Digital Infrastructure and Environmental Performance: Antagonists or team players?

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# Three modern-day phenomena and their connections

Whilst talking about a few of the most ongoing and interesting social phenomena of the late 20th and the beginning 21st century, digital revolution and climate change, a third societal process does inevitably come up sooner or later: globalization. As globalization is both having a huge impact and being reliable on digital and environmental change, the first two mentioned phenomena are tightly interconnected to the globalization process.

It is well-known that globalization without new ways of digital communication around the globe such as the internet or social media, to just name a few, would not be the society-influencing, daily-life-changing social phenomena by which modern society is deeply formed (Clapp et al. 2011: 21). Maybe the youngest or at least the most recently discussed phenomena is environmental change with its concomitants like climate change or water pollution. But despite the relatively new emergence of environmental change as a worldwide discussed topic, it is still strongly connected to both globalization and digital infrastructure. Nearly all the problems and challenges world society is facing because of the changing environment are globalized problems which can’t be solved by single states and mostly not even by continental groups.

The connections between globalization and environment and the strings between digital infrastructure and globalized social processes seem to be discussed and examined under a lot of scientific aspects and by different academic approaches, the codependence of digital infrastructure and environmental performance still seems to give room for empirical research and a data-based analysis.

While one advantage of focusing on digital infrastructure and environmental performance is the above described rooms and possibilities for new empirical research, the area and the research topic are both largely extended ones. Therefore, and to live up to the common quality expectations of state-of-the-art empirical studies, this analysis does focus on three aspects of digital infrastructure influencing environmental performance of nations. These three aspects, that can be expected to be clarified and conceptualized during this study, are: Internet access and parcel shipping, internet usage and energy consumption and last, but not least internet access and environmental knowledge. These three branches of digital infrastructure should serve as explaining basics for the following questions: Do countries with a high developed digital infrastructure perform better or worse in environmental aspects? Or is the performance of countries regarding climate change and environmental problems even in some way dependent from its state of digital infrastructure?

In order to lead through the following empirical research, this question is trying to combine all interests and problems from above:

**How does the digital infrastructure of states affect their environmental performance?**

# The connection of Digital Infrastructure and Environmental Performance in the scientific discourse

As already mentioned, the connection between digitalization and environment are not as thoroughly discussed and analyzed in the scientific world as the social and economic relationships between globalization and digitalization or globalization and environmental issues. Nevertheless, still a lot of interests and expectations lie on many research areas regarding the interaction of digitalization and environmental sustainability. Many different academic fields have focused on the various possibilities and transformations digitalization could bring in the scientific discussion about sustainability issues. Even if this paper focusses on environmental and ecological problems, when browsing through literature and scientific papers regarding the changes brought by modern digital world, data protection and social justice do inevitably come up as other areas of sustainable development affected by digital change. Therefore scientific, humanistic and economic approaches have been made to discover the potential solutions and discuss the scientific revolution brought by digitalization. Especially geographic studies can be found often, concerning modern urban or suburban life affected through digitalization. Particularly technologies and projects like smart cities or smart homes are hereby discussed and analyzed frequently. Beyond that, another concept seems to become more relevant in academic research: The Internet of Things (IoT). From physicians over sociologists to politicians, a broad spectrum of actors seems to take interest in the development that nearly all common household items, but also many public goods and industry and economic related technologies are connected to the internet by some or another way. But not also this process at its core is monitored, also the possibilities and criteria for sustainable development of the IoT is followed by many groups of interest. In addition an even more recent and relatively unexplored phenomenon can be found in the latest papers concerning digitalization and IoT: the Internet of Everything (Bauer et al., 2014, p. 17; Deckert, 2020, p. 15). But the academic discourse does not only bring up positive changes and expectations brought to world throughout digitalization. Also, the risks and disadvantages of new digital structures traversing our daily life around the globe encourages the scientific community to further research. Hereby, due to its broad approach on the possibilities and risks of the development, a major conference at the Technical University Berlin must be mentioned: “Bits and Trees – the conference for digitalization and sustainability”. Held in November 2018, during this meet-up of experts and scientists of all areas discussed and brought up many ideas and issues that affect and touch or build the background for the chosen hypotheses of this examination. Regardless, most of the reports of the conference do operate on a qualitative level draw conclusions and advices of action based on the research and experience of the renowned experts. And here is where this examination tries to step in and approach the area in different ways of methods. The research question is tried to be answered in a quantitative manner based on international and detailed data from international regimes and organizations as the UN and the OECD. Thus, the core of the analyzed research question is if countries with a higher and better developed digital infrastructure perform better in environmental issues? A difference in the status-quo of digitalization and environmental performance in the different parts of the world is doubtlessly findable in the scientific discourse.[[1]](#footnote-1) Countless studies and reports show the gaps and disparities in the development of both areas, underlined throughout many data sources (Esty and Porter, 2005; Soumitra et al., 2016). Thus, the point of interest of this paper is, whether it is possible to visualize the impact of digital infrastructure on environment by conduct a data-based analysis?

Altogether many several items touched by this examination are discussed and analyzed in the academic discourse meanwhile the big link between digitalization and environmental performance is not analyzed completely, not for now after all. And naturally this paper does not claim to even begin with logicalizing and thoroughly explaining this connection, at least the goal is to try to start with searching and lightly connecting a few of the many pieces the big puzzle of sustainable and ecological digitalization provides.

# What is data-transmission? – a historical approach

As explained in the previous chapters, both digitalization and ecological issues as themselves and the connection between them are broad and differing phenomena, which cannot be explained or simplified by one theory or theoretical idea. Therefore, a different method of theoretical groundwork is used. At first one main hypothesis is built up by a broadly held theoretical approach but more importantly, grounded by two specific sub-hypotheses. Each of these will then be undercoated by different theoretical approaches from particulary research areas.

## Digital Infrastructure and Environmental Performance

When thinking about the issues of digitalization and modern information technology structures, mostly the internet, computers, glass fibers and data transmission are keywords that, amongst others, come to mind. But while the first three mentioned are items that belong to modern digital infrastructure and have been developed in the last 40 years, data transmission at its core is not that new of a concept having impact on the world as we know it. Basically, every written word is a kind of data transmission and has one goal or one advantage for humans: the transfer of knowledge. But until the 15th century and the invention of the letterpress, data transmission was, especially from the view of a modern human with basically the entire knowledge of the humanity in the pocket, incredibly tedious and expensive (Silver, 2013, p. 10). After thousands of years, where books or any other form of the written word and the ability to read and write were luxury, reserved to the most rich and mighty, the invention by Johannes von Gutenberg reduced the costs of books by three hundred times (Silver, 2013, p. 11). By rapidly increasing the knowledge and information flow, this innovation had major impact on the world and humankind, influencing religion, science and medicine, to just name a few. Furthermore, it paved the way for an even more groundbreaking development: digital data transmission, requiring modern digital infra structure. But how does all this belong to environmental issues? To answer that question, a close look on the similarities of both developments and a comparison of their concomitant phenomena helps. Both inventions brought exponential growth along. The letterpress increased the book printing largely, while digital data transmission enlarged the amount of transferred data steeply, measured in bits and bytes (Gossen and Kampffmeyer, 2019, p. 14; Silver, 2013, p. 18). Data transmission, whether analog or digital, relies on some sort of resource-intensive frameworks and this resource consumption is the connection to the environmental impacts of data transmission. The exponential growth of book printing required hitherto unknown masses of paper and further material essential to print the written word. The branching and exponential growth of information technology system and digital data transmission required and still requires even more resources, hard- and software serve as an example (Gossen and Kampffmeyer, 2019, p. 14f). Resource consumption has different and various effects on the environment, which will be discussed in the following part of the paper by the hypotheses grounded with a theory of technical character. In defiance of the initially seeming rather negative impact of digitalization on environment due to the resource consumption, also some other, maybe positive, but at least noteworthy observations do come up when comparing the development of book printing and digital data transmission. In addition to exponential growth concerning resource consumption also both developments contribute to the extreme increase of another phenomenon called information or knowledge growth (Silver, 2013, p. 18). Either through the expansion of book printing or by the massive growth of digital data traffic, both developments brought their time and human society an incredible rise in knowledge, due to the increased data and information flow and especially the broad access to it which lead the way to the age we life in, also called information era. Humans used this newly gained knowledge in all areas of personal, social and professional life. The resulting new solutions and explorations touched economics, industry, science and many more fields of study and more importantly human development. To name just one example, the industrial revolution never would have been possible without the increased flow of information through the western hemisphere by books. But as the history of the industrial revolution shows, the severe changes brought to the different areas also affected the environment in some way or another. Not necessarily bad, these changes provided new possibilities and framework conditions for the areas affecting environmental issues like economy or industry, but also to environmental changes itself. These ideas will be discussed by hypotheses with a social and economic backgrounds.

In summary the connection between digital infrastructure and environmental performance is solidified by the resource consumption data transmission always requires and the changes to human life brought by new data and more information. This leads to the main but undirected hypothesis (H1), grounded by the previously elaborated broad theoretical approach:

H1: States with different levels of digital infrastructure show different levels of environmental performance

The broad and general character is intended, as this hypothesis serves as an overlying, main hypothesis for providing access to the statistical and empirical part of this paper. Similar to the infamous concept of James Colemans’ bathtub as a micro-macro pattern to explain societal conditions with overlying collective hypothesis and underlying individual hypotheses, this paper tries to approach the complicated relation between digital infrastructure and environmental performance with the undirected hypothesis H1 on a macro-level (Coleman, 1991, p. 10ff). Different to the concept of Coleman, the underlying sub-theoretical approaches do not have individual character and therefore do not rely on individuals as actors. They are constructed to part up the diversified concept of H1 to analyze some of the processes within the assumed connection of environment and digitalization leading to the assumption of H1 that states which differ in digital infrastructure also differ in environmental performance.

## The environmental consequences of Parcel Shipping

As already mentioned, one hypothesis group relies on an economic and social background. Digitalization and increased data transmission surely had an impact on economics. Especially E-Commerce was an important concomitance, forming new ways of trade and sales markets. Relying on above mentioned new possibilities and framework conditions for environmental issues, online shopping was quickly adapted in the international trade system and soon became inevitable for many economic sectors (Gossen and Kampffmeyer, 2019, p. 107). For consumers and distributors E-Commerce brought many advantages. Consumers were no longer tied to business hours of malls, retail and wholesale trade and had new possibilities for networking and information opportunities such as product reviews or price comparison (Gossen and Kampffmeyer, 2019, p. 107). In short significantly more data is available when doing shopping in comparison to traditional trade structures. Distributors, meanwhile, had an increasing and fast-moving new sales market that is becoming more and more powerful and important. When at first online shopping seems to be a win-win situation, the environment must not be forgotten. As digitalization, E-Commerce itself has a concomitance. Online shopping would not be doable without parcel shipping and as E-Commerce has increased steeply, so has parcel shipping over the last few decades. Delivering almost every sort of goods to the costumers’ front door requires various environmental related steps of trade beginning from international shipping to local package delivery, everywhere CO2-emmisions are included. Two other side effects of parcel shipping having impact on the environment are the increased need for packaging material and the system of return shipment. In contrast to conventional trade, E-Commerce requires more intensive use of packaging material due to longer retail chances. The system of return shipment means, that many internet order businesses offer return services of order goods for free. That entails, because the costumer does not carry the risks and costs if the ordered good does not fit in some possible way, even more packages are ordered over CO2-intensive trade ways and even sent back, which therefore obviously doubles the CO2-emmison per ordered good. Furthermore, the waste of packaging material seems to be implied, as most of the packaging concepts are made for one-time use only. In addition, it is often cheaper for companies to discard the sent-back goods rather than reusing them, which leads to another waste of resources (Gossen and Kampffmeyer, 2019, p. 109). But despite all these effects of parcel shipping and online shopping it is also discusses that online shopping does not have more or less of an environmental footprint than conventional ways of trade. Also, traditional shopping requires resources to deliver goods to the relevant stores and means CO2-emissions during transport, which is also emitted when costumers do have to get to the stores in some way or another. This, and the idea that the internet can also be used to provide knowledge about environmental-friendly consumerism, can suggest that E-Commerce does not have a measurable effect on environmental performance (Gossen and Kampffmeyer, 2019, p. 109). This exactly is the edge where the following data-based examination takes effort to analyze whether it is possible to visualize the connection between digital infrastructure and environmental performance via hypotheses about parcel shipping. This process is conducted by two sub-hypotheses (SH1 & SH2):

SH1: The higher the digital infrastructure of a state, the higher is the states’ rate of parcel shipping per capita.

SH2: The higher the rate of parcel shipping per capita of a state, the lower is the states’ environmental performance index.

## Digital energy consumption – a technical approach

A second sub-hypothesis group is based on technical conditions. Hereby, the resource-related concept from the main theoretical approach, that data-transmissions always requires some form of resource-intensive framework will be applied on digital data transmission in detail. From now on, when speaking of digital infrastructure often the phrase Information and Communication Technologies (ICT) will be used. This term describes all applications and technologies related to information technology (IT) and telecommunication. ICT is fundamental for ensuring a working digital infrastructure, as it involves internet access, hardware and software for instance (Stobbe et al., 2015, p. 27). As ICT must be either produced with resources connected to the environment, rare commodities for hardware production serve as example here, or provided with energy, which small user devices or major server farms can exemplify, the connection gets clear (Langkau and Hilbig, 2019, p. 16). The mining of mineral raw materials required by the production of ICT cause ecological damage, especially in what is called the global south of the world. For example, one ton of lithium, manly used for the batteries of electronic devices, takes about 20 million liters of water while the production process, thereby harming humans, flora and fauna (Langkau and Hilbig, 2019, p. 15). [[2]](#footnote-2) In addition, the mix of many environment-damaging commodities in ICT-devices complicate the recycling process of the devices and the partly highly toxic used raw materials (Bax and Handke, 2019, p. 34). Not to forget, the following process of production and trade of electronic devices, but also the installment of infrastructure required by ICT like broadband and server farms, is responsible for CO2-emmisions and more so for energy consumption. The latter is the second issue responsible for environmental consequences of digital infrastructure. Already today, 33 million tons CO2-emmisions just in Germany and, on global sight, ten percent of the energy consumption are caused to provide for the operation of the Internet and Internet-enabled devices (Langkau and Hilbig, 2019, p. 14). Both the consumption of energy and resources in form of raw materials are not expected to decline or even stay on a steady level, which is caused by an increasing quantity of transmitted data and an already mentioned phenomenon: the Internet of Things (IoT) or respectively the Internet of Everything (IoE) (Langkau and Hilbig, 2019, p. 14). A complete attachment of nearly everything, beginning with common house-hold devices up to whole industry production processes, with Internet and ICT obviously increases both energy and raw material consumption. Nevertheless, similar to the arguments in the previous economic approach, also in the discussion about the environmental consequences of the digital infrastructure through raw material and energy consumption there are voices arguing that also conventional technologies of the ICT sectors, like analog television or videotapes produced said environmental consequences (Gröhn, 2018). And again this discussion is the point, where this examination steps in and tries to answer the question, if it is possible to show by data-based analysis whether states with higher developed digital infrastructure show environmental performance on a lower level or if this part of environmental connected issue does not have an impact on the environmental performance of countries. The analysis is conducted by the following sub-hypotheses (SH3 & SH4):

SH3: The higher the level of digitalization of a state is, the higher is the states’ overall energy consumption.

SH4: The higher the energy consumption of a state, the lower is the states’ environmental performance.

# Empirical Design

The research design of the examination is formed as a quantitative data-based analysis. The hypotheses are tested with a large quantity of cases. 121 countries are analyzed over a research period from 2007 to 2019. The frame of the research period is mostly given through the data availability of the independent variable (IV). The IV of H1, SH1 and SH3, *Digital Infrastructure (DI)* is measured through the Network Readiness Index (NRI), obtained by the World Economic Forum. The NRI includes nearly all facets and items of digital infrastructure from mobile internet access to the percentage of households with a personal computer per state. The IV of SH2, which is also the dependent variable (DV) of SH1, *Parcel Shipping (PS)* is measured in the states’ rate of parcels shipped per capita, obtained by the World Integrated Trade Solution (WITS) software. The IV of SH4, which is also the DV of SH3, *Energy Consumption (EC)* is measured via the total energy consumption per state, obtained by UN-Data, the statistical service department of the United Nations. The dependent variable of H1, SH1 and SH3, *Environmental Performance (EP)* is measured by the Environmental Performance Index (EPI), obtained by a study department of the University of Yale. The EPI contains performance characteristics like water consumption, air pollution or biodiversity. All characteristics are weighted and are the used to calculate the EPI per country.

Regarding the hypotheses, as already described, each of both sub-theoretical approaches are analyzed by two hypotheses that run alongside the examined connection between DI and EP. This type of design structure is serving to show closely where exactly and if in the big link between the IV and DV of the main hypothesis can be made visible – or not. Therefore, in H1 a negative effect on the DV is expected. But first and foremost, H1 serves to show that when countries differ in DI then they also can be expected to differ in EP. In SH1, the IV DI is expected to have a positive impact on the DV PS, or rephrased that a higher developed DI leads to more PS. Whereas in SH2, the DV EP is expected to be affected negatively by the IV PS because of the theoretically discussed environmental disadvantages of parcel shipping. In SH3 a positive impact of the IV DI is expected, whereas in SH4 it is expected, that EC has a negative impact on EP.

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# Confirmation

I hereby confirm that this paper is entirely my own work and that I have not used any additional assistance or resources other than indicated. All quotations, paraphrases, information and ideas that have been taken from other sources (including the Internet as well as other electronic sources) and other persons’ work have been cited appropriately and provided with the corresponding bibliographical references. The same is true of all drawings, sketches, pictures and other illustrations that appear in the text.

I am aware that the neglect to indicate the used sources is considered as fraud and plagiarism in which case sanctions are imposed that can lead to the suspension or permanent expulsion of students in serious cases.

Regensburg, 8/26/2020 Berg Jakob

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1. Hereby is not, different than before, the connection between the two issues meant, but the academic discourse focusing on each of both areas. [↑](#footnote-ref-1)
2. It is difficult to assign the environmental consequences to the states which consume lithium or other raw materials, due to the international production process. This problem will be discussed in the research design section later on. [↑](#footnote-ref-2)