

A Cultural Analysis of the Geographic Constraints of Technological Innovation

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Spring 2023

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

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Throughout human history, innovations in technology and technological systems have emerged in virtually every populated region of the world. However, as civilizations and cultures grew more distinct and defined, certain regions excelled at technological innovation, boasting infrastructure, transportation, weapons, medicine, and communications that vastly exceeded those of other societies. Two thousand years ago, these hubs of innovation were within societies such as the Roman Empire, Han China, and various empires in modern day India (NGS, 2015). While the geographic location of these hubs leading innovation have changed, the fact that they comprise constrained geographies remains true, and it is also apparent that the geography is only constraining further within those hubs. In the present day, the modern hubs of innovation are located most numerous in North America, primarily the US and Canada, as well as Western Europe and Eastern Asia. This can be observed qualitatively, simply by recognizing where some of the lead innovators in various fields are headquartered. These agglomerates include companies like Apple, Google, and Hewlett Packard leading innovations in consumer goods in Southern California, Huawei, Sony, and Samsung leading communications in Eastern Asia, and Novo Nordisk and Novartis being leaders in biotechnology in Europe (Sauter and Stebbins, 2018). While, in the present day, there are many factors that contribute to innovation, the cultural attributes of a region cannot be ignored, as the set of values bolstered by a group of people forms the paradigm through which a region or group of people behave, learn, create, and thus innovate. Therefore, it is important to consider: how do cultural attributes shape and form the geographic constraints of technological innovation?

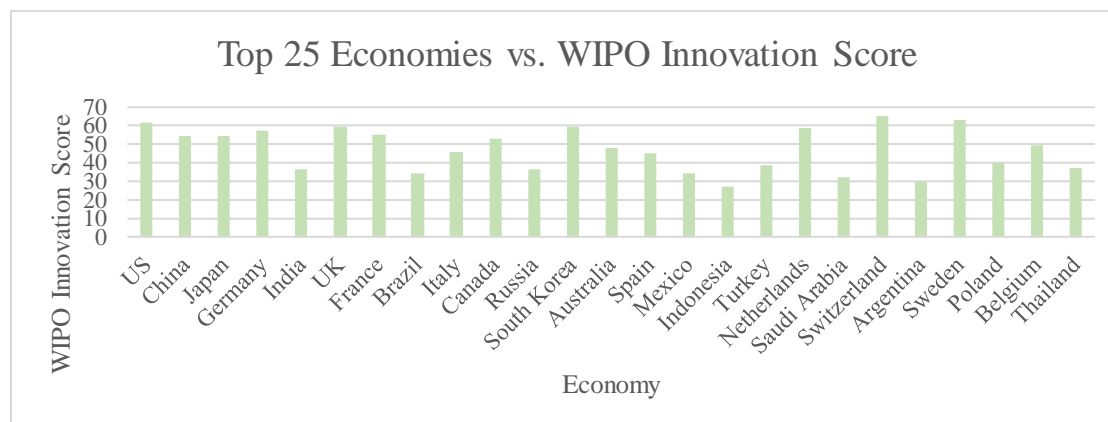
While this geography-based concentration of innovation is not a problem on its own, it leads to negative consequences for the regions not participating as much in technological innovation. The innovation hubs are responsible for the output of products and services to be

used globally, and this creates not only an economic dependency on the innovating regions, but also a cultural dependency that can harm local cultures through diffusion from innovating regions. More detrimentally, this constrained geography creates a cycle of talent migration frequently referred to as the “brain drain” (Dodani and LaPort, 2005). Talent, in this case, is defined as high level human capital which is represented by a high level of education or skilled labor. Innovation centers foster talent, which in turn further attracts talent on a global scale, causing the cycle to repeat itself while simultaneously decreasing the talent present in the regions of departure. This immigration leads to great economic success in the target destinations, but can be extremely damaging to the areas being depleted of talent. This migration can occur on small scales, for example migration from rural communities to larger cities within the United States, or it can occur on a large global scale. An ongoing, relevant example of this is the migration of medical personnel from India to various parts of Europe and North America. India is one of the largest producers of licensed doctors (Sinha, 2012), but has a remarkably low retention rate due to better working and living conditions as well as research opportunities abroad.

Reiterating the question as simply why is the geography of innovation constrained, it would be rational to point to a country or region’s wealth, as ample funding is a necessity to promote the research involved in modifying existing technologies or creating new technology altogether. While this certainly is a factor, a comparison of national GDPs with how innovative a country’s economy is shows that this is not always the case. Figure 1 shows that some of the largest economies, including Russia, Brazil, Italy, and India, are participating disproportionately less in technological innovation if a direct correlation between wealth and innovation were to exist, as one might reasonably expect.

Figure 1

Top 25 Economies by GDP vs. WIPO Innovation Score



Note: Bar graph showing the top 25 economies worldwide ranked by GDP with their respective WIPO innovation scores. There is no trend showing a relationship between economic strength and innovation score. GDP rankings sourced from World Bank Dataset.

This paper will analyze five cultural dimensions, as defined by Geert Hofstede in his 1980 theory, in order to determine if there are cultural characteristics that optimize a regional environment to foster innovation, and how these attributes as well as other promoting factors form geographic constraints. Hofstede's five cultural dimensions are power distance, individualism versus collectivism, masculinity versus femininity, uncertainty avoidance, and time orientation (ORPC, 2011). It is recognized, however, that there are limitations to and criticisms of Hofstede's dimensions, and an alternative framework for analysis will be discussed alongside the methodology and discussion.

Hofstede's Five Cultural Dimensions

Power distance in this context is defined as the extent to which lower ranking members of a society accept the social hierarchy without justification. This rank is not socioeconomic, however, and more particularly refers to political climate, political participation, and civil liberties. Therefore, a relevant metric to quantify this is how democratic a nation is. For example, a pure democracy such as Sweden would have a very low power distance score as individuals are

valued more equally throughout the society, whereas a monarchy like Saudi Arabia or an authoritarian regime such as in North Korea would receive a much higher power distance score. This concept affects the psychology of citizens, with disobeying authority being more common in countries with a low ranking, and questioning authority, whether it be legal or at home, being tabooer in countries with a higher ranking.

Individualism versus collectivism refers to the tendency of individuals to integrate into groups. More individualist societies emphasize the importance of personal achievement and individual rights, and stress the focusing on of one's own needs or the needs of their immediate family. A collectivist society is more concerned with the well-being of the whole society, placing emphasis primarily on relationships and loyalty. This cultural characteristic influences members personalities and also greatly influences how one might spend their time. For example, the United States is one of the most individualist countries and Americans are frequently regarded globally as "workaholics" that focus primarily on themselves, whereas many Central and South American societies are often more collectivist and may allocate more time for positive community involvement or time spent with family and friends.

Masculinity versus femininity, despite the label, has little to do with gender or gender relations. Hofstede, being a man of his time, associated characteristics such as courage, competition, assertiveness and strength with more masculine societies. Feminine societies, then, value cooperation, nurturing, relationships, and quality of life. By these definitions, Sweden is the most feminine society, and Japan in the most masculine society. This dimension most notably influences how members exist in their work environments, with masculine societies having longer working hours and more competitive academic cultures. Feminine societies tend to have shorter working hours and more supportive, collaborative academic cultures.

Measuring the uncertainty avoidance gauges a society's tolerance for uncertainty, risk, and ambiguity. This also translates to a society's acceptance of change. Countries with a high tolerance for uncertainty are more willing to accept change, and may demonstrate that by having less strict rules and regulations on a national level, and on a more personal level, for example, a student in a high uncertainty society may feel more comfortable admitting to not knowing the answer to a question to a teacher or may feel more comfortable asking for help. Conversely, a society with a low tolerance for uncertainty may have stricter rules and regulations, and on a personal level people may have greater reservations about asking others for help or taking on tasks with ambiguous outcomes.

Lastly, the time orientation dimension refers to how much emphasis a society puts on delaying gratification. A long-term oriented society may encourage delaying gratification and short-term success in the pursuit of long-term success. These societies place greater value on persistence, thrift, perseverance, and place more focus on the future. In contrast, short-term oriented societies place more focus on the present and value immediate reward. This relates to how much members of a society respect tradition, and is also important in determining the political climate and what issues are deemed important.

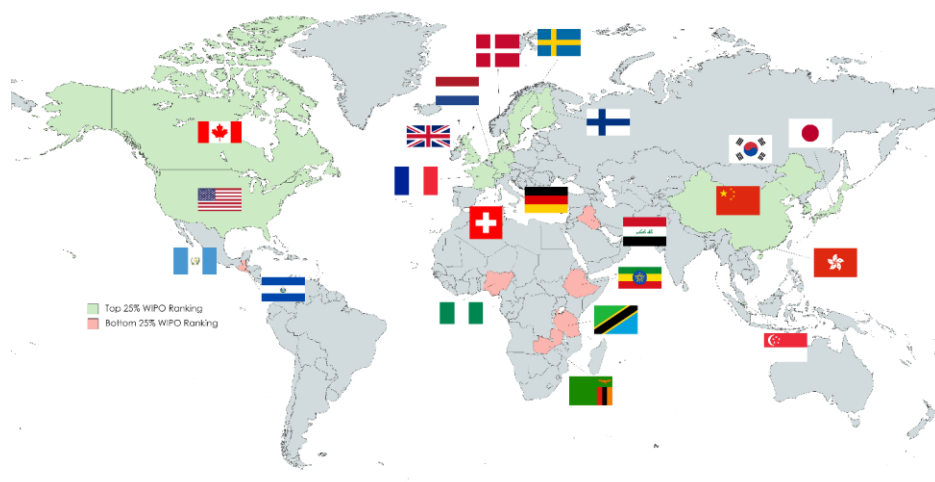
Methodology and Reasoning

Innovation and cultural attributes can be very qualitatively assessed characteristics through a plethora of different paradigms, and it is difficult to avoid bias in what is considered innovation as well as how cultural attributes are given numerical rankings. Immanuel Wallerstein's World Systems Theory offers stark criticism of the quantitative measurement of many societal attributes, including innovative tendencies. Some of these criticisms are of the very framework through which much of this research is conducted, so they are important to

address, and will be discussed more thoroughly later in the text. However, the scope of this analysis will focus on technological innovation. To make that distinction, technological innovation will be defined as the novel ways in which humanity observes and manipulates the natural world in order to create useful, tangible artefacts. This definition justifies the use of more objective, quantitative metrics such as those that follow in the data analysis. Country rankings of innovation were taken from the 2022 World Intellectual Property Organization (WIPO) innovation index (WIPO, 2021). This dataset was selected due to the fact that it uses quantitative data including patent application, publication output, startup frequency, and active research programs to score countries. 22 countries shown in Figure 2, 15 being in the top 25% of innovation scores, and 7 in the bottom 25% were selected based on data availability from Hofstede's Psychological Index (HPI, n.d.). Democracy scores were sourced from UNESCO's 2020 Democracy Index (EIU, 2020).

Figure 2

Map of Countries Selected for Innovation Analysis



Note: 22 selected countries for analysis. Bottom 25% WIPO scores shown in red, top 25% WIPO scores shown in green. The countries in the top 25% are the US, Canada, UK, France, Switzerland, Netherlands, Germany, Denmark, Sweden, Finland, China, South Korea, Hong Kong, Japan, and Singapore. The countries in the bottom 25% are Guatemala, El Salvador, Nigeria, Iraq, Ethiopia, Tanzania, and Zambia. They were selected based on recent, reputable data availability.

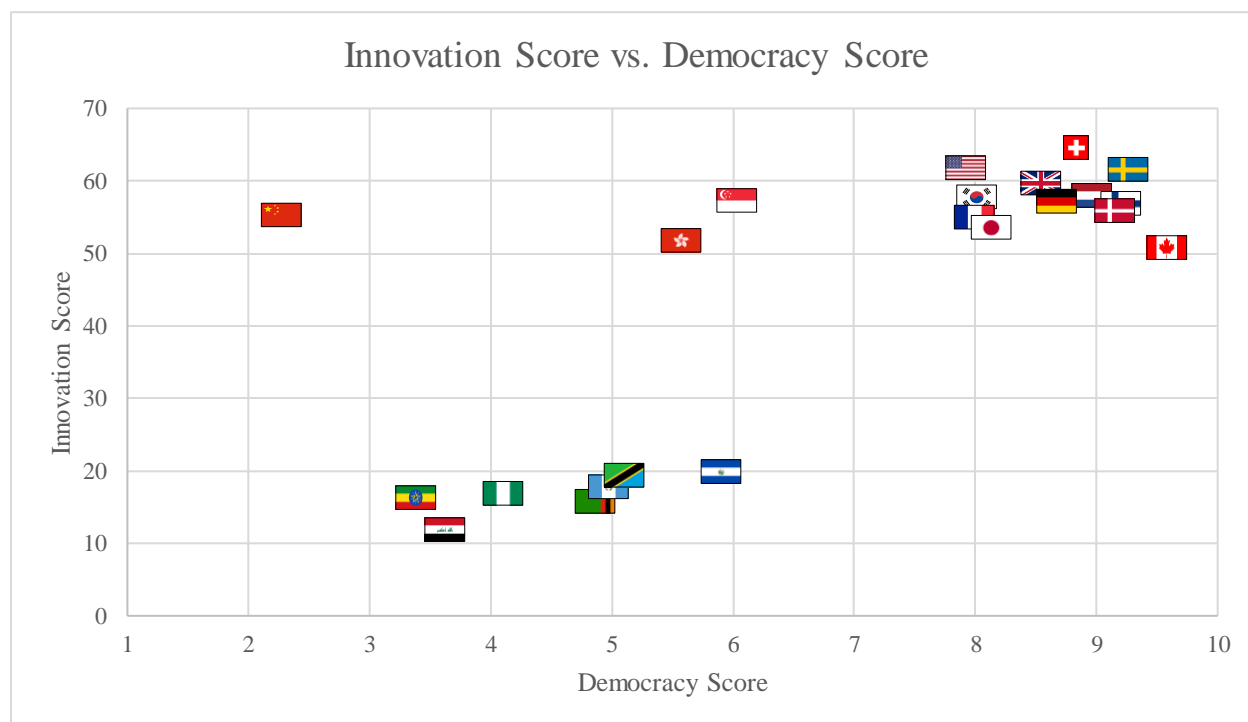
Figure 3*WIPO Innovation Score vs. Democracy Index Score*

Figure 3 shows a scatterplot of innovation scores plotted against that country's respective democracy score. A clear correlation is seen, with China as a significant outlier, between a higher democracy score and a higher innovation score. A low power distance to high innovation score has reasonable explanation. In a society with a low power distance rating, and therefore a higher democracy score, it is more normal for people to challenge the convention. Additionally, people in these societies enjoy greater individual civil liberties and may be freer to pursue what they desire. Any disapproval with the status quo also has a higher chance of being challenged and changed in a democratic society, and thus it does make sense that countries with a lower power distance see greater scores in innovation. China seems to be an exception to this apparent trend, as it is run by an authoritarian regime.

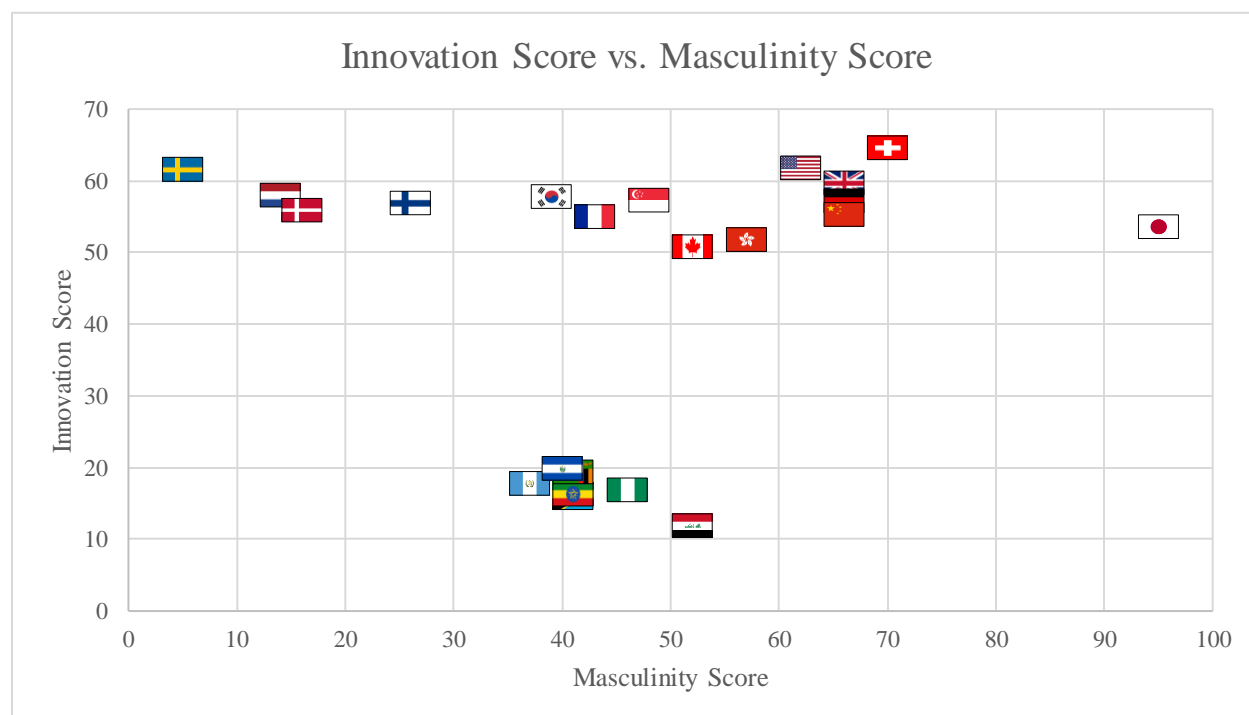
Figure 5*WIPO Innovation Score vs. Masculinity Score*

Figure 5 shows little correlation between masculinity and innovation, as there is a wide distribution among the top scoring countries. For the high scoring countries, there is a wide distribution across masculinity scores, and for low scoring countries there is a cluster in the middle range of scoring, indicating no strong relationship. The two poles of this scoring scale are emphasis on either competition or collaboration, both of which have the potential to lead to efficient innovation. Collaborative efforts join minds and offer differing perspective leading to more solutions to a problem, while competition offers greater motivation to reach goals. While competition can be beneficial to the short duration of research and technological development through desired rewards such as capital gain or prestige, collaboration joins the efforts of the otherwise competing parties and can be equally as beneficial to efficient progress.

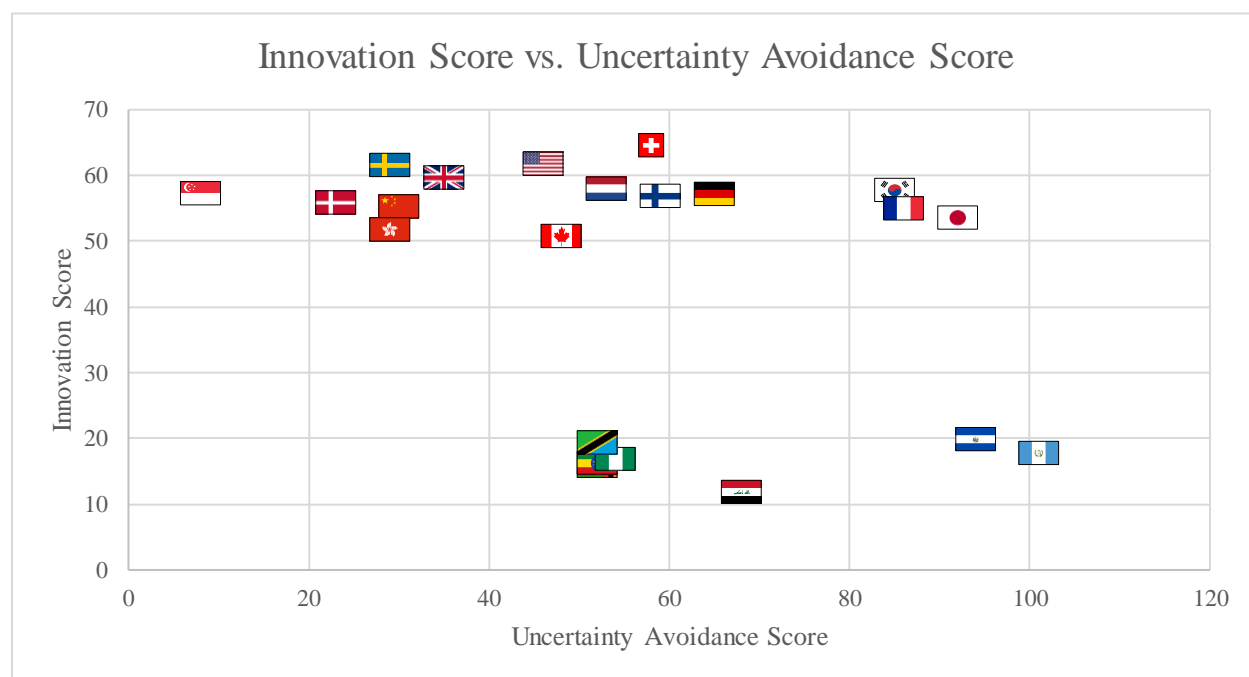
Figure 6*WIPO Innovation Scores vs. Uncertainty Avoidance Scores*

Figure 6 shows a slight negative correlation between uncertainty tolerance and innovation scores. Innovation scores decrease with decreasing tolerance for uncertainty. A low uncertainty avoidance leads to less fear about failing, and thus may contribute to a higher rate of startups with uncertain fates. People in these societies may be more willing to invest in high-risk ventures with the promise of high reward, and this combined with more startups can easily contribute to innovations in various technological fields. Conversely, fear of ambiguous outcomes and failure may cause a society to lean away from risky startups. This directly affects the rate at which innovative companies form and produce results, thus causing a decrease in the numerical metrics discussed prior such as patent applications, publication output, and research programs. Similarly, venture capitalists in risk-avoidant societies are less likely to invest in these operations out of fear of not getting a return on their investment.

Figure 7

WIPO Innovation Scores vs. Time-Orientation Scores.

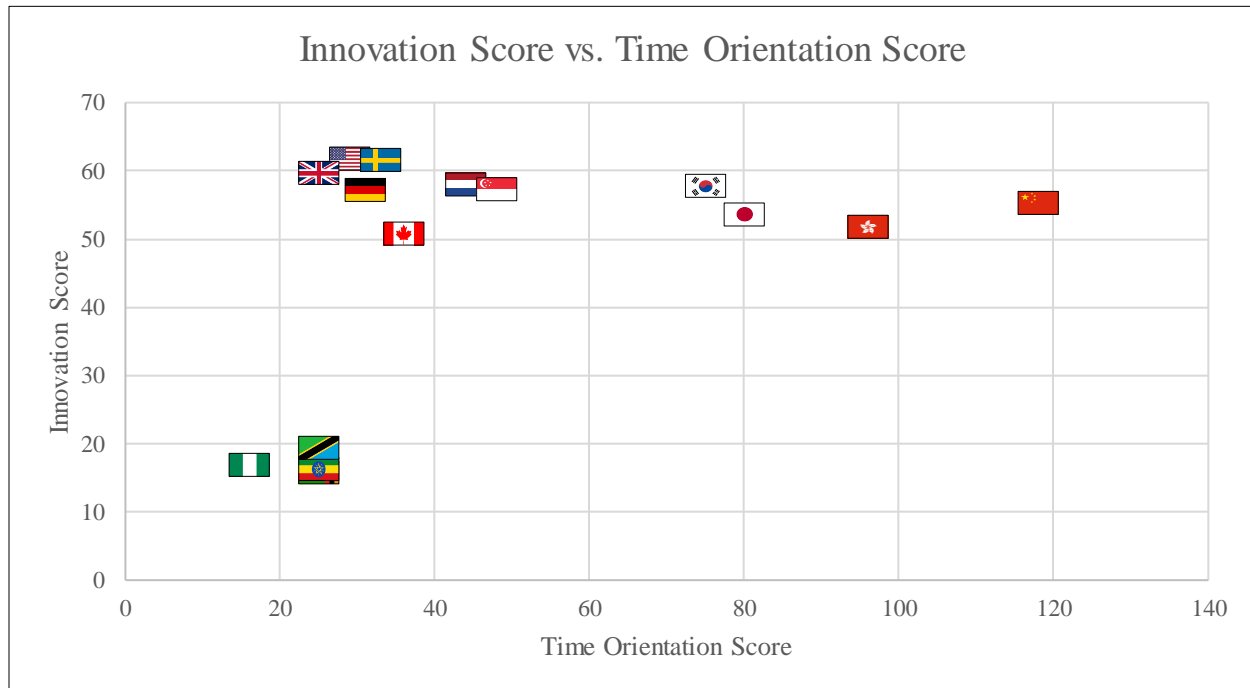


Figure 7 shows a slightly positive correlation between high scoring time orientation, or those that are long-term oriented, with high innovation scores. However, this trend is very weak and may require more data points to show a stronger relationship between innovative practices and time orientation. In short-term oriented societies, people may seek immediate gratification which may be associated with making decisions with uncertain outcomes with the aim to achieve reward as soon as possible. While these decisions can often lead to failure, they have potential to produce great outcomes resulting in reward for the creators and often innovative products being introduced to the market. Long-term oriented societies may operate on a broader schedule and produce at a slower rate, but the careful planning and caution exercised can yield higher rates of success. These societies also may not be as concerned with gratification and value patience and positive outcome over reward.

Discussion

Some strong correlations can be seen after data analysis. The strongest correlations with innovation scores exist between power distance and individualism. There are slight correlations between innovation scores, time orientation and uncertainty avoidance, while little correlation between innovation score and masculinity is evident. The criticisms of this quantitative assessment of both culture and innovation were mentioned previously in the text, and they are recognized but do not necessarily refute the methods used in this paper. Wallerstein's world system theory aims to stray away from three common analytical norms, two of which are relevant to this research. The first is using a whole nation-state bound within its geography as a unit of analysis.

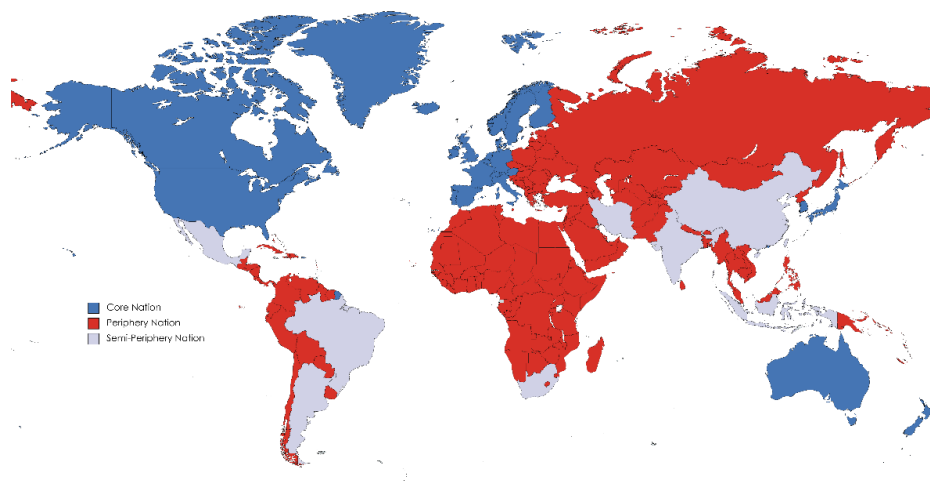
In historical and cultural analyses there is more sense in looking at the nation as it comprises a group of people, rather than the state and its geography as a nation-state can vary greatly in cultures throughout its boundaries. However, for the purpose of this research, the relationship between the people of a nation and its governing authority is related to the degree to which a country is innovative, as shown in the power-distance analysis in Figure 3. Within a nation-state, the governing body has authority over the people within the boundaries of that state, so it is reasonable to use the geographic boundaries of a nation-state, or the whole country, as a unit for the analysis of technological innovation.

Wallerstein's second criticism is that analyses often disregard the historical development of global systems that can strain the development of specific countries. This builds off of Chirot and Hall's 1982 Dependency Theory, which essentially states that the modern world trade system contains core and periphery states. The theory states that resources flow from periphery, or underdeveloped states, to developed core states, and the latter is the primary beneficiary of

this system (MIT, n.d.). Wallerstein's theory, however, subtly implies that this current world system is static and that core countries will remain core countries and peripheral countries will remain peripheral countries. It is true that this current system of global trade interaction is rather firmly set, but in theory a peripheral country could use wealth generated via resource production to invest in education, health, and infrastructure in order to become a producer, or core country. Wallerstein's theory is flawed in that it describes peripheral nations as poor and underdeveloped, however this is simply not the case. Saudi Arabia, labeled a periphery nation due to its primary export being crude oil (OEC, 2020), boasts a very high human development index (HDI) of 0.875 (UN, 2023) and is among the world's top 25 economies, yet has a WIPO innovation score of 31.8. The strongest trend shown from the data analysis is between that of innovation score and democracy index ranking, with more functional democracies scoring higher in innovation.

Figure 8

Map of Core and Periphery Nations



Note: Core and periphery nations according to Wallerstein's world systems theory.

Figure 8 shows a map of the core, periphery, and semi-periphery states, which in comparison with Figure 1 shows significant similarity between the core states and the top

innovating states. Additionally, the core states all have higher democracy scores and are classified as either pure democracies or flawed democracies. This agrees with the data analysis, showing democratic nations scoring higher on the WIPO innovation index. Therefore, a low power distance seems to be the most influential cultural dimension with regard to innovative tendencies. As previously mentioned, equal valuation of all members of society, ability to enact change, and allowing pursuit of personal interest allow for the challenging of convention. This can be reflected in many aspects of a country's culture, and directly impacts a society's ability to improve on and create new technology.

While some correlations are evident, it is important to note that cultural characteristics are not the only factors that contribute to innovation and fostering it. Other important factors such as their education systems are also extremely important and should also be taken into consideration, however it is still important to highlight cultural characteristics that innovative regions share. Societies could potentially model off of each other in an effort to increase innovation at home, which could decrease the emigration of talent from these areas by creating more opportunities for them domestically, which may increase the retention of talent. It is difficult to change a societies culture, but changes are possible, and emphasizing some of these optimal cultural dimensions in places less involved in innovation could gain them more of a platform in its involvement. On a smaller scale, these characteristics could be reflected in schools and workplaces to promote innovative practices. These small changes could be made overtime in order to more widely distribute the geography of innovation and increase the opportunities and general quality of life globally.

References

- 1) Boroush, M. National Center for Science and Engineering Statistics. *NSF* Available at: <https://nces.nsf.gov/pubs/nsf22330>. (Accessed: 13th February 2023)
- 2) Democracy index 2020 - Economist Intelligence Unit. Available at: <https://pages.eiu.com/rs/753-RIQ-438/images/democracy-index-2020.pdf>. (Accessed: 13th February 2023)
- 3) *Dimensionalizing cultures: The Hofstede model in context*. (n.d.). Retrieved March 15, 2023, from <https://scholarworks.gvsu.edu/cgi/viewcontent.cgi?article=1014&context=orpc>
- 4) Dodani, S., & LaPorte, R. E. (2005, November). *Brain drain from developing countries: How can brain drain be converted into wisdom gain?* *Journal of the Royal Society of Medicine*. Retrieved March 15, 2023, from <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1275994/>
- 5) *GDP (current US\$)*. Data. (n.d.). Retrieved March 15, 2023, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?most_recent_value_desc=true
- 6) Global innovation index 2021 - WIPO. Available at: https://www.wipo.int/edocs/pubdocs/en/wipo_pub_2000-section1.pdf. (Accessed: 13th February 2023)
- 7) Hofstede Cultural Dimension Scores - Country Comparison. *Clearly Cultural* Available at: <http://clearlycultural.com/geert-hofstede-cultural-dimensions/long-term-orientation/>. (Accessed: 13th February 2023)
- 8) Kounteya Sinha / TNN / Updated: May 14, 2012. (n.d.). *1,333 doctors migrated abroad last year: India News - Times of India*. *The Times of India*. Retrieved March 15, 2023,

from <https://timesofindia.indiatimes.com/india/1333-doctors-migrated-abroad-last-year/articleshow/13128728.cms>

- 9) Libretexts. (2022, January 5). *9.4H: Dependency theories*. Social Sci LibreTexts. Retrieved March 15, 2023, from [https://socialsci.libretexts.org/Courses/Collin_College/Introduction_to_Sociology/09%3A A Global Stratification and Inequality/9.04%3A Sociological Theories and Global Inequality/9.4H%3A Dependency Theories](https://socialsci.libretexts.org/Courses/Collin_College/Introduction_to_Sociology/09%3A_A_Global_Stratification_and_Inequality/9.04%3A_Sociological_Theories_and_Global_Inequality/9.4H%3A_Dependency_Theories)
- 10) National Geographic Society. (2015, August 7). *Technology and control in Ancient Rome*. National Geographic Society. Retrieved March 15, 2023, from <https://www.nationalgeographic.org/activity/technology-and-control-ancient-rome/>
- 11) Nations, U. (2023, January 23). *Human development index*. Human Development Reports. Retrieved March 15, 2023, from <https://hdr.undp.org/data-center/human-development-index#/indicies/HDI>
- 12) *Saudi Arabia (Sau) exports, imports, and trade partners*. OEC. (n.d.). Retrieved March 15, 2023, from [https://oec.world/en/profile/country/sau#:~:text=Exports%20The%20top%20exports%20of,Arab%20Emirates%20\(%249.21B\)](https://oec.world/en/profile/country/sau#:~:text=Exports%20The%20top%20exports%20of,Arab%20Emirates%20(%249.21B))
- 13) Sauter, M. B., & Stebbins, S. (2018, November 1). *Fortune 500 companies list: 1 out of 3 are located in just six major cities*. USA Today. Retrieved March 15, 2023, from <https://www.usatoday.com/story/money/business/2018/11/01/fortune-500-companies-list-cities/38215229/>
- 14) The role of individual variable pay in a collectivistic culture society. Available at: https://www.researchgate.net/publication/334509709_The_role_of_individual_variable_p

[ay in a collectivistic culture society an evaluation The role of individual variable pay in a collectivistic culture society an evaluation.](#) (Accessed: 13th February 2023)

15) Uncertainty avoidance (UAI) scores and rankings for 70 countries. Available at:

https://www.researchgate.net/figure/Uncertainty-Avoidance-UAI-Scores-and-Rankings-for-70-Countries_tbl1_288964749. (Accessed: 13th February 2023)

16) *World Map - Simple: Create a custom map*. MapChart. (n.d.). Retrieved March 15, 2023,

from <https://www.mapchart.net/world.html>

17) *World systems theory - Massachusetts institute of technology*. (n.d.). Retrieved March 15,

2023, from <https://web.mit.edu/esd.83/www/notebook/WorldSystem.pdf>