Annexes

Beyond Patent Counts: Cross-Country Evidence on Innovation Quality and Collaboration in New Energy Vehicles

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Table of contents

Annexe 1 - Cooperative Patent Classification:

Table 1.1: Codes selected for the analysis. CPC list as in Altenburg et al. (2022) and Becker et al. (2025)

Altenburg, Tilman, Nicoletta Corrocher, and Franco Malerba. 2022. 'China's Leapfrogging in Electromobility. A Story of Green Transformation Driving Catch-up and Competitive Advantage'. *Technological Forecasting and Social Change* 183 (October): 121914. https://doi.org/10.1016/j.techfore.2022.121914.

Becker, Tim, Sebastian Losacker, and Margherita Russo. 2025. 'Mapping European Regional Technological Capabilities to Support Decarbonization Pathways in the Automotive Industry'. *Progress in Economic Geography* forthcoming.

CPC classes		
Battery technologies	Battery technology	
		H01M 2/00 (Constructional details or processes of manufacture of the non-active parts)
		H01M 4/00 (Electrodes)
		H01M 6/00 (Primary cells; Manufacture thereof)
		H01M 8/00 (Fuel cells; Manufacture thereof)
		H01M 10/00 (Secondary cells; Manufacture thereof)
	Battery management technology	
		H02J (CIRCUIT ARRANGEMENTS OR SYSTEMS FOR SUPPLYING OR DISTRIBUTING ELECTRIC POWER; SYSTEMS FOR STORING ELECTRIC ENERGY)
		B60L 3/00 (Electric devices on electrically-propelled vehicles for safety purposes; Monitoring operating variables, e.g. speed, deceleration, power consumption)
		B60L 11/00 (Electric propulsion with power supplied within the vehicle)
		G01R 19/00 (Arrangements for measuring currents or voltages or for indicating presence or sign thereof)
		G01R 31/02 (Testing of electric apparatus, lines or components, for short-circuits, discontinuities, leakage of current, or incorrect line connection)
		G01R 31/04 (Testing connections, e.g. of plugs, of non-disconnectable joints)
		G01R 31/06 (Testing of electric windings, e.g. of solenoids, inductors, e.g. for polarity)
		G01R 31/07 (Testing of fuses)
		G01R 31/36 (Apparatus for testing electrical condition of accumulators or electric batteries, e.g. capacity or charge condition)
Entire vehicle controlling systems	Entire vehicle controlling systems	
		B60K 6/20 (the prime-movers consisting of electric motors and internal combustion engines, e.g. HEVs)
		B60L 15/00 (Methods, circuits, or devices for controlling the traction-motor speed of electrically-propelled vehicles)
		B60L 7/00 (Electrodynamic brake systems for vehicles in general)
		B60W 10/10 (Conjoint control of vehicle sub-units of different type or different function)
		B60W 10/20 (Control systems specially adapted for hybrid vehicles)
		H02J 7/00 (Circuit arrangements for charging or depolarising batteries or for supplying loads from batteries)
		B60W 20/00 (Control systems specially adapted for hybrid vehicles)
		B60W 30/00 (Purposes of road vehicle drive control systems not related to the control of a particular sub-unit, e.g. of systems using conjoint control of vehicle sub-units)
Motor technologies and control	Motor technology	
		H02K 17/00 (Asynchronous induction motors; Asynchronous induction generators)
		H02K 19/00 (Synchronous motors or generators)
		H02K 21/00 (Synchronous motors having permanent magnets; Synchronous generators having permanent magnets)
		H02K 23/00 (DC commutator motors or generators having mechanical commutator; Universal AC/DC commutator motors)
		H02K 25/00 (DC interrupter motors or generators)
		H02K 27/00 (AC commutator motors or generators having mechanical commutator)
		H02K 29/00 (Motors or generators having non-mechanical commutating devices, e.g. discharge tubes or semiconductor devices)
		H02K 41/00 (Propulsion systems in which a rigid body is moved along a path due to dynamo-electric interaction between the body and a magnetic field travelling along the path)
	Motor controlling technology	
		H02P 1/00 (Arrangements for starting electric motors or dynamo-electric converters)
		H02P 3/00 (Arrangements for stopping or slowing electric motors, generators, or dynamo-electric converters)
		H02P 5/00 (Arrangements specially adapted for regulating or controlling the speed or torque of two or more electric motors)
		H02P 6/00 (Arrangements for controlling synchronous motors or other dynamo-electric motors using electronic commutation dependent on the rotor position; Electronic commutators therefor)
		H02P 7/00 (Arrangements for regulating or controlling the speed or torque of electric DC motors)
		H02P 9/00 (Arrangements for controlling electric generators for the purpose of obtaining a desired output)
		H02P 21/00 (Arrangements or methods for the control of electric machines by vector control, e.g. by control of field orientation)
		H02P 23/00 (Arrangements or methods for the control of AC motors characterised by a control method other than vector control)
		H02P 25/00 (Arrangements or methods for the control of AC motors characterised by the kind of AC motor or by structural details)
		H02P 27/00 (Arrangements or methods for the control of AC motors characterised by the kind of supply voltage)
		H02P 29/00 (Arrangements for regulating or controlling electric motors, appropriate for both AC and DC motors)
		H02P 31/00 (Arrangements for r+B51+A26:D72+B51+A26:D72+B51+A26:D72+A25:D72+B51+A26:D72+A3:D72+B51+A26:D72+B51+A2+A26:D72

CPC CLASS in the category Y02T - Climate change mitigation technologies related to transportation,		
YEV	Advanced Technologies for Electric Vehicle Powertrain and Energy Infrastructure	
		Y02T10/64 Electric machine technologies in electromobility
		Y02T10/70 Energy storage systems for electromobility, e.g. batteries
		Y02T10/7072 Electromobility specific charging systems or methods for batteries, ultracapacitors, supercapacitors or double-layer capacitors
		Y02T10/72 Electric energy management in electromobility
		Y02T10/90 Energy harvesting concepts as power supply for auxiliaries' energy consumption, e.g. photovoltaic sun-roof
		Y02T10/92 Energy efficient charging or discharging systems for batteries, ultracapacitors, supercapacitors or double-layer capacitors specially adapted for vehicles
		Y02T90/10 Technologies relating to charging of electric vehicles
		Y02T90/12 Electric charging stations
		Y02T90/14 Plug-in electric vehicles
		Y02T90/16 Information or communication technologies improving the operation of electric vehicles
		Y02T90/167 Systems integrating technologies related to power network operation and communication or information technologies for supporting the interoperability of electric or hybrid vehicles, i.e. smartgrids a
		Y02T90/34 Fuel cell powered electric vehicles
YEV-HEV	Hybrid Electric Vehicles	
		Y10S 903/00 Hybrid Electric Vehicles, HEVs
		Y02T10/62 Hybrid vehicles
YIC	Advanced Powertrain Technologies for Internal Combustion Engine Vehicles	
		Y02T10/10 Internal combustion engine [ICE] based vehicles
		Y02T10/12 Improving ICE efficiencies
		Y02T10/30 Use of alternative fuels, e.g. biofuels
		Y02T10/40 Engine management systems
		Y02T10/60 Other road transportation technologies with climate change mitigation effect

Table 1.2: Technology fields and macro-groups

Cross tab of share of patents by technology field (as classified by the OECD source) and macro-group (as defined by the paper' Authors) of CPC codes in the data set (summary list in Annexe Table 1.1)

Technology Field (group)	Technology Field_Description	CPC.macrogroup battery	entire vehicle controllin..	motor	YEV	YEV-HEV	YIC
1. ELECTRIC ENGINEERING	Audio-visual technology	0.56%	0.81%	0.49%	0.29%	0.07%	0.01%
	Basic communication processes	0.58%	0.28%	0.43%	0.10%		0.03%
	Computer technology	1.85%	2.28%	0.31%	0.25%	0.17%	0.18%
	Digital communication	1.27%	0.76%	0.12%	0.45%	0.10%	0.01%
	Electrical machinery, apparatus, energy	61.82%	56.29%	72.92%	45.98%	5.72%	1.30%
	IT methods for management	1.35%	0.39%	0.06%	0.74%	0.03%	0.03%
	Semiconductors	0.36%	0.23%	0.12%	0.22%	0.03%	0.35%
	Telecommunications	2.39%	1.51%	0.37%	0.32%		0.01%
2. INSTRUMENTS	Analysis of biological materials	0.02%	0.01%				0.01%
	Control	1.05%	1.33%	4.11%	0.77%	0.03%	0.22%
	Measurement	9.31%	3.56%	2.25%	2.53%	0.38%	1.23%
	Medical technology	1.48%	1.35%	0.92%	0.11%		0.01%
	Optics	0.18%	0.17%	0.06%			
3. CHEMISTRY	Basic materials chemistry	0.05%	0.01%		0.06%	0.17%	0.53%
	Biotechnology	0.01%			0.01%	0.03%	
	Chemical engineering	0.07%	0.03%	0.37%	0.04%	0.07%	6.12%
	Environmental technology	0.07%	0.07%	0.04%	0.03%	0.10%	26.32%
	Food chemistry	0.01%					
	Macromolecular chemistry, polymers	0.03%			0.10%		0.03%
	Materials, metallurgy	0.07%		0.25%	0.56%	0.03%	0.95%
	Micro-structural and nano-technology	0.01%					
	Organic fine chemistry				0.07%		0.03%
	Pharmaceuticals	0.01%	0.01%				
	Surface technology, coating	0.17%	0.03%		0.17%	0.07%	0.21%
4. MECHANICAL ENGINEERING	Engines, pumps, turbines	1.37%	0.95%	5.46%	0.65%	3.02%	51.79%
	Handling	0.20%	0.30%	0.49%	0.71%	0.14%	0.15%
	Machine tools	0.22%	0.47%	1.78%	0.13%		0.12%
	Mechanical elements	0.16%	1.05%	0.64%	1.12%	8.91%	2.41%
	Other special machines	0.15%	0.26%	0.37%	0.57%	0.07%	0.15%
	Textile and paper machines	0.05%	0.06%		0.02%		0.03%
	Thermal processes and apparatus	0.44%	0.14%	0.68%	0.14%		1.81%
	Transport	13.51%	24.90%	6.04%	43.01%	80.07%	5.68%
5. OTHER FIELDS	Civil engineering	0.22%	0.37%	0.68%	0.46%	0.73%	0.23%
	Furniture, games	0.24%	0.61%	0.68%	0.24%		0.01%
	Other consumer goods	0.65%	1.75%	0.37%	0.03%	0.03%	
Totale complessivo		100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Annexe 2 - Quality of patents

Box 1: Patent quality indicators provided by the OECD: summary of the main characteristics.

Source: Authors' elaboration based on Squicciarini, M., H. Dernis, and C. Criscuolo. 2013. Measuring Patent Quality: Indicators of Technological and Economic Value. OECD Science, Technology and Industry Working Papers No. 2013/03. Vol. 2013/03. OECD Science, Technology and Industry Working Papers. https://doi.org/10.1787/5k4522wkw1r8-en.

The label of each indicator is in italics, the labels underscored are the ones selected for the cross-country comparison
The indices with less than 99% of values in our dataset are marked with a *

* **Breakthrough** inventions [*breakthrough*] are high-impact innovations which serve as a basis for future technological developments, new products or services. They are usually defined as the top 1% most cited patents within a year–technology cohort. These patents are considered to have a particularly strong influence on subsequent technological trajectories, although their identification suffers from truncation effects, as a 5–7-year window is needed to observe citations

<u>**Backwards citations**</u> [*bwd_cits*] are references made by a patent to prior art, i.e., earlier patents or published applications that the invention builds upon. They are generally included either by applicants or by examiners to delineate the novelty and scope of the invention. A higher number of backward citations often signals that the invention draws extensively on existing technological knowledge, while a lower number may be indicative of higher novelty. At the aggregate level (e.g., country, firm, or technology domain), backward citations provide insight into knowledge flows and the cumulative nature of innovation.

Citations to non-patent literature (NPL) [*npl_cits*] refer to references made by a patent to scientific publications, conference proceedings, datasets (e.g. DNA sequences, chemical compounds), or other scholarly sources. NPL citations measure the extent to which patented inventions build on scientific knowledge. They are often used as indicators of the contribution of public science to industrial technology and are associated with higher patent quality

Forward citations [*fwd_cits5, fwd_cits5_xy, fwd_cits7, fwd_cits7_xy*] mirrors the technological importance of the patent for the development of subsequent technologies, and reflects, to a certain extent, the economic value of inventions; "X" and "Y" citations refer, respectively, to documents that are particularly important when taken alone, to the point that a claimed invention cannot be considered novel, and to particularly relevant documents if combined with one or more documents of the same category. For this indicator, the time span considered must be restricted to 5 or 7 years to be effective.

Generality index [*generality*] relies on information concerning the number and distribution of citations received (5-year forward citations) and the technology classes (IPC) of the patents these citations come from; it can be used to identify, for example, general-purpose technologies.

* **Grant lag** [*grant_lag*] is the time elapsed between the filing date of the application and the date of the grant; applicants try to accelerate the grant procedure for their most valuable patents (more controversial claims lead to slower grants and those well-documented applications are approved faster): important patents are approved more quickly, and the granting delay decreases as industries move from the early stage of their innovation cycle to later stages.

* **Number of claims** [*claims*] determines the breadth of the rights conferred by a patent; a large number of claims also implies higher fees, hence, the number of claims in a patent document reflects not only the technological breadth of a patent, but also its expected market value.

<u>**Originality index**</u> [*originality*] measures the diversity of prior knowledge on which a patent build. It is based on the distribution of backward citations across different IPC technology classes: the more evenly citations are spread across diverse fields, the higher the originality. This reflects the degree to which an invention combines knowledge from different technological areas, potentially leading to more original outcomes

<u>**Patent family size**</u> [*family_size*] is proxied here by the number of patent offices at which a given invention has been protected. It may suffer from timeliness in the different patent offices. The value of patents is held to be associated with the geographical scope of patent protection, that is, with the number of jurisdictions in which patent protection has been sought (Lanjouw et al., 1998) and large international patent families have been found to be particularly valuable (Harhoff et al., 2003). Applicants might be willing to accept additional costs and delays of extending protection to other countries only if they deem it worthwhile.

* **Patent renewal** [*renewal*] is the count of years during which a granted patent is kept alive by paying maintenance fees, until it lapses, is withdrawn, or expires. Renewal decisions are costly; therefore, patents maintained for a longer time are generally considered more valuable. Renewal data are widely used in the economic literature to approximate the private value of inventions

Patent scope [*patent_scope*] is associated with the technological and economic value of patents. The technological breadth of patents in a firm's portfolio significantly affects the valuation of the firm, and that broad patents are more valuable when many possible substitutes in the same product class are available (Lerner, 1994). The index is defined as the number of distinct 4 digit IPC subclasses listed in the patent *p* document: The larger the number of distinct 4-digit IPC classes, the broader the scope index, and the higher the potential technological and market value of a patent

* **Quality index 4** [*quality_index_4*] is a composite indicator that combines multiple dimensions of patents' underlying quality, each weighted equally. The Quality Index 4 includes four core components: forward citations, patent family size, number of claims, and the generality index. The **Quality index 6** [*quality_index_6*] extends this measure by incorporating two additional dimensions—backward citations and grant lag—thus providing a broader and more refined proxy of both the technological relevance and the economic value of patented inventions.

Radicalness index [*radicalness*] (Shane, 2001) measures the extent to which a patent relies on knowledge from technological classes different from its own. It is calculated as the share of backward citations belonging to IPC classes not assigned to the focal patent itself. A higher value indicates that the invention departs more significantly from existing technological paradigms, hence being more "radical"

Table 2.1: quality indices by number of valid observations

The indices in red are those composing the *quality indicators 4* and *6* provided by the OECD data source, respectively: *forward citations, patent family size, number of claims, and the generality index*, in the *quality_index_4*. The *quality_index_6* [quality_index_6] extends this measure by incorporating two additional dimensions—*backwards citations and grant lag*

indice	n.patents	% valid
bwd_cits	60,080	100.0
family_size	60,080	100.0
fwd_cits5	60,080	100.0
fwd_cits5_xy	60,080	100.0
fwd_cits7	60,080	100.0
fwd_cits7_xy	60,080	100.0
npl_cits	60,080	100.0
patent_scope	60,080	100.0
radicalness	60,080	100.0
originality	59,665	99.3
claims	48,920	81.4
renewal	45,453	75.7
grant_lag	32,120	53.5
quality_index_4	32,118	53.5
quality_index_6	32,118	53.5
generality	19,836	33.0
breakthrough	332	0.6

Figure 2.1: distribution of indices with at least 99% valid values - original values

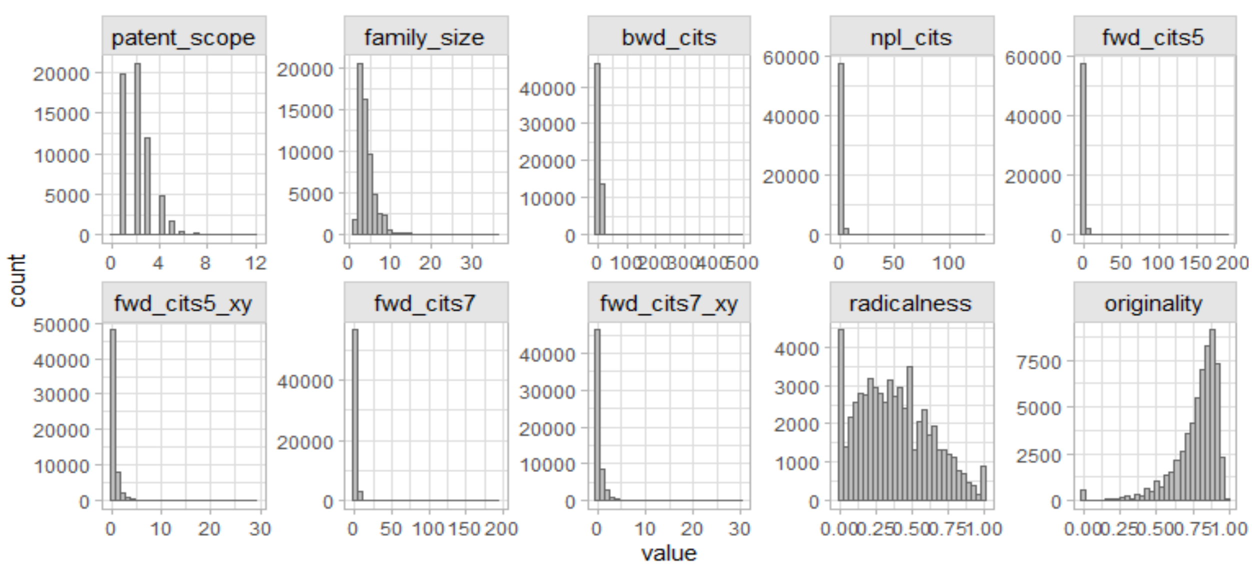


Figure 2.2: distribution of indices with at least 99% valid values - normalised values

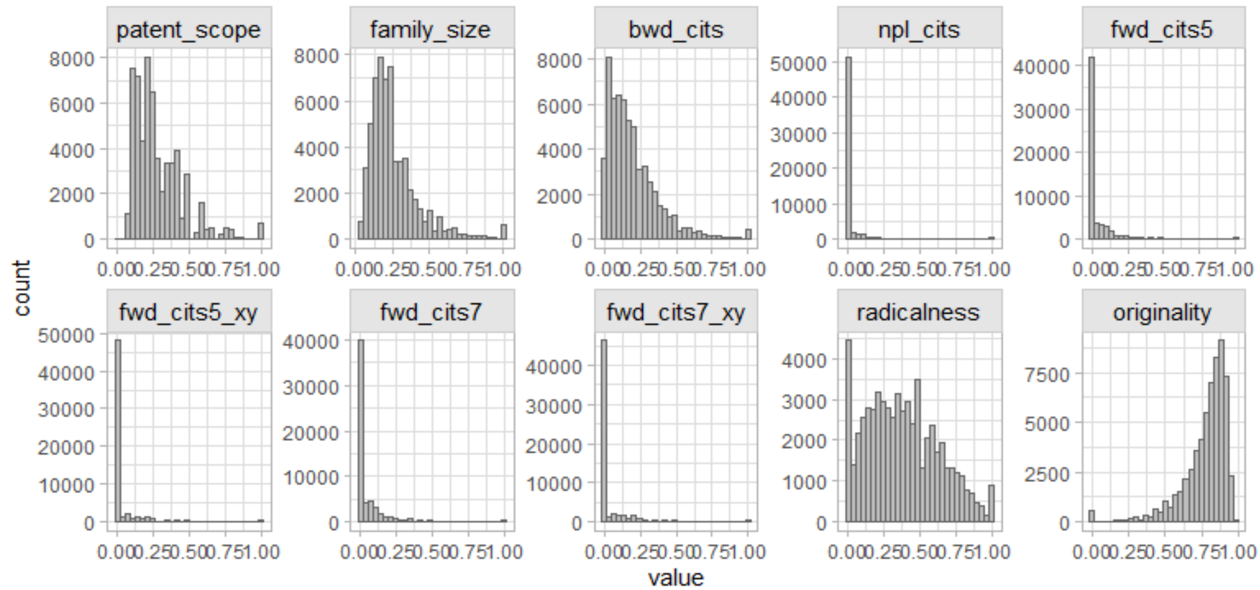


Table 2.2 Correlation matrix between patent quality indicators

	family_size	bwd_cits	radicalness	originality
radicalness				0.41
bwd_cits			0.05	0.22
family_size		0.33	0.04	0.02
patent_scope	0.25	0.31	-0.18	0.18

Annexe 3 - Results

3.1: Inventors' characteristics (inventors dataset)

Table 3.1: Patenting: inventors solo vs collaboration, inv_share by number of inventors

ctry_code	solo inventor	multiple inventors	Total	% solo inventor	% multiple inventors	average number of inventors in patents with multiple inventors	overall average number of inventors
JP	3,934	10,570	14,504	27.1	72.9	3.6	2.9
DE	3,125	7,411	10,536	29.7	70.3	3.0	2.5
US	2,282	7,758	10,040	22.7	77.3	3.4	2.9
KR	1,075	3,039	4,114	26.1	73.9	4.1	3.3
CN	776	2,987	3,763	20.6	79.4	3.9	3.3
FR	1,004	2,653	3,657	27.5	72.5	2.8	2.3
CH	300	641	941	31.9	68.1	2.4	2.0
GB	713	1,494	2,207	32.3	67.7	2.8	2.3
SE	571	1,144	1,715	33.3	66.7	2.7	2.2
IT	429	789	1,218	35.2	64.8	2.8	2.2
NL	215	530	745	28.9	71.1	2.7	2.3
OTH	2,072	4,568	6,640	31.2	68.8	2.8	2.3
Total	16,496	43,584	60,080	27.5	72.5	3.5	2.8

Inv_share for patents distinguished between: solo inventors and multiple inventors, e.g. in JP, 27.1% of inv_share is determined by patents with solo inventors.

Table 3.2: Number of inventors by type: always solo, mixed, always collaboration

ctry_code	always solo	mixed	always collaboration	Total	% always solo	% mixed	% always collaboration
JP	1,203	1,134	15,479	17,816	6.8	6.4	86.9
DE	1,266	799	12,421	14,486	8.7	5.5	85.7
US	1,185	523	15,774	17,482	6.8	3.0	90.2
KR	373	298	5,004	5,675	6.6	5.3	88.2
CN	369	140	6,048	6,557	5.6	2.1	92.2
FR	404	298	4,158	4,860	8.3	6.1	85.6
CH	129	58	1,100	1,287	10.0	4.5	85.5
GB	380	152	2,574	3,106	12.2	4.9	82.9
SE	202	168	1,396	1,766	11.4	9.5	79.0
IT	230	57	1,512	1,799	12.8	3.2	84.0
NL	105	48	847	1,000	10.5	4.8	84.7
OTH	1,179	349	8,968	10,496	11.2	3.3	85.4
Total	7,025	4,024	75,281	86,330	8.1	4.7	87.2

Table 3.3: inv_share by inventors' type

ctry_code	always solo	mixed	always collaboration	Total	% always solo	% mixed	% always collaboration
JP	1,553	3,931	9,020	14,504	10.7	27.1	62.2
DE	1,587	2,644	6,305	10,536	15.1	25.1	59.8
US	1,422	1,540	7,077	10,040	14.2	15.3	70.5
KR	472	999	2,643	4,114	11.5	24.3	64.3
CN	450	590	2,723	3,763	12.0	15.7	72.4
FR	494	926	2,238	3,657	13.5	25.3	61.2
CH	183	193	565	941	19.5	20.5	60.1
GB	469	413	1,326	2,207	21.2	18.7	60.1

ctry_code	always solo	mixed	always collaboration	Total	% always solo	% mixed	% always collaboration
SE	255	605	855	1,715	14.9	35.3	49.9
IT	276	221	720	1,218	22.7	18.2	59.2
NL	115	216	414	745	15.4	29.0	55.6
OTH	1,478	1,025	4,137	6,640	22.3	15.4	62.3
Total	8,754	13,302	38,024	60,080	14.6	22.1	63.3

Table 3.4: Inventors by number of patents in which they are involved

n. presences by inventors	n. inventors	inv_share	% inventors	% inv_share
1	57,483	20,697	66.6	34.4
2	13,939	9,729	16.1	16.2
3-5	10,397	13,141	12.0	21.9
6-10	3,134	7,864	3.6	13.1
11-20	1,056	5,055	1.2	8.4
>20	321	3,594	0.4	6.0
Total	86,330	60,080	100.0	100.0

Table 3.5: Inventors by number of patents in which they are involved, by country

	ctry_code	1	2	3-5	6-10	11-20	>20	Total
n.inventors	JP	10364	3112	2855	1043	348	94	17816
	DE	9750	2339	1715	502	147	33	14486
	US	12327	2717	1782	475	134	47	17482
	KR	3426	1001	792	291	113	52	5675
	CN	4656	927	662	193	80	39	6557
	FR	3285	778	578	164	45	10	4860
	CH	813	264	163	33	12	2	1287
	GB	2167	462	366	76	24	11	3106
	SE	1111	286	260	62	38	9	1766
	IT	1282	281	189	37	7	3	1799
	NL	719	154	83	20	19	5	1000
	OTH	7583	1618	952	238	89	16	10496
	Total	57483	13939	10397	3134	1056	321	86330
%	JP	58.2	17.5	16.0	5.9	2.0	0.5	100
	DE	67.3	16.1	11.8	3.5	1.0	0.2	100
	US	70.5	15.5	10.2	2.7	0.8	0.3	100
	KR	60.4	17.6	14.0	5.1	2.0	0.9	100
	CN	71.0	14.1	10.1	2.9	1.2	0.6	100
	FR	67.6	16.0	11.9	3.4	0.9	0.2	100
	CH	63.2	20.5	12.7	2.6	0.9	0.2	100
	GB	69.8	14.9	11.8	2.4	0.8	0.4	100
	SE	62.9	16.2	14.7	3.5	2.2	0.5	100
	IT	71.3	15.6	10.5	2.1	0.4	0.2	100
	NL	71.9	15.4	8.3	2.0	1.9	0.5	100
	OTH	72.2	15.4	9.1	2.3	0.8	0.2	100
	Total	66.6	16.1	12.0	3.6	1.2	0.4	100

Table 3.6: inv_share by number of patents in which inventors are involved, by country

	ctry_code	1	2	3-5	6-10	11-20	>20	Total
inv_share	JP	3602	2155	3540	2571	1645	990	14504
	DE	3699	1751	2322	1397	777	589	10536
	US	4150	1736	2042	1059	620	434	10040

	ctry_code	1	2	3-5	6-10	11-20	>20	Total
	KR	1074	634	877	639	434	456	4114
	CN	1362	532	714	400	316	439	3763
	FR	1304	603	871	502	245	132	3657
	CH	326	192	232	101	58	31	941
	GB	919	358	530	181	113	106	2207
	SE	473	251	420	198	253	121	1715
	IT	541	205	250	110	52	60	1218
	NL	290	113	112	51	92	87	745
	OTH	2956	1199	1231	653	451	150	6640
	Total	20697	9729	13141	7864	5055	3594	60080
%	JP	24.8	14.9	24.4	17.7	11.3	6.8	100
	DE	35.1	16.6	22.0	13.3	7.4	5.6	100
	US	41.3	17.3	20.3	10.5	6.2	4.3	100
	KR	26.1	15.4	21.3	15.5	10.6	11.1	100
	CN	36.2	14.1	19.0	10.6	8.4	11.7	100
	FR	35.7	16.5	23.8	13.7	6.7	3.6	100
	CH	34.7	20.4	24.7	10.8	6.2	3.3	100
	GB	41.6	16.2	24.0	8.2	5.1	4.8	100
	SE	27.6	14.6	24.5	11.5	14.7	7.0	100
	IT	44.4	16.9	20.5	9.0	4.3	4.9	100
	NL	38.9	15.1	15.0	6.9	12.4	11.7	100
	OTH	44.5	18.1	18.5	9.8	6.8	2.3	100
	Total	34.4	16.2	21.9	13.1	8.4	6.0	100

Figure 3.1: inv_share by macro group and number of patents in which inventors are involved

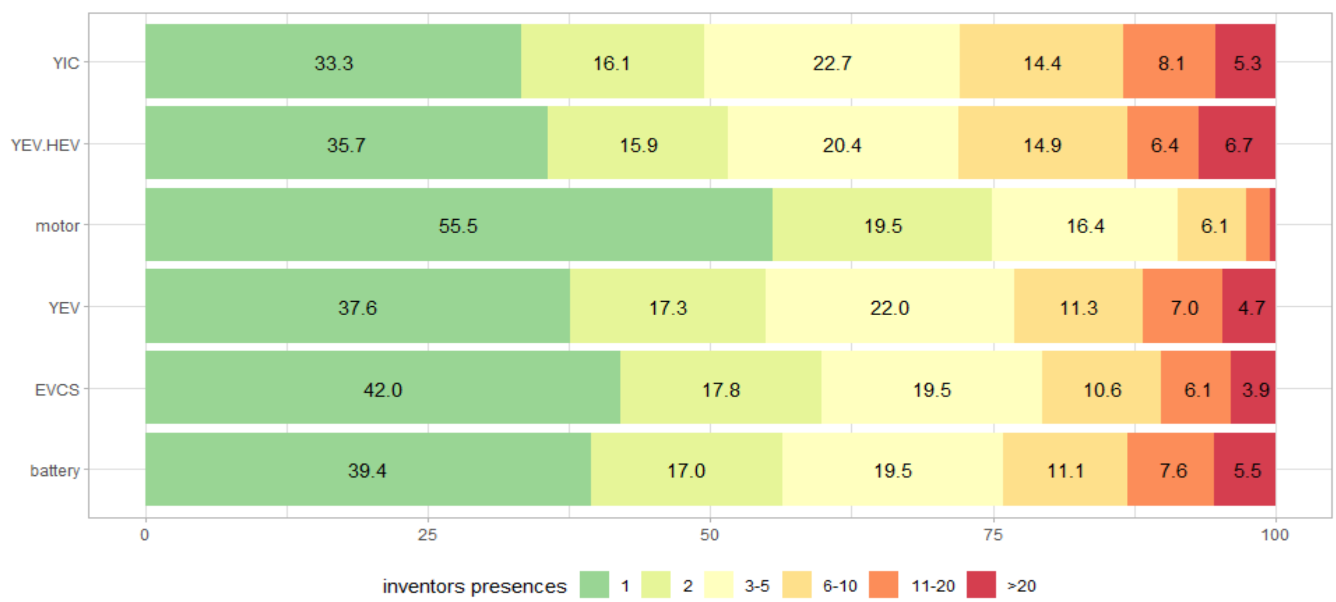


Table 3.7: Patents by number of inventors

	CPC.macrogroup	1	2	3	4	5	6-10	>10	Total
n.patents	battery	6821	6320	4776	2981	1717	2038	146	24799
	EVCS	5705	4861	3689	2331	1383	1621	116	19706
	YEV	4861	4341	3297	2274	1411	1467	103	17754
	motor	652	577	440	299	143	155	13	2279
	YEV.HEV	1088	991	721	525	301	308	27	3961

	CPC.macrogroup	1	2	3	4	5	6-10	>10	Total
	YIC	3536	3360	2652	1693	948	979	81	13249
	Total	**16496**	**14954**	**11612**	**7458**	**4372**	**4829**	**359**	**60080**

%	battery	27.5	25.5	19.3	12.0	6.9	8.2	0.6	100.0
	EVCS	29.0	24.7	18.7	11.8	7.0	8.2	0.6	100.0
	YEV	27.4	24.5	18.6	12.8	7.9	8.3	0.6	100.0
	motor	28.6	25.3	19.3	13.1	6.3	6.8	0.6	100.0
	YEV.HEV	27.5	25.0	18.2	13.3	7.6	7.8	0.7	100.0
	YIC	26.7	25.4	20.0	12.8	7.2	7.4	0.6	100.0
	Total	**27.5**	**24.9**	**19.3**	**12.4**	**7.3**	**8.0**	**0.6**	**100.0**

Figure 3.2: inv_share by macro group and number of inventors

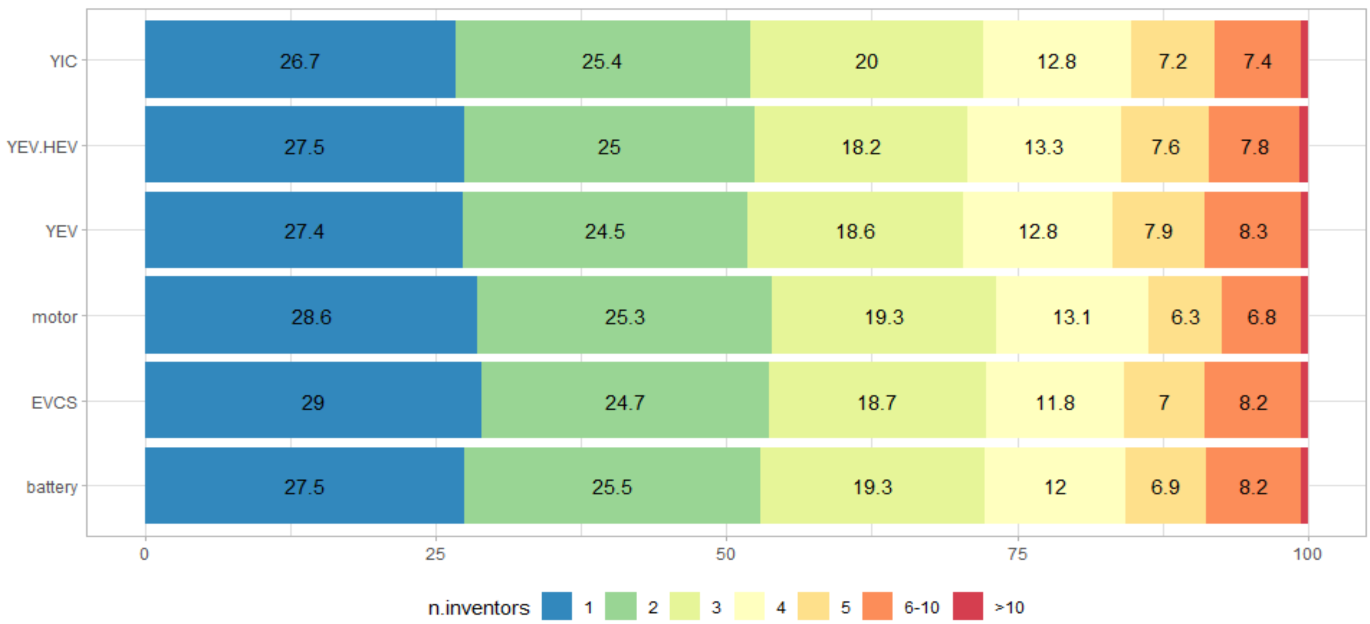


Table 3.8: number of periods in which inventors are active

n active periods	Frequency	Percent
1	75,484	87.4
2	9,277	10.7
3	1,569	1.8
Total	86,330	100.0

3.2 Applicants (applicants dataset)

3.2.1 Concentration

Table 3.9: Concentration of applications by applicant

ctry_code	Gini concentration index	% of app_share in the first decile	n. applicants
KR	0.8933	89.4	392
JP	0.8749	84.2	817
SE	0.8446	83.2	182
DE	0.8235	80.0	1,415
FR	0.8161	79.1	570
CH	0.7942	77.0	284
CN	0.7865	76.8	769
NL	0.7349	72.3	183
US	0.7349	69.1	2,395
GB	0.6674	65.1	560
IT	0.6198	59.9	428

Figure 3.3: app_share concentration in applicants by country

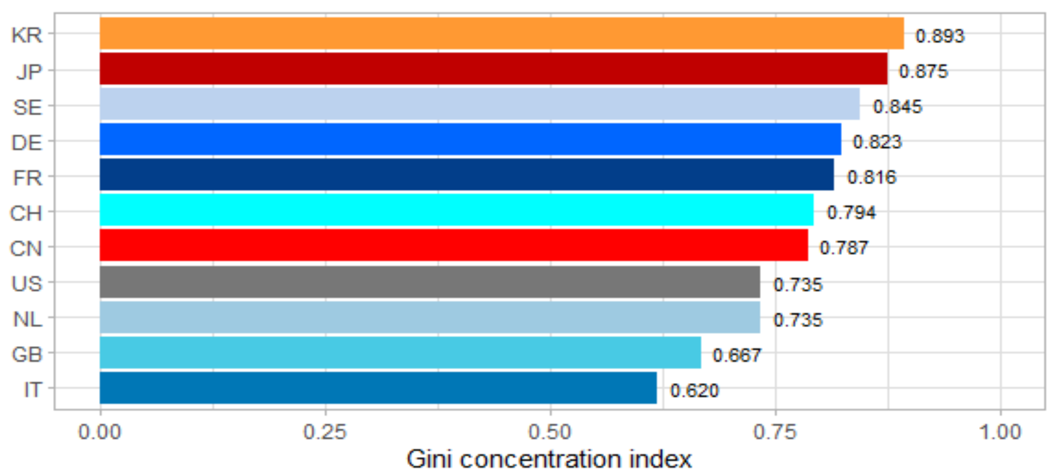


Figure 3.4: app_share concentration in applicants by country and period

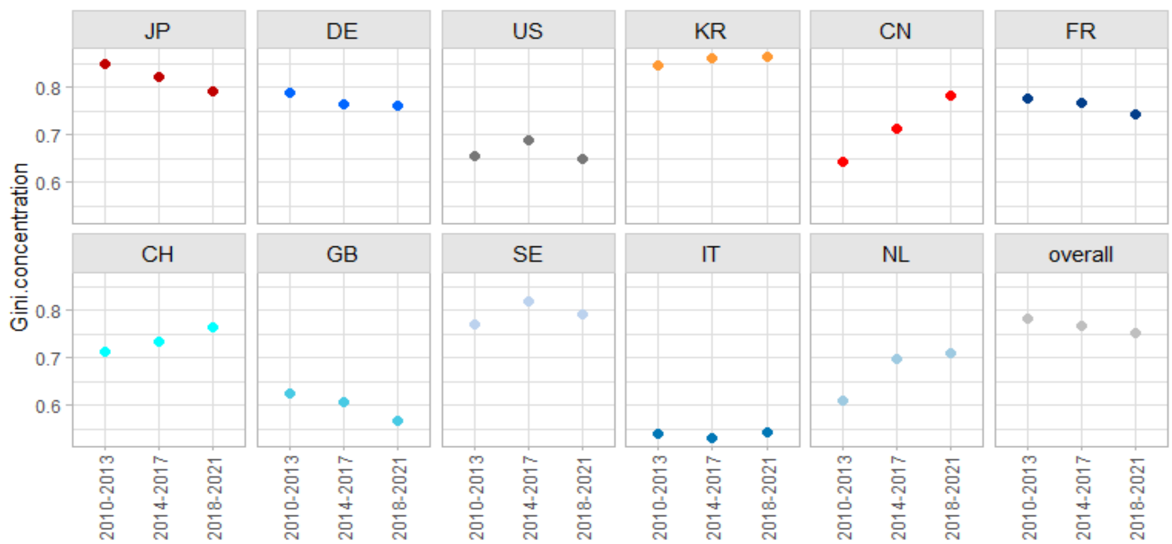


Table 3.10: Concentration of applications in applicants by macro-group

CPC macro-group	Gini concentration index	% of app_share in the first decile	n. applicants
battery	0.754	72.6	5,433
EVCS	0.747	72.1	4,499
YEV	0.767	73.7	3,665
motor	0.621	59.1	786
YEV.HEV	0.776	73.3	650
YIC	0.811	79.5	1,964

Table 3.11: Top 50 applicants ordered by app_share

applicant	ctry_code_top	app_share	% app_share	cumulative % app_share	n. total applications	n. total inventors	n. applications with inventors of differente country	n. of different countries	n. of different inventors from different countries	% of inventors from different country
TOYOTA JIDOSHA CO LTD	JP	2,534	4.2	4.2	2,656	2,570	14	3	23	0.9
ROBERT BOSCH GMBH	DE	1,435	2.4	6.6	1,547	2,195	314	21	451	20.5
SIEMENS AG	DE	1,095	1.8	8.4	1,100	1,318	297	19	306	23.2
NISSAN MOTOR CO LTD	JP	972	1.6	10.0	1,082	1,279	82	8	119	9.3
GENERAL ELECT CO	US	765	1.3	11.3	767	1,133	256	19	340	30.0
LG CHEM LTD	KR	760	1.3	12.6	764	904	38	3	54	6.0
SAMSUNG ELECT CO LTD	KR	687	1.1	13.7	707	1,135	26	7	63	5.6
RENAULT SAS	FR	636	1.1	14.8	716	815	79	10	120	14.7
PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD	JP	589	1.0	15.8	589	723	2	1	4	0.6
VOLKSWAGEN AG	DE	532	0.9	16.7	553	835	23	10	37	4.4

applicant	ctry_code_top	app_share	% app_share	cumulative % app_share	n. total applications	n. total inventors	n. applications with inventors of differente country	n. of different countries	n. of different inventors from different countries	% of inventors from different country
ABB SCHWEIZ AG	CH	531	0.9	17.5	537	891	441	26	688	77.2
HONDA MOTOR CO LTD	JP	490	0.8	18.4	505	904	20	5	26	2.9
VOLVO TRUCK CORP	SE	445	0.7	19.1	449	423	101	7	137	32.4
LG ENERGY SOLUTION LTD	KR	444	0.7	19.8	446	522	4	1	7	1.3
SAMSUNG SDI CO LTD	KR	434	0.7	20.6	521	695	228	6	168	24.2
CO LTD TOSHIBA	JP	434	0.7	21.3	484	659	0	0	0	0.0
AUDI AG	DE	431	0.7	22.0	447	562	21	9	32	5.7
LG ELECT INC	KR	410	0.7	22.7	415	710	5	3	6	0.8
SCANIA CV AB	SE	377	0.6	23.3	379	327	12	5	21	6.4
MAZDA MOTOR CORP	JP	347	0.6	23.9	351	513	2	1	3	0.6
HUAWEI TECH CO LTD	CN	337	0.6	24.4	337	534	29	7	47	8.8
MITSUBISHI ELECT CORP	JP	325	0.5	25.0	332	475	15	4	25	5.3
GUANGDONG OPPO MOBILE TELECOM CORP LTD	CN	307	0.5	25.5	310	90	0	0	0	0.0
HITACHI LTD	JP	306	0.5	26.0	314	671	14	5	22	3.3
BAYERISCHE MOTOREN WERKE AG	DE	283	0.5	26.5	289	561	52	9	72	12.8
QUALCOMM INC	US	275	0.5	26.9	275	376	3	2	3	0.8
CONTINENTAL AUTOMOTIVE GMBH	DE	274	0.5	27.4	276	318	83	13	89	28.0
BYD CO LTD	CN	264	0.4	27.8	277	359	0	0	0	0.0
PSA AUTOMOBILES SA	FR	245	0.4	28.2	252	332	7	5	10	3.0
MITSUBISHI HEAVY IND LTD	JP	242	0.4	28.6	250	338	2	1	5	1.5
CONTEMPORARY AMPEREX TECH CO LTD	CN	240	0.4	29.0	242	293	1	1	1	0.3
JOHNSON MATTHEY PLC	GB	240	0.4	29.4	244	312	125	9	132	42.3
YAMAHA HATSUDOKI CO LTD	JP	236	0.4	29.8	237	251	1	1	2	0.8
HITACHI AUTOMOTIVE SYSTEMS LTD	JP	235	0.4	30.2	239	391	2	2	3	0.8
MITSUBISHI JIDOSHA KOGYO CO LTD	JP	232	0.4	30.6	241	328	0	0	0	0.0
LSIS CO LTD	KR	230	0.4	31.0	231	149	0	0	0	0.0
CEA & AUX ENERGIES ALTERNATIVES	FR	228	0.4	31.4	251	351	5	6	9	2.6
HAMILTON SUNDSTRAND CORP	US	228	0.4	31.8	228	222	33	8	39	17.6
JAGUAR LAND ROVER LTD	GB	220	0.4	32.1	220	266	0	0	0	0.0
ZF FRIEDRICHSHAFEN AG	DE	219	0.4	32.5	220	303	15	6	15	5.0
KYOCERA CORP	JP	210	0.3	32.8	211	120	0	0	0	0.0
PEUGEOT CITROEN AUTOMOBILES SA	FR	210	0.3	33.2	211	223	2	2	2	0.9
SONY CORP	JP	209	0.3	33.5	210	294	22	5	42	14.3
HUAWEI DIGITAL POWER TECH CO LTD	CN	208	0.3	33.9	208	287	14	3	16	5.6

applicant	ctry_code_top	app_share	% app_share	cumulative % app_share	n. total applications	n. total inventors	n. applications with inventors of differente country	n. of different countries	n. of different inventors from different countries	% of inventors from different country
VESTAS WIND SYSTEMS AS	OTH	203	0.3	34.2	203	212	78	13	79	37.3
KON PHILIPS NV	NL	194	0.3	34.5	204	225	5	1	8	3.6
CO LTD TOYOTA JIDOSHOKKI	JP	188	0.3	34.8	208	275	0	0	0	0.0
VOLVO CAR CORP	SE	181	0.3	35.1	184	282	10	3	18	6.4
BASF CORP	US	176	0.3	35.4	185	273	101	5	121	44.3
ISUZU MOTORS LTD	JP	173	0.3	35.7	178	162	0	0	0	0.0

3.2.2 Activity of applicants

Table 3.12: Applicants by number of patents in which they are involved

n. presences by applicant	n. applicants	app_share	% applicants	% app_share
1	6,426	5,592	62.3	9.3
2	1,447	2,627	14.0	4.4
3-5	1,242	4,137	12.0	6.9
6-10	513	3,608	5.0	6.0
11-20	302	4,178	2.9	7.0
>20	383	39,938	3.7	66.5
Total	10,313	60,080	100.0	100.0

Table 3.13: Applicants by number of patents in which they are involved by country

	ctry_code	1	2	3-5	6-10	11-20	>20	Total
n.applicants	JP	352	122	125	69	61	88	817
	DE	814	220	180	94	48	59	1415
	US	1470	342	302	140	63	78	2395
	KR	248	56	49	16	4	19	392
	CN	505	107	77	35	18	27	769
	FR	327	96	77	28	21	21	570
	CH	162	42	41	10	16	13	284
	GB	378	77	63	18	13	11	560
	SE	106	22	31	11	4	8	182
	IT	315	45	41	13	6	8	428
	NL	125	22	13	11	7	5	183
	OTH	1624	296	243	68	41	46	2318
	Total	6426	1447	1242	513	302	383	10313
%	JP	43.1	14.9	15.3	8.4	7.5	10.8	100
	DE	57.5	15.5	12.7	6.6	3.4	4.2	100
	US	61.4	14.3	12.6	5.8	2.6	3.3	100
	KR	63.3	14.3	12.5	4.1	1.0	4.8	100
	CN	65.7	13.9	10.0	4.6	2.3	3.5	100
	FR	57.4	16.8	13.5	4.9	3.7	3.7	100
	CH	57.0	14.8	14.4	3.5	5.6	4.6	100
	GB	67.5	13.8	11.2	3.2	2.3	2.0	100
	SE	58.2	12.1	17.0	6.0	2.2	4.4	100
	IT	73.6	10.5	9.6	3.0	1.4	1.9	100
	NL	68.3	12.0	7.1	6.0	3.8	2.7	100
	OTH	70.1	12.8	10.5	2.9	1.8	2.0	100
	Total	62.3	14.0	12.0	5.0	2.9	3.7	100

Table 3.14: app_share by number of patents in which applicants are involved by country

	ctry_code	1	2	3-5	6-10	11-20	>20	Total
app_share	JP	284	200	385	472	865	12304	14509
	DE	743	411	611	666	646	7516	10593
	US	1242	636	1027	1028	914	5277	10125
	KR	209	102	153	105	58	3635	4261
	CN	415	182	237	222	241	2277	3574
	FR	265	156	232	176	257	2290	3375
	CH	151	80	157	74	220	1274	1958
	GB	358	151	219	145	184	830	1887
	SE	98	43	115	82	66	1227	1632
	IT	278	84	148	83	92	393	1078
	NL	118	44	48	73	85	439	807
	OTH	1432	538	805	479	550	2476	6280
	Total	5592	2627	4137	3608	4178	39938	60080
%	JP	2.0	1.4	2.7	3.3	6.0	84.8	100
	DE	7.0	3.9	5.8	6.3	6.1	70.9	100
	US	12.3	6.3	10.1	10.2	9.0	52.1	100
	KR	4.9	2.4	3.6	2.5	1.3	85.3	100
	CN	11.6	5.1	6.6	6.2	6.7	63.7	100
	FR	7.8	4.6	6.9	5.2	7.6	67.8	100
	CH	7.7	4.1	8.0	3.8	11.3	65.1	100
	GB	19.0	8.0	11.6	7.7	9.7	44.0	100
	SE	6.0	2.6	7.0	5.1	4.0	75.2	100
	IT	25.8	7.8	13.7	7.7	8.5	36.4	100
	NL	14.6	5.5	5.9	9.1	10.5	54.4	100
	OTH	22.8	8.6	12.8	7.6	8.8	39.4	100
	Total	9.3	4.4	6.9	6.0	7.0	66.5	100

Table 3.15: number of periods in which applicants are active

n active periods	Frequency	Percent
1	8,190	79.4
2	1,415	13.7
3	708	6.9
Total	10,313	100.0

3.2.3 Solo vs multiple applicants

Table 3.16: Patenting: applicants solo vs collaboration, app_share by number of applicants

ctry_code	solo applicant	multiple applicants	Total	% solo applicant	% multiple applicants	average number of applicants in patents with multiple applicants
JP	13,582	927	14,509	93.6	6.4	1.9
DE	10,175	418	10,593	96.1	3.9	1.5
US	9,859	266	10,125	97.4	2.6	2.0
KR	3,854	407	4,261	90.4	9.6	1.7
CN	3,275	299	3,574	91.6	8.4	1.9
FR	3,067	308	3,375	90.9	9.1	1.7
CH	1,914	44	1,958	97.7	2.3	1.3
GB	1,850	37	1,887	98.0	2.0	1.2
SE	1,614	18	1,632	98.9	1.1	1.5

ctry_code	solo applicant	multiple applicants	Total	% solo applicant	% multiple applicants	average number of applicants in patents with multiple applicants
IT	1,027	51	1,078	95.3	4.7	1.8
NL	781	26	807	96.7	3.3	1.1
OTH	5,991	289	6,280	95.4	4.6	1.7
Total	56,989	3,091	60,080	94.9	5.1	2.2

Table 3.17: Number of applicants by type

ctry_code	always solo	mixed	always collaboration	Total	% always solo	% mixed	% always collaboration
JP	453	179	185	817	55.4	21.9	22.6
DE	1,131	118	166	1,415	79.9	8.3	11.7
US	1,906	96	393	2,395	79.6	4.0	16.4
KR	269	31	92	392	68.6	7.9	23.5
CN	519	46	204	769	67.5	6.0	26.5
FR	348	77	145	570	61.1	13.5	25.4
CH	244	17	23	284	85.9	6.0	8.1
GB	501	20	39	560	89.5	3.6	7.0
SE	160	8	14	182	87.9	4.4	7.7
IT	341	22	65	428	79.7	5.1	15.2
NL	163	4	16	183	89.1	2.2	8.7
OTH	1,848	82	388	2,318	79.7	3.5	16.7
Total	7,883	700	1,730	10,313	76.4	6.8	16.8

Table 3.18: app_share by applicants type

ctry_code	always solo	mixed	always collaboration	Total	% always solo	% mixed	% always collaboration
JP	2,750	11,590	169	14,509	19.0	79.9	1.2
DE	3,432	7,046	116	10,593	32.4	66.5	1.1
US	7,685	2,279	161	10,125	75.9	22.5	1.6
KR	639	3,464	158	4,261	15.0	81.3	3.7
CN	1,832	1,572	170	3,574	51.3	44.0	4.8
FR	869	2,412	94	3,375	25.7	71.5	2.8
CH	997	941	20	1,958	50.9	48.0	1.0
GB	1,396	472	19	1,887	74.0	25.0	1.0
SE	563	1,063	6	1,632	34.5	65.1	0.4
IT	725	323	30	1,078	67.3	30.0	2.8
NL	486	309	12	807	60.2	38.3	1.5
OTH	4,638	1,433	209	6,280	73.8	22.8	3.3
Total	26,012	32,904	1,165	60,080	43.3	54.8	1.9

Table 3.19: Patents by number of applicants by macro-group

	CPC.macrogroup	1	2	3	4	5	>5	Total
n.patents	battery	23661	1001	132	39	15	11	24859
	EVCS	18746	875	81	22	6	11	19741
	YEV	16498	1110	122	23	5	12	17770
	motor	2200	75	11	3			2289
	YEV.HEV	3734	210	14	2	2		3962
	YIC	12684	512	46	11	7	1	13261
	Total	57091	2679	287	72	31	24	60184

	CPC.macrogroup	1	2	3	4	5	>5	Total
%	battery	95.2	4.0	0.5	0.2	0.1	0.0	100.0
	EVCS	95.0	4.4	0.4	0.1	0.0	0.1	100.0
	YEV	92.8	6.2	0.7	0.1	0.0	0.1	100.0
	motor	96.1	3.3	0.5	0.1			100.0
	YEV.HEV	94.2	5.3	0.4	0.1	0.1		100.0
	YIC	95.6	3.9	0.3	0.1	0.1	0.0	100.0
	Total	94.9	4.5	0.5	0.1	0.1	0.0	100.0

3.2.4 Cross-country Collaborations

Table 3.20: cross-country collaboration of applicants by country - app_share

ctry_code_top	No	Yes	Total	% Yes
JP	14,397	112	14,509	0.8
DE	10,414	179	10,593	1.7
US	10,039	86	10,125	0.9
KR	4,167	94	4,261	2.2
CN	3,533	41	3,574	1.1
FR	3,258	117	3,375	3.5
CH	1,929	29	1,958	1.5
GB	1,863	24	1,887	1.3
SE	1,625	7	1,632	0.4
IT	1,061	17	1,078	1.5
NL	787	20	807	2.5
OTH	6,159	121	6,280	1.9
Total	59,232	848	60,080	1.4

Table 3.21: cross-country collaboration of applicants by CPC.macrogroup - app_share

CPC.macrogroup	No	Yes	Total	% Yes
battery	24,493	306	24,799	1.2
EVCS	19,440	266	19,706	1.3
motor	2,245	34	2,279	1.5
YEV	17,399	355	17,754	2.0
YEV.HEV	3,894	67	3,961	1.7
YIC	13,097	152	13,249	1.1
Total	59,232	848	60,080	1.4

Table 3.22: Number of applicants for collaboration between countries

ctry_code	always one country	mixed	always cross country	Total	% always one country	% mixed	% always cross country
JP	778	34	5	817	95.2	4.2	0.6
DE	1,334	46	35	1,415	94.3	3.3	2.5
US	2,250	45	100	2,395	93.9	1.9	4.2
KR	378	10	4	392	96.4	2.6	1.0
CN	715	11	43	769	93.0	1.4	5.6
FR	515	34	21	570	90.4	6.0	3.7
CH	260	13	11	284	91.5	4.6	3.9
GB	527	15	18	560	94.1	2.7	3.2
SE	173	5	4	182	95.1	2.7	2.2
IT	404	13	11	428	94.4	3.0	2.6

ctry_code	always one country	mixed	always cross country	Total	% always one country	% mixed	% always cross country
NL	175	4	4	183	95.6	2.2	2.2
OTH	2,161	56	101	2,318	93.2	2.4	4.4
Total	9,670	286	357	10,313	93.8	2.8	3.5

Table 3.23: app_share for collaboration between countries by applicants

ctry_code	always one country	mixed	always cross country	Total	% always one country	% mixed	% always cross country
JP	8,009	6,497	3	14,509	55.2	44.8	0.0
DE	4,863	5,691	39	10,593	45.9	53.7	0.4
US	8,533	1,553	40	10,125	84.3	15.3	0.4
KR	1,655	2,602	4	4,261	38.8	61.1	0.1
CN	3,099	441	34	3,574	86.7	12.3	0.9
FR	1,564	1,796	16	3,375	46.3	53.2	0.5
CH	1,142	801	15	1,958	58.3	40.9	0.8
GB	1,489	389	9	1,887	78.9	20.6	0.5
SE	582	1,048	2	1,632	35.7	64.2	0.1
IT	878	194	6	1,078	81.4	18.0	0.6
NL	492	309	6	807	60.9	38.3	0.8
OTH	5,165	1,047	68	6,280	82.2	16.7	1.1
Total	37,469	22,368	243	60,080	62.4	37.2	0.4

3.3 Application share by applicant's country and inventors' country

Table 3.24: app_share by applicant's country and inventors country

applicant country	inventors same country	inventors other countries	Total	% of inventors other countries
aJP	14,233	276	14,509	1.9
aDE	9,063	1,530	10,593	14.4
aUS	8,323	1,802	10,125	17.8
aKR	3,981	280	4,261	6.6
aCN	3,363	211	3,574	5.9
aFR	2,986	389	3,375	11.5
aCH	652	1,306	1,958	66.7
aGB	1,517	370	1,887	19.6
aSE	1,362	270	1,632	16.5
aIT	983	95	1,078	8.8
aNL	577	230	807	28.5
aOTH	4,652	1,628	6,280	25.9
Total	51,692	8,388	60,080	14.0

3.3.1 bipartite network

Table 3.25: patents by applicants and inventors country

		inventors ctry_code												
	applicant ctry_code	iJP	iDE	iUS	iKR	iCN	iFR	iCH	iGB	iSE	iIT	iNL	iOTH	Total
n.patents	aJP	14,411	47	78	2	7	89	4	27	10	6	6	63	14,750
	aDE	51	9,902	305	49	93	175	79	69	36	38	53	710	11,560
	aUS	77	460	9,252	38	189	133	41	203	36	29	45	758	11,261
	aKR	11	139	56	4,064	2	0	0	4	0	0	1	125	4,402
	aCN	4	33	56	0	3,449	2	0	8	60	9	11	52	3,684
	aFR	76	96	47	3	33	3,265	20	22	1	29	2	109	3,703
	aCH	11	198	196	9	62	155	943	192	221	88	54	364	2,493
	aGB	24	84	171	3	26	26	5	1,677	16	6	7	73	2,118
	aSE	23	30	52	22	11	69	7	5	1,423	14	11	55	1,722
	aIT	0	8	43	0	3	9	11	1	0	1,050	2	43	1,170
	aNL	4	30	46	0	4	17	21	74	1	13	659	52	921
	aOTH	37	428	627	13	127	148	77	218	47	83	19	5,345	7,169
	Total	14,729	11,455	10,929	4,203	4,006	4,088	1,208	2,500	1,851	1,365	870	7,749	64,953
app_share	aJP	14,349	40	66	2	6	47	4	23	10	4	4	50	14,605
	aDE	46	9,773	280	27	86	165	73	62	34	36	40	689	11,309
	aUS	68	447	9,181	34	177	126	40	197	36	27	45	738	11,115
	aKR	11	74	51	4,036	2	0	0	4	0	0	1	123	4,300
	aCN	2	29	45	0	3,420	2	0	8	60	8	10	41	3,624
	aFR	42	88	35	2	32	3,187	19	20	1	25	2	96	3,548
	aCH	11	189	191	9	62	143	936	191	221	88	54	360	2,454
	aGB	20	78	162	3	25	25	4	1,654	16	6	7	66	2,065
	aSE	23	27	52	22	10	68	7	4	1,418	14	11	53	1,709
	aIT	0	6	41	0	2	5	8	0	0	1,036	2	38	1,139
	aNL	2	26	43	0	4	14	21	73	1	13	645	51	893
	aOTH	26	412	604	10	114	136	69	209	46	79	18	5,269	6,993
	Total	14,600	11,187	10,751	4,145	3,938	3,917	1,181	2,445	1,841	1,335	840	7,575	63,755
inv_share	aJP	14,362	40	59	2	6	83	2	19	9	4	2	35	14,622
	aDE	35	9,608	227	44	70	103	47	42	24	32	36	513	10,781
	aUS	55	316	8,857	30	117	97	20	135	22	14	28	516	10,208
	aKR	8	132	44	4,047	2	0	0	4	0	0	0	117	4,354
	aCN	2	25	42	0	3,417	1	0	7	58	6	10	43	3,612
	aFR	71	76	28	2	24	3,184	12	12	1	19	2	65	3,495
	aCH	10	140	160	4	42	121	804	170	173	60	43	261	1,988
	aGB	16	60	119	3	19	23	3	1,608	5	5	4	50	1,914
	aSE	20	21	41	22	8	62	7	2	1,396	12	6	42	1,640
	aIT	0	3	35	0	1	4	6	0	0	1,020	0	24	1,094
	aNL	3	20	39	0	4	13	12	68	1	9	625	35	829
	aOTH	24	303	499	11	98	102	44	169	30	53	12	5,043	6,388
	Total	14,605	10,743	10,150	4,164	3,807	3,793	956	2,237	1,719	1,236	769	6,746	60,925

Figure 3.5 Applicants-inventors countries as bipartite network - top countries

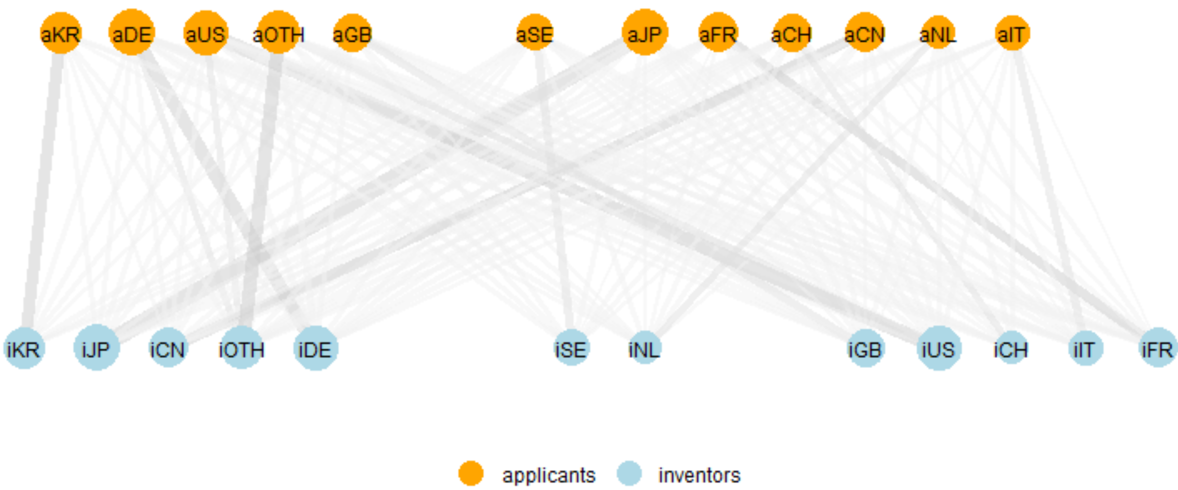


Figure 3.6: Applicants-inventors countries as bipartite network - top countries - only relationships between applicants and inventors from other countries

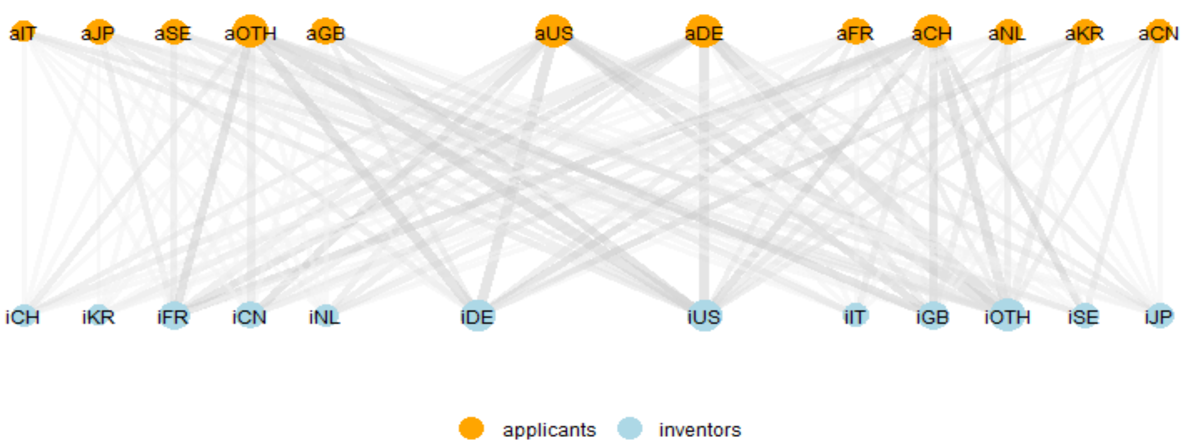


Figure 3.7: Applicants-inventors countries as bipartite network - top countries - excluding other countries

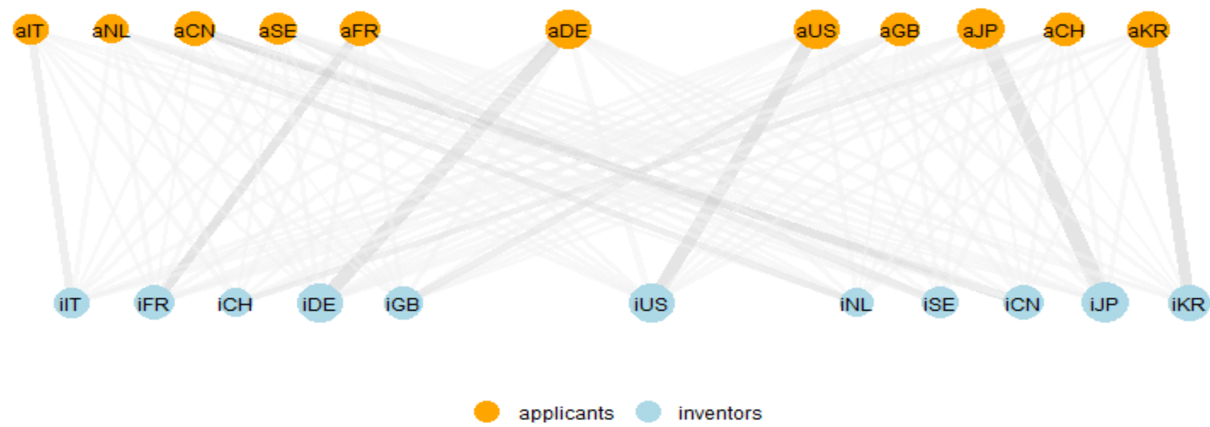
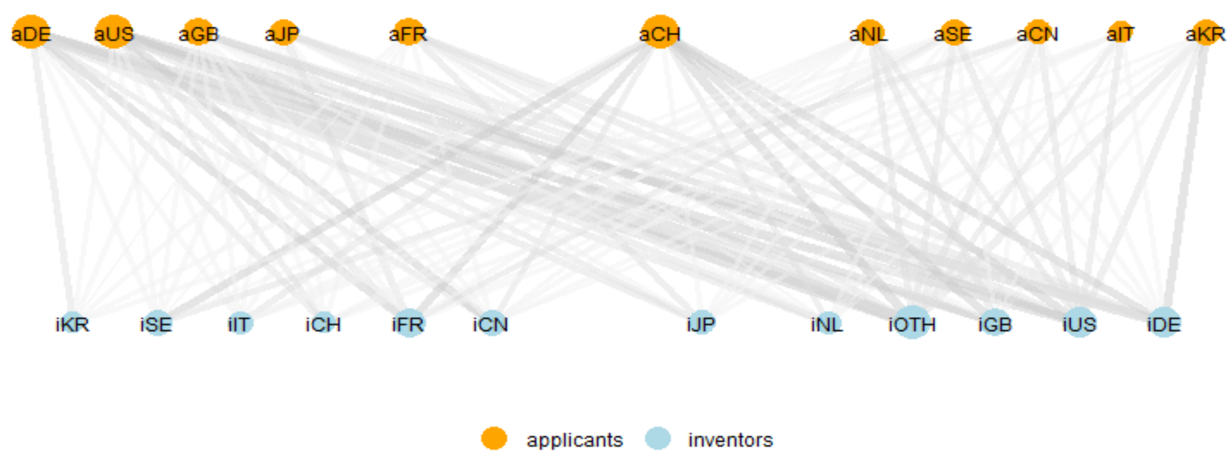


Figure 3.8: Applicants-inventors' countries as bipartite network - top countries - only relationships between applicants of top countries and inventors from other countries - excluding applicants of other countries



3.4 Quality of patents- inventors (inventors dataset)

3.4.1 Quality by single or multiple inventors

Table 3.26: Average values of quality indices by country and number of inventors in a patent

ctry_code_top	patent_scope single	patent_scope multiple	family_size single	family_size multiple	bwd_cits single	bwd_cits multiple	radicalness single	radicalness multiple	originality single	originality multiple
JP	0.292	0.305	0.240	0.250	0.217	0.230	0.353	0.319	0.790	0.780
DE	0.259	0.270	0.222	0.246	0.177	0.193	0.409	0.381	0.761	0.761
US	0.295	0.306	0.283	0.301	0.206	0.218	0.435	0.427	0.799	0.787
KR	0.285	0.272	0.296	0.275	0.181	0.174	0.377	0.327	0.765	0.734
CN	0.261	0.260	0.277	0.281	0.193	0.218	0.355	0.321	0.735	0.734
FR	0.270	0.268	0.223	0.252	0.171	0.170	0.398	0.374	0.766	0.755
CH	0.262	0.267	0.260	0.256	0.199	0.164	0.372	0.386	0.772	0.769
GB	0.257	0.297	0.260	0.316	0.159	0.191	0.426	0.373	0.768	0.769
SE	0.274	0.282	0.228	0.248	0.217	0.216	0.375	0.362	0.778	0.783
IT	0.267	0.268	0.235	0.242	0.180	0.187	0.407	0.388	0.786	0.771
NL	0.258	0.256	0.268	0.268	0.141	0.151	0.477	0.461	0.792	0.774
Total	0.277	0.287	0.249	0.267	0.194	0.207	0.391	0.363	0.777	0.768

Figure 3.9: Average values of quality indices by country and number of inventors in a patent

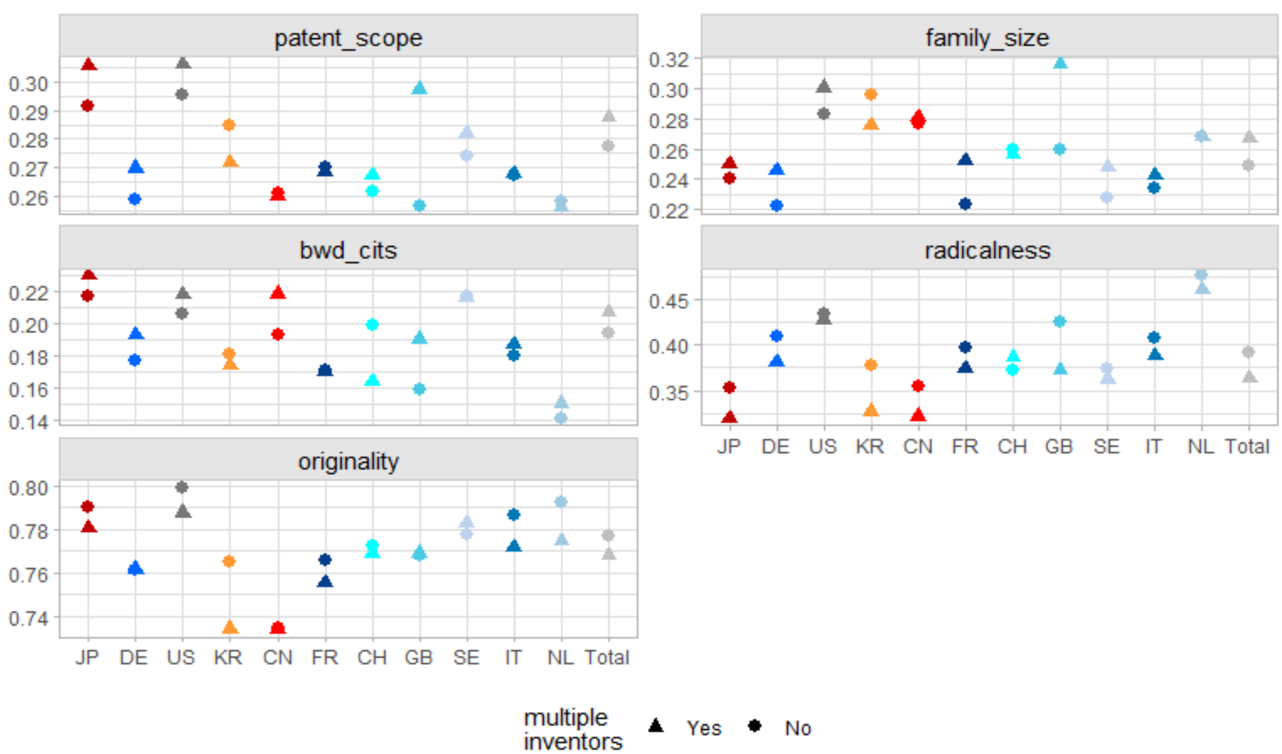


Figure 3.10: Average values of the mean rank of the quality indices by country and number of inventors in a patent

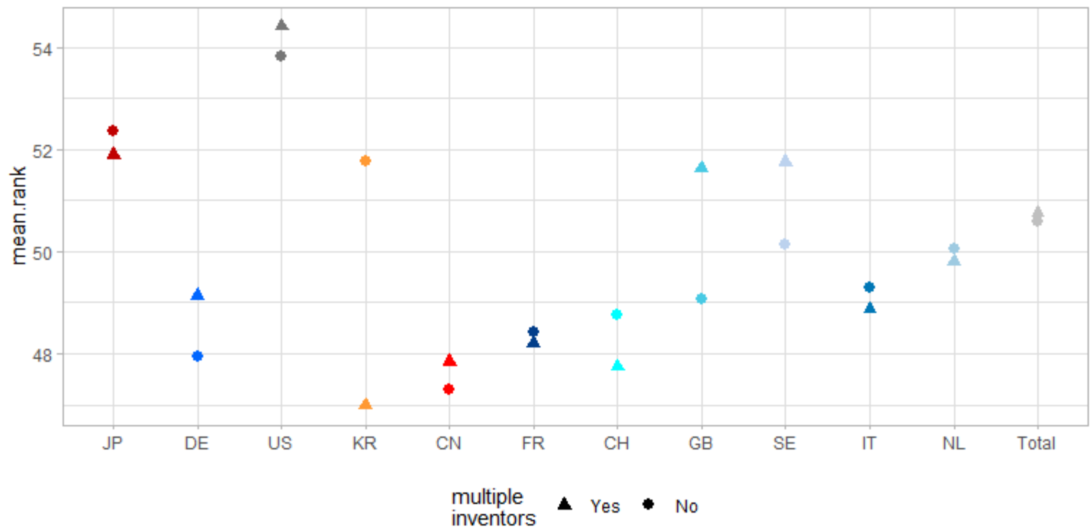


Table 3.27: Average values of quality indices by country and number of inventors in a patent - Kruskal-Wallis test and effect size

quality index	ctry	avg.single.inventor	avg.multiple.inventors	KW.test.signif	effect
patent_scope	JP	0.292	0.303	**	negligible
	DE	0.259	0.269	**	negligible
	US	0.295	0.299		negligible
	KR	0.285	0.270	**	negligible
	CN	0.261	0.263		negligible
	FR	0.270	0.268		negligible
	CH	0.262	0.261		negligible
	GB	0.257	0.285	**	negligible
	SE	0.274	0.282	.	negligible
	IT	0.267	0.268		negligible
	NL	0.258	0.257		negligible
	Total	0.277	0.283	***	negligible
family_size	JP	0.240	0.249	***	negligible
	DE	0.222	0.243	***	negligible
	US	0.283	0.290	*	negligible
	KR	0.296	0.278	***	negligible
	CN	0.277	0.279		negligible
	FR	0.223	0.251	***	negligible
	CH	0.260	0.265	*	negligible
	GB	0.260	0.301	***	negligible
	SE	0.228	0.249	**	negligible
	IT	0.235	0.246	*	negligible
	NL	0.268	0.265		negligible
	Total	0.249	0.261	***	negligible
bwd_cits	JP	0.217	0.227	*	negligible
	DE	0.177	0.188	**	negligible
	US	0.206	0.206		negligible
	KR	0.181	0.176		negligible
	CN	0.193	0.213	***	negligible
	FR	0.171	0.170		negligible
	CH	0.199	0.166	***	small
	GB	0.159	0.183	*	negligible

quality index	ctry	avg.single.inventor	avg.multiple.inventors	KW.test.signif	effect
	SE	0.217	0.211		negligible
	IT	0.180	0.195		negligible
	NL	0.141	0.156		negligible
	Total	0.194	0.201	.	negligible
radicalness	JP	0.353	0.323	***	negligible
	DE	0.409	0.387	***	negligible
	US	0.435	0.425		negligible
	KR	0.377	0.332	***	negligible
	CN	0.355	0.325	**	negligible
	FR	0.398	0.376	*	negligible
	CH	0.372	0.394		negligible
	GB	0.426	0.385	***	negligible
	SE	0.375	0.363		negligible
	IT	0.407	0.391		negligible
	NL	0.477	0.449		negligible
	Total	0.391	0.368	***	negligible
originality	JP	0.790	0.780	***	negligible
	DE	0.761	0.763		negligible
	US	0.799	0.787	***	negligible
	KR	0.765	0.739	***	negligible
	CN	0.735	0.735		negligible
	FR	0.766	0.757	**	negligible
	CH	0.772	0.768		negligible
	GB	0.768	0.767		negligible
	SE	0.778	0.780		negligible
	IT	0.786	0.775	.	negligible
	NL	0.792	0.775	.	negligible
	Total	0.777	0.769	***	negligible
mean.rank	JP	52.347	51.783		negligible
	DE	47.930	49.012	**	negligible
	US	53.823	53.470		negligible
	KR	51.776	47.435	***	small
	CN	47.282	47.915		negligible
	FR	48.413	48.287		negligible
	CH	48.749	48.116		negligible
	GB	49.071	50.719	*	negligible
	SE	50.121	51.369		negligible
	IT	49.283	49.450		negligible
	NL	50.047	49.739		negligible
	Total	50.584	50.432		negligible

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

The average values of the quality indices show significant differences between patents made by a single inventor and those made by multiple inventors, but the effect size is negligible.

3.4.2 Quality by inventors only within the country vs multiple countries

Table 3.28: Average values of quality indices by country and cross-country inventors in a patent

ctry_code_top	patent_scope single	patent_scope multiple	family_size single	family_size multiple	bwd_cits single	bwd_cits multiple	radicalness single	radicalness multiple	originality single	originality multiple
JP	0.304	0.302	0.248	0.333	0.228	0.249	0.322	0.329	0.781	0.774
DE	0.266	0.288	0.238	0.288	0.189	0.210	0.386	0.368	0.762	0.758
US	0.304	0.316	0.298	0.311	0.214	0.236	0.430	0.408	0.788	0.790
KR	0.273	0.248	0.277	0.295	0.174	0.190	0.330	0.415	0.736	0.758

ctry_code_top	patent_scope single	patent_scope multiple	family_size single	family_size multiple	bwd_cits single	bwd_cits multiple	radicalness single	radicalness multiple	originality single	originality multiple
CN	0.258	0.306	0.280	0.296	0.218	0.192	0.322	0.341	0.732	0.766
FR	0.267	0.286	0.246	0.276	0.171	0.166	0.376	0.385	0.757	0.745
CH	0.272	0.257	0.249	0.270	0.168	0.170	0.375	0.402	0.762	0.782
GB	0.288	0.313	0.304	0.336	0.185	0.195	0.387	0.342	0.770	0.762
SE	0.279	0.298	0.243	0.263	0.222	0.176	0.362	0.378	0.785	0.761
IT	0.265	0.287	0.238	0.271	0.181	0.227	0.393	0.376	0.774	0.773
NL	0.257	0.254	0.272	0.243	0.144	0.188	0.462	0.470	0.777	0.775
Total	0.286	0.297	0.263	0.296	0.205	0.209	0.365	0.383	0.769	0.771

Figure 3.11: Average values of quality indices by country and cross-country inventors in a patent

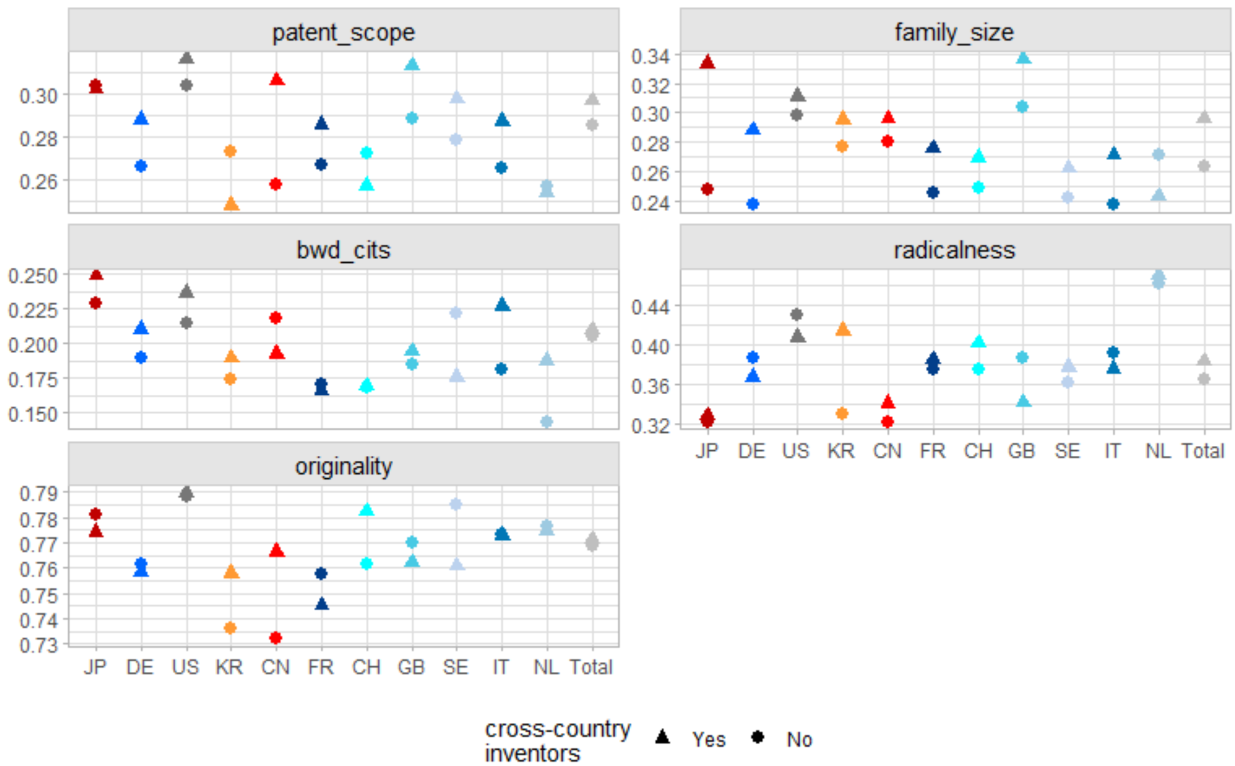


Figure 3.12: Average values of the mean rank of the quality indices by country and cross-country inventors in a patent

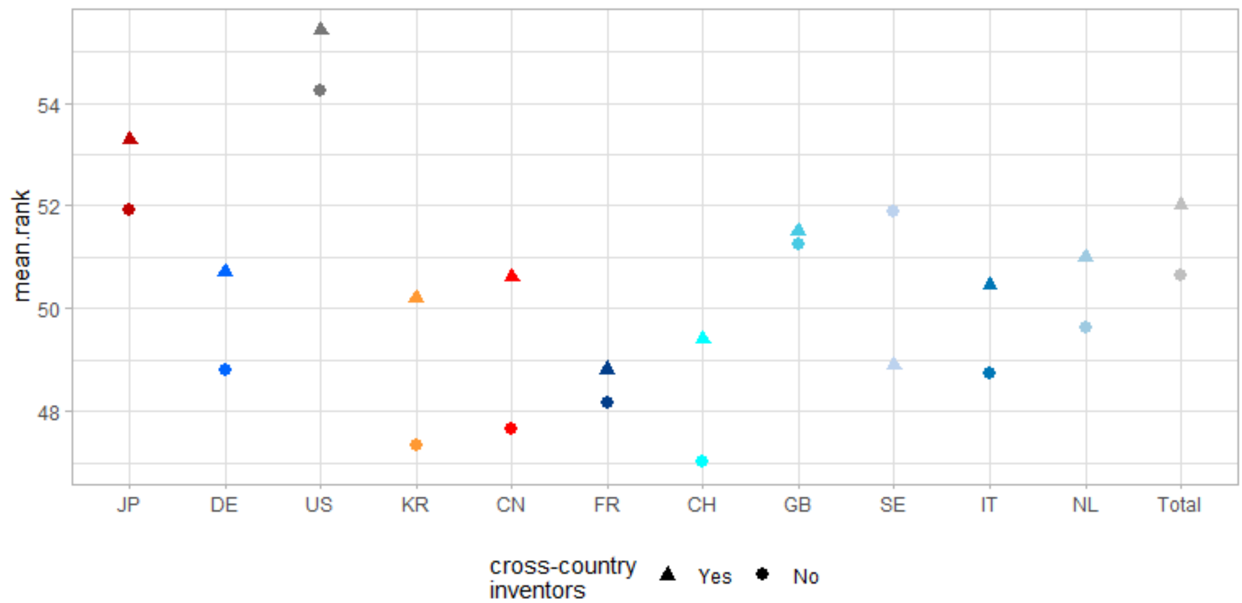


Table 3.29: Average values of quality indices by country and number of inventors in a patent - Kruskal-Wallis test and effect size

indice	ctry	avg.single.country	avg.multiple.countries	KW.test.signif	effect
patent_scope	JP	0.300	0.305		negligible
	DE	0.263	0.287	***	negligible
	US	0.298	0.304		negligible
	KR	0.274	0.269		negligible
	CN	0.259	0.301	***	negligible
	FR	0.266	0.286		negligible
	CH	0.266	0.255	.	negligible
	GB	0.273	0.291		negligible
	SE	0.277	0.298		negligible
	IT	0.266	0.280		negligible
	NL	0.256	0.263		negligible
	Total	0.282	0.286		negligible
family_size	JP	0.246	0.322	***	negligible
	DE	0.232	0.276	***	negligible
	US	0.286	0.301	***	negligible
	KR	0.282	0.303		negligible
	CN	0.279	0.281		negligible
	FR	0.238	0.284	***	negligible
	CH	0.257	0.273	**	negligible
	GB	0.285	0.308		negligible
	SE	0.238	0.275		negligible
	IT	0.236	0.278	**	negligible
	NL	0.270	0.246	*	negligible
	Total	0.257	0.280	***	negligible
bwd_cits	JP	0.224	0.250		negligible
	DE	0.183	0.195		negligible
	US	0.205	0.210	.	negligible
	KR	0.177	0.161		negligible

indice	ctry	avg.single.country	avg.multiple.countries	KW.test.signif	effect
	CN	0.211	0.189	*	negligible
	FR	0.170	0.173		negligible
	CH	0.177	0.171		negligible
	GB	0.174	0.186		negligible
	SE	0.218	0.179	***	small
	IT	0.184	0.225	*	negligible
	NL	0.142	0.193	***	small
	Total	0.200	0.192	***	negligible
radicalness	JP	0.331	0.337		negligible
	DE	0.394	0.390		negligible
	US	0.431	0.402	***	negligible
	KR	0.344	0.365		negligible
	CN	0.330	0.350		negligible
	FR	0.381	0.384		negligible
	CH	0.371	0.414	***	negligible
	GB	0.402	0.373	*	negligible
	SE	0.366	0.373		negligible
	IT	0.398	0.385		negligible
	NL	0.458	0.450		negligible
	Total	0.373	0.387	**	negligible
originality	JP	0.783	0.777		negligible
	DE	0.762	0.766	.	negligible
	US	0.790	0.786	**	negligible
	KR	0.746	0.757		negligible
	CN	0.732	0.762	***	negligible
	FR	0.760	0.750		negligible
	CH	0.764	0.777		negligible
	GB	0.768	0.764		negligible
	SE	0.782	0.758		negligible
	IT	0.778	0.781		negligible
	NL	0.780	0.778		negligible
	Total	0.771	0.769		negligible

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Table 3.30: Average values of mean rank, by country and number of inventors in a patent - Kruskal-Wallis test and effect size

ctry	avg.single.country	avg.multiple.countries	KW.test.signif	effect
JP	51.917	53.365		negligible
DE	48.437	50.774	***	negligible
US	53.545	53.540		negligible
KR	48.544	49.636		negligible
CN	47.597	49.977	*	negligible
FR	48.118	49.731		negligible
CH	47.595	49.326		negligible
GB	50.162	50.577		negligible
SE	51.211	49.487		negligible
IT	49.021	51.467	.	negligible
NL	49.517	51.048		negligible
Total	50.457	50.708		negligible

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

3.5 Quality of patents – applicants (applicants dataset)

Figure 3.13: Box plot of quality indices by country

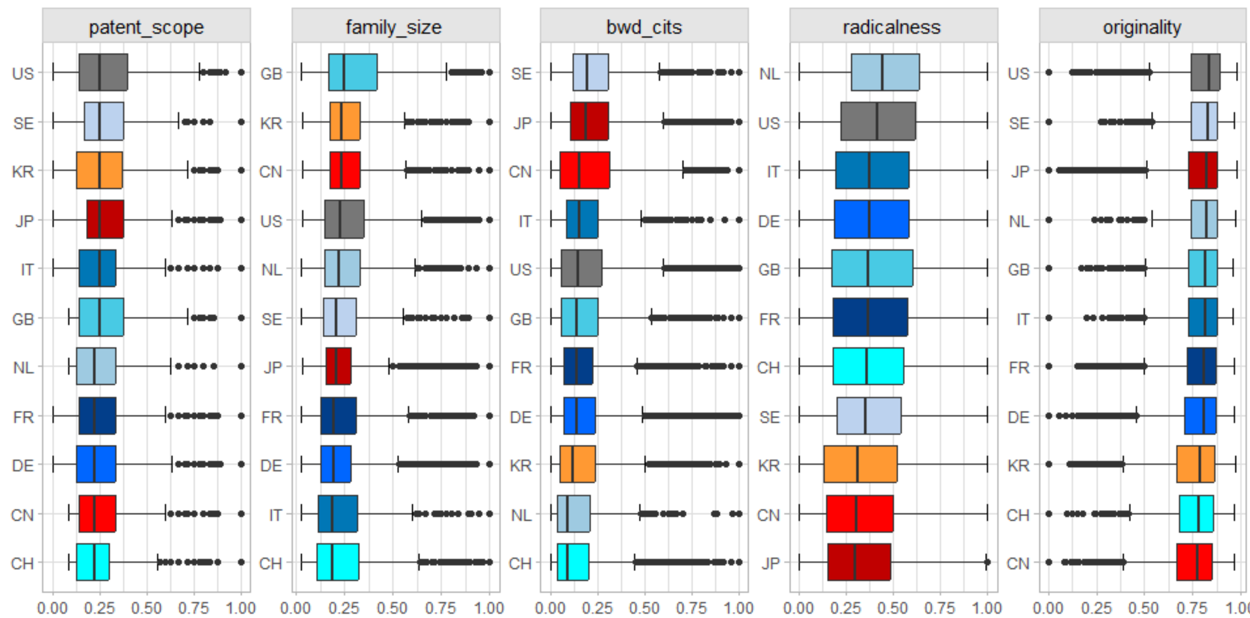


Table 3.31: Kruskal.Wallis test on differences of quality indices between countries

quality.index	statistic	df	p.value	signif	effect size eta^2	effect
patent_scope	614.13	11	< 2.2e-16	***	0.0099	negligible
family_size	1,059.37	11	< 2.2e-16	***	0.0172	small
bwd_cits	1,586.62	11	< 2.2e-16	***	0.0259	small
radicalness	1,206.57	11	< 2.2e-16	***	0.0196	small
originality	1,135.87	11	< 2.2e-16	***	0.0185	small
mean.rank	**1,098.26**	**11**	**< 2.2e-16**	*******	**0.0178**	**small**

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Figure 3.14: Box plot of quality indices by country and macro-group

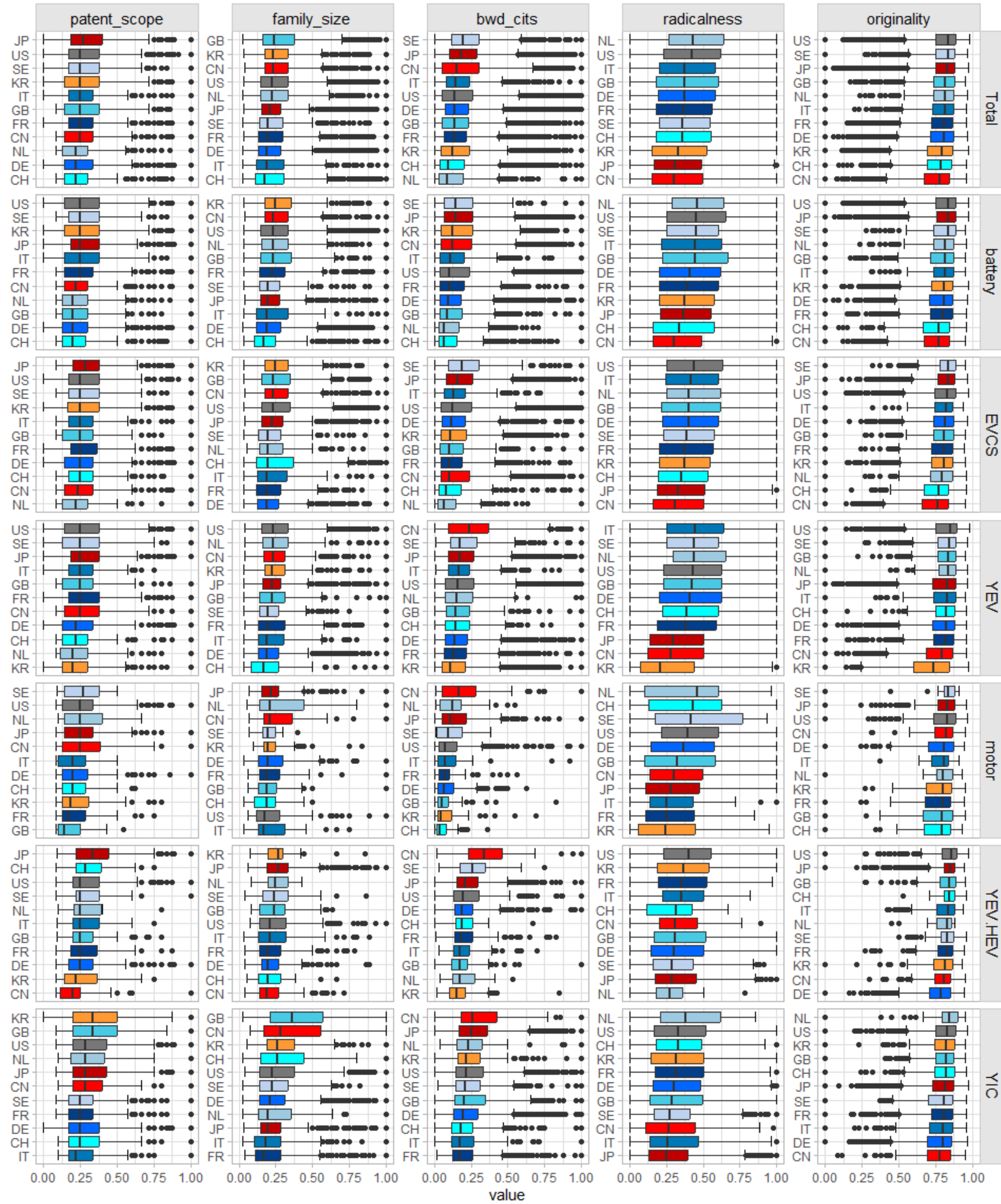


Figure 3.15 - Median of patents' quality indices, by country, in total and CPC macro-group

Only the 11 countries accounting for the 90% of all patents are listed. For each quality index, countries are ranked in decreasing order of the patents' median quality for the total of patents.
The five selected indices - Patent family size [*family_size*], Backwards citations [*bwd_cits*], Radicalness index [*radicalness*], Patent scope [*patent_scope*], Originality index [*originality*] – are the ones with an MDA>0.6. Cross country differences are significant (p-value>0.0001)

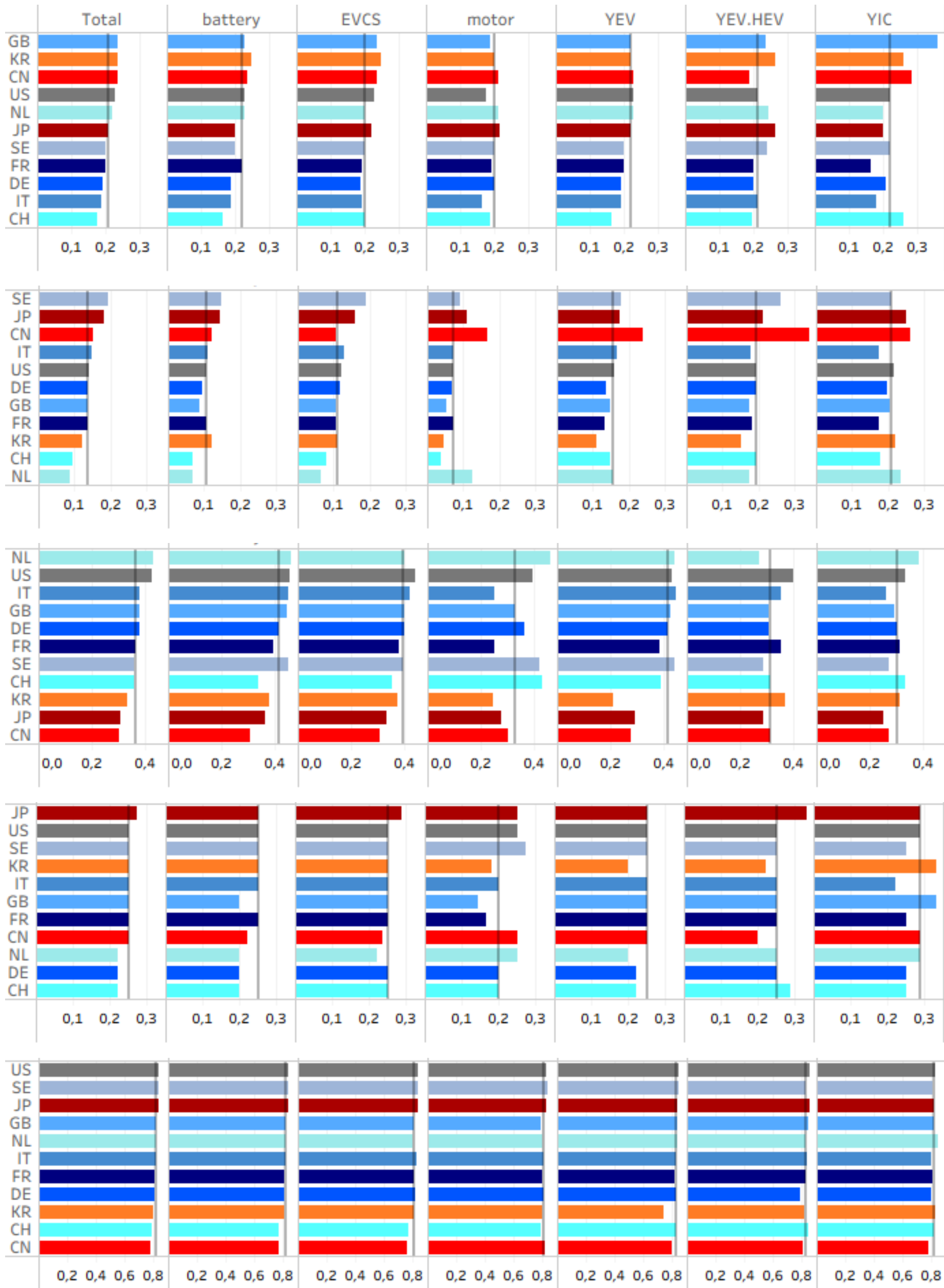
Patent family size expected value of the patent

Backwards citations knowledge flows and the cumulative nature of innovation

Radicalness index departure from existing technological paradigms

Patent scope potential technological and market value of a patent

Originality index degree at which it combines knowledge from different technological areas



median mean rank

Table 3.32: Kruskal.Wallis test on differences of normalized ranking between countries by CPC macro-groups

CPC.macrogroup	statistic	df	p.value	signif	effect size eta^2	effect
battery	755.36	11	< 2.2e-16	***	0.0297	small
EVCS	540.58	11	< 2.2e-16	***	0.0265	small
YEV	553.19	11	< 2.2e-16	***	0.0300	small
motor	69.43	11	1.57e-10	***	0.0254	small
YEV.HEV	392.41	11	< 2.2e-16	***	0.0950	medium
YIC	442.83	11	< 2.2e-16	***	0.0323	small

*** p<0.001, ** p<0.01, * p<0.05, . p<0.1

Figure 3.16: Mean rank: median values by country and macro-group, the vertical line represents the overall median

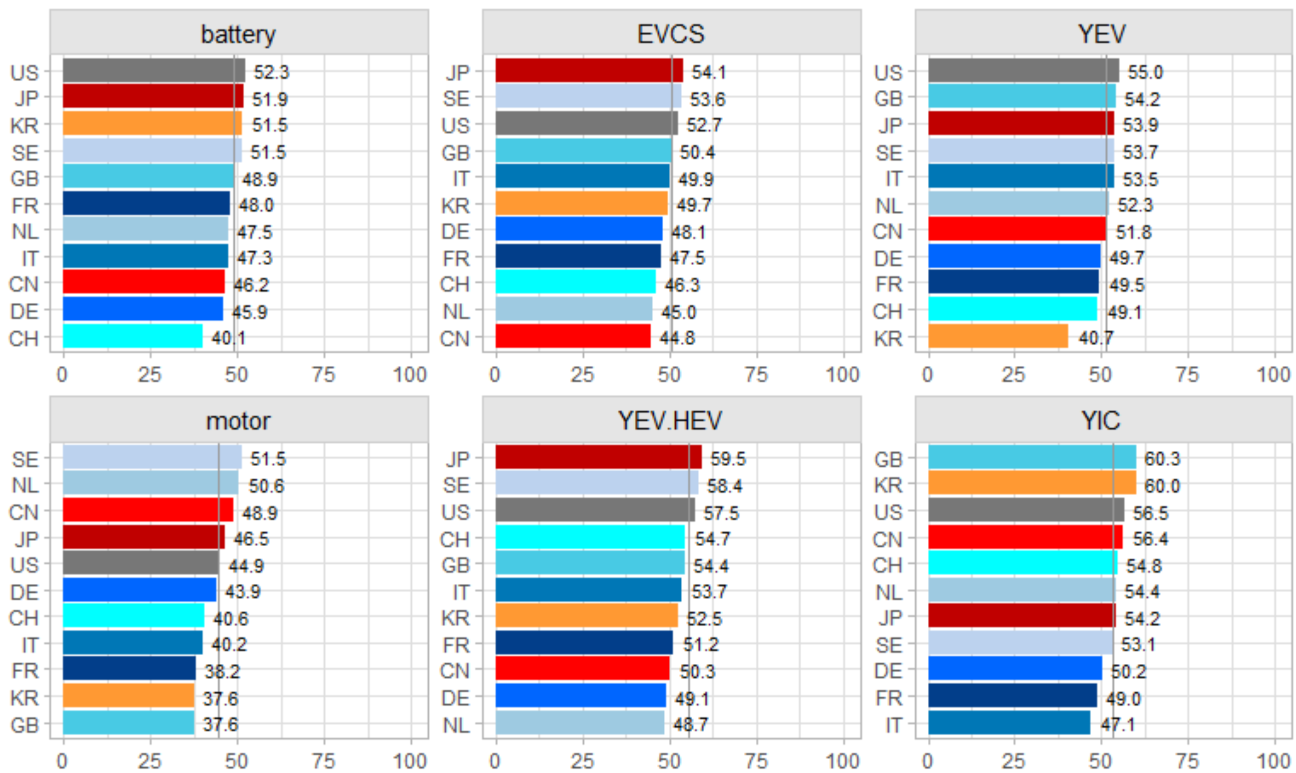


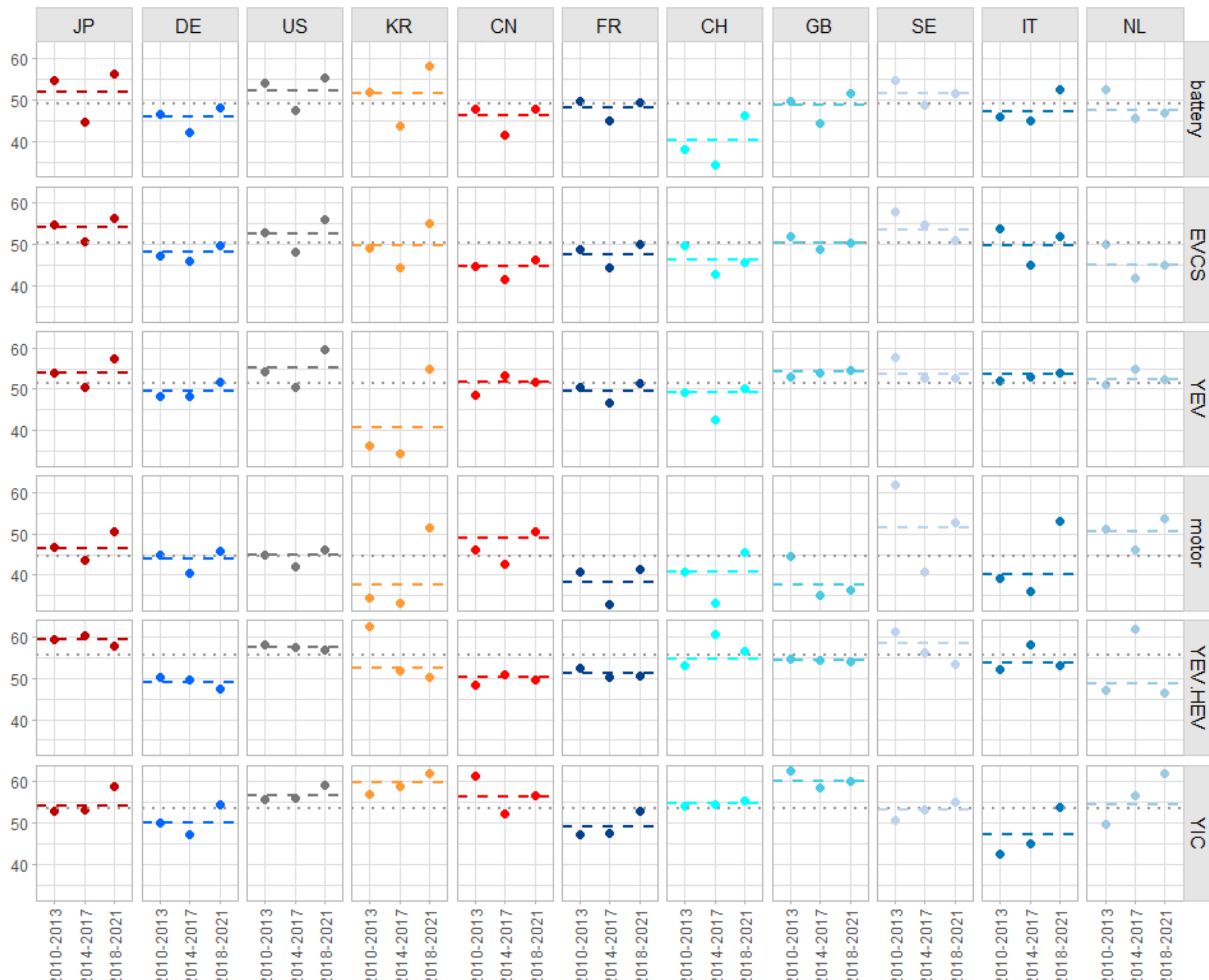
Table 3.33: normalised ranking, median values by country and macro-group

ctry_code_top	battery	EVCS	YEV	motor	YEV.HEV	YIC	Total
JP	51.92	54.10	53.85	46.52	59.46	54.20	52.85
DE	45.87	48.06	49.65	43.94	49.08	50.16	48.15
US	52.34	52.66	55.05	44.86	57.48	56.54	53.54
KR	51.53	49.73	40.70	37.63	52.53	59.96	47.96
CN	46.22	44.76	51.77	48.94	50.31	56.44	47.36
FR	47.98	47.50	49.49	38.22	51.23	48.95	48.31
CH	40.06	46.30	49.06	40.63	54.75	54.77	44.18
GB	48.87	50.42	54.17	37.63	54.40	60.27	53.06
SE	51.49	53.63	53.67	51.46	58.36	53.13	53.26

ctry_code_top	battery	EVCS	YEV	motor	YEV.HEV	YIC	Total
IT	47.26	49.88	53.54	40.19	53.74	47.10	49.81
NL	47.47	45.01	52.29	50.57	48.68	54.37	48.81
Total	48.96	50.17	51.86	44.45	55.61	53.48	50.46

Figure 3.17: Mean rank: Median values by country, period and macro-group

dashed line: country median over the entire period; dotted line: overall median over the entire period



Annexe 4 - Random forest

4.1 all patents

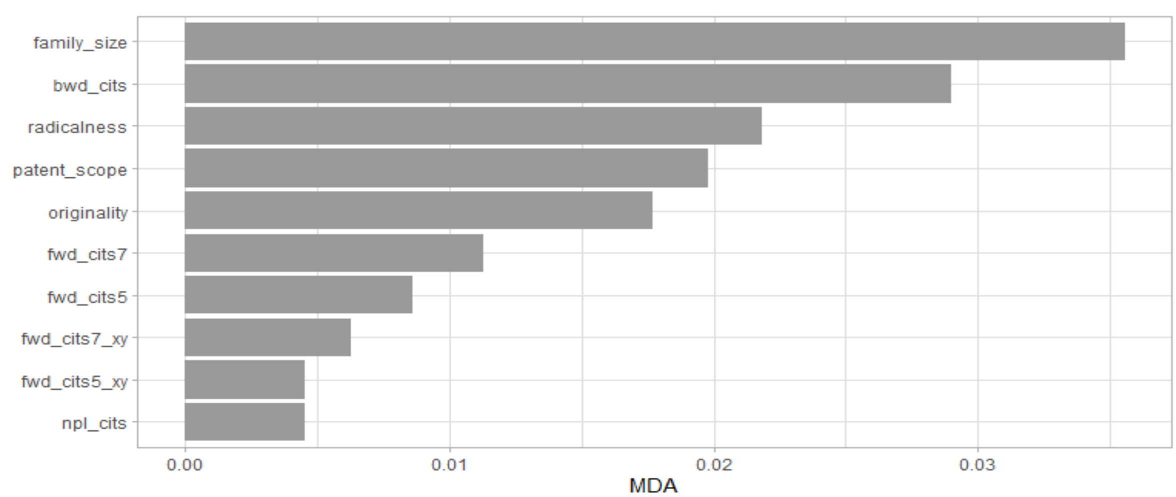
Table 4.1: random forest confusion matrix

ctry_code	JP	DE	US	KR	CN	FR	CH	GB	SE	IT	NL	OTH	class.error	Sensitivity	Specificity	Balanced Accuracy
JP	10,324	1,697	1,665	286	140	177	20	29	13	9	8	235	0.2930	0.7070	0.6027	0.6548
DE	4,225	3,552	1,727	332	146	103	67	34	24	19	33	446	0.6683	0.3317	0.8122	0.5720
US	3,858	1,878	3,454	202	178	73	27	42	9	11	4	368	0.6582	0.3418	0.8370	0.5894
KR	1,995	713	739	592	117	7	14	12	1	2	2	114	0.8626	0.1374	0.9782	0.5578
CN	1,576	569	519	142	590	22	15	4	3	2	5	145	0.8357	0.1643	0.9842	0.5742
FR	1,489	1,018	594	47	47	73	29	11	3	11	10	135	0.9789	0.0211	0.9908	0.5059
CH	560	628	415	36	41	32	103	16	1	1	1	124	0.9474	0.0526	0.9959	0.5243
GB	717	384	498	27	29	15	13	144	1	2	1	58	0.9238	0.0762	0.9967	0.5365
SE	842	405	216	26	18	8	4	4	70	2	1	41	0.9572	0.0428	0.9987	0.5207
IT	416	331	209	15	15	13	4	4	4	36	0	43	0.9670	0.0330	0.9989	0.5159
NL	248	202	230	12	13	11	10	5	2	0	29	62	0.9648	0.0352	0.9988	0.5170
OTH	2,308	1,525	1,405	102	157	62	36	30	14	9	6	666	0.8946	0.1054	0.9673	0.5363

Table 4.2: Random forest summary statistics

Accuracy:	0.325
Cohen's Kappa:	0.163
Error rate %:	67.550

Figure 4.1: Random forest variable importance - Mean Decrease Accuracy

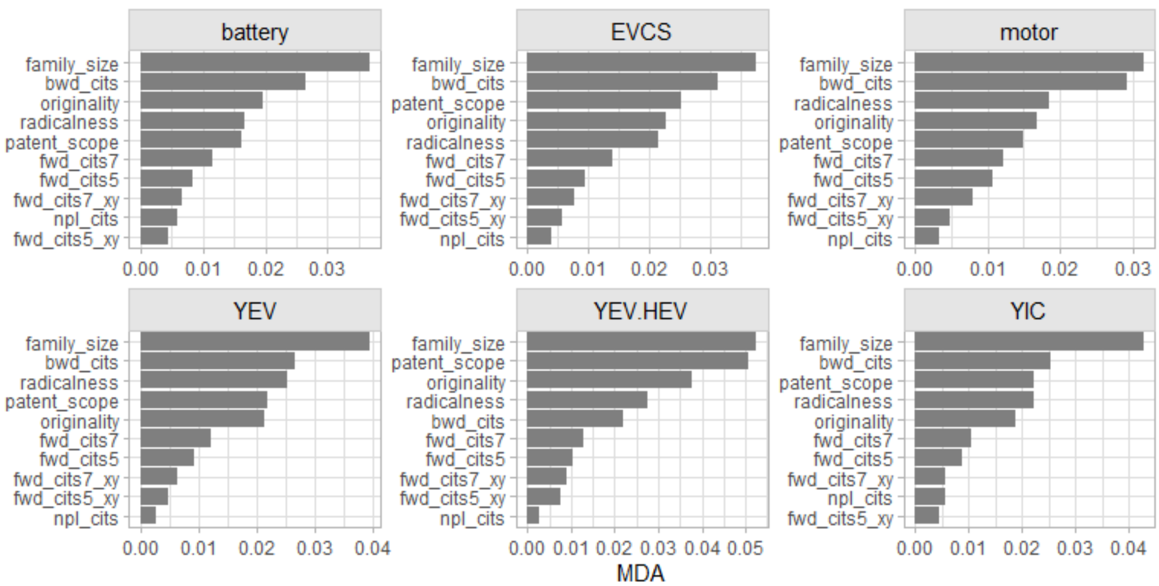


4.2 by CPC.macrogroup

Table 4.3: Random Forest by CPC macro-group, summary statistics

CPC.macrogroup	Accuracy	Cohen's Kappa	Error rate %
battery	0.309	0.169	69.09
EVCS	0.332	0.184	66.77
motor	0.354	0.190	64.58
YEV	0.370	0.172	63.00
YEV.HEV	0.469	0.258	53.10
YIC	0.377	0.181	62.25

Figure 4.2: Random Forest by CPC macro-group: variable importance - Mean Decrease Accuracy



Annexe 5 - Quality ranking of countries in three largest macro-groups, by CPC code (classes with >100 patents)

Legenda: For each of the selected macro-group, the countries listed are those where there is a significant difference (Kruskal-Wallis test). CPC codes with effect.size=large are shown in black, CPC codes with effect.size=medium are shown in grey, and CPC codes with effect.size=small are shown in light grey.

Figure 5.1: Battery technologies (Battery),

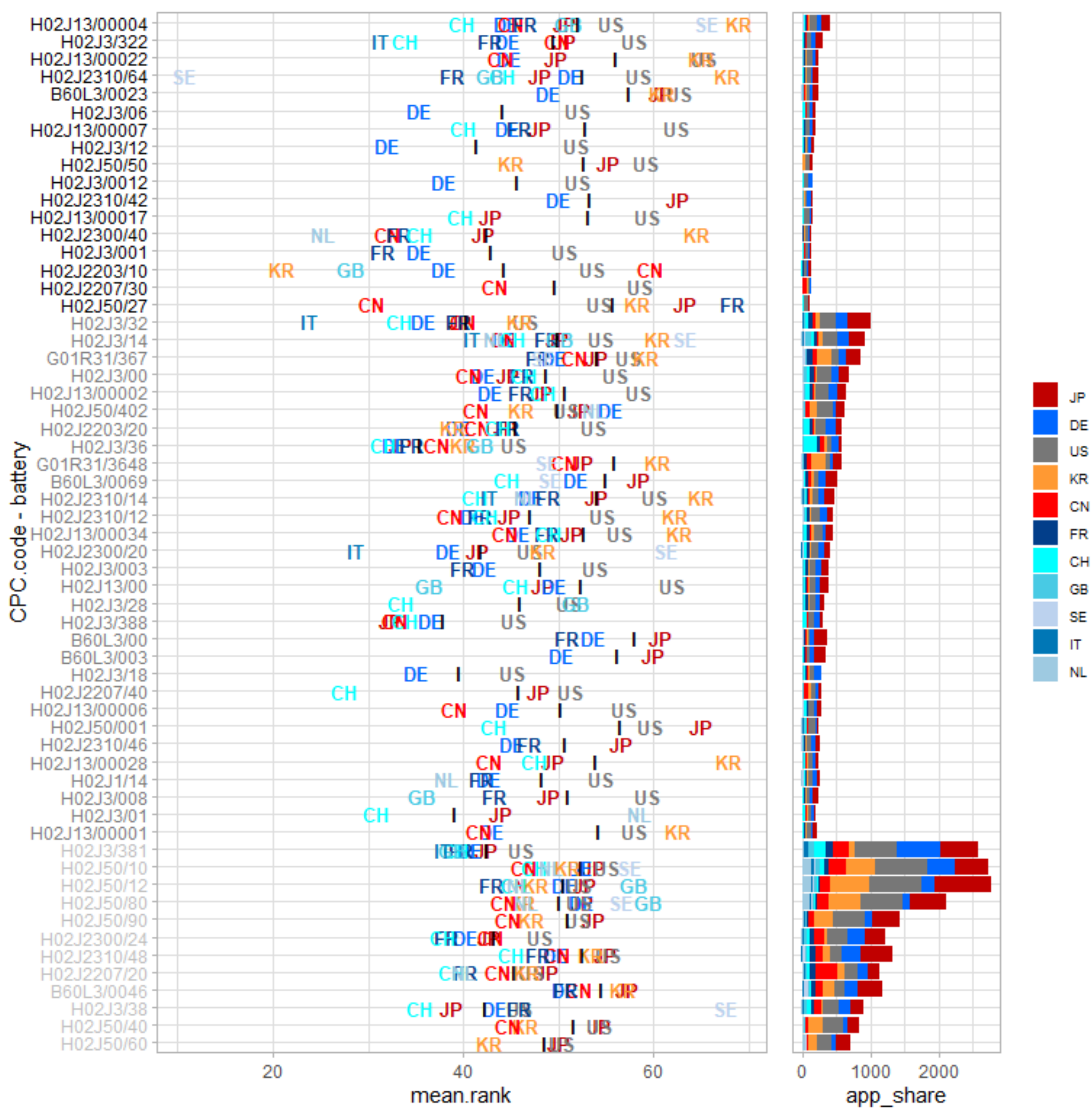


Figure 5.2 - Entire vehicle controlling systems (EVCS),

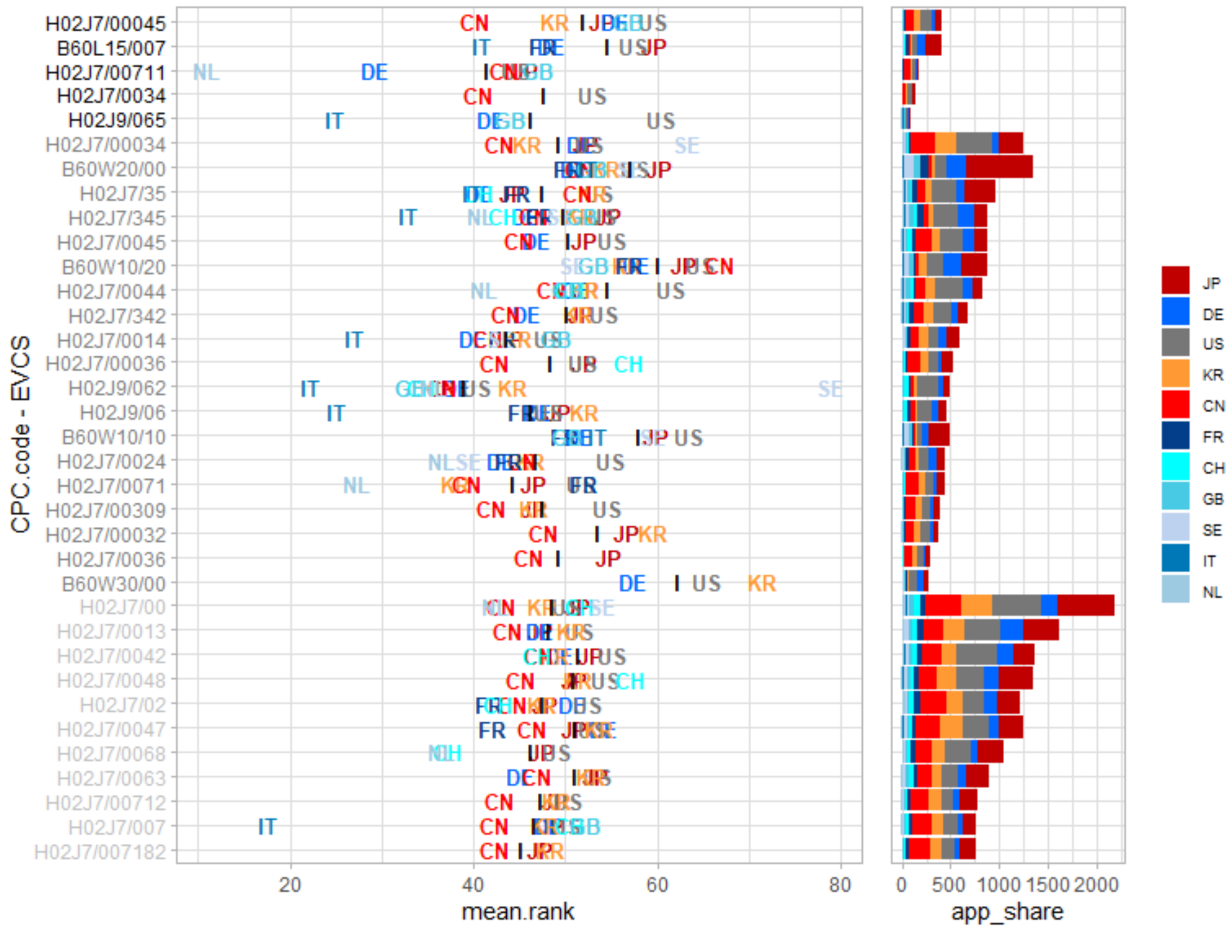


Figure 5.3: Advanced Technologies for Electric Vehicle Powertrain and Energy Infrastructure (YEV)