Is culture a contributing factor of strong science?

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Abstract

Many factors such as economy size, capital resources, and size of national publication market seem to be related to the scientific performance of nations. In this paper we link the national culture values with scientific performance of 53 nations. We focus on the year 2010. Our study uses three datasets: 1) Hofstede's data on national culture, 2) data on migration share of societies, and 3) citation impact data. We found that four dimensions of culture (i.e. individualism, power distance, uncertainty avoidance, and indulgence) correlate practically and statistically significantly with scientific impact of nations. The findings are discussed in mirror of cultural theories.

Keywords: culture, citation impact, scientific performance, research quality

Introduction

Many factors such as economy size (Gantman 2012; Baker et al. 2015; Ertekin 2014; Monge-Nájera and Nielsen 2005; Mueller 2016; Shukla and Bauer 2012), population size (Monge-Nájera and Nielsen 2005), share of investments in research and development (Baker et al. 2015; Erfanian and Ferreira Neto 2017; Mueller 2016; Shukla and Bauer 2012), applied technologies (Shukla and Bauer 2012), number of university graduates or researchers (Erfanian and Ferreira Neto 2017; Shukla and Bauer 2012), governmental policies and regulations and natural, human, and capital resources (Harzing and Giroud 2014), size of national publication market (Mueller 2016) and the perceptions toward academic research (science culture) (Ertekin 2014; Inönü 2003; Shukla and Bauer 2012) seem to be related to the scientific performance of nations. However, the findings on the effect of population size on scientific performance is not conclusive. For example, research (Baker et al. 2015) shows that smaller European countries are more prolific than other larger ones. Furthermore, the (English) language proficiency has been reported[1] as a positive predictor of scientific performance of countries in some disciplines such as social sciences, medicine, and agricultural sciences.

Furthermore, free mobility of scholars seems to contribute to a better scientific system (Sugimoto et al. 2017). A recent research (Wagner and Jonkers 2017) illustrates the importance of openness of nations for their scientific performance. The research shows that countries' investments in research and development (R&D) correlate with the number of published articles, but investment does not have a significant relationship with scientific impact (measured by citations).

However, previous science communication studies were mostly focused on "objective" metrics, and cultural values "were never a formal part of these efforts towards science indicators"(Shukla and Bauer 2007). While existing literature has revealed important findings on scientific performance of nations, more in-depth investigations are still in demand to reveal the possible connections of cultural values and the scientific performance of nations. Thus, the current study positions the following research question: how are cultural values related to the scientific performance of nations? To answer this question, Hofstede's national culture dimensions (Hofstede et al. 2010) are used as theoretical framework.

Theoretical framework

Two theoretical approaches of national culture are frequently used in cross-cultural studies. The first (Hofstede et al. 2010) perceives national culture as a stable construct which does not change in short term (or it changes in very long time period), and the second (Inglehart 1997) assumes the dynamics of national culture during time. Recent research (Beugelsdijk and Welzel 2018) shows that both approaches are complementary, and although young generations seem to become more individualist (which supports the dynamic approach), one can assume that nearly half of national culture values are stable. In other words, the core national culture dimensions should be durable over time. Therefore, because of several evidences (Beugelsdijk et al. 2015; Beugelsdijk and Welzel 2018) on the stability of Hofstede's national culture dimensions over time, the theoretical framework of national culture values applied in this study assumes relatively stable constructs. Hofstede et al. (2010) propose to categorize the world countries into six bi-polar dimensions of national culture: individualism versus collectivism, small versus large power distance, low versus high uncertainty avoidance, indulgence versus restraint, low versus high uncertainty avoidance, masculinity versus femininity, and short- versus long-term orientations.

As Hofstede (2011) explains, the individualism-collectivism dimension is the extent of group orientations among people in a country. In individualist nations, the people are supposed to take care of themselves and their close family members, while in collectivist nations, the people are bounded by in-group loyalties. The power distance shows the degree of acceptance of power inequality among the individuals in lower classes and it is manifested in interactions of people in family (parent-children), schools (teacher-students), working places (manager-employee) and country (authorities-citizens). The uncertainty avoidance refers to the capacity of individuals in a country to recover quickly from vague or ambiguous situations. The masculinity-femininity shows the degree in which nations have overlapped or separated gender roles and values. The perceptions of people towards the time and their following behaviors shape the time orientation dimension. Finally, the indulgence versus restraint dimension refers to the degree of freeness or regulation of gratification in a country.

Methods

Datasets

This research used three datasets to investigate the relationships of national culture and performance (citation impact) of nations. In order to align the three national-level datasets, the year 2010 was selected as reference point. This was done because the last update of Hofstede's cultural data was available for the year 2010.

1) Hofstede's data on national culture: Hofstede's data on national culture (Hofstede 2010) is available for about 100 world nations. This dataset shows the nations' scores (on a scale of 0-100) in six bi-polar dimensions of culture, that is individualism versus collectivism, small versus large power distance, low versus high uncertainty avoidance, indulgence versus restraint, low versus high uncertainty avoidance, masculinity versus femininity, and short- versus long-term orientations. The data is freely available for academic use.

2) Citation impact data: The national performance data were exported from the Max Planck Society's in-house database which is based on the Web of Science (Clarivate Analytics). They included the national proportions of papers (articles and reviews published in 2010) belonging to the 1% ($PP_{top\ 1\%}$) and 10% ($PP_{top\ 10\%}$). $PP_{top\ 10\%}$ is the proportion of papers (published by a country) which belongs to the 10% most frequently cited papers within their subject categories and publication years (correspondingly, $PP_{top\ 1\%}$ refers to the top 1%) (Hicks et al. 2015). The national numbers of (highly cited) papers were weighted by the number of countries on a paper. Thus, we used fractional instead of full counting of papers. For example, if there were three countries mentioned on a paper, each country received 1/3 of the paper.

3) The migration shares of nations: The migration share data were extracted from the United Nations, Department of Economic and Social Affairs (referring to the year 2010)(United Nations (Department of Economic and Social Affairs - Population Division) 2017). The migration share of nations is defined as the share of migrants of the total population of a country. This data was available for 233 world nations (for the years 1990-2017).

Statistics

Because of non-normal distributions of the used data and relatively low sample sizes (Bishara & Hittner, 2012), Spearman correlation coefficients were computed and reported for the

datasets besides Pearson correlation coefficients (see Appendix 1). The results reveal similar correlation coefficients of national culture dimensions and citation impact metrics.

Results

We found that four dimensions of culture (i.e. individualism, power distance, uncertainty avoidance, and indulgence) correlate practically and statistically significantly with scientific impact of nations (see Table 1). Although correlation does not mean causality, the investigated variables of culture and citation impact seem to be related. Our findings are stable at different thresholds (included countries with minimum 500, 750, and 1000 published papers) and different citation metrics (measured by nations' $PP_{top\ 10\%}$ and $PP_{top\ 1\%}$). In addition, since national dimensions of cultures might be obliterated by migrant influences (Wagner and Jonkers 2017), we controlled for the possible effect of nations' openness (assessed by migrant shares) (see Table 1).

Table 1. Pearson correlation coefficients of national culture dimensions and scientific impact of nations – after controlling for migrant shares of nations[*]

Indicator:		$PP_{top\ 10\%}$			$PP_{top\ 1\%}$	
Paper threshold for including countries:	≥500	≥750	≥1000	≥500	≥750	≥1000
Power distance	-0,67	-0,71	-0,74	-0,63	-0,68	-0,70
Individualism	0,58	0,64	0,64	0,65	0,71	0,71
Uncertainty avoidance	-0,40	-0,45	-0,46	-0,44	-0,46	-0,48
Indulgence	0,39	0,44	0,45	0,37	0,45	0,45

* Notes:
≥500: nations, which had minimum 500 publications, were included in the analysis (N = 53)
≥750: nations, which had minimum 750 publications, were included in the analysis (N = 48)
≥1000: nations, which had minimum 1000 publications, were included in the analysis (N = 47)
All correlations are statistically significant at the 0.01 level (2-tailed).
The correlations of the citation impact metrics with the additional dimensions of culture such as masculinity [-0.04, 0.12] and long-term orientation [0.03, 0.14] were not statistically significant, and they were not included in the table.

Generally, citation impact has a statistically significantly positive correlation with individualism and indulgence and a statistically significantly negative correlation with power distance and uncertainty avoidance. In other words, individualist nations (e.g., USA and UK) and those nations with flat cultures (such as Scandinavian countries) are more likely to produce papers with high citation impact. Another interesting finding is the low (and not statistically significant) correlations of long-term orientation and citation impact (see the notes of Table 1). Modern science is often criticized for its short-term orientation (Azoulay et al. 2011; Groen-

Xu et al. 2017). It is assumed that short-term orientation in research is the result of new public management regimes at universities including evaluations focusing on research performance in the last few years. Previous research (Groen-Xu et al. 2017) confirms that time pressures of researchers such as short-term deadlines result in higher number of publications, but in journals with lower impact factors.

To have a better understanding of the characteristics of correlations of cultural dimensions and citation impacts, we drew the scatterplots of statistically significant and strong correlations from Table 1. We exemplarily focus on the dimension with the highest correlation with citation impact in figure 1. The scatterplots for all significant correlations are in the Appendix 1. Figure 1 shows the correlation of power distance and the citation impact of nations (measured by $PP_{top\ 10\%}$). The size of bubbles shows the national number of publications in year 2010 (divided by 1000). The world nations are colored according to their continents. As the results show, the countries of Asia (yellow-colored) (except Singapore and Israel), Africa (orange-colored) and South America (purple-colored) all are scattered in downright corner of figure 1. Those countries have large power distance and are collectivist nations but have low citation impact.
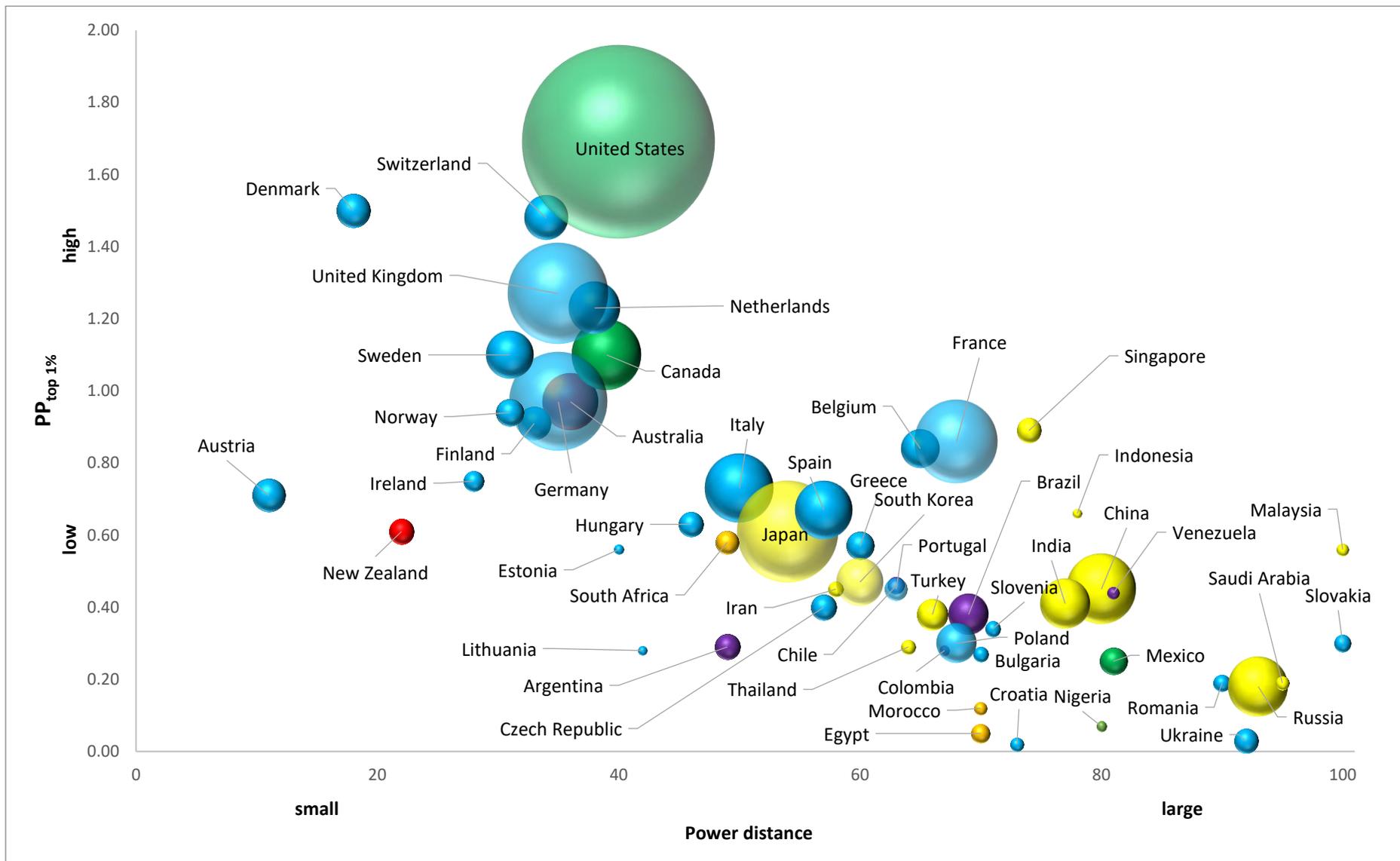
Although Singapore is a large power distant nation, it has a high citation impact. We used the Academic Connectedness (Nature Index 2019), the Openness Index (Wagner and Jonkers 2017), and the Global Creativity Index (Florida et al. 2011) of Singapore to interpret this result. According to the Openness Index (measured by sending and receiving immigrants and international co-authorships), Singapore is the second most open nation in the world. In addition, Singapore is among the best academically connected nations of the world (measured by co-authorships) (Nature Index 2019). The Global Creativity Index (Florida et al. 2011) (measured by three drivers of national technology, talent, and tolerance) ranks Singapore as the most creative nation in Asia. Of the investigated Asian countries in this study, just Israel has low power distance, and accordingly has high citation impact, and is placed at the top-left quadrant of figure 1.

The citation impact patterns of European countries (blue-colored) are relatively direct (except France, Belgium, and Portugal), that is, the countries with small power distance have high citation impact and are scattered in the top-left quadrant of the graphic, and those with large power distance have low citation impact and are appeared in the down-right quadrant of the graphic. This pattern is similar for countries of North America (green-colored) and Oceania

(red-colored). Of investigated countries of North America in this study, just Mexico is regarded as a large power distant nation, and accordingly has low citation impact.

Generally, the individualist nations have small power distance. However, France and Belgium are exceptions. They are both individualist nations and have large power distance. This combination seems to lead to efficient interactions in society (Hofstede n.d.). In other words, in Belgium and France, individuals have voice in the societal systems (e.g., education, health, public institutions), and simultaneously, the power inequality might be an accepted norm. In addition, both countries have very high uncertainty avoidance scores, and this makes academic works as foundation for detailed and contextual information (Hofstede n.d.) in those nations. The focus on academic work is noticeable in the high academically connectedness of those countries in the Nature Index (Nature Index 2019) and the relatively high citation impact of Belgium and France in this study.

The size of academic productions (visualized by the size of bubbles in Figure 1) does not seem to be a contributing factor to the national citation impact. As it is seen those countries with relatively high number of publications (such as Russia, China, Japan, and India) are placed in the down-right corner of figure 1. This is also shown in the higher impact of smaller nations such as Netherlands, Switzerland, and Scandinavian countries which cluster in the top-left quadrant of the graphic. The productive nations are regarded as large power distant and collectivist nations. In such nations, the education system is hierarchical and injective. That means the educators are regarded as unquestioned authorities (Hofstede 2011).

Figure 1. Power distance and scientific impact of nations (measured by PP$_{top\ 1\%}$). The size of bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue, and Australia in red color).

On the opposite side, there are flat Scandinavian cultures which (1) benefit the interactive education process and participatory design (Gregory 2003) in society systems and (2) respect the learners' efforts in solving the problems with creative methods. Thus, it is reasonable that those nations which have small power distances in societal systems (e.g., education) act more creative and produce more quality work and get higher citation impact.

Discussion

Our findings may show the embeddedness of scientific performance (measured in terms of citation impact) in national cultures. It adds the often-neglected cultural insight to the science communication system. The findings reveal that not only openness of nations, but also migrant shares of nations and cultural planning might lead to strong science. Our data highlights the importance of European approaches and initiatives to science communication such as the European Research Area (ERA, aimed at free interactions of research, researchers and technology). However, our results and the possible conclusions should be interpreted against the following limitations:

1) The findings of this study are based on aggregate data and analysis. Inferences from aggregate data to the individual level (i.e. ecological fallacy)(Piantadosi et al. 1988) should be avoided. For instance, a correlation between individualism and citation impact at the national level does not necessarily mean that this relationship is valid at the individual level.

2) In this study, Hofstede's quantitative dimensions of culture is used, because of its wide disciplinary applicability. However, quantitative models of culture (Taras et al. 2009) and the separation of dynamic and stable approaches of culture (Beugelsdijk and Welzel 2018) have been criticized. Furthermore, the role of globalization in reshaping the world cultures have been emphasized questioning stable approaches (Castells 1997).

3) The statistically significant correlations of cultural dimensions with citation impact of nations in this research does not point to causation. The difference between correlation and causation is described thoroughly in the literature (Altman and Krzywinski 2015). While the correlation coefficients show a clear link between national culture dimensions and citation impact in this study, it does not necessarily reveal that a specific national culture causes a certain level of citation impact.

4) While our findings show a substantial correlation of cultural dimensions and citation impact, they can be scarcely used to manage science in a certain way.

References

Altman, N., & Krzywinski, M. (2015). Points of Significance: Association, correlation and causation. *Nature Methods, 12*, 899–900

Azoulay, P., Graff Zivin, J. S., & Manso, G. (2011). Incentives and creativity: evidence from the academic life sciences. *The RAND Journal of Economics, 42*(3), 527-554.

Baker, D. P., Crist, J. T., Zhang, L., Powell, J. J. W., Shima, K., & Stock, M. (2015). Science Productivity, Higher Education Development and the Knowledge Society (SPHERE Project) Final Report.

Beugelsdijk, S., Maseland, R., & Van Hoorn, A. (2015). Are Scores on Hofstede's Dimensions of National Culture Stable over Time? A Cohort Analysis. *Global Strategy Journal, 5*(3), 223-240.

Beugelsdijk, S., & Welzel, C. (2018). Dimensions and dynamics of national culture: Synthesizing Hofstede with Inglehart. *Journal of Cross-Cultural Psychology, 49*(10), 1469-1505.

Castells, M. (1997). *End of Millennium: The Information Age, Economy, Society and Culture*. Cambridge: Blackwell Publishers, Inc. .

Erfanian, E., & Ferreira Neto, A. B. (2017). Scientific output: labor or capital intensive? An analysis for selected countries. [journal article]. *Scientometrics, 112*(1), 461-482, doi:10.1007/s11192-017-2369-z.

Ertekin, C. (2014). Scientific Research and Scientific Performance Evaluation. *Turkish Journal of Neurology, 20*(2), 32-36.

Florida, R., Mellander, C., & Stolarick, K. (2011). Creativity and prosperity: The global creativity index. https://tspace.library.utoronto.ca/bitstream/1807/80125/1/Florida%20et%20al_2011_Creativity%20and%20Prosperity.pdf.

Gantman, E. R. (2012). Economic, linguistic, and political factors in the scientific productivity of countries. *Scientometrics, 93*(3), 967-985.

Gregory, J. (2003). Scandinavian approaches to participatory design. *International Journal of Engineering Education, 19*(1), 62-74.

Groen-Xu, M., Teixeira, P. A., Voigt, T., & Knapp, B. (2017). Short-Termism in Science: Evidence from the UK Research Excellence Framework. *Available at SSRN 3083692*.

Harzing, A.-W., & Giroud, A. (2014). The competitive advantage of nations: An application to academia. *Journal of Informetrics, 8*(1), 29-42.

Hicks, D., Wouters, P., Waltman, L., De Rijcke, S., & Rafols, I. (2015). Bibliometrics: the Leiden Manifesto for research metrics. *Nature News, 520*(7548), 429.

Hofstede, G. (2010). Dimension data matrix. https://geerthofstede.com/research-and-vsm/dimension-data-matrix/.

Hofstede, G. (2011). Dimensionalizing cultures: The Hofstede model in context. *Online readings in psychology and culture, 2*(1), doi:10.9707/2307-0919.1014.

Hofstede, G. (n.d.). Compare countries: Belgium. https://www.hofstede-insights.com/product/compare-countries/.

Hofstede, G., Hofstede, G. J., & Minkov, M. (2010). *Cultures and organizations: Software of the mind* (3ed.). New York: McGrawhill.

Inglehart, R. (1997). *Modernization and postmodernization: Cultural, economic, and political change in 43 societies*: Princeton university press.

Inönü, E. (2003). The influence of cultural factors on scientific production. *Scientometrics, 56*(1), 137-146.

Monge-Nájera, J., & Nielsen, V. (2005). The countries and languages that dominate biological research at the beginning of the 21st century. *Revista de Biología Tropical, 53*(1-2), 283-294.

Mueller, C. E. (2016). Accurate forecast of countries' research output by macro-level indicators. *Scientometrics, 109*(2), 1307-1328.

Nature Index (2019). Connected world: patterns of international collaboration. https://www.natureindex.com/country-outputs/collaboration-graph.

Piantadosi, S., Byar, D. P., & Green, S. B. (1988). The ecological fallacy. *American journal of epidemiology, 127*(5), 893-904.

Shukla, R., & Bauer, M. W. (2007). The science culture index (SCI): Construction and validation: A comparative analysis of engagement, knowledge and attitudes to science across India and Europe. UK: NCAER & LSE.

Shukla, R., & Bauer, M. W. (2012). The Science Culture Index (SCI). In M. W. Bauer, R. Shukla, & N. Allum (Eds.), *The culture of science: How the public relates to science across the globe* (pp. 179-199). New York: Routledge.

Sugimoto, C. R., Robinson-García, N., Murray, D. S., Yegros-Yegros, A., Costas, R., & Larivière, V. (2017). Scientists have most impact when they're free to move. *Nature News, 550*(7674), 29.

Taras, V., Rowney, J., & Steel, P. (2009). Half a century of measuring culture: Review of approaches, challenges, and limitations based on the analysis of 121 instruments for quantifying culture. *Journal of International Management, 15*(4), 357-373.

United Nations (Department of Economic and Social Affairs - Population Division) (2017). Trends in International Migrant Stock: The 2017 revision (United Nations database, POP/DB/MIG/Stock/Rev.2017) https://www.un.org/en/development/desa/population/migration/data/estimates2/estimates17.asp.

Wagner, C. S., & Jonkers, K. (2017). Open countries have strong science. *Nature News, 550*(7674), 32.

Acknowledgements

Appendix. Supplementary tables and figures

Table 1. Pearson correlation coefficients of national culture dimensions and citation impact of nations*

Indicator:	$PP_{top\ 10\%}$			$PP_{top\ 1\%}$		
Paper threshold for including countries:	≥500	≥750	≥1000	≥500	≥750	≥1000
Power distance	-0,70	-0,72	-0,75	-0,67	-0,70	-0,73
Individualism	0,64	0,66	0,67	0,70	0,73	0,73
Uncertainty avoidance	-0,50	-0,55	-0,56	-0,52	-0,55	-0,57
Indulgence	0,44	0,53	0,53	0,42	0,52	0,53
Migrant share	0,52	0,51	0,51	0,46	0,45	0,45

* Notes:
≥500: nations, which had minimum 500 publications, were included in the analysis (N = 53).
≥750: nations, which had minimum 750 publications, were included in the analysis (N = 48).
≥1000: nations, which had minimum 1000 publications, were included in the analysis (N = 47).
All correlations are statistically significant at the 0.01 level (2-tailed).
The correlations of the citation impact metrics with the additional dimensions of culture such as masculinity [-0.05, -0.14] and long-term orientation [0.06, 0.12] were not statistically significant, and they were not included in the table.

Table 2. Pearson correlation coefficients of national culture dimensions and citation impact of nations – after controlling for migrant share of nations*

Indicator:	$PP_{top\ 10\%}$			$PP_{top\ 1\%}$		
Paper threshold for including countries:	≥500	≥750	≥1000	≥500	≥750	≥1000
Power distance	-0,67	-0,71	-0,74	-0,63	-0,68	-0,70
Individualism	0,58	0,64	0,64	0,65	0,71	0,71
Uncertainty avoidance	-0,40	-0,45	-0,46	-0,44	-0,46	-0,48
Indulgence	0,39	0,44	0,45	0,37	0,45	0,45

* Notes:
≥500: nations, which had minimum 500 publications, were included in the analysis (N = 53).
≥750: nations, which had minimum 750 publications, were included in the analysis (N = 48).
≥1000: nations, which had minimum 1000 publications, were included in the analysis (N = 47).
All correlations are statistically significant at the 0.01 level (2-tailed).
The correlations of the citation impact metrics with the additional dimensions of culture such as masculinity [-0.04, 0.12] and long-term orientation [0.03, 0.14] were not statistically significant, and they were not included in the table.

Table 3. Spearman correlation coefficients of national culture dimensions and citation impact of nations*

Indicator:	$PP_{top\ 10\%}$			$PP_{top\ 1\%}$		
Paper threshold for including countries:	≥500	≥750	≥1000	≥500	≥750	≥1000
Power distance	-0,72	-0,73	-0,76	-0,71	-0,75	-0,77
Individualism	0,56	0,59	0,60	0,65	0,69	0,70
Uncertainty avoidance	-0,48	-0,52	-0,52	-0,49	-0,52	-0,53
Indulgence	0,48	0,59	0,59	0,45	0,59	0,59
Migrant share	0,55	0,57	0,55	0,53	0,55	0,54

* Notes:
≥500: nations, which had minimum 500 publications, were included in the analysis (N = 53).
≥750: nations, which had minimum 750 publications, were included in the analysis (N = 48).
≥1000: nations, which had minimum 1000 publications, were included in the analysis (N = 47).
All correlations are statistically significant at the 0.01 level (2-tailed).
The correlations of the citation impact metrics with the additional dimensions of culture such as masculinity [-0.04, 0.08] and long-term orientation [0.06, 0.18] were not statistically significant, and they were not included in the table.

Table 4. Spearman correlation coefficients of national culture dimensions and citation impact of nations - after controlling for migrant share of nations*

Indicator:	PP$_{top 10\%}$			PP$_{top 1\%}$		
Paper threshold for including countries:	**≥500**	**≥750**	**≥1000**	**≥500**	**≥750**	**≥1000**
Power distance	-0,63	-0,66	-0,69	-0,62	-0,68	-0,71
Individualism	0,40	0,48	0,49	0,54	0,61	0,62
Uncertainty avoidance	-0,45	-0,47	-0,47	-0,46	-0,46	-0,47
Indulgence	0,40	0,44	0,44	0,36	0,44	0,44

* Notes:

≥500: nations, which had minimum 500 publications, were included in the analysis (N = 53).

≥750: nations, which had minimum 750 publications, were included in the analysis (N = 48).

≥1000: nations, which had minimum 1000 publications, were included in the analysis (N = 47).

All correlations are statistically significant at the 0.01 level (2-tailed).

The correlations of the citation impact metrics with the additional dimensions of culture such as masculinity [-0.04, 0.12] and long-term orientation [0.03, 0.14] were not statistically significant, and they were not included in the table.
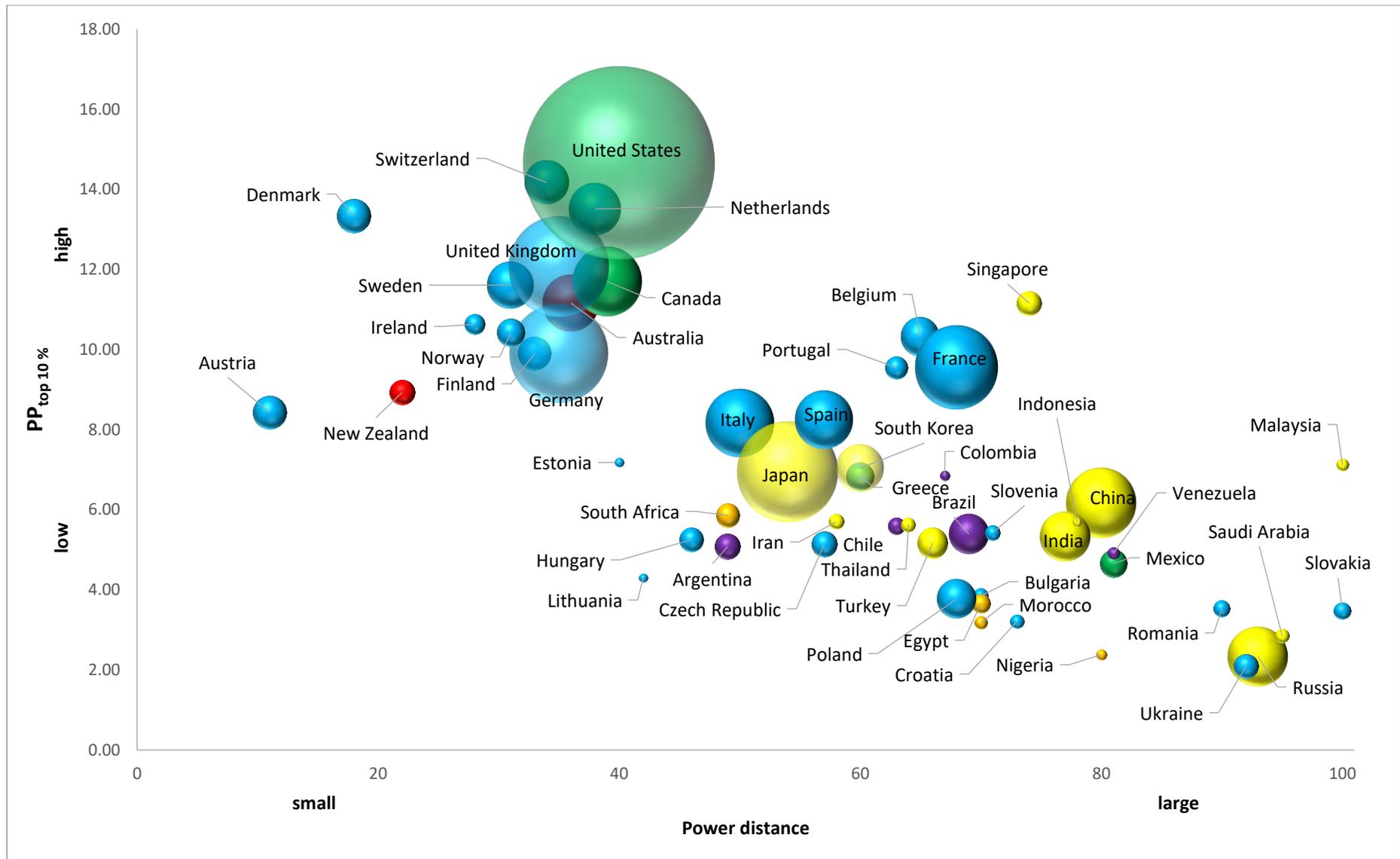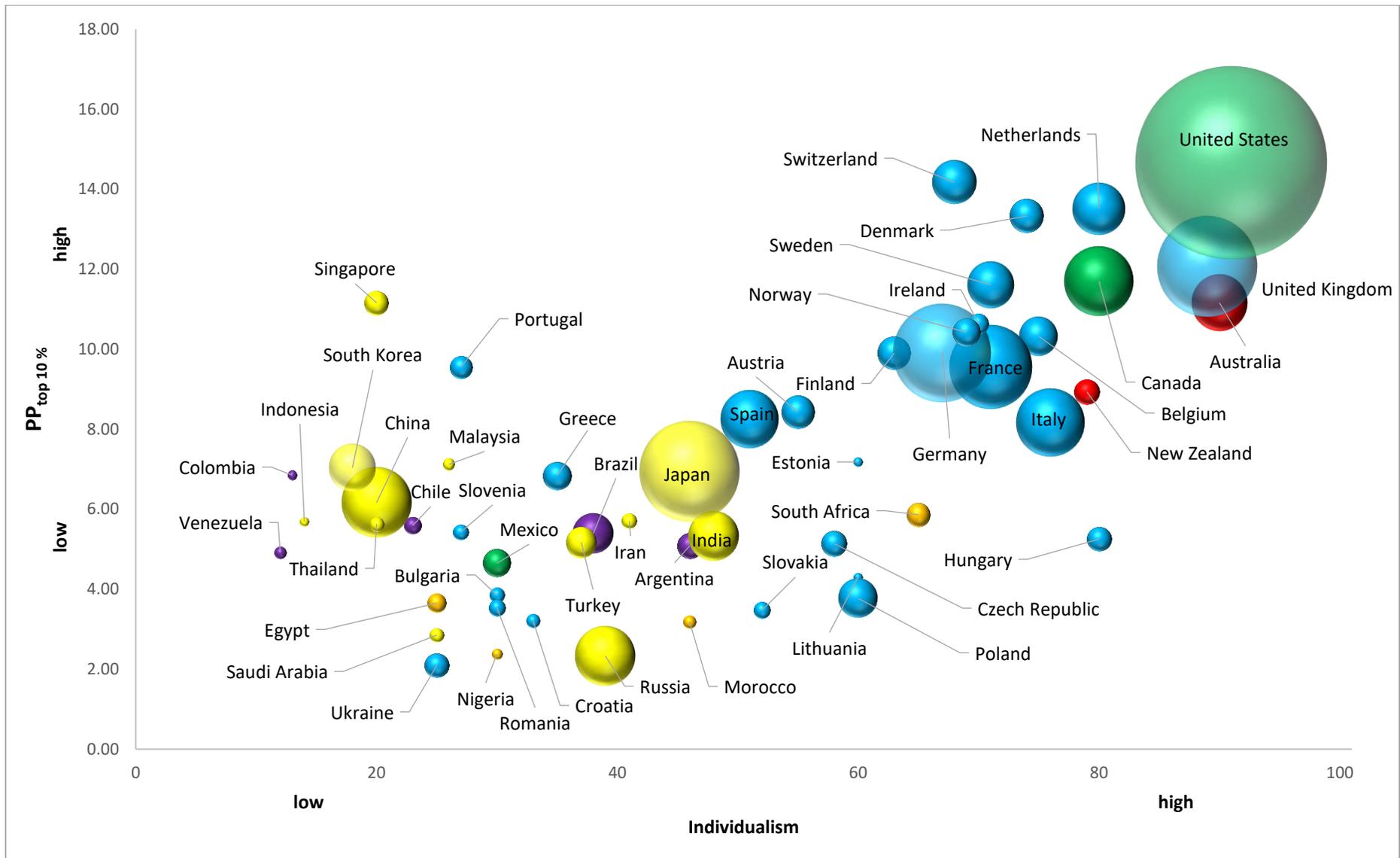
Figure 1. Power distance and citation impact of nations (measured by PP$_{top\ 1\%}$). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).

Figure 2. Power distance and citation impact of nations (measured by PP_top 10%). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color)
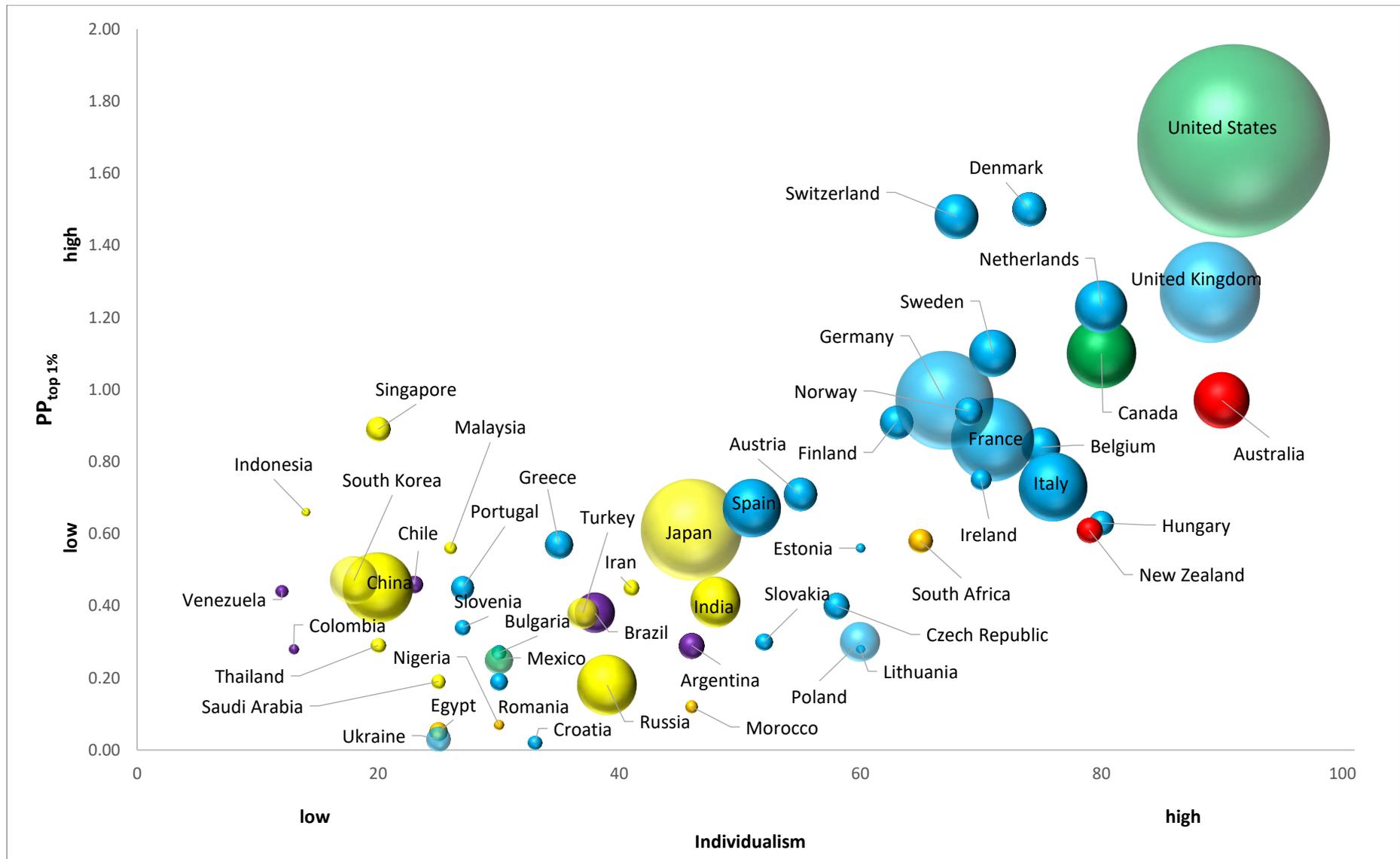
Figure 3. Individualism and scientific impact of nations (measured by PP_{top 10%}). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).

Figure 4. Individualism and scientific impact of nations (measured by PP$_{top\ 1\%}$). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).
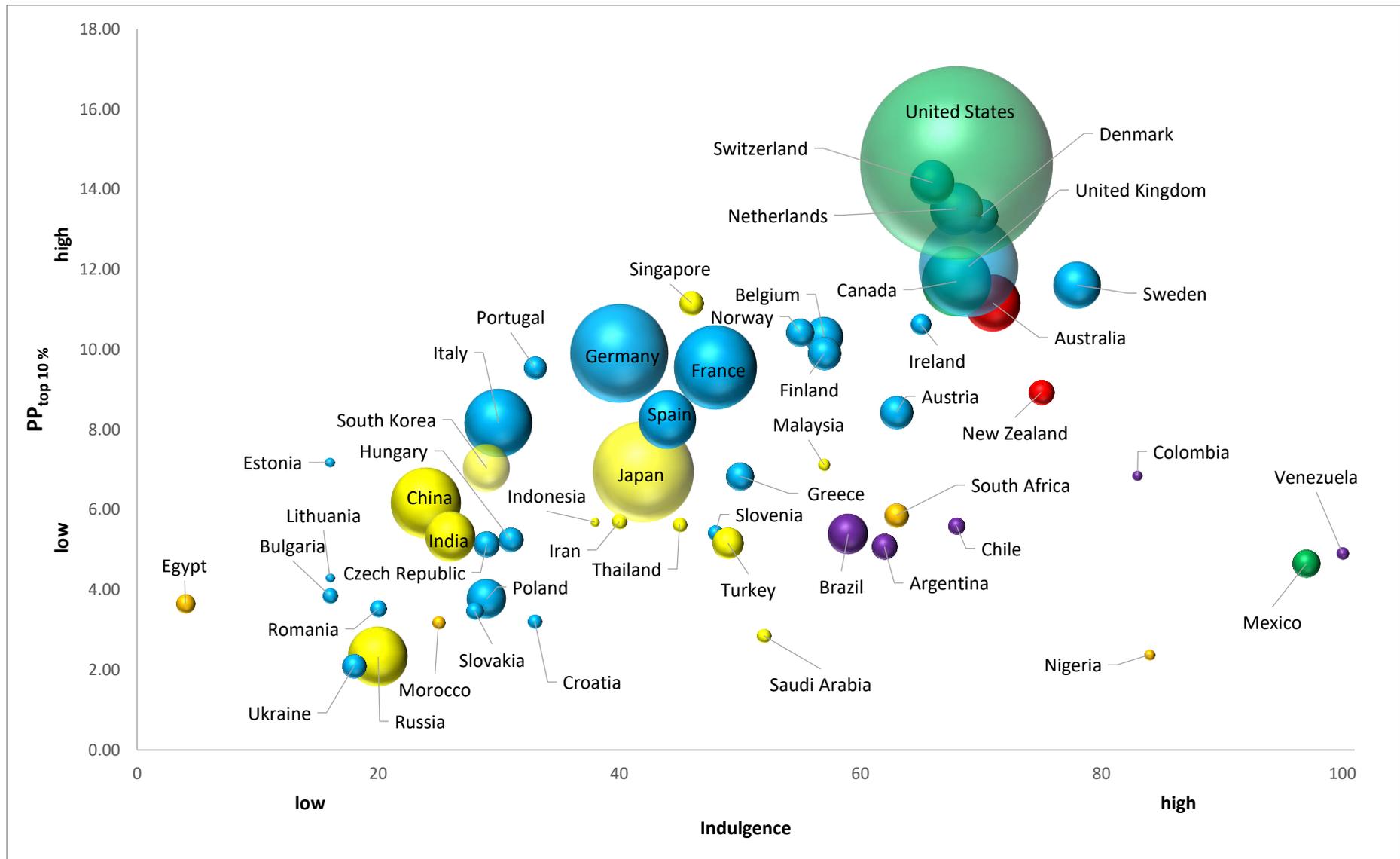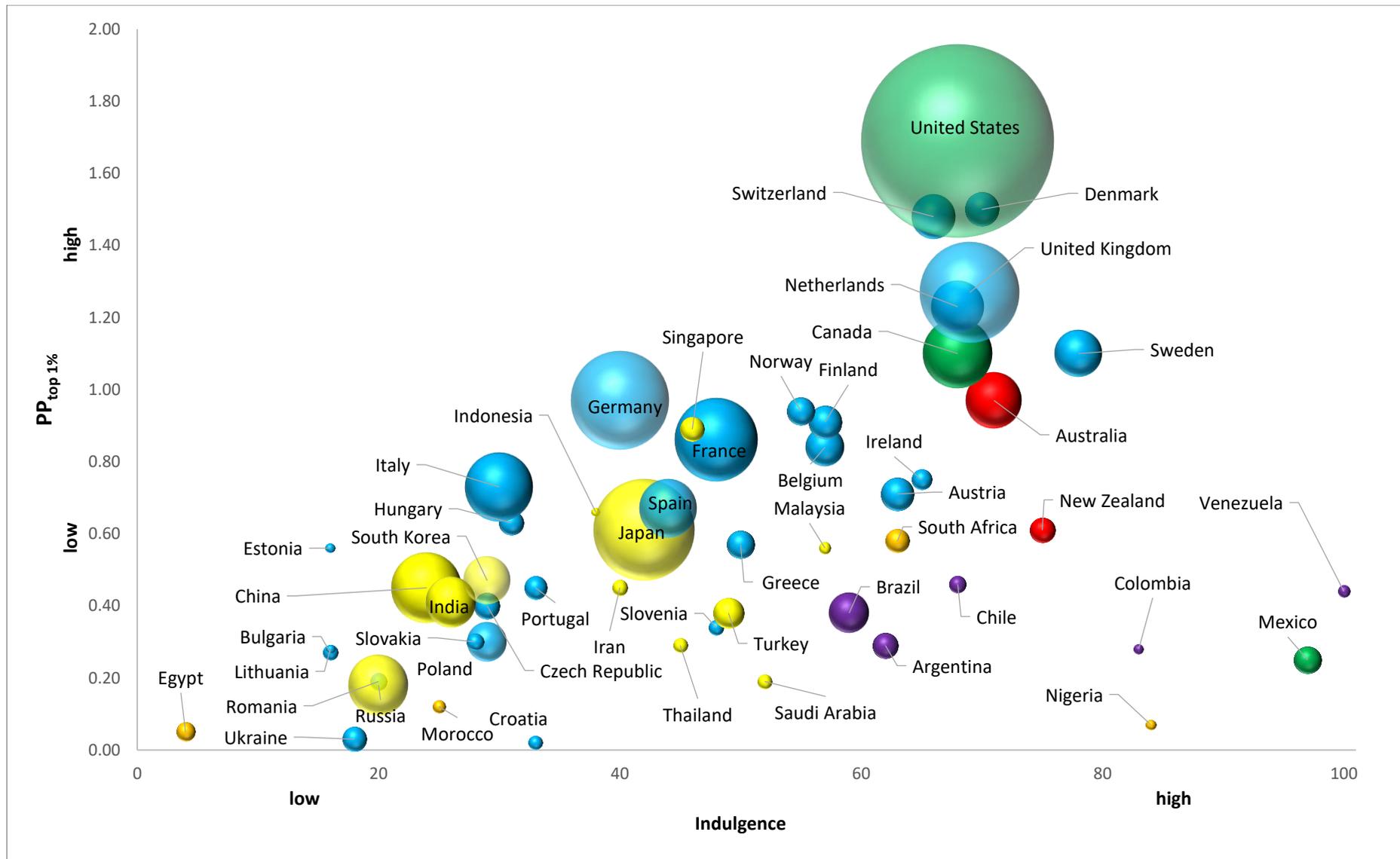
Figure 5. Indulgence and scientific impact of nations (measured by PP$_{top\ 10\%}$). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).

Figure 6. Indulgence and scientific impact of nations (measured by PP_top 1%). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).
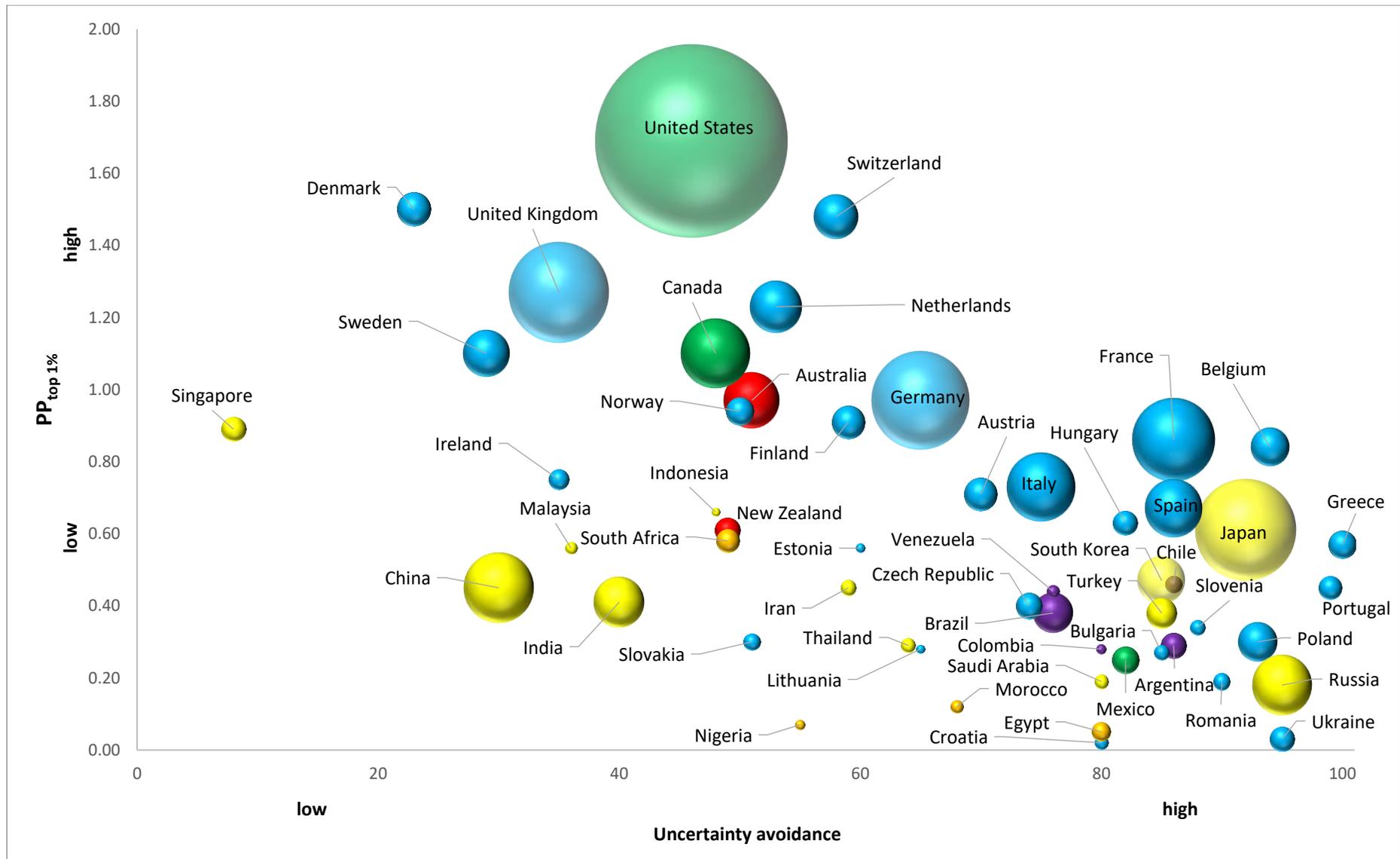
Figure 7. Uncertainty avoidance and scientific impact of nations (measured by $PP_{top\ 1\%}$). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).
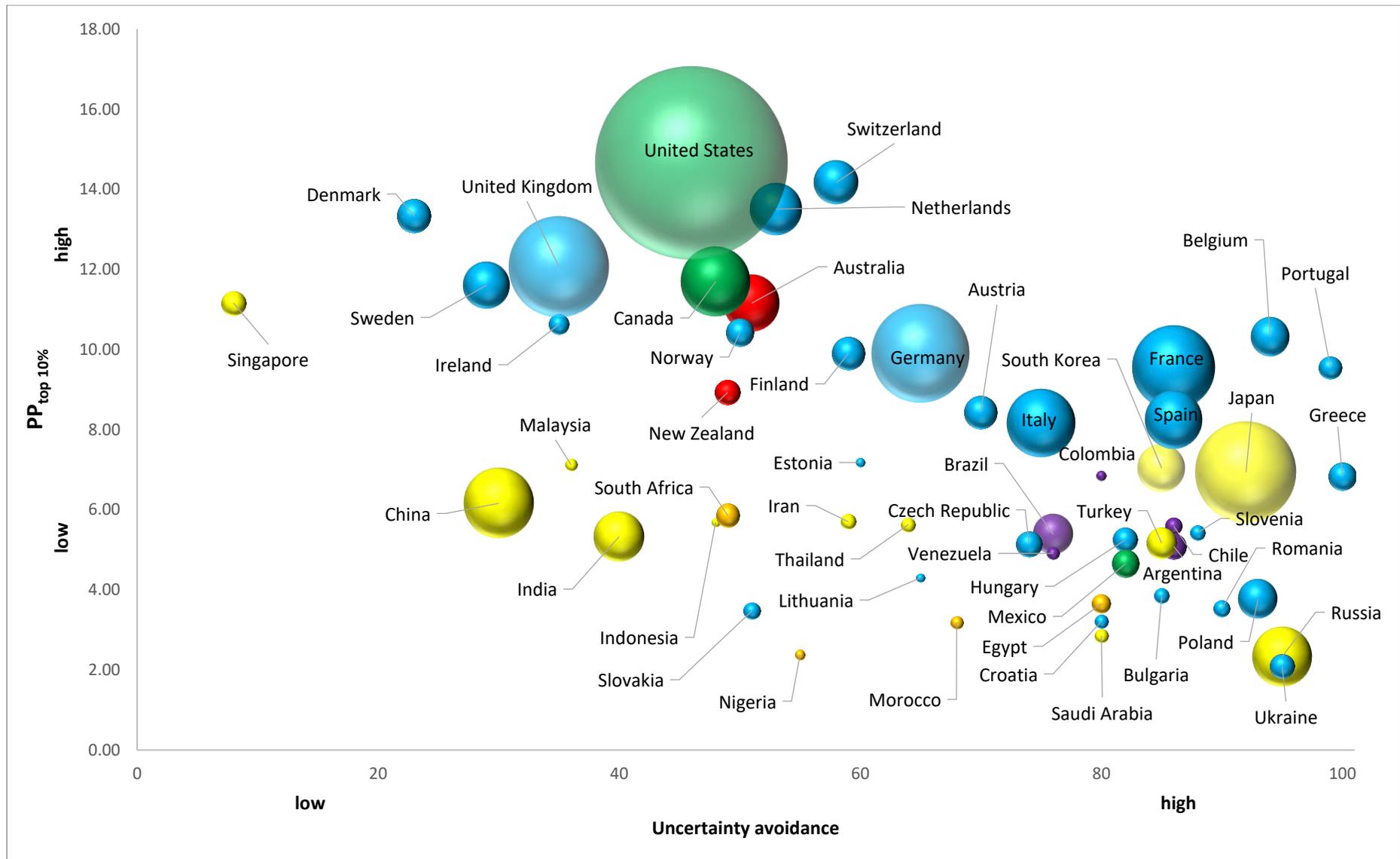
Figure 8. Uncertainty avoidance and scientific impact of nations (measured by PP$_{top 10\%}$). The size of the bubbles shows the number of publications of countries in year 2010 (divided by 1000). The world nations (N = 53) are colored according to their continents (Asia yellow, Africa orange, North America green, South America purple, Europe blue and Australia in red color).