JOINT STUDY ERA - JRC

INSIGHTS INTO RAILWAY INNOVATION THROUGH PATENTING TRENDS

2021

EUROPEAN UNION AGENCY FOR RAILWAYS

European Commission

The European Commission's science and knowledge service

Joint Research Centre

Contents

Disclaimer

The present document is a joint study by the European Union Agency for Railways and the Joint Research Centre of the European Commission. It is a non-legally binding document of an analytical and explorative nature. It does not necessarily represent the view of other EU institutions and bodies.

Authors: VAN BALEN Mitchell, PASIMENI Francesco, GEORGAKAKI Aliki

How to cite: van Balen, M., Pasimeni, F., Georgakaki, A., *Insights into railway innovation through patenting trends*, European Union Agency for Railways, Valenciennes, 2021. JRC124878

Acknowledgment for helpful comments: BOELMAN Elisa, GKOUMAS Konstantinos, HOLVAD Torben, MARMIER Alain, MARQUES DOS SANTOS Fabio, TOURNIER Ny Tiana, TZIMAS Evangelos

1. Patents and railways

Patents have played a crucial role in developing the railway sector ever since rails were first put down[1]. In knowledge intensive and competitive sectors like railways, the patent system proved to be essential to protect inventions, enabling inventors to further develop a product and financially benefit from their engagement.

Throughout history the railway sector embraced numerous inventions that led to substantially higher levels of comfort, reliability, and performance. Yet despite those leaps, the sector remains under continuous pressure to perform even better in face of competition from other modes of transport. It could be said that innovation is not only necessary for rail to maintain its modal share, but also critical towards reclaiming a larger role in society.

In this context it is useful to reflect on how patenting may evolve in the face of several developments:

Greater competition:

- Inefficiencies in public railway operations pushed regulators towards promoting deregulation. In the US, the Staggers Act drastically improved the productivity and volume of rail freight transport[2]. Likewise, the more recent Railway Packages in the EU, seem to foster greater competition and growth[3]. The increase of market dynamics should favour investments in modern, more performant rolling stock, which in turn should push for more inventions.
- Another aspect concerns the development of new markets. The development of the Chinese railway system has been remarkable, where large investments in infrastructure and rolling stock promoted the uptake of domestic and international inventions. In other markets, large manufacturers try to expand with innovative products to meet local demands and win tenders. These developments foster higher patenting activity as well.

Flagship projects and coordinated research:

- Beyond incremental improvements to existing products, huge efforts are put in developing game-changing technologies. This includes automated train operations, hydrogen and battery technology, Hyperloop systems, 5G enabled future rail mobile communication system as well as a reinvigorated push for Maglev operations[4]. Each of these efforts translates into new patents being filed.
- The way in which research is organised evolves as well. In Europe a so-called joint undertaking was established, where public and private actors pool resources to address key innovation challenges. This initiative, named Shift2Rail, started in 2014 and is foreseen to be prolonged till 2027. Resource pooling and coordination are likely to impact the type and number of inventions.

Technical harmonisation

- A final pivotal development is the creation of the harmonised technical specifications for interoperability (TSIs) in Europe. The TSIs aim to reduce divergences resulting from national rules with the aim to create a single European railway area. This in turn is likely to result in more focused innovation efforts across the technical spectrum.

In short, developments in the competitive landscape, research investments and governance, as well as the further harmonisation of technical requirements are likely to drastically change railway innovation.

[1] Murfitt, S, (2017) "The English Patent System and Early Railway Technology 1800-1852", University of York
[2] Finger, M. & Montero, J. (2020), "Handbook on Railway Regulation: Concepts and Practice", Edward Elgar Publishing
[3] EC (2021), Seventh monitoring report on the development of the rail market, Brussels
[4] Gkoumas et al., (2021), "Rail transport research and innovation in Europe" (JRC124883)

Aim of the study

The developments above alter the role and scope of innovation in the railway sector. Patent statistics provide a unique insight into the sector's past and future innovation dynamics. As such, patent studies can help us understand where the sector came from, and what to expect for the years to come.

This study explores the role of innovation and patents in the railway sector, with a specific focus on the European Union. Particularly, the following questions shall be answered:

- How did the patenting of railway inventions in the EU evolve since 2000?
- How does the EU rail sector perform in terms of patenting inventions versus other regions?
- What are potential areas of growth for the EU rail sector?
- To what extent can changes in patenting activity be attributed to competition, research projects and harmonisation efforts?

After a concise methodology section, these questions are answered by investigating patent statistics from different perspectives.

2. Method

The study has been conducted by the Joint Research Centre of the European Commission (JRC) and the European Union Agency for Railways (ERA). The detailed method for the analysis of patents has been described in several JRC publications[5,6,7]. The most essential information that is needed to interpret the results of this study is provided below.

Data source

This study builds on data from the Patent Statistical Database (PATSTAT) as provided by the European Patent Office. PATSTAT is an established resource for statistical patent analyses and includes most of the patent fillings across the world. The PATSTAT 2020 autumn version data was processed to improve accuracy and completeness[8], after which patent statistics from 2000 till 2017 were extracted. This timeframe was set because the publication of patent data is typically delayed for reasons of confidentiality[9], so that complete coverage could be guaranteed up until 2017.

Key concepts

The following five concepts are essential to understand and interpret the study results.

- **Patent** is understood by the European Patent Office as a '*legal title that gives inventors the right, for a limited period (usually 20 years), to prevent others from making, using or selling their invention without their permission in the countries for which the patent has been granted.*'[10]
- **Patent families** (**or inventions**) measure the inventive activity. Patent families include all patent documents relevant to a distinct invention (e.g. applications to multiple authorities). Focusing on patent families rather than patents prevents double counting. A fraction of the family is allocated to each applicant and relevant technology. Annex 1 describes this in greater detail.
- **High-value inventions** refer to patent families that include patent applications filed in more than one patent office.
- **International inventions** consider, in a patent family, only patent applications protected in a country different to the residence of the applicant. More details are provided in Annex 1.
- **Green inventions** refer to patent families that cover technologies that mitigate the emission of greenhouse gases in the framework of the Kyoto Protocol and the Paris Agreement, as well as those technologies that facilitate the adaption to the adverse effects of climate change[11].

Geographical scope

The study compares patenting trends of the EU as a whole with that of countries with a strong performance in railway innovation. The following countries and regions are assessed in the analyses.

- EU: The 27 European Union Member States
- CN: People's Republic of China
- JP: Japan
- US: United States of America
- KR: Republic of Korea (i.e. South Korea)
- RoW: Rest of World, meaning all other countries not covered above

[5] Pasimeni F. & Fiorini A. (2017). SETIS Database: Data Management for R&I Key Performance Indicators (JRC108754)
[6] Fiorini A., Georgakaki A., Pasimeni F. & Tzimas E. (2017). Monitoring R&I in Low-Carbon Energy Technologies (JRC105642)
[7] Pasimeni, F., Fiorini, A. & Georgakaki, A. (2019) Assessing private R&D spending in Europe for climate change mitigation technologies via patent data. World Patent Information, 59, 1-11
[8] Pasimeni, F. (2019). SQL query to increase data accuracy and completeness in PATSTAT. World Patent Information, 57, 1-7
[9] Pasimeni, F. & Georgakaki, A. (2020) Patent-Based Indicators: Main Concepts and Data Availability (JRC121685)
[10] https://www.epo.org/service-support/glossary.html#p
[11] https://www.cooperativepatentclassification.org/index

On top of comparing the geographical regions above, Chapter 3 provides a closer look on the patenting performance of individual EU Member States.

Taxonomy of railway inventions

Elaborate systems exist to codify patents by field and function. This study uses the Cooperative Patent Classification (CPC) system as it allows for the desired level of granularity and provides information on green inventions.

Although many Asian countries did not assign CPC codes until recently, and their use in domestic applications is not yet consistently applied, our analyses show that CPC codes are to a very high extent allocated to originally Asian patents that are filed in other patent offices[12]. As the present analysis will focus on comparisons based on high value inventions (hence inventions that are filed in more than one patent office), there is no substantial impact on the accuracy of the results by choosing for the CPC classification. In the rare cases where the results may be impacted by the chosen classification scheme, it will be clearly mentioned.

To translate the vocabulary of patent officers to that of most railway professionals, a concordance table was developed. A total of 1247 unique patent codes were linked to the so-called structural subsystems of railways (See Annex 1 for more information).

Table 1 shows the names and definitions of the four subsystems that were aligned with the patent codes. With the CPC classification it was possible for the Infrastructure and Rolling Stock subsystems to provide a further breakdown into Level 2 subcategories.

Subsystem	Level	Definition
Control, command and signalling (CCS)	1	All the trackside and onboard equipment required to ensure safety and to command and control movements of trains authorised to travel on the network.
Energy (ENE)	1	The energy supply system, including overhead lines.
Infrastructure (INF)	1	Covers all the following INF subcategories
INF-rail	2	Rails, rail joints, and general track elements
INF-fastenings	2	Elements to fix the rail to sleepers
INF-sleepers	2	Elements to which the rail is fixed
INF-ballast	2	Foundation on which track elements are positioned
INF-switches	2	Elements to guide, shunt and transfer vehicles on the network
INF-crossings	2	Elements for rail/road level crossings
Rolling stock (RST)	1	Covers all the following RST subcategories
RST-traction	2	Traction elements (e.g locomotive and pantographs)
RST-bodies	2	Passenger carriages and freight wagons
RST-suspensions	2	Underframes, bogies and wheel axles
RST-couplings	2	Couplers, draw-gear and buffers
RST-brakes	2	Vehicle fitted related braking material

Table 1 Railway invention taxonomy

More detailed information on the methodology to link the subsystems and CPC codes is provided in Annex 1 of this report.

[12] Degroote, B., & Held, P. (2018). Analysis of the patent documentation coverage of the CPC in comparison with the IPC with a focus on Asian documentation. World Patent Information, 54, S78-S84.

Limitations

As for all patent studies, there are several limitations to consider. Firstly, the level of patenting is influenced by domestic policies. It makes that the regional comparability of some statistics is limited, particularly for non-high-value inventions. Therefore this study shall mainly focus on high-value inventions.

Another point is that not all inventions are patented. This may be due to costs considerations or even to hide certain innovative activities from the public eye and potential competitors. As such, patent statistics provide a comprehensive, but not complete insight into innovative activities.

A last consideration is that the study builds primarily on quantitative insights. A follow-up study could aim to corroborate and/or reject several of the assumptions that are developed based on the provided analyses.

3. Patenting in the European Union

A look into the number of inventions by EU country shows that the vast share of patents is filed by German applicants. This can be explained by the country's strong manufacturing base, both of domestic and international companies. In fact, as Figure 1 shows, Germany is responsible for over half of all observed inventions in the EU. All countries that account for less than one percent of the total have been grouped under 'All others'.

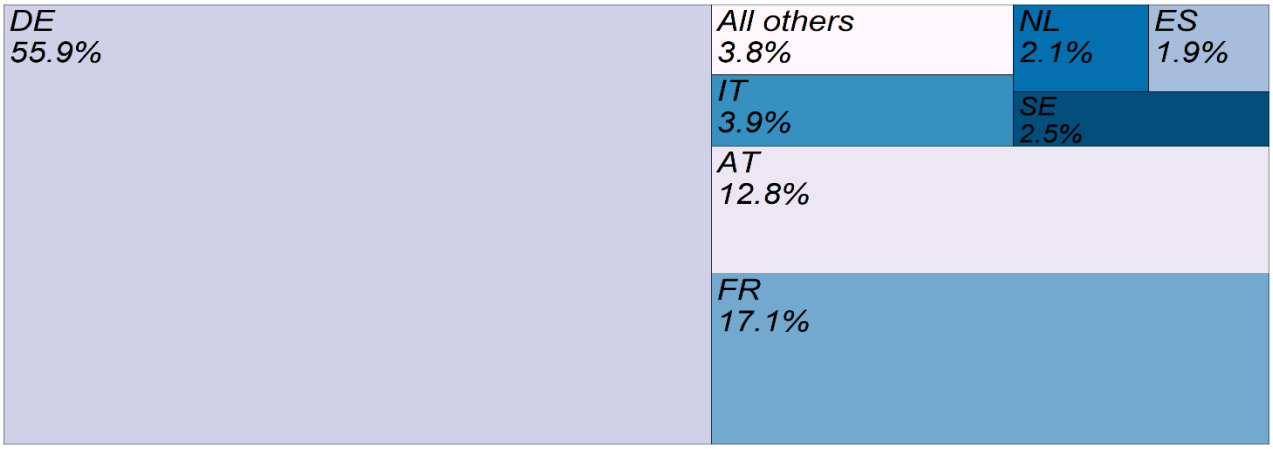

Figure 1 Share of total inventions for the EU (2000-2017)

Figure 2 presents the patenting performance of all EU countries on a log scale (totals are at the top of the bars). The second line of bars shows which share of the inventions are so-called high value inventions: inventions that were filed in at least two different patent offices. Considering the applicants' efforts to protect an invention in multiple countries it provides an indication of the invention's overall market value. Interestingly, France and Austria show higher percentages on this indicator than Germany.

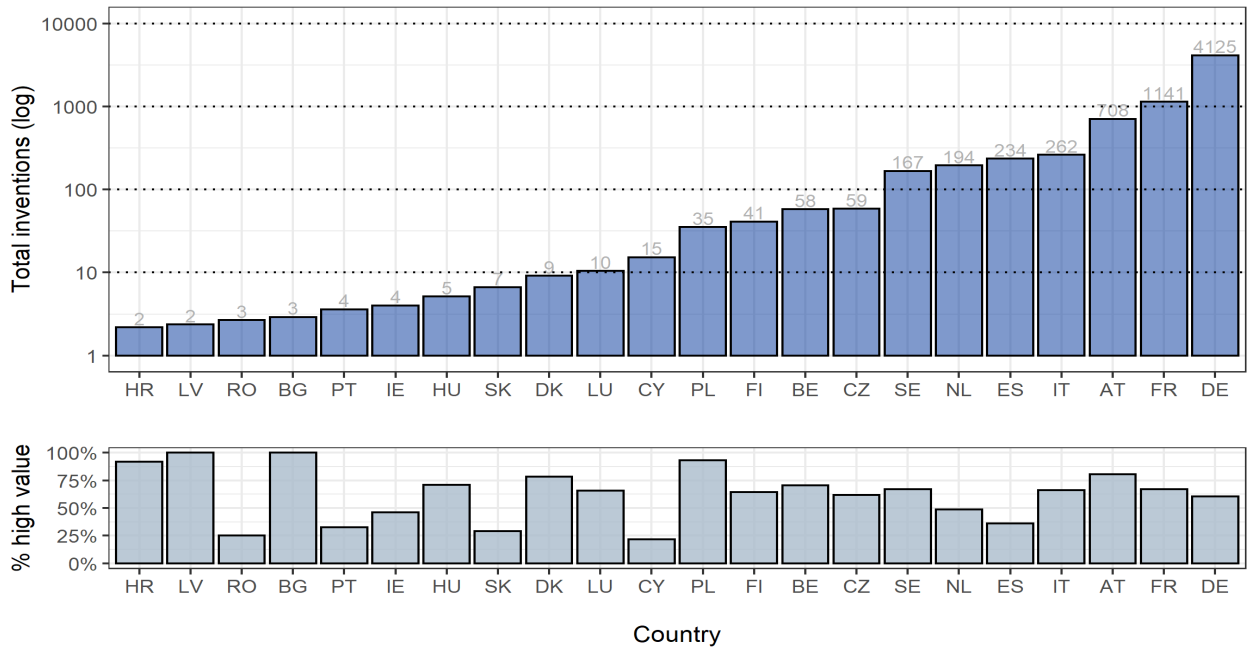

Figure 2 All inventions by MS on log scale, and the share of high value inventions (2000 – 2017)

As described in the introduction, the railway sector has evolved considerably over the past decades. Likewise, patenting trends show several shifts. Figure 3 indicates that especially in the fields of CCS and RST there have been big steps in innovative activity. These growth spurts seem to commence in 2010 and have continued since.

On the energy and general infrastructure side, however, patenting activity remained surprisingly stable over time. A high level of maturity and stability in solutions can be explanatory factors. Moreover, in these fields there have been comparatively fewer steps towards technical harmonisation. The divergence between the subsystems related to rolling stock and fixed installations may therefore be indicative of the impact of the changed legislative framework. Such factors are explored in greater depth in the last chapter.

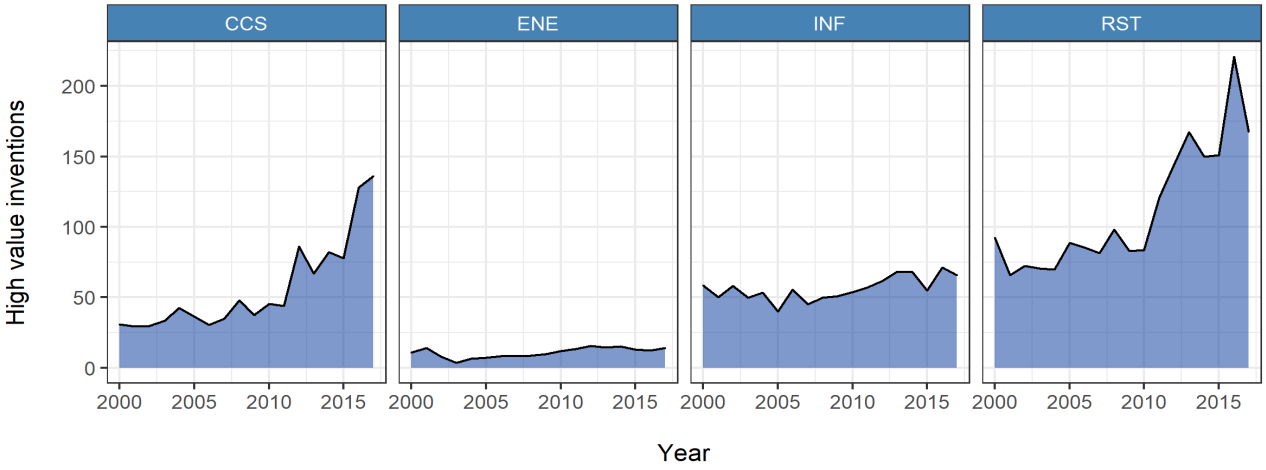

Figure 3 EU patenting trend by subsystem (Level 1)

Dissecting patenting trends to the sublevels provides additional information. For one, Figure 4 shows that activity for all sublevels of the infrastructure subsystem remained stable over time. For the rolling stock subsystem innovative activity was particularly strong in the field of bodies, which accounts for the largest share of the observed growth.

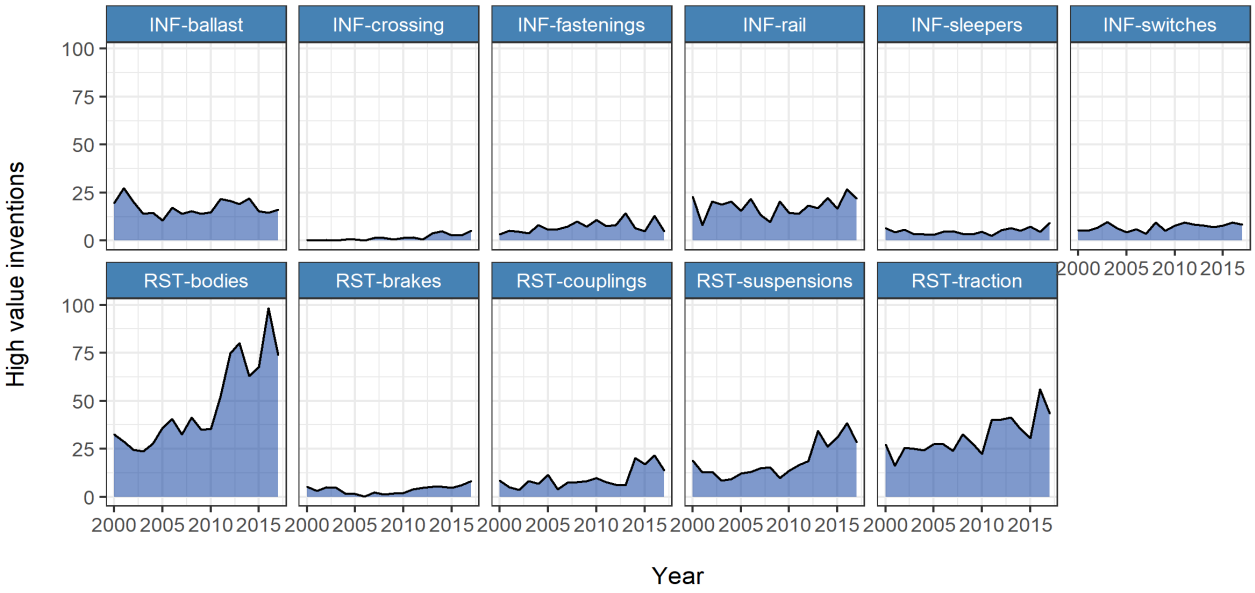

Figure 4 EU patenting trend by subsystem (Level 2)

4. EU compared to the world

Several interesting developments in patenting are also observed beyond the EU. Figure 5 shows the patenting trends of five major world economies and the rest of the world. On the left side the performance is shown in terms of all inventions in scope. Clearly, the sudden spurt of China since 2013 is most noticeable. Yet this figure needs to be treated with caution.

First, this study uses the CPC system to map railway inventions. The recent, and not yet consistent, application of the system in Asia has an effect on the trends observed for patents filled in domestic offices only. This partially explains why the number of Chinese rail inventions suddenly peaks. Another explanation for this surge concerns a recent domestic policy which supports patent filings[13,14]. A final explanatory factor may be that many foreign companies (from the EU and US in particular) have established subsidiaries in China to benefit from the domestic patent law, sometimes not for commercialisation purposes but as part of a defensive strategy to avoid imitation.[15]

When using high value inventions as a benchmark (Figure 5, right side) it is noticeable that the overall number of inventions is considerably lower and that the EU tops the list. Having said that, Chinese applicants are increasingly seeking international protection for their inventions and have now taken over the second spot in terms of high-value inventions.

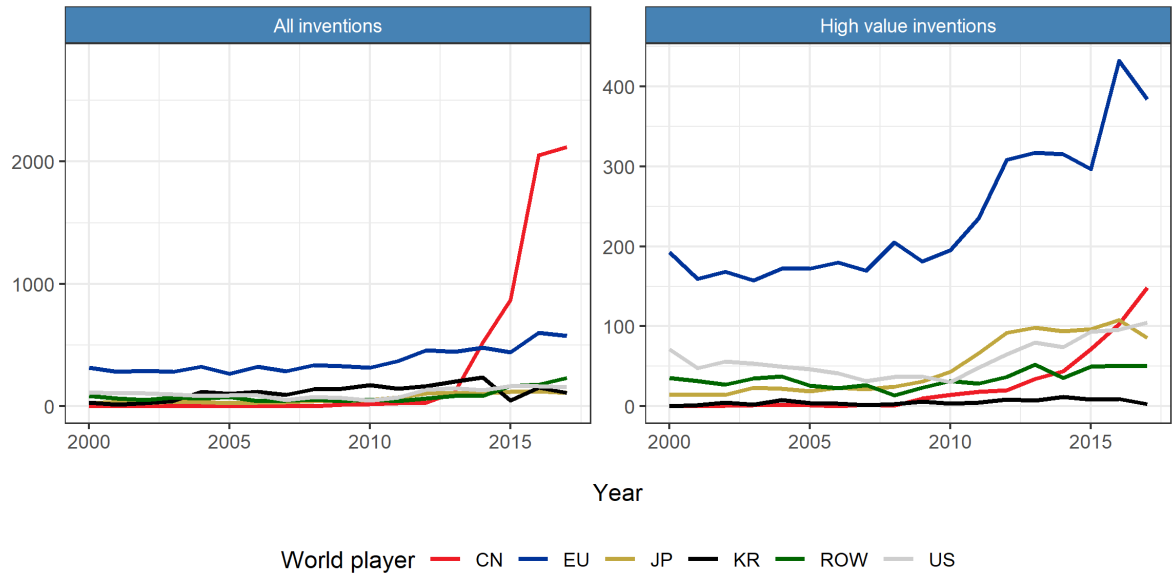

Figure 5 Inventions by country/region

Figure 6 complements this view by showing details per subsystem and the evolution between 2000 and 2017. The vertical axis is specific for each country or region, so that the focus can be put on the evolutions, rather than the absolute numbers. Note that the values for the EU are the same as in Figure 3.

[13] Preziosi, N et al. (2019) China – Challenges and Prospects from an Industrial and Innovation Powerhouse, EUR 29737 EN, Publications Office, Luxembourg, 2019, ISBN 978-92-76-02997-7, doi:10.2760/445820, JRC116516.
[14] China Power Team. "Are Patents Indicative of Chinese Innovation?" China Power. February 15, 2016. Updated August 26, 2020. Accessed September 11, 2020. https://chinapower.csis.org/patents/
[15] Pasimeni, F., Fiorini, A. & Georgakaki, A. International Landscape of the Inventive Activity on Climate Change Mitigation Technologies. A patent analysis (*forthcoming*).

In all cases an increase of CCS and RST inventions is noted. However, the growth is more marked in certain countries. In Japan, for instance, the growth commenced earlier than in the EU, while in China the increase is steeper.

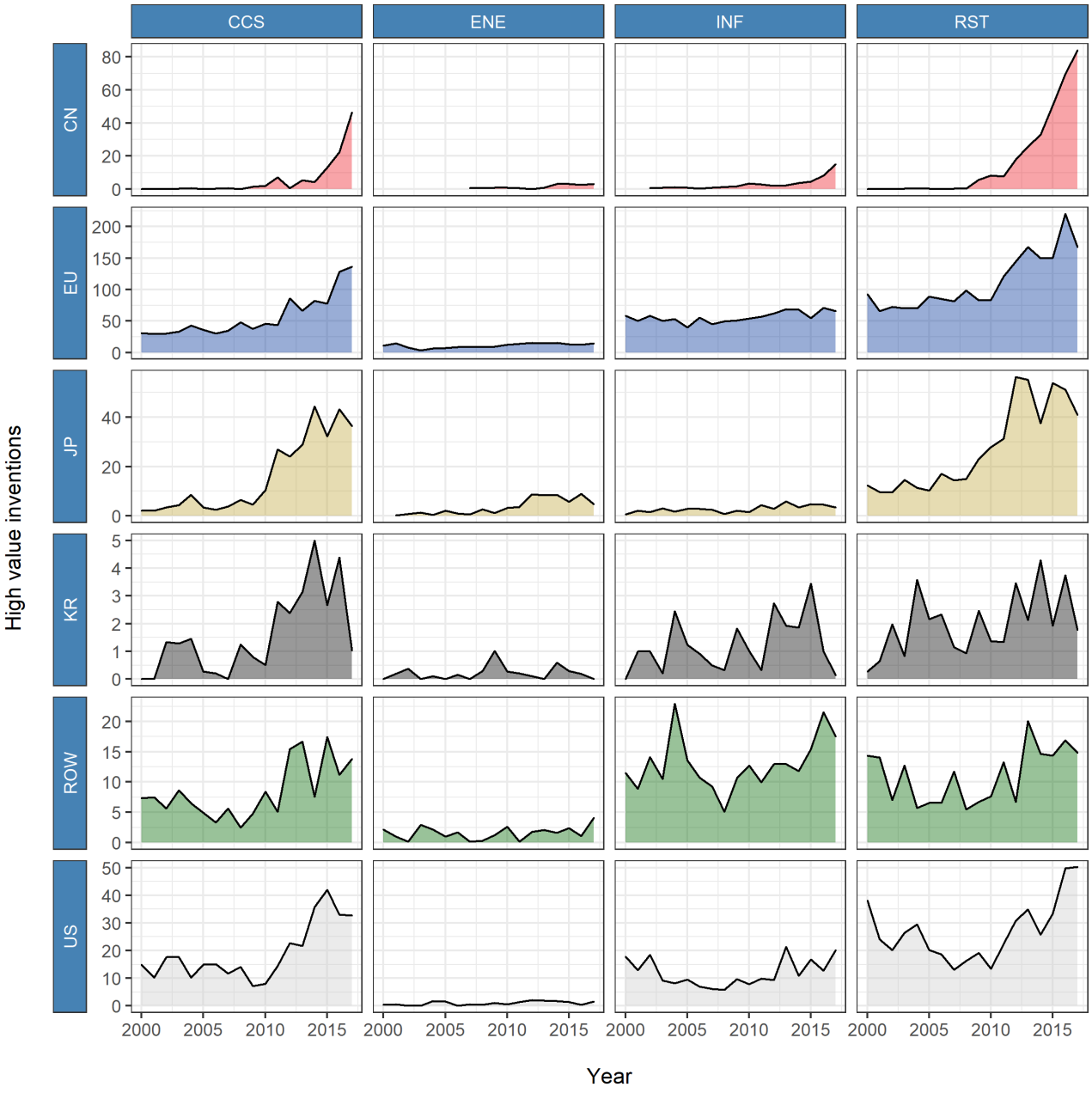

Figure 6 High value inventions by country/region and subsystem (2000 – 2017)

The enduring growth in patenting activity thus proves to be a global phenomenon. One exception is observed in the US, where the trend on high value RST inventions shows a U-shape, with the lowest activity between 2007 and 2010.

5. Green inventions

The CPC system to codify patents indicates whether an invention could make a direct contribution to climate change mitigation. As such, it provides information on the 'green' nature of a certain invention.

Figure 7 shows two complementary insights. Above the sum of high value green inventions is provided, showing that the EU is by far the region where most 'green' inventions are created. This holds true particularly for rolling stock inventions. The fact that the EU has the largest number of green high-value inventions can be explained by the 'green' know-how built in the last decades when business opportunities arose together with a favourable regulatory framework that pushes green inventions.

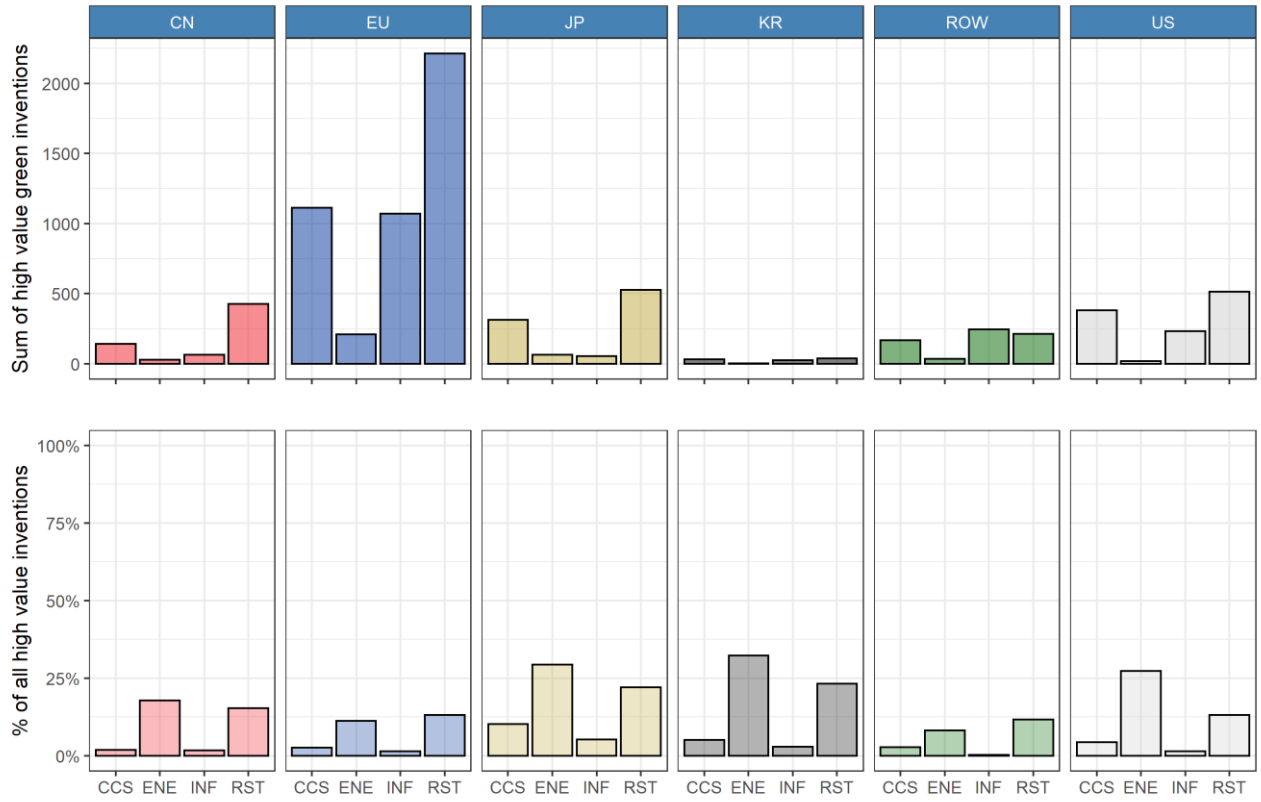

Figure 7 Total number of green inventions and share of all inventions by country/region (2000 – 2017)

The bottom bars of Figure 7 put the absolute numbers into a different perspective. It shows that particularly Japan and South Korea are relatively more active in developing 'green' technologies. This insight may be useful for the European railway sector to evaluate and compare its invention portfolio with other regions to understand which steps can be made towards greening the sector even further.

6. International flow of inventions

Inventors patent their inventions in other countries to protect and monetise their ideas. Aggregate flows on 'who files where' indicate where inventors think the greatest market opportunities lay.

Figure 8 shows the international flows of patenting activity for each of the four subsystems. The origin is shown at the left and the destination at the right. The size of the flows is indicative of the total inventions that are 'exported'. Also note that the size is relative to the total. Hence the bigger the flow, the larger the share of a country/region in all exporting activity for that subsystem. Note that the Republic of Korea and the Rest of the World were excluded because their absolute number of inventions were relatively low and the readability of the visualisations needed to be assured.

A first observation is that the EU and Japan are most active in exporting inventions in the fields of CCS, ENE and RST. For INF inventions, the EU is the most dominant player. It is also noteworthy that while China shows a surge in patenting activity (recall Figure 5) this is not fully reflected in international patenting activity. Still, China is an important destination for foreign inventors either because of growing market opportunities or because of the need to act against possible imitation.

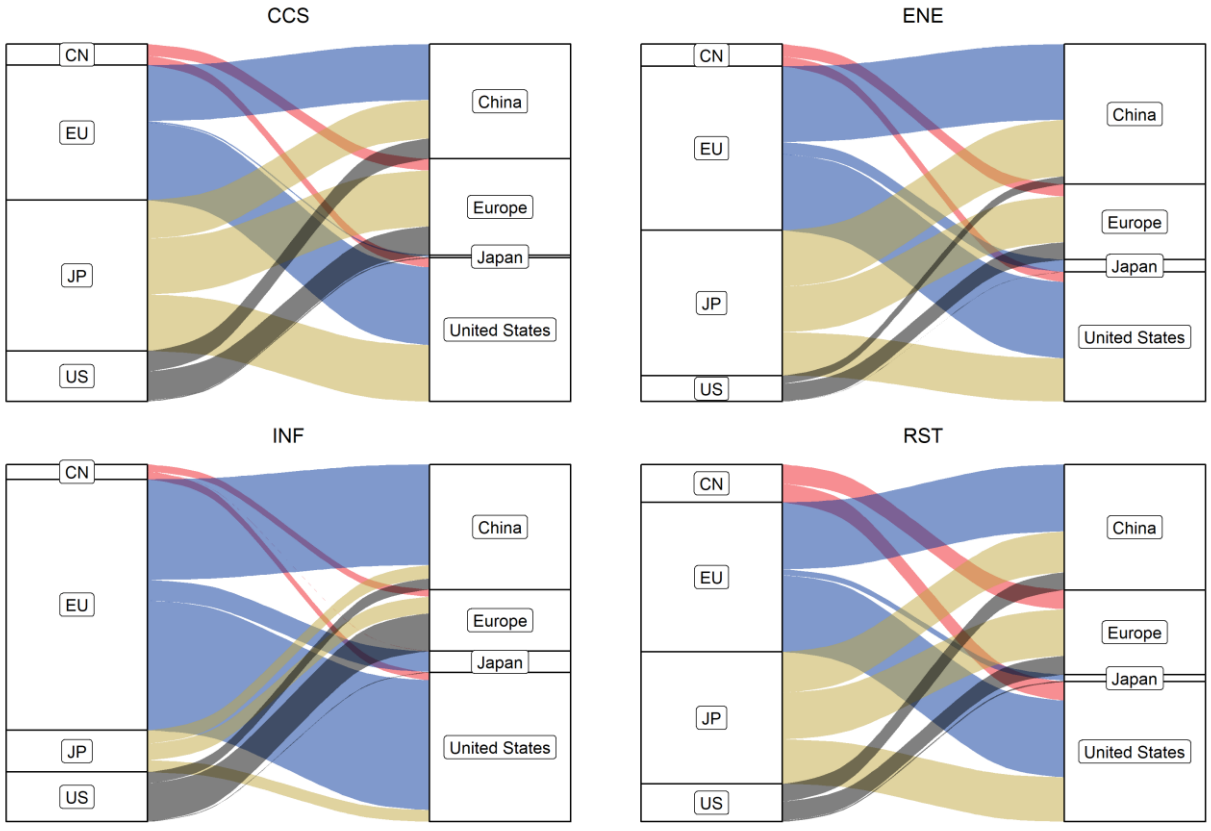

Figure 8 Origin (left) and destination (right) of international inventions by subsystem (2000 – 2017)

Figure 9 provides an additional perspective by showing the absolute flows of high value international inventions between 2000 and 2017. It clearly highlights that neither the EU, China nor the US are strongly interested in exporting inventions to Japan. It is indicative of the value of the Japanese market for those regions, which is probably smaller due to the strong market position of domestic firms and specific national requirements.

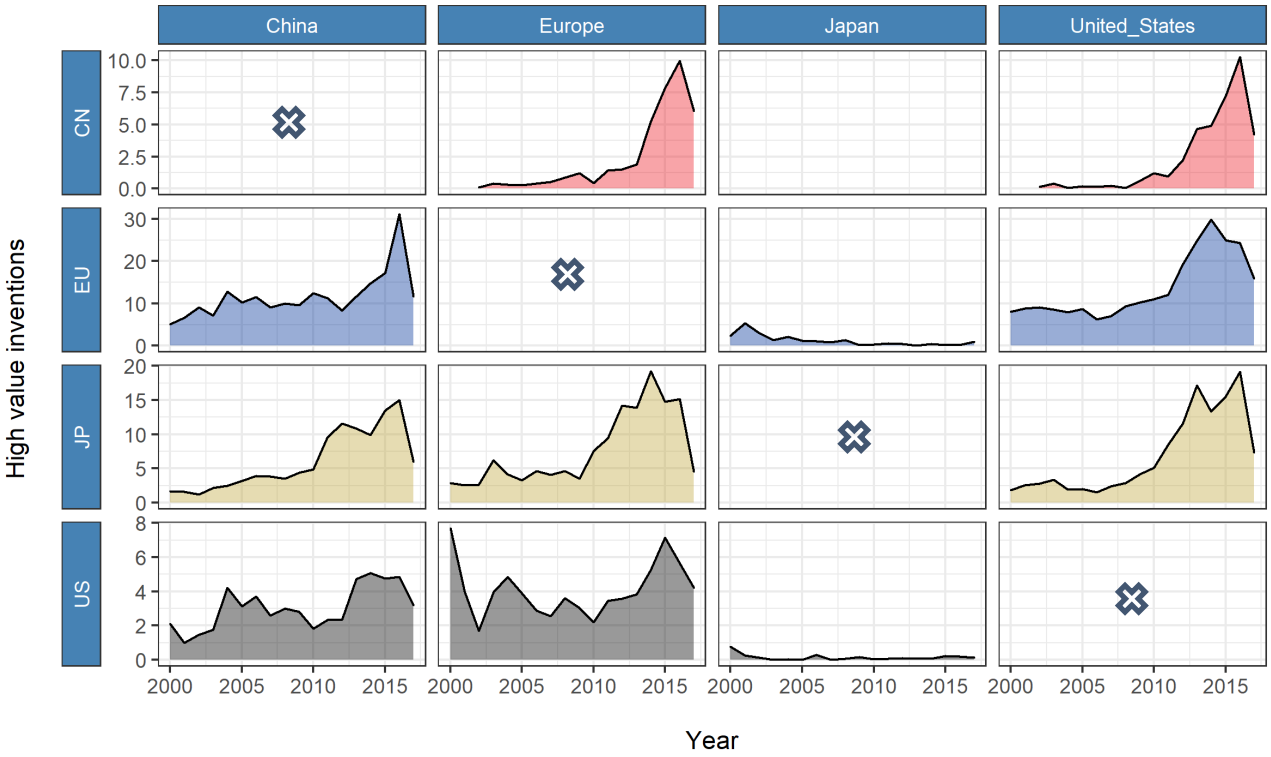

Figure 9 Origin (rows) and destination (columns) of high value international inventions (2000 – 2017)

Another observation is that Chinese, EU and Japanese inventors are increasingly exporting their inventions, particularly since 2010. For American inventors there is no strong growth pattern visible.

7. Specialisation and market structure

Some countries and regions can focus on a specific field of technology, while disregarding others. If a region's patenting intensity in a technology is relatively higher than that of a reference region (or the world), it could be said that the region is specialised[16]. The so-called specialisation index (SI) is calculated as follows:

$$SI = \left(\frac{\sum_i Patents}{\sum Patents}\bigg|_j\right) \Big/ \left(\frac{\sum_i Patents}{\sum Patents}\bigg|_{ref}\right) - 1$$

In this report, `i` concerns the region under consideration and `j` the subsystem. This chapter focuses specifically on China, EU, Japan and the United States, while the reference region (i.e. 'ref') is the entire world. The comparison is thus not made between the selected regions, but against the global average. According to the SI formula, a value of 0 implies that the patenting intensity is equal to the world. An SI below 0 means a below average specialisation while all values above 0 are indicative of a regional specialisation.

Figure 10 shows the outcome of the analysis for high-value inventions. A first observation is that the SI can fluctuate considerably from one year to another. Some fluctuations are influenced by the (low) absolute number of high value inventions. Therefore, it is advisable to look at the trends rather than one point in time. As such, we disregard most of the peak values for China before 2010.

For the EU it appears that there is no strong specialisation in any field, showing average performances in all fields of innovation. China seem to maintain a specialisation in rolling stock inventions as of 2012.

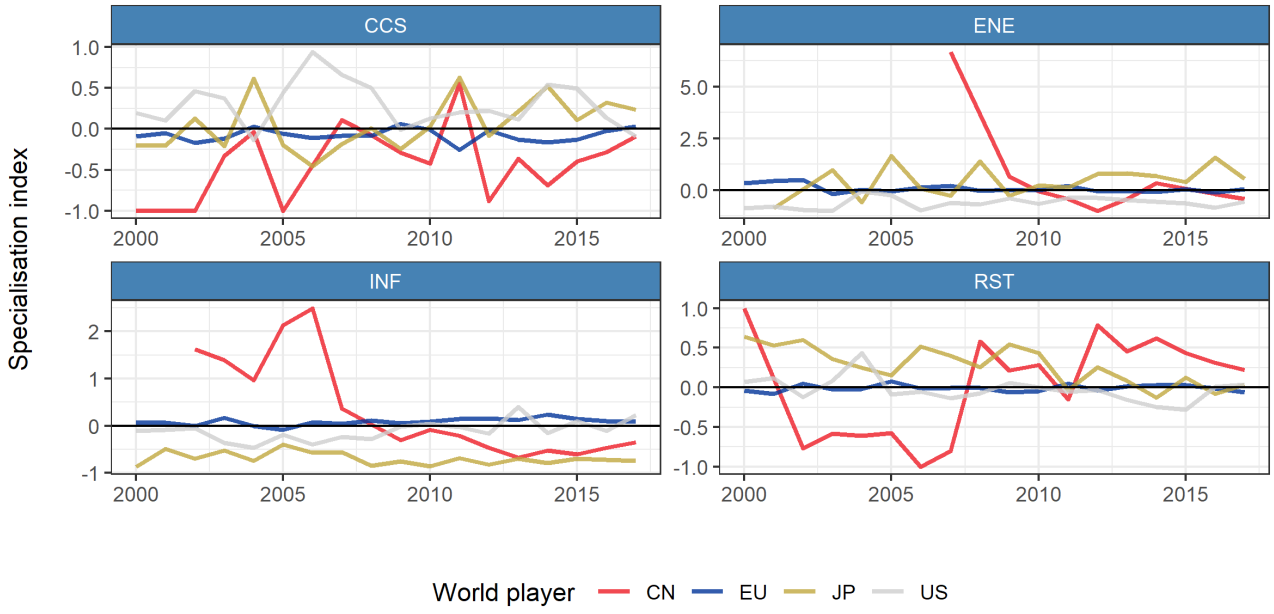

Figure 10 Specialisation index by subsystem (L1) and world player for high value inventions

Japan shows a higher SI for the energy subsystem and a positive trend on CCS. The field of infrastructure is not one in which Japan evidences a particular specialisation. The US notes a higher SI for CCS inventions, while scoring lower for the other subsystems.

[16] Fiorini, A., Georgakaki, A., Jimenez Navarro, J., Marmier, A., Pasimeni, F. and Tzimas, E. (2017). Energy R&I financing and patenting trends in the EU: Country dashboards 2017 edition (JRC109654).

Based on these first analyses, no strong patterns come to the fore, suggesting that each country and/or region maintains and promotes a diverse portfolio of inventions across all of the four subsystems. Further analysis is certainly needed to make stronger statements on this topic.

Figure 11 provides an additional perspective on how countries / regions organise their innovation system. The vertical axis shows the level of market concentration using the Herfindahl–Hirschman Index (HHI). The index calculates the innovative output of an organisation in relation to the total size of the 'industry'. The closer the HHI moves towards 1, the more concentrated the industry is. In the context of this report, a HHI of 1 implies that there is one organisation responsible for all inventions. If the HHI approximates 0, it means that there is a very large number of organisations that all have a similar (small) output of inventions. As of a HHI of 0.25 one typically speaks of an oligopoly and as of 0.60 about a monopoly. The figure shows the results by subsystem and country/region, taking an average of the 2000-2017 values to mitigate the effect of annual fluctuations.

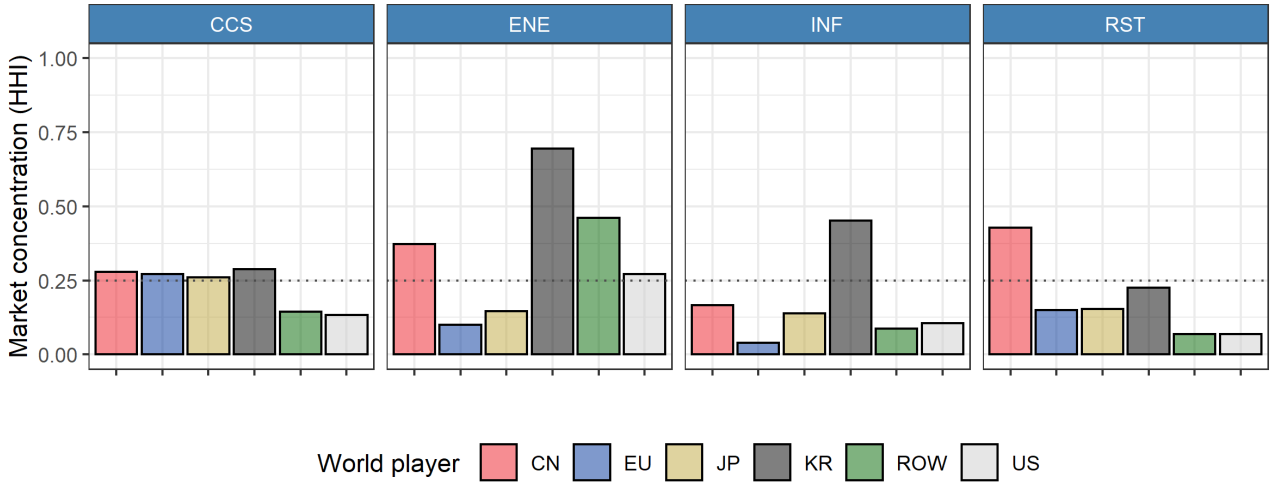

Figure 11 Market concentration (HHI) for high value inventions (average 2000-2017)

It is noticeable that for Korea the level of concentration is considerably higher than in other countries, bar China in the field of rolling stock. In the EU the figures are low, evidencing that a large number of players are active in the EU market. It highlights that the intra-sectoral competitive dynamics in the EU are likely greater than in other regions.

8. Top innovators

The previous sections aggregated all inventions by country or region. Behind these statistics there are the actual inventors and firms, which this section shall focus on.

Several points need to be considered to interpret the following results. First, the PATSTAT patent statistics show the initial inventor/applicant, not the current owner. Analysing patenting trends for organisations is thus complexified by mergers and acquisitions, as well as purchases and sales of individual patents. The mapping of these dynamics falls outside the scope of this study. Instead, the period of analysis is shortened to 2010-2017 to limit the impact of these dynamics on the results.

Second, in this study patents are attributed to an organisation based on the name of the filing organisation. Yet, each organisation can file patents through subsidiaries that carry a name that does not resemble the name of the holding. So while attributing patents to organisations based on their names is a reasonable and common approach, it does not necessarily guarantee the allocation of all patents to a holding.

Third, this study applies fractional counting to allocate patents to organisations. However, organisations that allocate multiple CPC codes outside the scope of this study, will score lower than those organisations that would only allocate B codes (See Annex 1, Table A1.1. for an illustration). As such, the results may be skewed by the type of patents an organisation files and the CPC code allocation approach it applies.

These factors combined call for caution when interpreting the results. At the same time, the analyses do provide a useful general insight into the world's main rail innovators and how their patenting behaviours evolve.

Figure 12 shows the top innovators in terms of all inventions filed between 2010 and 2017. Besides the total number of inventions, it shows the destination of those inventions. Figure 13 shows the same information, but for high value inventions which implies that inventions protected only domestically are excluded.

The differences are striking. CRRC ranks first in terms of all inventions, but fourth for high value inventions. This is indicative of the organisation's domestic focus. The same logic applies to the Korean KRRI, which falls out of the top 10 when looking solely at high value inventions.

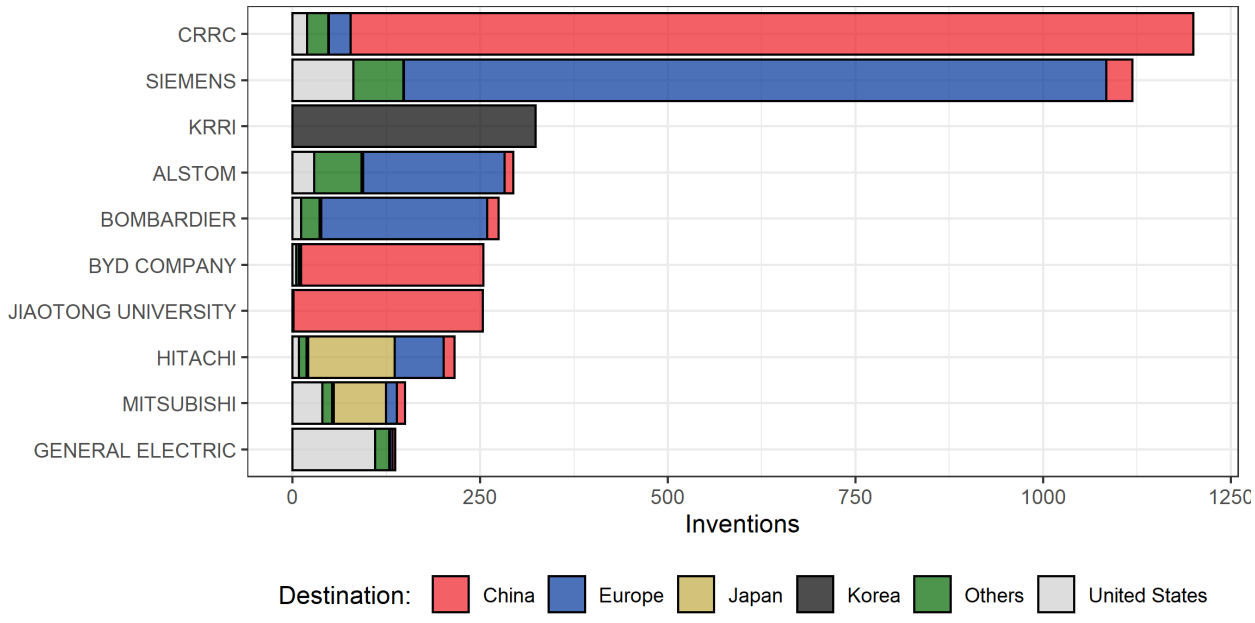

Figure 12 Top 10 innovators for all inventions and their destination (2010 – 2017)

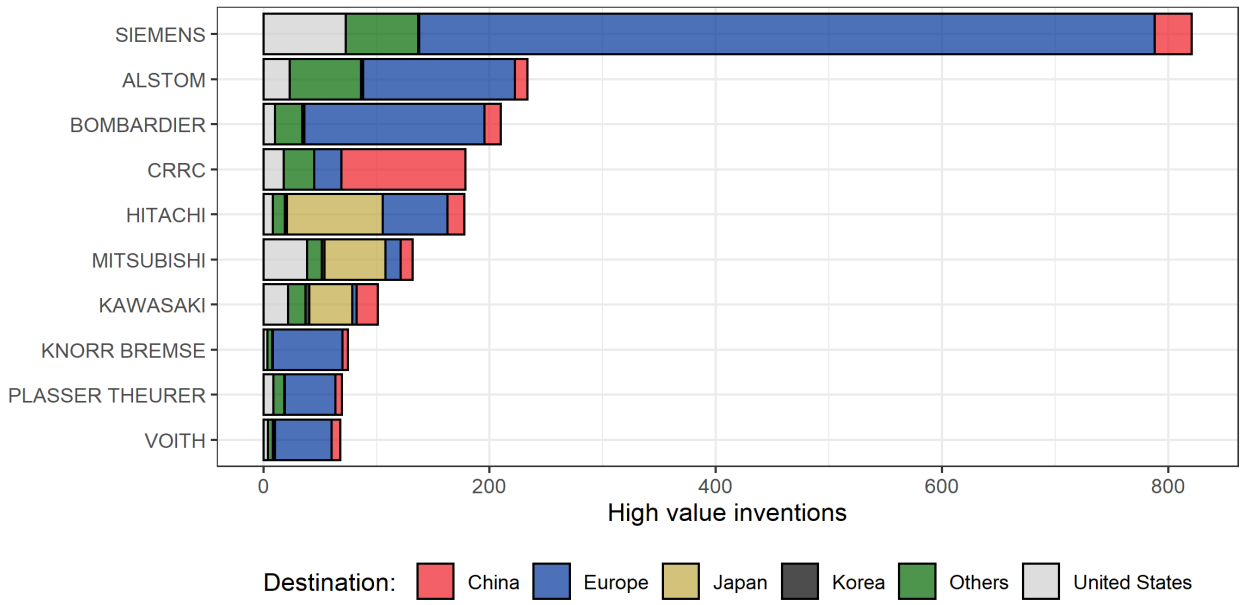

Figure 13 Top 10 innovators for high value inventions and their destination (2010 – 2017)

The last figure shows that six European companies are in the top 10, followed by three Japanese firms. Besides that, there is one Chinese firm in the list. This picture may look radically different if Chinese firms were to export a larger number of domestic inventions towards other regions.

The final figure of the report, Figure 14, focuses on the top 5 inventor firms in more depth by focusing on the number of high value inventions by year and subsystem. Generally, the firms seem to follow the patterns that were observed in chapter 4, meaning that there is a greater focus on inventions in CCS and RST, whereas ENE and INF remain stable. There are a few notable exceptions. Bombardier seemed to file comparatively less patents in the field of CCS compared to its direct competitors, as does CRRC. Hitachi, on the other hand, shows a steep increase in patenting in the CCS field.

In the field of RST Bombardier is a prominent player. CRRC shows a recent but drastic surge in high value inventions over the last 3 years, highlighting that its entry in the top 10 is the consequence of relatively recent actions. Siemens, finally, appears to have emphasized CCS and RST inventions equally, as an increasing output is observed in both fields.

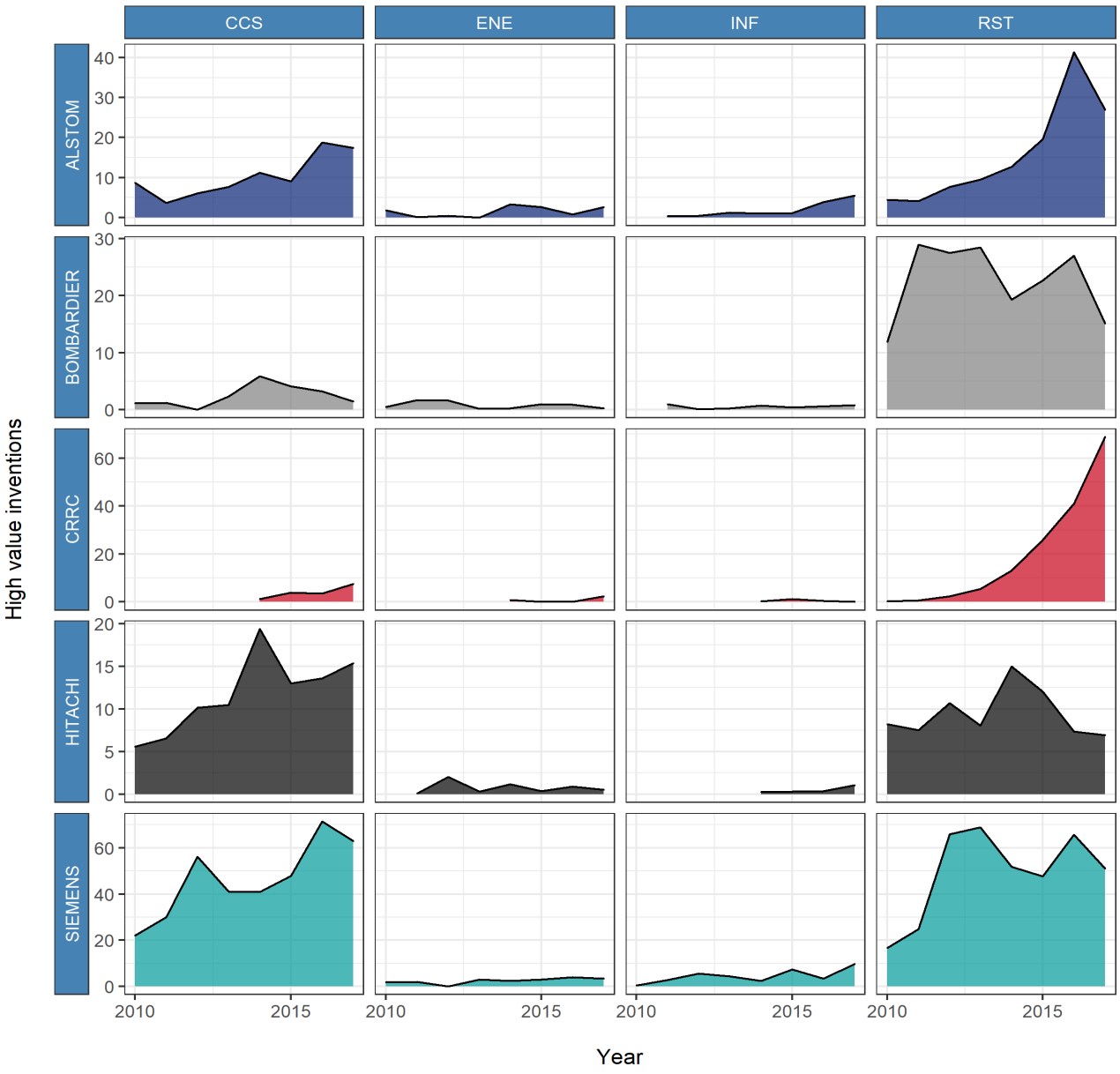

Figure 14 Patenting trend by Top 5 high value innovators and subsystem (L1)

9. Discussion

The report started with four questions. A large amount of data has been collected and analysed to provide novel insights. This chapter recaps the findings and reflects on the extent to which the questions can be answered.

How did the patenting of railway inventions in the EU evolve since 2000?

A key observation is that an increasing number of inventions is developed in the EU, predominantly in the fields of rolling stock and CCS. A closer look at the type of rolling stock inventions showed that particularly inventions related to bodies, suspensions, and traction are on the rise.

It is also noted that Germany, with a strong development and manufacturing base, is responsible for over half of the inventions by the EU railway sector. Together with France and Austria, more than 85% of the EU's inventions are covered. As such, the innovative activity of the sector is highly concentrated in a few countries.

How does the EU rail sector perform versus other regions?

A few points stick out. A first observation is that the number of Chinese inventions have grown substantially over the last decade and in terms of absolute numbers have overtaken those by European railway innovators. At the same time, the EU remains dominant in terms of high value inventions. In fact, on the list with the top 10 inventors, six European firms show up.

In absolute terms, Europe is also home to most green inventions. In terms of shares of green inventions compared to all inventions, the position of the EU is less strong, as Japan and South Korea top the list.

Patents are primarily used to protect and commercialise inventions in the domestic market. When European players export their inventions, it is mostly towards the US and China. This export of inventions is gaining speed in the last few years, suggesting that EU firms are becoming more successful in promoting their products abroad.

What are potential areas of growth for the EU rail sector?

The specialisation index analysis compared patenting activity in a region relative to what occurs globally. The analysis provides a first look into possible competitive advantages of a region for a specific subsystem. The results were mostly ambiguous, showing weak trends and relatively low levels of specialisation. As such, the analysis suggests that there is no specific subsystem in which the EU rail industry evidences a strong comparative specialisation. Instead, it implies that research activities in the EU are undertaken across the technological spectrum.

At the same time it is clear that the greatest strides are being made in CCS and rolling stock inventions, not only in the EU but around the world. Data suggests that continued activity in these fields are critical for maintaining and deepening a competitive advantage. Additional research should further investigate this topic on specialisation, using different data gathering and analysis techniques.

The market structure analysis showed that the railway sector in terms of patent output is considerably less concentrated in the EU, particularly when compared with Korea and China. It suggests that intra-sectoral competitive dynamics in the EU are relatively strong.

To what extent can changes in patenting activity be attributed to competition, research projects and harmonisation efforts?

The final question is the most complex one to answer. Admittedly, using only patent statistics and without a more thorough inquiry with inventors in the railway sector and innovation scholars, this question should be dealt with carefully. Still there are some interesting findings that do hint at the effect of recent developments.

- The surge in inventions across the EU co-occurs simultaneously with legislative efforts to harmonise technical specifications and the allocation of greater public budgets to research initiatives. However, it is too early to associate the rise in patenting with recent European research initiatives.
- The upward trend in patenting is particularly strong in the fields of CCS and rolling stock, while infrastructure and energy related inventions remain stable. Exactly the first two fields are impacted most by harmonisation efforts. The creation of a single European market for products is therefore likely to have spurred innovative activity.
- The fact that Chinese, European and Japanese firms are increasingly exporting inventions is indicative of greater competition in the market and the globalisation of the railway sector. This cannot be seen independently from changes in the regulatory landscape, both in terms of competition law and technical harmonisation. This competition, in turn, is likely to push firms towards greater innovation to keep offering competitive products across the globe.

Like for the previous questions, additional qualitative analyses would provide useful clarifications.

Annex 1 Methodological notes

The JRC methodology uses patent families as a proxy for inventions. Patent families include all documents relevant to a distinct invention, including patent applications to multiple jurisdictions (or patent offices) as well as those following regional, national, and international routes. Statistics are produced based on applicants only (as the owners of the patent and, thus, directly financing R&D activities) and considering different categories of applicants, namely companies, universities, and government non-profit organisations. If there are multiple documents per invention and when more than one applicant or technology code is associated with an application, fractional counting is used to apportion effort between applicants or technological areas, thus preventing multiple counting. The year of the invention is the priority year of the family.

For example, Table A1.1 shows an illustrative example of two patent families. Regarding patent family F_1, only 0.40 of this invention refers to ERA subsystems and it is of high-value (i.e., invention protected to two distinct patent offices: O_1 and O_2). 50% of F_1 is international, assuming that O_1=C_1 and O_2≠C_1. F_1 is a 'green' invention since it is also tagged via the Y-schema of the Cooperative Patent Classification that identifies inventions related to climate change mitigation technologies. 0.66 of F_2 is related to ERA subsystems, but this inventions is not of high-value, not international and not 'green'.

Table A1.1. Overview on how fractional counts are allocated

Patent family	Priority year	Patent application	Patent office	Applicant	County applicant	CPC	ERA subsystems	Y-CPC	Fractional count	High-value	Interna-tional	Green
F_1	2016	P_1	O_1	A_1	C_1	B61D 25/00	RST	Y02T 30/42	**0.10**	Y	N	Y
						E01B 3/00	INF		**0.10**			
						H01L 31/04	n/a		0.10			
						H02S 20/30	n/a		0.10			
						H02S 40/32	n/a		0.10			
		P_2	O_2			B61D 25/00	RST	Y02T 30/42	**0.10**		Y	
						E01B 3/00	INF		**0.10**			
						H01L 31/04	n/a		0.10			
						H02S 20/30	n/a		0.10			
						H02S 40/32	n/a		0.10			
F_2	2016	P_3	O_3	A_2	C_3	B61C 13/00	RST	n/a	**0.33**	N	N	N
						B61D 27/00	RST		**0.33**			
						E02D 29/00	n/a		0.33			

High-value considers EU countries separately, while for international inventions European countries (EPO Members) are viewed as one macro-category. For example, a patent family protected in two EU countries (e.g. Germany and France) is considered high-value, while a patent application by a French applicant to the German patent authority (or to the EPO) is not considered international. The table below illustrates which flows are considered international and which are not.

Table A1.2. Overview on which flows qualify as international

International flow?			Patent office / Destination							
			Europe			Others	China	Japan	Korea	United States
			EPO	EU	No EU					
Country / Origin	EU	EU	No	No	No	Yes	Yes	Yes	Yes	Yes
	ROW	No EU	No	No	No	Yes	Yes	Yes	Yes	Yes
		Others	Yes	Yes	Yes	Yes/No	Yes	Yes	Yes	Yes
	CN		Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	JP		Yes	Yes	Yes	Yes	Yes	No	Yes	Yes
	KR		Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
	US		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No

The final table of this annex provides an insight into the linkages between the CPC groups and the subsystem taxonomy as applied by this report. It is clear that most CPC groups are linked to the B section (i.e. on 'Performing operations; Transporting'). The INF subsystem is linked to a group outside the B section, namely E01B, which specifically considers 'permanent way; permanent-way tools; machines for making railways of all kinds'.

Table A1.3. Correlation table CPC–Subsystems, showing the number of patent codes within each CPC group that were linked to the subsystems

CPC group	SUBSYSTEM			
	INF	RST	ENE	CCS
B60L	0	40	0	0
B60M	0	0	43	0
B61B	0	0	0	0
B61C	0	74	0	0
B61D	0	168	0	0
B61F	0	111	0	0
B61G	0	86	0	0
B61H	0	59	0	0
B61J	16	0	0	0
B61K	28	3	0	0
B61L	29	0	0	269
E01B	321	0	0	0

The European Commission's science and knowledge service

Joint Research Centre