patents). This suggests, as expected, that patenting process involves mainly the most high-tech sectors. “Medium-low” and “low technology” group involve respectively 274,286 and 370,280 patents.

Furthermore, the patents related to innovative industries such as biotechnology, nanotechnology, green and laser-optical are listed using a standardized IPC classification (Table 3 in Appendix A). Specifically, the IPC classes of biotechnology patents are provided in the Annex 6 of Eurostat indicators (Eurostat, 2007), whereas the classes of Green patents rely on by the WIPO database. Differently, the Nanotechnology and the Laser-Optics patents are aggregated on the basis of Eurostat (2014).

The largest group is Green technology (151,947), followed by biotechnology with 126,100 patents and Laser-Optics involving 77,847 patents. The smallest is Nano technology group (4,663 patents). The overlapping across these industries is very limited (lower than 10%) with the exception of the overlapping between bio and green technology (about 20%).

## 3. **A persistent European flow of innovations**

The macro European region has been characterized by a long structural period of social expansion and economic growth. Also patenting activity, related to the European inventive capability and specifically measured by referring to EU patents, followed the same trend. Similarly to overall European trend of economic development, the yearly distribution of patents (Figure 1) shows a smoothing and slowing growth of innovation productivity since 2007.

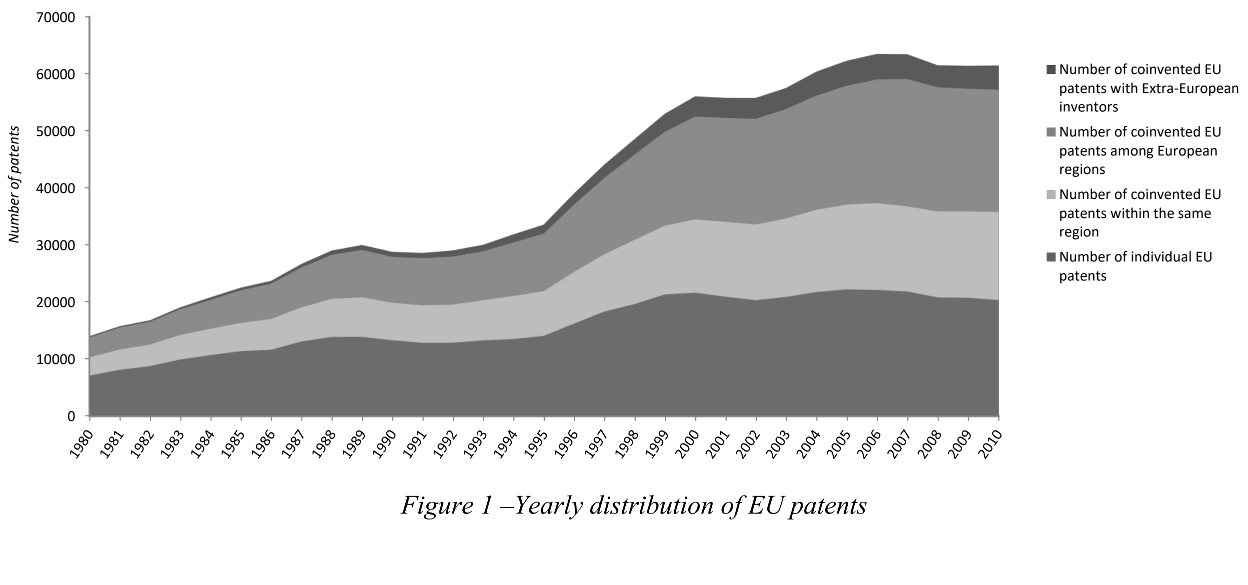



*Figure 1 –Yearly distribution of EU patents*

Figure 1 also shows the trend of individual and co-invented patents. The latter are further partitioned in co-invented patent involving only inventors of the same region (intra-regional networks), involving also inventors from other regions (inter-regional networks) and involving extra-European inventors (global networks). The trend suggests the propensity to co-patents is strongly growing compared to individual patents since the second half of 90's. Conversely, the number of individual patents is slowly decreasing since 2000. Interesting to observe, the share of individual patent in 30 years has diminished from 50% to 40%, while the share of co-invented patents among the EU regions has increased from 23% to about 30%. Moreover, the inter-regional collaboration increases faster than intra-regional one.

The inventive activity in EU has been growing very fast in the last decades (Figure 1): from an average number of 13,000-15,000 patents issued yearly in the first period of the 1980s, to the 29,000-30,000 of the 1990s, to the 50,000-52,000 of the 2000s up to the 60,000 of the last years of the decade (2008-2010).

The cumulative distribution in 30-year window of time makes more evident the previous findings (Figure 2).

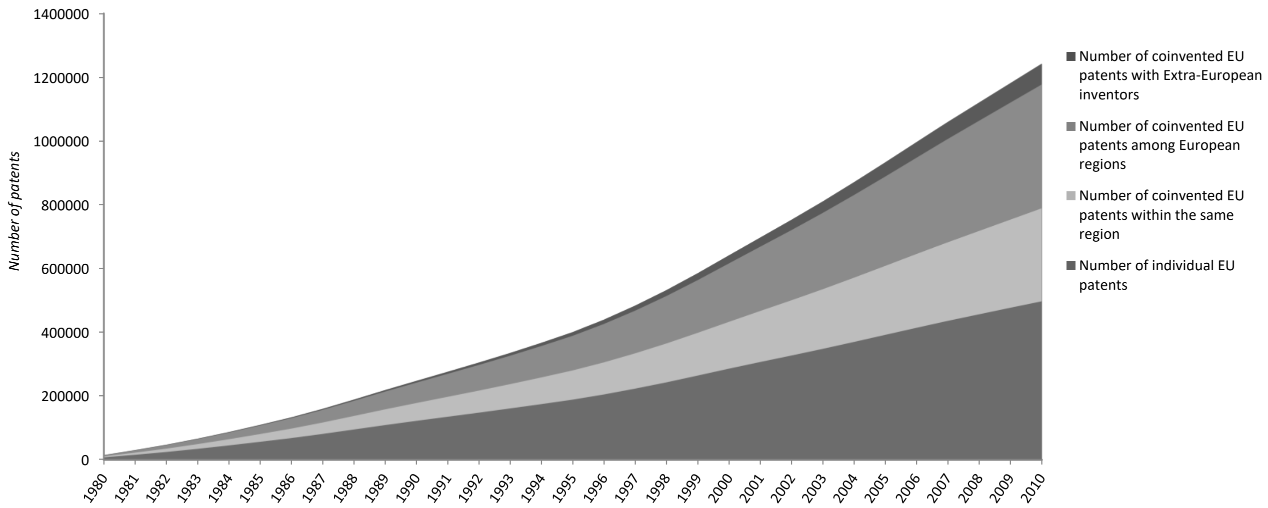



*Figure 2 –Cumulative distribution of EU patents*

Similarly, the longitudinal analysis highlights the increasing relevance of extra-European inventors above all since 1995. Specifically, more detailed data (Figure 3) highlight most of the extra-European collaborations involves inventors from USA, Canada and Japan. However, since 1995, the relevance of developed countries is decreasing as compared to the growing role of inventors from BRICS. The latter are increased from a percentage close to 0% until less than 10%.

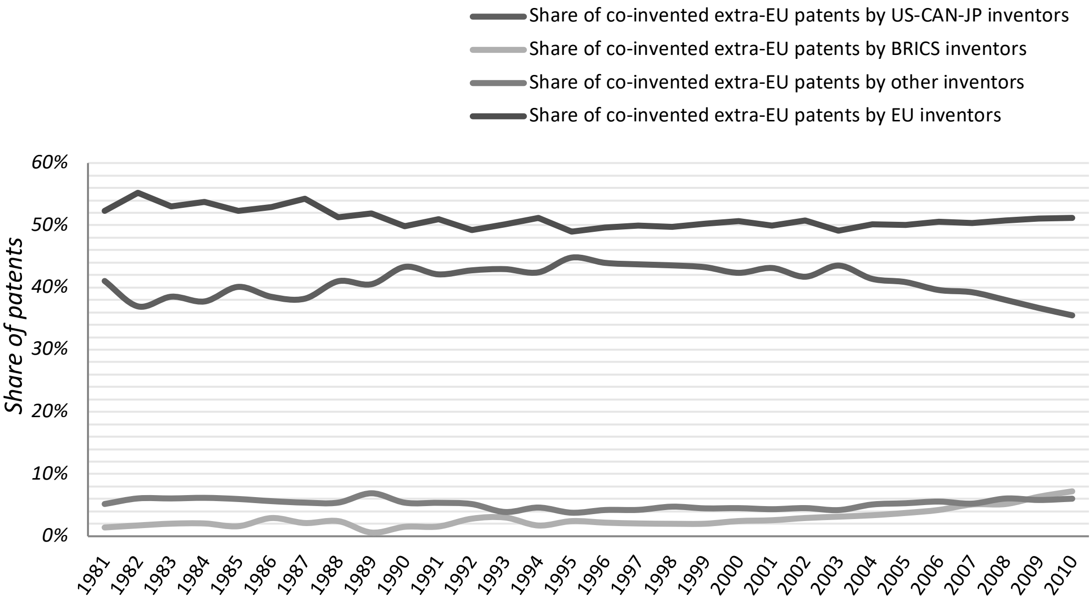



*Figure 3 –Yearly share of patents involving Extra- European inventors*

About 35-40% of the co-invented patents with extra-European regions (Figure 3) are related to inventors localized in advanced countries (US, Canada, and Japan), and this share has been quite stable for all years of the period, while we observe a systematic growth of patenting activity deriving from BRICS, whose importance has reached, in the last years (2006-2010), the level of patenting of all others non-EU countries.

During the entire period considered by our analysis, the EPO data based has registered 2,516,942 patents of which about half, 1,242,457 were involving at least one European inventors (this category will be here defined as EU patents). If we shift our analysis to the number of inventors (Tab. 3), we see that the number of inventors of the EPO patents is about 4,5 million, but the number of inventors related to EU patents is only about 2 million (1,921,002 units). EPO patents in Europe have a slightly larger number of inventors (Tab. 4) than EU patents in all years considered, and also on average 1.82 vs. 1.55. This could be interpreted as a higher technological complexity of "foreign" patent weighted on "European" patents with at least one European inventor. This is corroborated from the fact that the share of EPO collective patent on total patent is also higher than the share of EU patent on total patent (64.91 vs. 60.01), which signal, again, a higher level of complexity. Tab 5 allow us to explore better the geographical dimension of collective inventions in Europe. Considering the total collective patents (680,517), the number of patents that have been invented by a network of inventors localized in more than one European regions are the majority (388,557), while patents with a more local dimension, where the network of inventors is concentrated in one individual unit or among different units or organization located in the same region are less numerous (291,960), corresponding to a percentage of 42.9%. In relation with this category, our data base does not allow us to distinguish regional innovation networks from internal-to-the-firm networks, because we elaborate data on the basis of inventors' addresses. However, these data show the significant amount of large regional and extra-regional knowledge flows.

In Table 1 the total weighted number and growth rate of EPO patents are shown considering three 10-year windows of time (1980-1990, 1990-2000 and 2000-2010) and the cumulated number from 1980 to 2010. Similarly, Table 1 also summarizes the weighted number and growth rate of EU patents, as previously classified.

*Tab. 1 - Cumulative statistics and growth rate of EPO and EU patents from 1980 to 2010*

| *Variables* | *CumPat 1980-1990* | *CumPat 1990-2000* | *CumPat 2000-2010* | *CumPat 1980-2010* | *GrwRate 80-90/00-10* | *GrwRate 90-00/00-10* |
|---|---|---|---|---|---|---|
| **EPO patents** | **443818** | **798545** | **1251295** | **2493658** | **1,819** | **0,567** |
| Number of individual EPO patent | 192156 | 286557 | 393153 | 871866 | 1,046 | 0,372 |
| *%* | *43,30%* | *35,88%* | *31,42%* | *34,96%* | - | - |
| Number of co-invented EPO patents | 251662 | 511988 | 858142 | 1621792 | 2,410 | 0,676 |
| *%* | *56,70%* | *64,12%* | *68,58%* | *65,04%* | - | - |
| **EU patents** [(1)] | **232780** | **393293** | **602408** | **1228481** | **1,588** | **0,532** |
| Number of individual EU patents | 114514 | 163502 | 211745 | 489761 | 0,849 | 0,295 |
| *%* | *49,19%* | *41,57%* | *35,15%* | *39,87%* | - | - |
| Number of co-invented EU patents | 118266 | 229791 | 390663 | 738720 | 2,303 | 0,700 |
| *%* | *50,81%* | *58,43%* | *64,85%* | *60,13%* | - | - |
| **Co-invented EU patents** | **118266** | **229791** | **390663** | **738720** | **2,303** | **0,700** |
| within the same region | 52755 | 90871 | 145144 | 288770 | 1,751 | 0,597 |
| *%* | *46,63%* | *43,23%* | *41,41%* | *42,85%* | - | - |
| among European regions | 60384 | 119319 | 205360 | 385063 | 2,401 | 0,721 |
| *%* | *53,37%* | *56,77%* | *58,59%* | *57,15%* | - | - |
| involving Extra-European inventors | 5127 | 19601 | 40159 | 64887 | 6,833 | 1,049 |
| *%* | *4,34%* | *8,53%* | *10,28%* | *8,78%* | - | - |
| **Co-invention with Extra-European inventors** [(2)] | **5127** | **19601** | **40159** | **64887** | **6,833** | **1,049** |
| Share of US-CA-JP inventors | 2054 | 8472 | 16010 | 26536 | 6,795 | 0,890 |
| *%* | *40,06%* | *43,22%* | *39,87%* | *40,90%* | - | - |
| Share of BRICS inventors | 92 | 433 | 1784 | 2309 | 18,391 | 3,120 |
| *%* | *1,79%* | *2,21%* | *4,44%* | *3,56%* | - | - |
| Share of other Extra-European inventors | 300 | 877 | 2112 | 3289 | 6,040 | 1,408 |
| *%* | *5,85%* | *4,47%* | *5,26%* | *5,07%* | - | - |
| Share of European inventors | 2680 | 9820 | 20250 | 32750 | 6,556 | 1,062 |
| *%* | *52,27%* | *50,10%* | *50,42%* | *50,47%* | - | - |

*[(1)] EU patent is EPO patent involving at least an European inventor*

*[(2)] Since the same patent may involve both US, CAN, JP, BRICS and other inventors, the sum of inventors' share is shown for each cluster of inventors in order to not replicate the patent more times.*

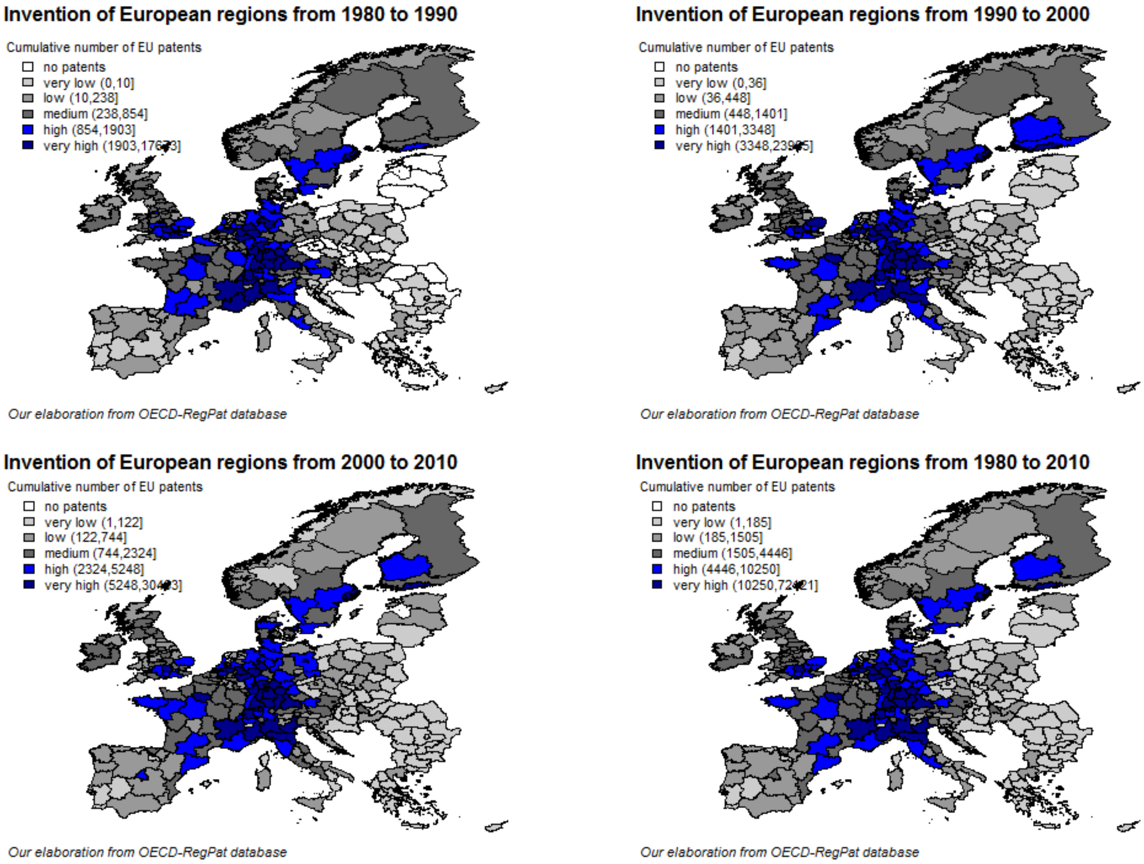
Finally, considering the total inventors' productivity is measured as the average number of EPO and EU patents per inventor, there is to note that in all period considered, the average number of inventors of EPO patents is 1,828, thus higher than the average number of EU patents (1,592), showing a signal of a superior complexity existing in foreign patents protecting IPR in Europe. The complexity of innovation is also growing systematically with the time in both samples.

## 4. The geography of invention in EU

An important aspect referred to the analysis of inventors networks is their geographical localization. We have analyzed the EPO data base for European Regions at the level of NUT2 for the 28 EU countries, adding Switzerland and Norway, thus considering 30 countries and 284 regions. In Figure 4a, innovation intensity per region *r* and year *y* is measured based on EU patents by operationalizing the sum of inventor shares weighted for regional shares, relative to each patent *i*, aggregated according the inventors' region of localization and the patents' priority year. Looking at the figure, it is confirmed that Germany reasserts its economic and technological position, emerging as the innovative heart of Europe.

The Patent intensity by region indicator shows the existence of a highly concentrated core of innovative regions in EU, along the well-known and very much discussed old "blue banana", which starts in Finland and Sweden, descending along Germany, Switzerland, south east of France, and North of Italy, stopping with Rome (in the Lazio region). During the 30 years considered, absolute growth in international inventive activity involves a selected number of regions of the "blue banana" and the sun belt of north of Italy and South of France.

*Fig. 4a - Patent intensity by region based on the cumulative number*

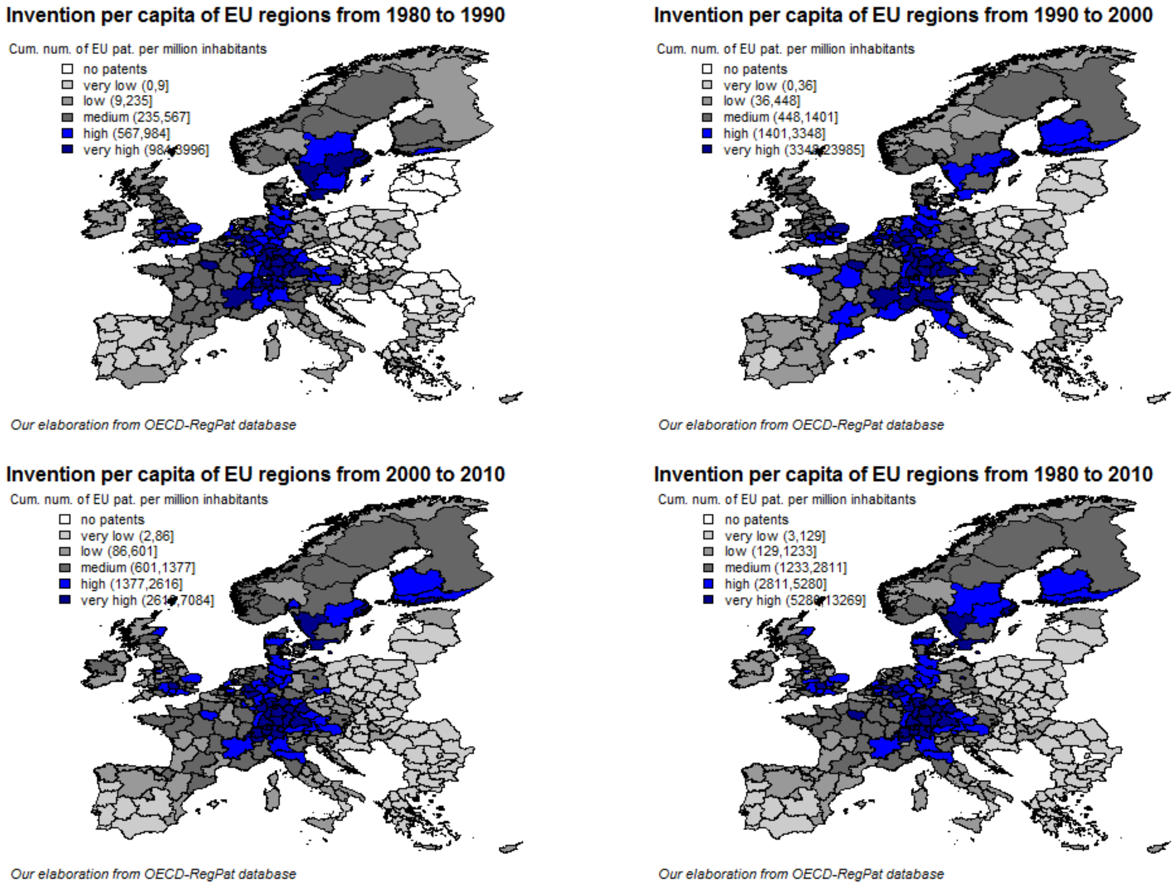



*Note: Invention of European regions is based on EU patents involving at least a European inventor. Breaks in the legend correspond to percentile 0th, 25th, 50th, 75th, 90th and 100th.*

In addition, in Europe, three blue spots are emerging: a) the regions of South of England; b) some central regions of France (based around Paris and, in the last period, the area which connects Paris to the Bretagne), and, finally, c) the areas belonging to south of France (Provence, Rhone-Alps, Midi Pyrenees which includes Toulouse) and Catalonia (centered to Barcelona). The blue core of European regions is surrounded by a strong grey area with adjacent regions. Spain, South of Italy, extreme north of England, Greece and Eastern countries exhibit, in general, a much lower level of innovativeness.

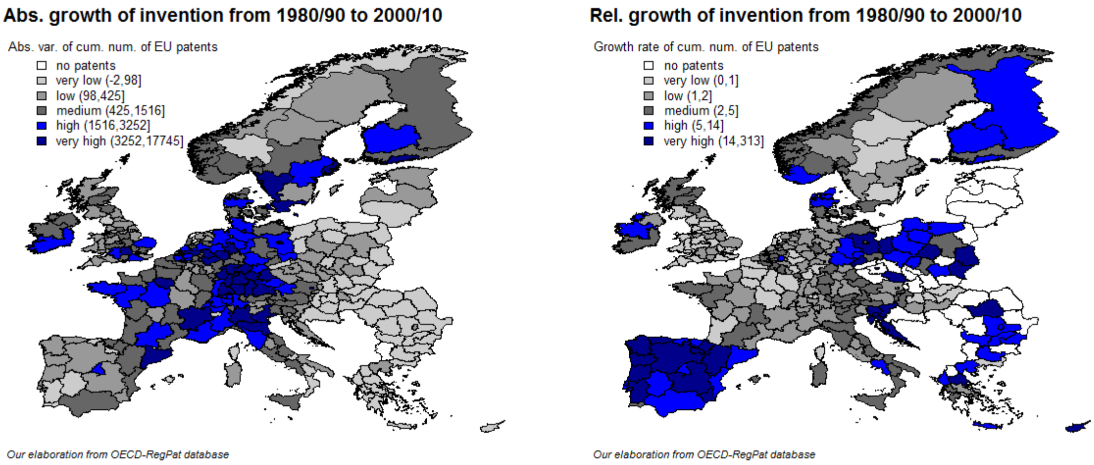
Weighting the number of patents for capita we obtain an even more restrict area of innovative "core" regions, where, for instance, the very populated regions of Provence, Piedmont, Tuscany, Veneto, and Lazio loose the position of high innovation intensity regions, together with Midi Pyrenees, and Catalonia.

*Fig. 4b - Patent intensity per capita by region based on the cumulative number*




*Note: Invention of European regions is based on EU patents involving at least a European inventor. Breaks in the legend correspond to percentile 0th, 25th, 50th, 75th, 90th and 100th.*

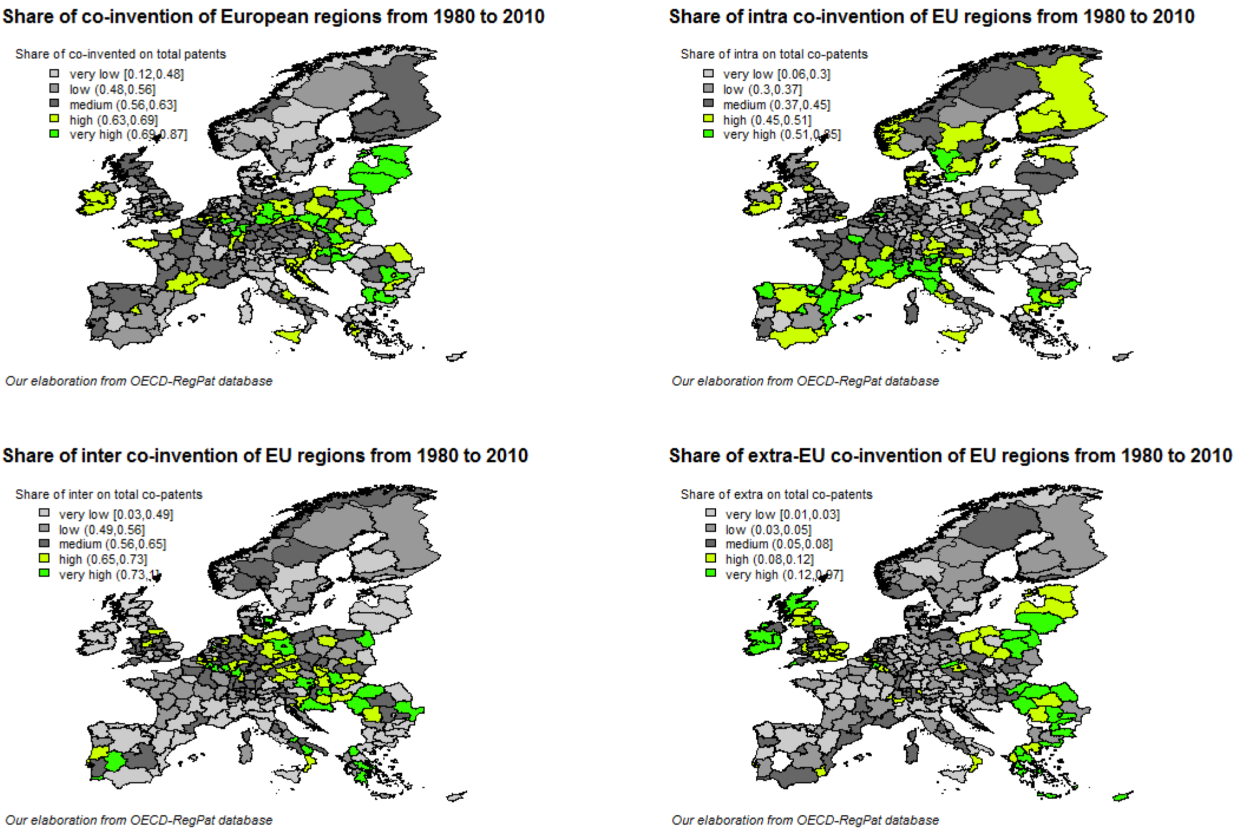
*Fig. 5 – Variation of patent intensity by region over 30-year window of time*




In terms of variation of patent intensity by region two measures can help us to detach the phenomenon: the absolute and relative variation. The highest shares of absolute variations occur among the most innovative regions of the "blue banana" and the areas already identified, while, clearly higher relative growth rates are significant among some weakest European regions, of all Spain, Ireland, Finland, Campania, Denmark and Poland.

The co-invention of patents, in absolute terms, is similar to patenting distribution (Figure 4 a), and for these reasons the figures are not reported here. Co-inventions within regions appears to be a very geographically diffused typology, involving with a high intensity the northern countries of Norway and Finland, South of England, Germany, some regions of the former East Europe, North of Italy and a large number of regions of France. These types of collective innovations are clearly benefiting from the advantages of proximity, where actors can recombine close and complementary knowledge.

*Fig. 6 – Share of co-invention on total invention and share of intra-regional, interregional, and extra-European co-invention on total co-invention*




*Note: Co-invention of European regions is based on EU patents involving more than a unique inventor. Intra regional co-invention of European regions is based on EU patents involving more than a unique inventor and they are from the same region. Inter regional co-invention of European regions is based on EU patents involving more than a unique inventor and they are from the different European regions. Extra-European co-invention of European regions is based on EU patents involving more than a unique inventor and some of them are from extra-European regions. Breaks in the legend correspond to percentile 0th, 25th, 50th, 75th, 90th and 100th.*

Figure 6 is weighting the percentage of co-inventions on the total number of patents granted. It is interesting to observe that a very different picture of European regions emerges: peripheral regions of EU, where patenting activity is more weaker, are those where relatively higher is the intensity of co-invented patents measured on total patents.

We can thus, hypothesize, that weak innovative peripheral regions, being characterized by a low number of inventors, have to recur to a more intense use of collective inventions, as a modality that allows those organizations placed within unfavorable areas, to better release new knowledge exploitation and exploration.

The first picture on the right shows the share of co-inventions in relation to interregional flows. Higher shares of co-invented patents on total patents are characterizing *in primis* the regions belonging to the North Italy, South of France and North of Spain, where this phenomenon is probably connected with the significant presence of clusters and industrial districts. The modality of high interregional innovative activity on total patent characterizes, in contrast, several regions of Eastern Europe, South of Italy and South of Spain. Co-inventions here is probably correlated to the presence of numerous cooperative EU projects. Higher number of co-invented patents on total registered patents involving extra EU-regions, are visible at the extreme periphery of Eastern EU and in Scotland and Ireland. Those areas are characterized by MNEs localizations.

## 4. The innovative sectors

In this section we will analyze the European inventing activity considering the most innovative sectors created by the recent development of new technologies such as: the green-environmental innovations, the biotech advancements, the laser & optics new technologies, and nano-tech new materials. These four sectors (Tabs. 5-8) cover about 160.000 patents of which 65-83% of them are belonging to the category of co-invented patents.

The biggest area here identified is that one of green technologies (with about 70,000 patents), on which Europe is probably the more advanced regional area in the global economy, thanks to the strict regulations adopted at political level and the firm environmental practices developed that have pulled innovation in science and technology, both in firms and in the European research centers and universities. 60% of EU patents are co-invented patents.

*Tab. 5 - Cumulative statistics and growth rate of Bio-Tech EPO and EU patents from 1980 to 2010*

| *Variables* | *CumPat 1980-1990* | *CumPat 1990-2000* | *CumPat 2000-2010* | *CumPat 1980-2010* | *GrwRate 80-90/00-10* | *GrwRate 90-00/00-10* |
|---|---|---|---|---|---|---|
| **EPO patents** | **19545** | **50548** | **56007** | **126100** | **1.866** | **0.108** |

| | | | | | | |
|---|---|---|---|---|---|---|
| Number of individual EPO patent | 3970 | 8084 | 8347 | 20401 | 1.103 | 0.033 |
| % | *20.31%* | *15.99%* | *14.90%* | *16.18%* | - | - |
| Number of co-invented EPO patents | 15575 | 42464 | 47660 | 105699 | 2.060 | 0.122 |
| % | *79.69%* | *84.01%* | *85.10%* | *83.82%* | - | - |
| **EU patents** (1) | **7061** | **18473** | **20885** | **46419** | **1.958** | **0.131** |
| Number of individual EU patents | 1357 | 2652 | 2677 | 6686 | 0.973 | 0.009 |
| % | *19.22%* | *14.36%* | *12.82%* | *14.40%* | - | - |
| Number of co-invented EU patents | 5704 | 15821 | 18208 | 39733 | 2.192 | 0.151 |
| % | *80.78%* | *85.64%* | *87.18%* | *85.60%* | - | - |
| **Co-invented EU patents** | **5704** | **15821** | **18208** | **39733** | **2.192** | **0.151** |
| within the same region | 2002 | 4675 | 5518 | 12195 | 1.756 | 0.180 |
| % | *40.29%* | *36.98%* | *37.23%* | *37.60%* | - | - |
| among European regions | 2967 | 7968 | 9303 | 20238 | 2.135 | 0.168 |
| % | *59.71%* | *63.02%* | *62.77%* | *62.40%* | - | - |
| involving Extra-European inventors | 735 | 3178 | 3387 | 7300 | 3.608 | 0.066 |
| % | *12.89%* | *20.09%* | *18.60%* | *18.37%* | - | - |
| **Co-invention with Extra-Eurpean inventors** (2) | **735** | **3178** | **3387** | **7300** | **3.608** | **0.066** |
| Share of US-CA-JP inventors | 298 | 1455 | 1426 | 3179 | 3.785 | -0.020 |
| % | *40.54%* | *45.78%* | *42.10%* | *43.55%* | - | - |
| Share of BRICS inventors | 15 | 46 | 82 | 143 | 4.467 | 0.783 |
| % | *2.04%* | *1.45%* | *2.42%* | *1.96%* | - | - |
| Share of other Extra-European inventors | 47 | 175 | 201 | 423 | 3.277 | 0.149 |
| % | *6.39%* | *5.51%* | *5.93%* | *5.79%* | - | - |
| Share of European inventors | 375 | 1501 | 1679 | 3555 | 3.477 | 0.119 |
| % | *51.02%* | *47.23%* | *49.57%* | *48.70%* | - | - |

*(1) EU patent is EPO patent involving at least an European inventor*

*(2) The whole is less than the sum of the parts because of EU co-patents with Extra-European inventors may involve both US, CAN, JP, BRICS and other inventors*

*Tab. 6- Cumulative statistics and growth rate of Green-Tech EPO and EU patents from 1980 to 2010*

| *Variables* | *CumPat 1980-1990* | *CumPat 1990-2000* | *CumPat 2000-2010* | *CumPat 1980-2010* | *GrwRate 80-90/00-10* | *GrwRate 90-00/00-10* |
|---|---|---|---|---|---|---|
| **EPO patents** | **26816** | **55215** | **69916** | **151947** | **1.607** | **0.266** |
| Number of individual EPO patent | 11088 | 17242 | 22351 | 50681 | 1.016 | 0.296 |
| % | *41.35%* | *31.23%* | *31.97%* | *33.35%* | - | - |
| Number of co-invented EPO patents | 15728 | 37973 | 47565 | 101266 | 2.024 | 0.253 |
| % | *58.65%* | *68.77%* | *68.03%* | *66.65%* | - | - |
| **EU patents** (1) | **13838** | **25241** | **31494** | **70573** | **1.276** | **0.248** |
| Number of individual EU patents | 6415 | 9468 | 11915 | 27798 | 0.857 | 0.258 |
| % | *46.36%* | *37.51%* | *37.83%* | *39.39%* | - | - |
| Number of co-invented EU patents | 7423 | 15773 | 19579 | 42775 | 1.638 | 0.241 |
| % | *53.64%* | *62.49%* | *62.17%* | *60.61%* | - | - |
| **Co-invented EU patents** | **7423** | **15773** | **19579** | **42775** | **1.638** | **0.241** |
| within the same region | 3042 | 5462 | 6906 | 15410 | 1.270 | 0.264 |
| % | *43.81%* | *39.60%* | *39.32%* | *40.23%* | - | - |
| among European regions | 3901 | 8332 | 10659 | 22892 | 1.732 | 0.279 |
| % | *56.19%* | *60.40%* | *60.68%* | *59.77%* | - | - |
| involving Extra-European inventors | 480 | 1979 | 2014 | 4473 | 3.196 | 0.018 |
| % | *6.47%* | *12.55%* | *10.29%* | *10.46%* | - | - |
| **Co-invention with Extra-European inventors** (2) | **480** | **1979** | **2014** | **4473** | **3.196** | **0.018** |
| Share of US-CA-JP inventors | 198 | 896 | 797 | 1891 | 3.025 | -0.110 |
| % | *41.25%* | *45.28%* | *39.57%* | *42.28%* | - | - |
| Share of BRICS inventors | 5 | 38 | 81 | 124 | 15.200 | 1.132 |
| % | *1.04%* | *1.92%* | *4.02%* | *2.77%* | - | - |
| Share of other Extra-European inventors | 29 | 104 | 147 | 280 | 4.069 | 0.413 |
| % | *6.04%* | *5.26%* | *7.30%* | *6.26%* | - | - |
| Share of European inventors | 247 | 941 | 987 | 2175 | 2.996 | 0.049 |

| | | | | | | |
|---|---|---|---|---|---|---|
| % | 51.46% | 47.55% | 49.01% | 48.63% | - | - |

[(1)] *EU patent is EPO patent involving at least an European inventor*

[(2)] *The whole is less than the sum of the parts because of EU co-patents with Extra-European inventors may involve both US, CAN, JP, BRICS and other inventors*

*Tab. 7 - Cumulative statistics and growth rate of Nano-Tech EPO and EU patents from 1980 to 2010*

| *Variables* | *CumPat 1980-1990* | *CumPat 1990-2000* | *CumPat 2000-2010* | *CumPat 1980-2010* | *GrwRate 80-90/00-10* | *GrwRate 90-00/00-10* |
|---|---|---|---|---|---|---|
| **EPO patents** | **66** | **1313** | **3284** | **4663** | **48.758** | **1.501** |
| Number of individual EPO patent | 20 | 269 | 631 | 920 | 30.550 | 1.346 |
| % | *30.30%* | *20.49%* | *19.21%* | *19.73%* | - | - |
| Number of co-invented EPO patents | 46 | 1044 | 2653 | 3743 | 56.674 | 1.541 |
| % | *30.30%* | *20.49%* | *19.21%* | *19.73%* | - | - |
| **EU patents** [(1)] | **24** | **422** | **1077** | **1523** | **43.875** | **1.552** |
| Number of individual EU patents | 5 | 81 | 173 | 259 | 33.600 | 1.136 |
| % | *20.83%* | *19.19%* | *16.06%* | *17.01%* | - | - |
| Number of co-invented EU patents | 19 | 341 | 904 | 1264 | 46.579 | 1.651 |
| % | *79.17%* | *80.81%* | *83.94%* | *82.99%* | - | - |
| **Co-invented EU patents** | **19** | **341** | **904** | **1264** | **46.579** | **1.651** |
| within the same region | 7 | 114 | 322 | 443 | 45.000 | 1.825 |
| % | *43.75%* | *39.45%* | *41.60%* | *41.06%* | - | - |
| among European regions | 9 | 175 | 452 | 636 | 49.222 | 1.583 |
| % | *56.25%* | *60.55%* | *58.40%* | *58.94%* | - | - |
| involving Extra-European inventors | 3 | 52 | 130 | 185 | 42.333 | 1.500 |
| % | *15.79%* | *15.25%* | *14.38%* | *14.64%* | - | - |
| **Co-invention with Extra-European inventors** [(2)] | **3** | **52** | **130** | **185** | **42.333** | **1.500** |
| Share of US-CA-JP inventors | 1 | 22 | 57 | 80 | 56.000 | 1.591 |
| % | *33.33%* | *42.31%* | *43.85%* | *43.24%* | - | - |
| Share of BRICS inventors | 0 | 1 | 4 | 5 | - | 3.000 |
| % | *0.00%* | *1.92%* | *3.08%* | *2.70%* | - | - |
| Share of other Extra-European inventors | 0 | 3 | 9 | 12 | - | 2.000 |
| % | *0.00%* | *5.77%* | *6.92%* | *6.49%* | - | - |
| Share of European inventors | 2 | 27 | 62 | 91 | 30.000 | 1.296 |
| % | *66.67%* | *51.92%* | *47.69%* | *49.19%* | - | - |

[(1)] *EU patent is EPO patent involving at least an European inventor*

[(2)] *The whole is less than the sum of the parts because of EU co-patents with Extra-European inventors may involve both US, CAN, JP, BRICS and other inventors*

*Tab. 8 Cumulative statistics and growth rate of Optics&Laser-Tech EPO and EU patents from 1980 to 2010*

| *Variables* | *CumPat 1980-1990* | *CumPat 1990-2000* | *CumPat 2000-2010* | *CumPat 1980-2010* | *GrwRate 80-90/00-10* | *GrwRate 90-00/00-10* |
|---|---|---|---|---|---|---|
| **EPO patents** | **16768** | **30010** | **31069** | **77847** | **0.853** | **0.035** |
| Number of individual EPO patent | 6265 | 9427 | 9379 | 25071 | 0.497 | -0.005 |
| % | *37.36%* | *31.41%* | *30.19%* | *32.21%* | - | - |
| Number of co-invented EPO patents | 10503 | 20583 | 21690 | 52776 | 1.065 | 0.054 |
| % | *62.64%* | *68.59%* | *69.81%* | *67.79%* | - | - |
| **EU patents** [(1)] | **6419** | **9768** | **10138** | **26325** | **0.579** | **0.038** |
| Number of individual EU patents | 2688 | 3374 | 3024 | 9086 | 0.125 | -0.104 |
| % | *41.88%* | *34.54%* | *29.83%* | *34.51%* | - | - |
| Number of co-invented EU patents | 3731 | 6394 | 7114 | 17239 | 0.907 | 0.113 |
| % | *58.12%* | *65.46%* | *70.17%* | *65.49%* | - | - |
| **Co-invented EU patents** | **3731** | **6394** | **7114** | **17239** | **0.907** | **0.113** |
| within the same region | 1760 | 2752 | 2949 | 7461 | 0.676 | 0.072 |
| % | *48.94%* | *47.46%* | *45.75%* | *47.10%* | - | - |
| among European regions | 1836 | 3047 | 3497 | 8380 | 0.905 | 0.148 |
| % | *51.06%* | *52.54%* | *54.25%* | *52.90%* | - | - |

| | | | | | | |
|---|---|---|---|---|---|---|
| involving Extra-European inventors | 135 | 595 | 668 | 1398 | 3.948 | 0.123 |
| *%* | *3.62%* | *9.31%* | *9.39%* | *8.11%* | - | - |
| **Co-invention with Extra-European inventors** [(2)] | **135** | **595** | **668** | **1398** | **3.948** | **0.123** |
| Share of US-CA-JP inventors | 59 | 271 | 271 | 601 | 3.593 | 0.000 |
| *%* | *43.70%* | *45.55%* | *40.57%* | *42.99%* | - | - |
| Share of BRICS inventors | 2 | 17 | 24 | 43 | 11.000 | 0.412 |
| *%* | *1.48%* | *2.86%* | *3.59%* | *3.08%* | - | - |
| Share of other Extra-European inventors | 6 | 20 | 35 | 61 | 4.833 | 0.750 |
| *%* | *4.44%* | *3.36%* | *5.24%* | *4.36%* | - | - |
| Share of European inventors | 69 | 287 | 337 | 693 | 3.884 | 0.174 |
| *%* | *51.11%* | *48.24%* | *50.45%* | *49.57%* | - | - |

*(1) EU patent is EPO patent involving at least an European inventor*
*(2) The whole is less than the sum of the parts because of EU co-patents with Extra-European inventors may involve both US, CAN, JP, BRICS and other inventors*

The innovative efforts have characterized both the 1990s and even more the 2000s.

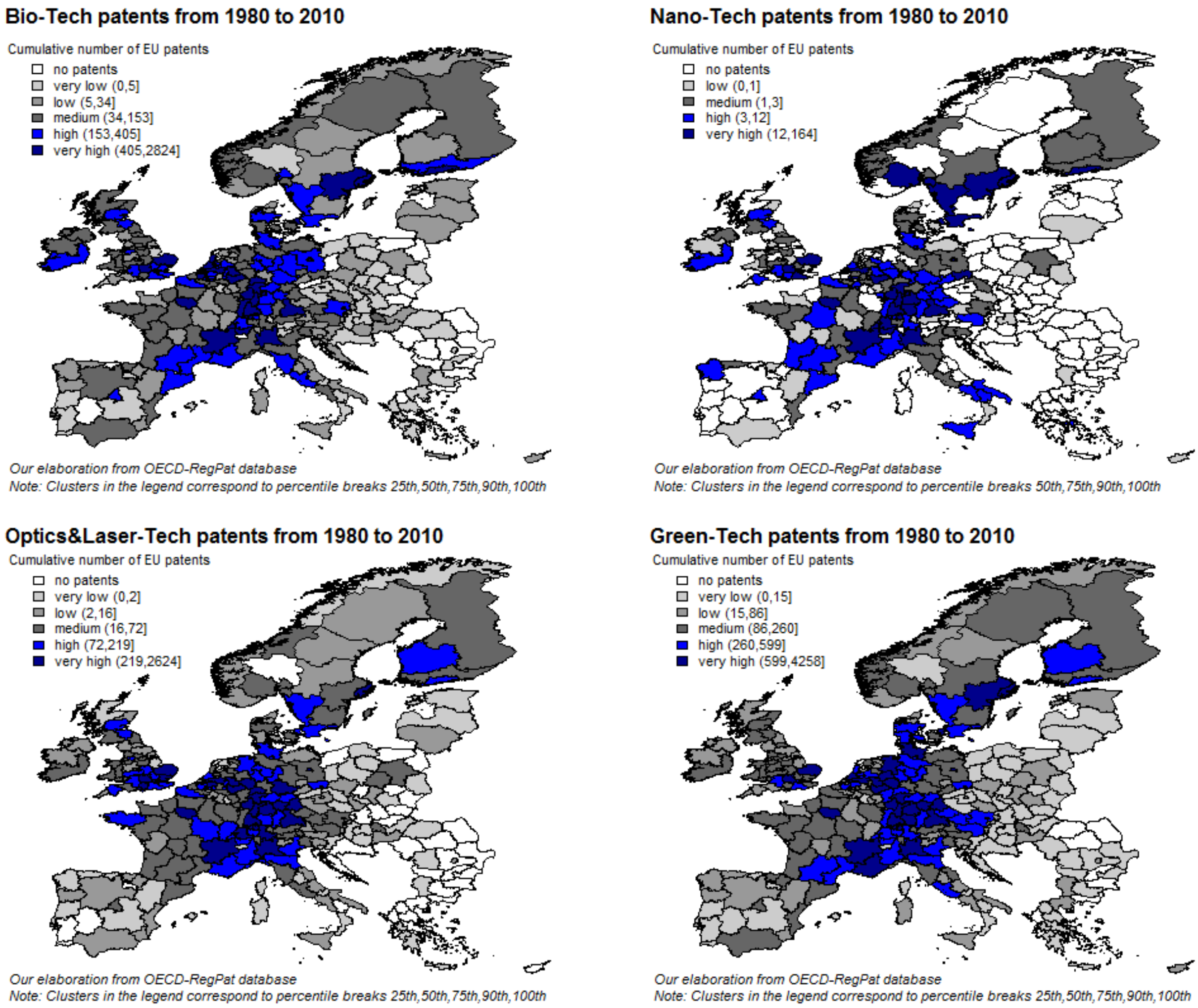
Biotech technologies appear to form the second sector in terms of size (about 46.000 patents). Despite the biotech revolution is born in US in the 1980s, it seems that in part, European organizations have been able to close in part the gap. Also patenting activity in this sector is mainly the result of collective inventions (85% of all EU patents are co-invented by more than one individual). For the 18% of the cases co-invented patents are involving extra-European inventors. The innovative efforts have characterized significantly both the 1990s and the 2000s. However, the size of EU patenting is smaller than in the previous case, representing only 37% of the total international innovative activity (EPO patents).

The third sector analyzed is related to optical and laser technologies, with a cumulative number of 26.000 patents. During 1990s and 2000s the inventive activity was growing at an average growth of about new 700 patent per year. In this sector the category of co-invented patents is inferior, and reaches only the 65% of total patents. For the 8% of cases extra-European inventors are involved in the co-invention activity.

The sector of nano-technologies and new materials represent the smallest of our sample (only about 15.000 patents). The decade of 2000s represents a particular moment of great expansion of the patenting activity. 82% of patents are co-invented. About 15% are involving extra-European inventors. EU patents represent about 33% of all innovative activity conducted at international level (EPO patents).

Looking at the geographical distributions of inventors in innovative sectors (Figure 7), we can observe that the territorial pattern of green technologies is that one that more resemble the geographical distributions both of cumulated patents and co-inventions, with a large central EU core around Germany, and a dense area in the sun belt of Nord Italian and French regions, and in the North with the great district of London and the South of Finland and Sweden.  It is important also to observe the Danish peninsula  and the extension towards Holland.

*Fig. 7 – Patent intensity by region and by innovative sector*




Biotech specialized areas are more restricted to a limited number of regions, with the exclusion of many advance areas of Italy, North of France, Spain, Greece,  and  Eastern EU countries.  Optical and laser technologies involve also the European blue banana together with the south sunbelt, where Italy and France are connected. Nano technologies represent a very small technological niche, where also some peripheral regions of UK, South of Italy, and Spain  are represented. Overall, this picture suggests that the geography of new innovative sectors in EU overlap very much with the most traditionally innovative areas.

## 5. Conclusions

Innovation activity in EU measured through the analysis of patenting activity and collaborative patenting, by the extent of innovator networks, has shown a persistent pattern of growth, particularly in the last decade (2000-2010). Some research results deserve a specific attention.

First, we must emphasizes the rise of collective co-inventions, which emerged clearly by our analysis based on the "big data" provided by the Regpat, both considering the dimension of intra-regional and interregional inventive networks.

Second, the concentration of innovation activity appears a structural long-term feature of the European regions, and designs the most innovative central kernel of European regions which integrates some former eastern European regions into the "blue banana" of South of England, South of Norway, Sweden, and Finland, with Germany, Holland, and Denmark, but also we see here the remarkable presence of the European sunbelt, which connects, and broke in two parts, Italy and France. In Spain, only Catalonia and Madrid are entering into the areas of the most advanced innovative regions.

Third, despite the existing of numerous policy and programs, the innovative divide of the early 1980s has not much changed. Novel sectors (innovative sectors like green, bio-tech, optic&laser, and nano) are emerging in the same places where old innovators were established in the post-war period. The relatedness of old and new sectors stresses the importance of regional branching (Boschma and Frenken, 2011; Tanner, 2014). Regions with the highest number of cumulative inventors are also those where co-invention levels are high, and where the dynamics of innovation is more sustained. During the period considered, 1980-2010, the number of inventors per patent has been constantly growing, and in the case of innovative sectors, it tends to be systematically higher than the average.

Fourth, in regions characterized by low level of innovativeness, co-inventions measured on total patents exhibits quite high levels. This means that weak regions are recurring to external knowledge flows to balance their technological inferiority, and to better explore the access to new radical knowledge, also assisted by the numerous EU programs. However, the role of partnering strategies and the influence of different knowledge flows from advanced to less developed regions deserves further investigations.

**Annex 1**

APPENDIX A

*Table 1- Technological manufacturing industries classification*

| *Manufacturing industries* | *NACE codes (2-digit level)* |
|---|---|
| High-technology | 21 Manufacture of basic pharmaceutical products and pharmaceutical preparations<br>26 Manufacture of computer, electronic and optical products |
| Medium-high-technology | 20 Manufacture of chemicals and chemical products<br>27 to 30 Manufacture of electrical equipment, Manufacture of machinery and equipment n.e.c., Manufacture of motor vehicles, trailers and semi-trailers, Manufacture of other transport equipment |
| Medium-low-technology | 19 Manufacture of coke and refined petroleum products<br>22 to 25 Manufacture of rubber and plastic products, Manufacture of other non-metallic mineral products, Manufacture of basic metals, Manufacture of fabricated metal products, except machinery and equipment<br>33 Repair and installation of machinery and equipment |
| Low-technology | 10 to 18 Manufacture of food products, beverages, tobacco products, textiles, wearing apparel, leather and related products, wood and of products of wood, paper and paper products, printing and reproduction of recorded media.<br>31 to 32 Manufacture of furniture, Other manufacturing |

*Table 2- NACE Rev. 2 – IPC V8 concordance (NACE 2-digit level)*

| *NACE* | *Sector definition* | *Patents' IPC* |
|---|---|---|
| 10 | Manufacture of Food Products | A01H A21D A23B A23C A23D A23F A23G A23J A23K A23P C12J C13F C13J C13K A23L001 A23L003 C13B A01J |
| 11 | Manufacture of Beverages | C12C C12F C12G C12H A23L002 |
| 12 | Manufacture of Tobacco Products | A24B A24D A24F |
| 13 | Manufacture of Textiles | D06C D04G D04H D06J D06M D06P D06Q D04D D06N |
| 14 | Manufacture of Wearing Apparel | A41B A41C A41D A41F |
| 15 | Manufacture of Leather and Related Products | A43B A43C B68B B68C |
| 16 | Manufacture of Wood and of Products of Wood and Cork, except Furniture; Manufacture of Articles of Straw and Plaiting Materials | B27D B27H B27M B27N |
| 17 | Manufacture of Paper and Paper Products | B42F D21C D21H D21J |
| 18 | Printing and Reproduction of Recorded Media | B41M B42D B44F |
| 19 | Manufacture of Coke and Refined Petroleum Products | C10G C10L |
| 20 | Manufacture of Chemicals and Chemical Products | C07B C07C C07F C07G C12S C40B C08B C08F C08G C08K C08L C05B C05C C05D C05F C05G C09B C09C C09K C10B C10C C10H C10J C10K C01B C01C C01D C01F C01G C25B B01J F25J B09B B09C C02F G21F C08J F17C F17D A01N A01P C09D B27K C09F C11D D06L A61K008 A61Q C08H C06D C09G C09H C09J C10M C11B C11C C23F C23G C14C A62D D01C C10N C06C C06B F42B F42D D01F |

| | | |
|---|---|---|
| 21 | Manufacture of Basic Pharmaceutical Products and Pharmaceutical Preparations | A61P C07D C07H C07J C07K C12N C12P C12Q A61K(except A61K008) |
| 22 | Manufacture of Rubber and Plastic Products | B67D B29C B29D B60C C08C B29B |
| 23 | Manufacture of Other Non-Metallic Mineral Products | B32B C03C C03B B28B B28C E03D C04B |
| 24 | Manufacture of Basic Metals | B22D C21B C21C C21D C22B C22C C22F C25C C25F B21C G21H |
| 25 | Manufacture of Fabricated Metal Products, except Machinery and Equipment | B21G F27D A44B A47H F22B F22G F24J F16T F17B G21C G21D G21B B63G F41A F41B F41C F41F F41G F41H F41J F42C G21J B22F C23D C25D E05B E05D E05F E06B A01L F16B E05C |
| 26 | Manufacture of Computer, Electronic and Optical Products | G11C H01C H01F H01G H01J H01L H05K C30B B82B B81B B81C B82Y G06C G06D G06E G06F G06G G06J G06N G06T G02F G09C G08B H04B H04J H04K H04M H04Q H04L H03B H03C H03D H03G H03H H03M G03H H03J H04H H04N H04R H04S H04W H01Q H01S H03K H03L H03F F15C G01B G01C G01D G01F G01H G01J G01M G01N G01R G01S G01W G12B G01Q G04R G01V G01K G01L G05B G08C G05F G04B G04C G04D G04F G04G A61N H05G G21K H05H G02B G02C G03B G03C |
| 27 | Manufacture of Electrical Equipment | H02K H02N H02P H02B H02J H01M H01B H02G H01H H01R F21H F21K F21L F21M F21S F21V H01K F21P F21Q F21W F21Y A21B A45D A47G A47J A47L B01B D06F E06C F24B F24C F24D F25C F25D H05B B60M B61L G08G G10K H01T H02H H02M H05C H01P |
| 28 | Manufacture of Machinery and Equipment N.E.C. | B23F F01B F01C F01D F03B F03C F03D F03G F04B F04C F04D F23R F15B F16C F16D F16F F16H F16K F16M G05D G05G F01K F01M F01N F01P F02G F02C F02K A47K F23G F27B B66B B66D B66F B61B B60S E02C G07B G07C G07D G07F G07G G09D G09G G11B B41J B41K B43M G06K G06M G10L G03G F24F F24H F28F H05F G01G C10F B01D B04C B05B A62C F23J B65G B66C C12L F22D F23B F23C F23D F23H F23K F23L F23M F25B F28B F28C F28D F28G F16G F23N A01B A01C A01D A01F A01G A01K A01M B27L B24D B21K B21L B25B B25C B25F B25G B25H B26B B27G B21D B21F B21H B21J B23B B23C B23D B23G B23H B23K B23P B23Q B24B B24C B25D B25J B26F B27B B27C B27F B27J B28D B30B B44C B65F001 B65F005 B65F007 B65F009 F15D A21C A22B A22C A23N A24C A41H A42C A43D B02B B02C B05C B05D B06B B07B B07C B08B B21B B22C B26D B31B B31C B31D B31F B41B B41C B41D B41F B41G B41L B41N B42B B42C B44B B65B B65C B65H B67B B67C B68F C13C C13D C13G C13H C23C D06G D06H D21B D21D D21G E01C E02D E02F E21B E21D E21F F04F F16N F26B E01D E01F E21C D01B D01D D01G D01H D02G D02H D02J D03C D03D D03J D04B D04C D05B D05C D06B D21F E05G E01H B01F B03B B03C B03D C14B F16P |
| 29 | Manufacture of Motor Vehicles, Trailers and Semi-Trailers | B60B B60D B60G B60H B60J B60K B60L B60N B60P B60Q B60R B60T B62D F01L F02B F02D F02F F02M F02N F02P F16J G01P B60W |
| 30 | Manufacture of Other Transport Equipment | B65F003 B60F B60V B61C B61D B61F B61G B61H B61J B61K B62C B62H B62J B62K B62L B62M B63B B63C B63H B63J B64B B64C B64D B64F B64G E01B F03H |
| 31 | Manufacture of Forniture | A47B A47C A47D A47F |
| 32 | Other Manufacturing | F16L A45C D07B A41G A42B A44C A45B A45F A46B A46D A63B A63C A63D A63F A63G A63H A63J A63K B43K B43L B44D B62B B68G C06F F23Q G10B G10C G10D G10F G10G G10H A61B A61C A61D A61F A61G A61H A61J A61L A61M C12M not A61K except A61K 8/* B01L B04B G01T G21G A62B G09B G09F G03D G03F |
| 42 | Civil Engineering | E03B E03C E02B |

| | | |
|---|---|---|
| 43 | Specialised Construction Activities | E04G E04B E04C E04D E04F E03F E04H |
| 62 | Computer Programming, Consultancy and Related Activities | G06Q |
| Co-IPC | remove this code and allocate by following the co-IPC | F16S B29K B29L C12R |

*Note: We associated IPC B65D to prevalent NACE 22, even though it should be more properly associated to NACE 13 (5,88%), 22 (35.96%), 23 (21.31%), 25 (15.17%), 17 (20,44%) and 16 (1,25%); IPC B65F001, B65F005, B65F007, B65F009 are associated to NACE 28, whereas the IPC B65F003 to NACE 30; A61K e A61K008 are respectively associated to NACE 21 and 20; C07B, C07C, C07F, C07G, C12M, C12S and C40B are associated to NACE 20.*

*Table 3 - Innovative industries classification*

| *Sectors* | *Patents' IPC* |
|---|---|
| Bio Technology | A01H001/00 A01H004/00 A61K038/00 A61K039/00 A61K048/00 C02F003/34 C40B040/00 C40B070/00 C40B080/00 C40B010/00 G01N027/327 G01N033/53 G01N033/54 G01N033/55 G01N033/57 G01N033/74 G01N033/76 G01N033/78 G01N033/88 G01N033/92 C12N C12P C12Q |
| Nano Technology | B81B B82B B82Y |
| Green Technology | A01G023/00 A01G025/00 A01H A01N025/00 A01N065/00 A43B001/12 A43B021/14 A61L011/00 A62D003/00 A62D003/02 A62D101/00 B01D045/00 B01D051/00 B01D053/00 B01D053/02 B01D053/04 B01D053/047 B01D053/14 B01D053/14 B01D053/22 B01D053/24 B01D053/62 B01D053/92 B01D053/96 B03B009/06 B03C003/00 B09B B09C B22F008/00 B29B017/00 B60K006/00 B60K006/10 B60K006/20 B60K006/28 B60K006/30 B60K016/00 B60L003/00 B60L007/10 B60L007/22 B60L008/00 B60L009/00 B60L011/16 B60L011/18 B60W010/26 B60W020/00 B61D017/02 B62D035/00 B62D035/02 B62D067/00 B62K B62M001/00 B62M003/00 B62M005/00 B62M006/00 B63B001/34 B63B001/40 B63B035/00 B63B035/32 B63H009/00 B63H013/00 B63H016/00 B63H019/02 B63H019/04 B63H021/18 B63J004/00 B64G001/44 B65F B65G005/00 C01B031/20 C01B033/02 C02F C04B007/24 C04B0077/30 C04B018/04 C04B018/10 C05F C08J011/00 C08J011/04 C08J011/28 C09K003/22 C09K003/32 C09K005/00 C09K011/01 C09K017/00 C10B021/18 C10B053/00 C10B053/02 C10G001/10 C10J C10L005/48 C10L001/00 C10L001/02 C10L001/14 C10L003/00 C10L005/00 C10L005/40 C10L005/42 C10L005/44 C10L005/46 C10L005/48 C10L005/48 C10L009/00 C10L010/02 C10L010/06 C11B011/00 C11B013/00 C11B013/04 C12M001/107 C12N001/13 C12N001/15 C12N001/21 C12N005/10 C12N015/00 C12P005/02 C14C003/32 C21B003/04 C21B005/06 C21B007/22 C21C005/38 C22B007/00 C22B007/04 C22B019/30 C22B025/06 C23C014/14 C23C016/24 C25C001/00 C30B029/06 D01F013/00 D01F013/04 D01G011/00 D21B001/08 D21B001/32 D21C005/02 D21C011/00 D21F005/20 E02B015/04 E02D003/00 E03C001/12 E03F E04B001/90 E04B001/62 E04B001/74 E04B001/80 E04B001/88 E04B002/00 E04B005/00 E04B007/00 E04B009/00 E04C001/41 E04C001/40 E04C002/284 E04C002/296 E04D001/28 E04D003/35 E04D013/00 E04D013/16 E04D013/18 E04F013/08 E04F015/18 E04H001/00 E04H012/00 E06B003/263 E21B041/00 E21B043/16 E21F017/16 F01K F01N003/00 F01N003/38 F01N009/00 F02B043/00 F02B075/10 F02C001/05 F02C003/28 F02C006/18 F02M021/02 F02M027/02 F03D F03D011/04 F03G004/00 F03G004/06 F03G005/00 F03G005/08 F03G006/00 F03G006/06 F03G007/04 F03G007/05 F03G007/08 F16H003/00 F16H003/78 F16H048/00 F16H048/30 F21K099/00 F21L004/00 F21L004/02 F21S009/03 F22B001/00 F22B001/02 F23B080/02 F23B090/00 F23C009/00 F23G F23J007/00 F23J015/00 F24D003/00 F24D005/00 F24D011/00 F24D011/02 F24D015/04 F24D017/00 F24D017/02 F24D019/00 F24F005/00 F24F012/00 F24H004/00 F24H007/00 F24J001/00 F24J002/00 F24J002/04 F24J002/06 F24J002/42 F24J002/54 F24J003/00 F24J003/06 F24J003/08 F25B027/00 F25B027/02 F25B030/00 F25B030/06 F25J003/02 F26B003/00 F26B003/28 F27B001/18 F27B015/12 F27D017/00 F28D017/00 F28D020/00 F28D020/02 G01R G02B007/183 G05F001/67 G06Q G08B021/12 G08G G21B G21C G21D G21F009/00 H01G009/155 H01G009/20 H01J009/50 H01J009/52 H01L025/00 H01L025/03 H01L025/16 H01L025/18 H01L027/142 H01L027/30 H01L031/00 H01L031/058 H01L031/078 H01L033/00 H01L033/64 H01L051/42 H01L051/48 H01L051/50 |

| | |
|---|---|
| | H01M002/00 H01M002/04 H01M004/86 H01M004/98 H01M006/52 H01M008/00 H01M008/24 H01M010/44 H01M010/46 H01M010/54 H01M012/00 H01M012/08 H01M014/00 H02J H02K007/18 H02K029/08 H02K049/10 H02N006/00 H02N010/00 H05B033/00 |
| Laser-Optical Technology | H01S G02B G02C G03B G03C |

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