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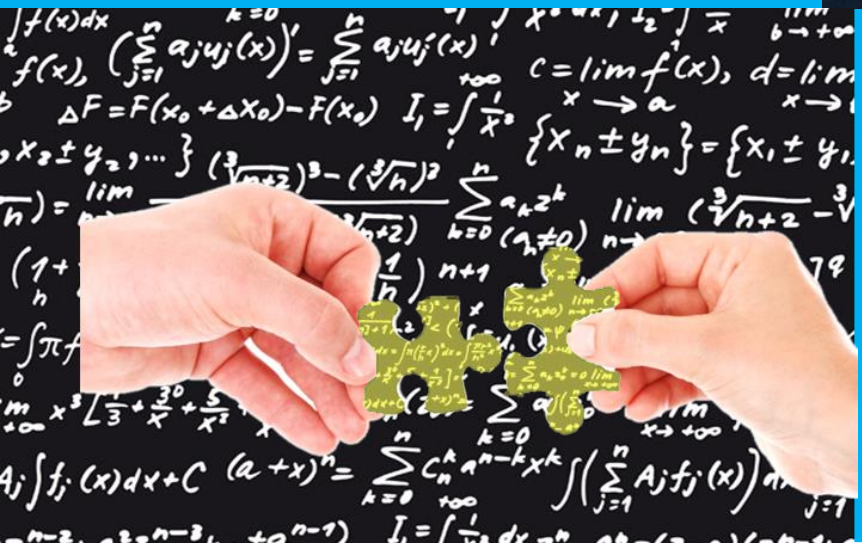
Harnessing Digital Trade to advance the Sustainable Development Goals: An Empirical Study



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ASIA-PACIFIC RESEARCH AND TRAINING NETWORK ON TRADE

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WORKING PAPER

Harnessing Digital Trade to advance the Sustainable Development Goals: An Empirical Study

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Abstract

Trade's profound digital transformation has spurred a new era of digital trade. However, little is known about the impact of digital trade and related policies on sustainable development. To investigate this, our exploratory study employs Fixed-Effects (FE) regressions, linking digital trade variables with all Sustainable Development Goals (SDGs) through SDG targets organized into 4 main areas of development: economic, social, environmental, and governance and global partnerships. Our findings point to a statistically significant and positive relationship between the advancement of SDG targets and the growth of digital trade, particularly in the social and environmental areas. The results related to economic development and governance and global partnerships present a more varied picture. Integrating digital trade policies into regional agreements could significantly enhance the prospects of achieving the SDGs but it remains critical to bridge the digital divide to leverage the full benefits of digital trade.

Keywords: Sustainable development, SDGs, digital trade, digital trade policies, trade facilitation

JEL Codes: F10, F13, Q01

Table of Contents

List of tables

List of figures

1. Introduction

The dynamic interplay between digital technology and trade has swiftly transformed traditional trade practices and spurred a new era of digital trade, which the IMF-UNCTAD-OECD-WTO (2023) define as “All international trade that is digitally ordered and/or digitally delivered”. According to UNESCAP-UNCTAD-UNIDO (2023), in 2022, digitally deliverable services (a common proxy for total digital trade) already represented the majority of services traded globally, with this trend expected to intensify going forward. As such, digital trade has become the centerpiece of a host of new policy challenges and understanding its relationship with sustainable development has become key in promoting a successful digital transition. Yet, owing to digital trade’s relatively recent and ever-changing nature, this is a topic that is still largely unexamined.

In this context, this paper adds to the existing literature by offering a wide-ranging empirical exercise investigating how digital trade, digital trade provisions and internet penetration might impact the SDGs. We build regressions models utilizing OECD-WTO BATIS statistics on digital deliverable services (DDSs) and ESCAP data on digital trade provisions in regional trade agreements (DTPs) to link digital trade and related provisions to 32 SDG targets spread across 4 areas of intervention: economic, social, environmental, and governance and global partnerships. Our models leverage large country-year panel data across SDG targets and employs a country Fixed Effects identification strategy to ensure the derivation of robust estimations. We complement this empirical exercise with an extensive literature review that provides a rich framework to interpret our results and distil policy recommendations.

While some limitations naturally arise from the wide scope of the paper, we hope to lay the groundwork on the intricate relationship between digital trade and sustainable development and shed some light for future research. Key findings from this paper were included in the UNESCAP-UNCTAD-UNIDO flagship report on ‘Unleashing Digital Trade and Investment for Sustainable Development’ (2023). All technical and methodological support to the findings published therein can be found below.

The rest of this paper is organized as follows. In section 2, we start by exploring the nature and potential measurements of Digital Trade, Digital Trade Provisions, and the SDGs. We then exhaustively analyse the existing literature linking digital technologies, digitalization and sustainable development, covering all SDGs. In section 3, we deep dive into the paper’s empirical approach, laying down the fundamentals of our models, the underlying assumptions, and core limitations. In section 4 we examine the results of all significant regressions, bridging them with the existing literature. Section 5 concludes the paper, providing suggestions for future research.

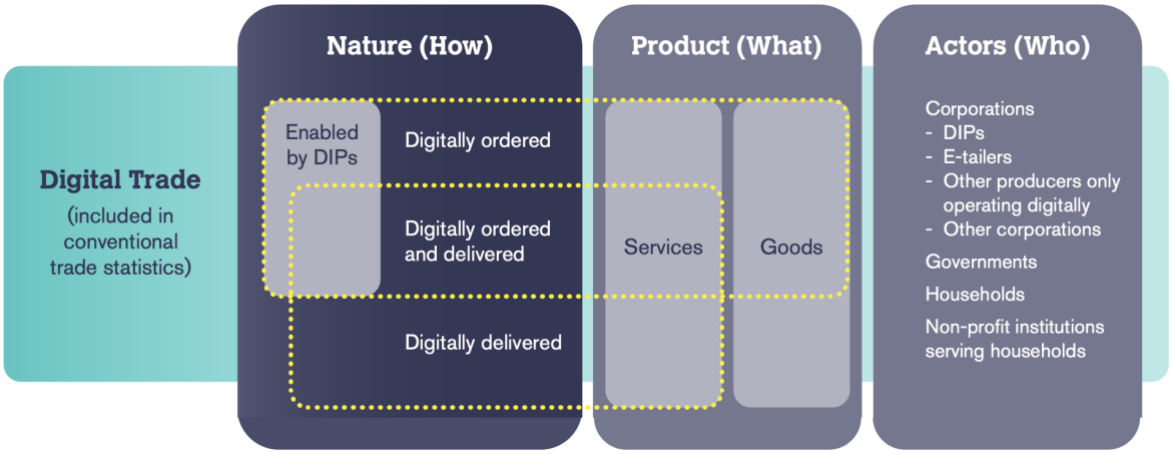
2. Literature Review

What is digital trade?

While the definition of digital trade is constantly evolving, the IMF, OECD, UNCTAD, and the WTO, in the second edition of the Handbook on Measuring Digital Trade (2023), have harnessed widespread consensus in understanding digital trade as "All international trade that is digitally ordered and/or digitally delivered".

This is such that, digitally ordered trade encompasses all international transactions in goods and services conducted over computer networks specifically designed to place and receive orders – i.e., international e-commerce –, digitally delivered trade denotes all international transactions in services that are remotely delivered over computer networks – i.e., ICT-enabled services –, and digitally ordered and delivered trade corresponds to all international transactions meeting at the intersection of all above-mentioned criteria. Conceptually, Figure 1 summarizes this definition.

Figure 1: The conceptual framework for digital trade



Source: Based on IMF-UNCTAD-OECD-WTO (2023).
Notes: DIP stands for digital intermediation platforms, which are defined as "Online interfaces that facilitate, for a fee, the direct interaction between multiple buyers and multiple sellers, without the platform taking economic ownership of the goods or rendering the services that are being sold (intermediated)".

As Figure 1 illustrates the concept of digital trade is centred around the nature of transactions (the “How”) rather than on the nature of the products transacted (the “What”). This reflects the understanding that the same product might fall under the scope of digital trade depending on how it has been ordered or delivered. In contrast, readily available trade statistics disaggregate trade according to sector and product categories – e.g., HS codes, ISIC codes etc. –, seldomly recording transactions’ delivery or ordering modes. In essence, this indicates that existing statistics have yet to effectively capture digital trade flows. As a result, identifying useful proxies to represent digital trade trends is crucial at this early stage of digital trade statistical measurement. Below we deepen the discussion on how to adequately proxy digital trade.

How can digital trade be measured?

While indirect proxies such as the use of ICT goods and services (also called ICT-enablers) or internet penetration have been widely used to mirror digital trade variations in the past (OECD 2018 & 2021), their usage has been in gradual decline. Indeed, as more direct proxies of digital trade have become available – albeit with varying coverage –, these have become preferred variables for mirroring digital trade. In this regard, the IMF-UNCTAD-OECD-WTO (2023) have compiled the many different potential sources for proxying digital trade and, more specifically, its sub-components: i.e., digitally delivered and digitally ordered trade.

Measuring digitally ordered trade, both in goods and services, has proven to be problematic. While, in principle, estimates can be derived from a variety of sources, such as business or household surveys, VAT reports, card payment data or customs declaration, the lack of a common reporting framework has made it highly challenging to achieve comparability across sources and economies. Furthermore, as the IMF-UNCTAD-OECD-WTO (2023) noted, these methods can only provide rough estimates of total digitally ordered trade volume. They state that “no single [available] source can offer a holistic measure for digitally ordered [trade] at the economy level.” For those reasons, the use of digitally ordered trade measurements has been limited and other proxies have been more commonly preferred.

Indeed, most digital trade literature has instead turned to measuring digitally delivered trade or, equivalently, digitally delivered services . In particular, digitally deliverable services (DDSs) – a sub-set of total services already recorded in national statistics – serve as the most common proxy for digital trade (ADB, 2022; Fu et al, 2022 Di, Zhi, Song, & Zhang, 2022).

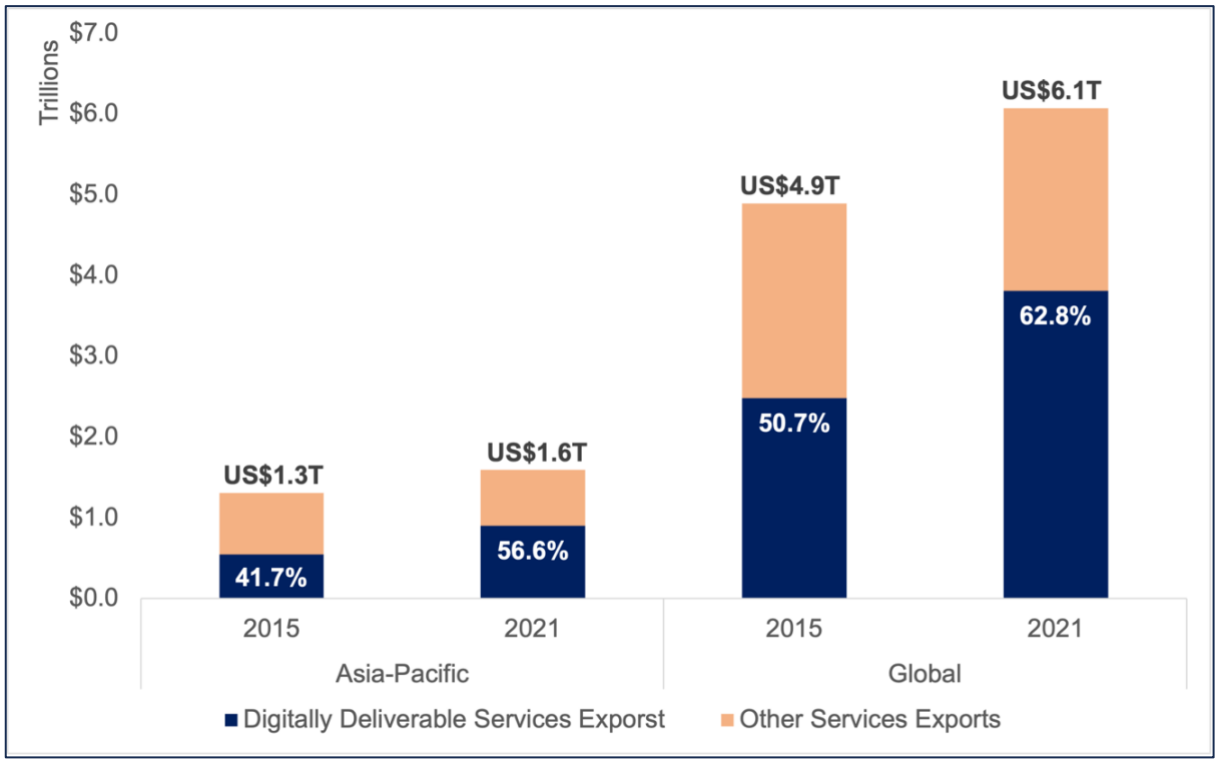
Digitally deliverable services are a set of service categories, such as Financial Services or Telecommunications, that were identified to be potentially digitally delivered – i.e., that can be delivered remotely via an ICT network (IMF-UNCTAD-OECD-WTO, 2023). As several studies have shown, upwards of 80% of DDSs are, in fact, digitally delivered, meaning that DDSs serve as an upper-bound on total digitally delivered trade (UNCTAD, 2015; BEA, 2012). Moreover, the IMF-UNCTAD-OECD-WTO (2023) noted that most digitally delivered services are also likely to be digitally ordered. As a result, changes in DDSs are expected to reflect wider trends in digitally ordered services – i.e. international e-commerce in services.

While Digitally Deliverable Services (DDS) do not directly include digitally-ordered goods – i.e. international e-commerce in goods –, their growing importance in various aspects such as internet services, e-marketplace services, online payment and finance services, and e-logistics significantly aids the process of ordering, payment, and tracking in digital transactions. This suggests that the growth and expansion of DDS can provide valuable insights into broader trends in international e-commerce involving goods. Therefore, while not a direct measure, the proliferation and use of DDS can act as an indicative measure of general trends in the digital trade sector. As such, in this paper, DDSs are used as a proxy for total digital trade. Disaggregated data on DDSs is available from multiple sources and databases such as in UNCTAD, US Department of Commerce (USDOC) or in the OECD-WTO Balanced Trade Statistics (BaTiS) — the dataset used in this paper.

How has digital trade evolved? — 2015-2021

Over the past decades, digital trade has grown considerably. In particular, during the 2015-2021 period alone, global digitally delivered services (DDSs) – the suggested proxy for total digital trade – grew by an annualized 6.3%. In Asia and the Pacific, these services grew even faster at an annualized 7.5%. This can be compared to the 3.1% and 2.9% annualized global and regional growth registered in total services exports, respectively. As a result of these trends, DDSs' prominence in global and regional services exports has risen substantially. In 2021, well over half of global (62.85%) and regional (56.6%) services exports were attributed to it (Figure 2).

Figure 2: Growing trend of Digitally Deliverable Services in Total Services Trade: 2015-2022

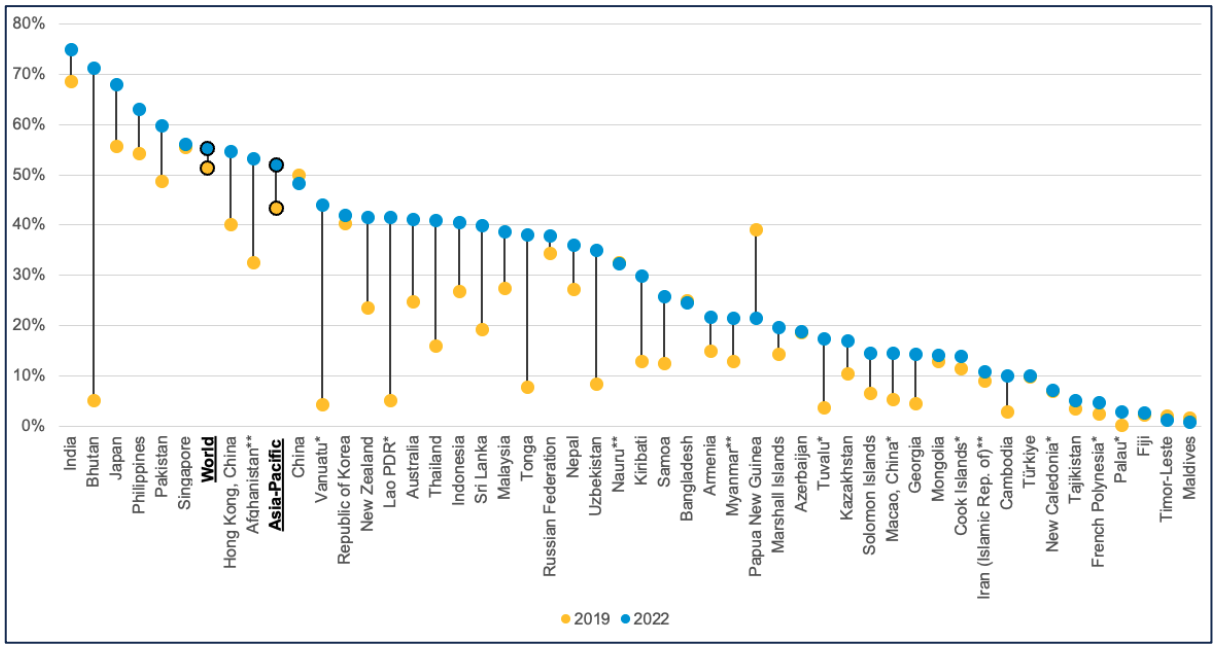


Source: Authors based on BATIS Services Trade data and WTO Commercial Services Trade between 2015 and 2021.

Note: To maintain data consistency across years, only economies with both digital trade and total exports data for all years were used. As a result, the world aggregated consisted of 182 economies, while the Asia-Pacific aggregated consisted of 46.

Asia and the Pacific's dynamic digital growth over the past years has translated into an increase in the region's prominence in global digital trade. Between 2015 and 2021, Asia and the Pacific's share of digital trade grew from 22% to 24%. However, digital trade's prominence at the economy level, remain extremely heterogenous. Indeed, countries like India, Bhutan, Japan, the Philippines, or Pakistan, where digitally deliverable services represent over 60% of their total services exports, starkly contrast with economies like Maldives, Timor-Leste, Fiji, or Palau, that record less than 5% (Figure 3). This substantial variability in digital trade participation, highlights the accentuated digital divide felt across the region. While digital trade is booming and becoming a central piece in most economic activities, many small developing economies are falling behind.

Figure 3: Percentage of digitally deliverable services in total services exports for the Asia-Pacific economies, 2019 and 2022



Source: UNESCAP-UNCTAD-UNIDO (2023), Chapter 2, Figure 2.3, P.30.
Notes: * 2021 instead of 2022; ** 2020 instead of 2022.

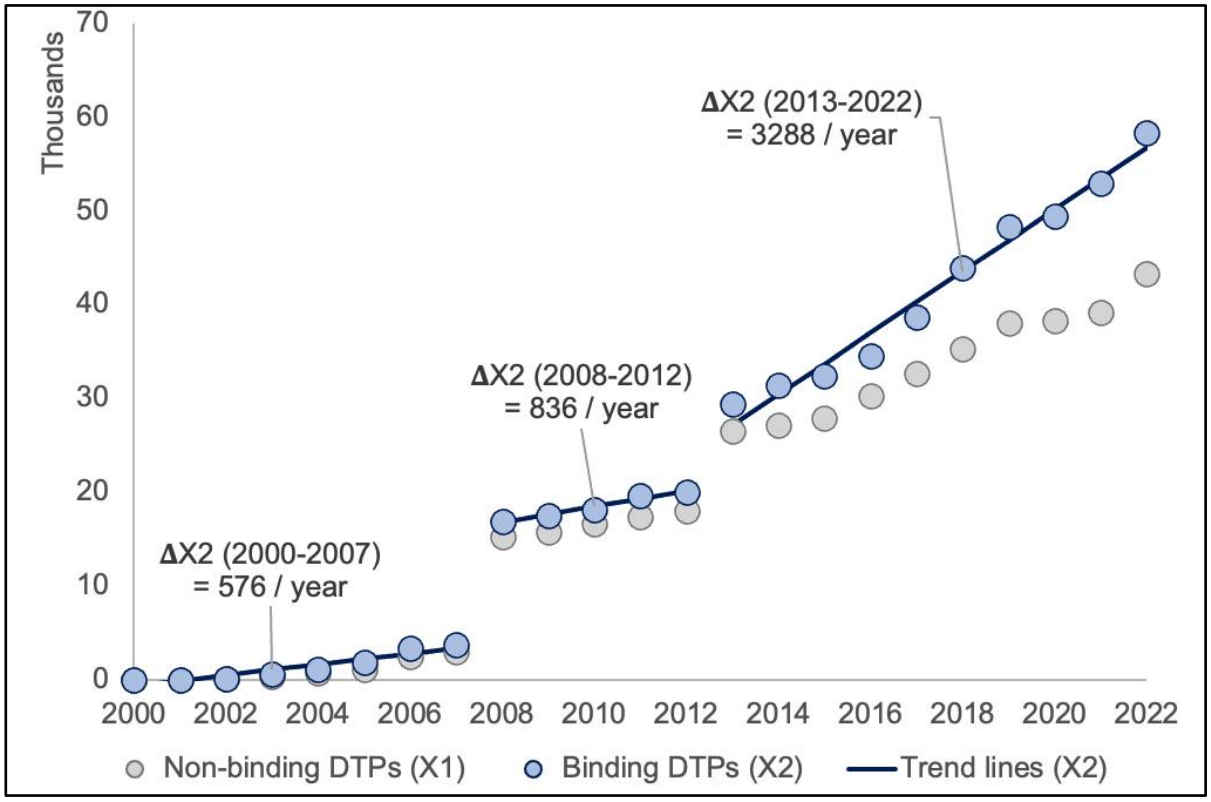
Digital Trade Provisions in International Trade Agreements

While the first record of a digital trade provision (DTPs) in an international trade agreement dates back to the Jordan-USA Preferential Trade Agreement (PTA) signed in 2000 (Nicolas Köhler-Suzuki, 2023), its adoption was relatively slow until the 2010s (Figure 4). Then, mirroring the rise in digital trade's prominence, the number of new DTPs rapidly accelerated. Indeed, since 2013, 3288 new binding DTPs have come into force every year, compared to just 836 in the period between 2008 to 2012.

In addition, digital trade provisions have also quickly expanded both in terms of scope and in terms of commitment. As Figure 4 highlights, the difference between the number of binding and non-binding DTPs has been ever-increasing since 2000. Evidence of this shift can be seen in recent PTAs such as the Comprehensive and Progressive Agreement for Trans-Pacific Partnership (CPTPP) or the United States-Mexico-Canada Agreement (USMCA), where the digital economy and trade have become centerpiece. Several digital trade agreements such as the Digital Economy Partnership Agreement (DEPA) or Australia-Singapore Digital Economy Agreement

have also emerged as comprehensive “digital-only” trade agreements. The comprehensiveness nature of DTPs has been observed in the texts of recent digital trade agreements. For instance, the USMCA trade agreement recognizes the importance of “frameworks that promote consumer confidence in digital trade and of avoid unnecessary barriers to its use and development”. The Australia-Singapore Digital Economy agreement compels parties to “recognize the need to create an environment that enables and supports, and is conducive to, experimentation and innovation”.

Figure 4: Growing trend of Digital Trade Provisions (DTPs) in Preferential Trade Agreements (PTAs), 2000-2022



Source: Authors based on TAPED (Burri, Callo-Müller and Kugler, 2022)
Note: In the figure ΔX2 denotes the slope of the trend line for each of the periods indicated. This can thus be understood as that period’s average yearly variation of binding provisions (X2).

While understanding the effects of digital trade provisions on the Sustainable Development Goals (SDGs) is still in its early stages, there is increasing research interest in exploring how specific policy areas related to digital trade intersect with various aspects of development. Generally, the findings from these studies have been

encouraging. For instance, UNESCAP (2021) research estimates that implementing cross border paperless trade — a provision in the Cross-border Paperless Trade Agreement (CPTA) — has contributed to a reduction in CO2 emissions of between 8.9 million and 23.4 million tons. Andrea Durkin (2017) suggests that trade facilitation agreements with measures such as electronic document processing and customs can reduce delays and mishandling of perishable goods and increase food safety and quality. Lastly, research by OECD (2021) and CITES (2022) highlight the use of trade facilitation measures like e-certifications in creating efficiencies in Sanitary and Phytosanitary (SPS) systems and e-permits to curb the illicit trade in endangered animal species. In this context, this paper aims to add to the existing literature by offering a wider-ranging empirical exercise that can understand the role of digital trade cooperation, regulatory readiness, and coherence – proxied by DTPs – in sustainable development.

To measure DTPs in PTAs, several databases provide timely updates on this rapidly evolving regulatory space. For instance, the St. Gallen Endowment for Prosperity through Trade's (SGEPT) Digital Policy Alert provides a "record of policy changes that affect cross-border digital commerce". Nemoto and Gonzalez (2021) created the OECD digital trade inventory to provide greater transparency and visibility to existing digital trade standards, while Burri, Callo-Müller and Kugler (2022) created the above-mentioned Trade Agreements Provisions on Electronic-commerce and Data (TAPED) database, providing a comprehensive dataset on provisions and articles affecting digital trade in trade agreements across five policy areas in preferential trade agreements. Similarly, UNESCAP in Semenova et al (2023) use a powerful text algorithm to comprehensively extract the appropriate provisions and articles based on specific key words. This database provides the flexibility to calculate customized datasets that can fit our panel data structure. For that , data from Semenova et al (2023) have been utilized in this paper.

The Sustainable Development Goals (SDG)

The SDG framework consists of 17 goals (Figure 5), spanning 4 areas of development – social, economic, environmental and partnerships. These goals have been translated into 169 targets and 241 indicators, for which data is regularly collected and made available via the UN-SDG portal. This data allows researchers and institutions to closely track SDG development across all areas of intervention globally.

Figure 5: The 17 Sustainable Development Goals (SDGs)

Source: Adapted from https://sdgs.un.org/goals

Linking the SDGs, digitalization, and digital trade

While digital trade has been the subject of immense research over the past decades, its connection with the SDGs is yet to be explored. Indeed, most of the existing research focuses more broadly on the impact of digitalization and digital technologies on the SDGs. Our understanding on the relationships between digital trade and digitalization will help us bridge this gap and build a rich backdrop to understand the potential influence paths of digital trade on the SDGs. Below we review the existing literature for each SDG area: economic, social, environmental, governance and global partnerships.

Economic SDGs (1, 2, 8 and 9)

Economic SDGs comprise of goals 1 (No Poverty), 2 (Zero Hunger), 8 (Decent Work and Economic Growth), and 9 (Industry, Innovation, and Infrastructure). Overall, digital technologies and digitalization are considered to promote economic SDGs. These are often linked with increased productivity, a shift towards higher value addition activities and an overall expansion of job opportunities. Moreover, economic goals are heavily influenced through many of the beneficial social, environmental, and institutional impacts that will be approached in further detail below. In contrast, the digital divide is identified as the main threat to digitalization's contribution to economic advancement.

In an environment where digital access is largely drawn among income lines, the benefits accruing from digitalization might be poorly distributed and accentuate existing inequalities. Below we deepen this discussion for each individual economic SDG.

As above-explored, digitalization has a promising role in promoting goals in a wide array of areas such as health, education, inequality, institutions, and the environment. Naturally, these are all key areas of intervention to successfully tackle structural poverty (SDG 1). As such, the literature reviewed throughout this section is as relevant for each individual target as it is herein.

Nevertheless, another avenue for poverty eradication is the promotion of decent work and economic growth (SDG 8). In this regard, several studies have shown a promising role for digitalization. Indeed, Baker and Le (forthcoming) found that a 1% increase in digital services trade value corresponds to a 3% rise in a country's GDP per capita. Kohnert (2020) and Lyon et al (2021) find that access to web-based platforms and e-commerce contribute to economic growth and poverty alleviation. In effect, digital platforms provide exposure to new entrepreneurship and job opportunities as well as easing access to a wider range of goods and services. Ernesto Lopez-Cordova (2020) also highlights that digital platforms reduce information asymmetries, which improves market functioning and reduces transaction costs. According to the author, this directly translates into lower costs of travel and higher demand for tourism services in countries where digital platforms exist.

International e-commerce and social media platforms are also a crucial part of any business strategy, allowing firms to connect with wider audiences. These can be particularly important for MSMEs in smaller developing economies as Chen et al (2019) investigate. For these businesses, the authors say, local growth opportunities are particularly scarce, making it vital to be able to reach oversea opportunities via digital platforms of goods and services. Likewise, during the COVID-19 pandemic, USAID et al. (2021) and As'ad et al. (2021) found that many MSMEs managed to survive by leveraging social media and e-commerce.

Digitalization is also an important tool to leverage an economy's industry, innovation, and infrastructure (SDG 9). Ezell and Koester (2023) state that cost effective and accessible digital services influence productivity and innovation. In fact, Hajishirzi (2022) insists that the impact of data on productivity and expansion is higher than traditional innovation.

Apart from the poverty alleviation and economic growth channels through which digitalization is contributing to end global hunger (SDG 2), the literature has also highlighted its potential role in revolutionizing agricultural supply chains. Indeed, digital

initiatives such as EarthOptics, Apollo Agriculture, Ulula, FoodLogiq, Algramo, and Buy-From-Women offer farmers support throughout the whole production process, promoting higher efficiency and sustainability (Bain & Co, 2023; UN Women, 2020). At early stages, these projects offer intelligence on the soil and the weather, along with credit and financing options, especially for small stakeholders. In later stages, interventions focus on promoting food traceability and efficiency, as well as in implementing smart packaging and waste management solutions. Jouanjean (2019) has also found evidence for digitalization's role in improving transparency, traceability, and data reliance in agri-food value chains, supporting these initiatives' work.

Notably, the positive impacts of digitalization examined in previous studies are ubiquitously reliant on a strong internet connectivity and ICT infrastructure. Indeed, as an ITU (2022) highlights, affordable access to devices and broadband internet, together with appropriate digital skills are required to navigate the digital landscape safely, as well as to recognize opportunities presented by digitalization.

Nevertheless, the ITU (2022) reports that 30% of the world population (i.e., 2.9 billion people) are not connected to the internet. Furthermore, many among the online population are not "connected meaningfully", owing to persistent gaps in digital skills and internet connections. Moreover, 1 in 3 people who can connect to the internet choose not to, due to lack of devices, skills and awareness of the benefits and opportunities. UNCTAD (2021) also found that many MSMEs, especially in developing countries, lacked proficiency to take advantage of e-commerce opportunities and fulfill growing online sales during the pandemic. This is mostly attributed to the lack of internal capabilities, high costs of adoption, poor infrastructure and lack of information affecting ICT adoption among MSMEs. The digital divide is thus a key issue to address in order to effectively reap the benefits of digitalization.

Social SDGs (3, 4, 5, 10)

Social SDGs comprise of goals 3 (Good Health and Well-Being), 4 (Quality Education), 5 (Gender Equality), and 10 (Reduced Inequality). In general, digitalization and digital technologies are largely recognized as engines for social development, widening access to health and education and promoting economic opportunities. Nevertheless, the literature also points towards the dangerous role of the growing digital divide, which – as with economic development – threatens to accentuate existing divergences. Below we deepen this discussion, reviewing each social SDG individually.

Several studies have linked higher digitalization levels with better healthcare outcomes (SDG 3). This relationship materializes both through digitalization's potential to

catalyze access to urgent and affordable care via “telemedicine”, as well as to improve diagnostic and treatment through access to better information and web-based tools.

Indeed, UNCTAD (2022) reports that access to healthcare increased with higher e-commerce and other digital tools usage. Zhang et al (2022) found that higher digitalization contributed to a reduced infant mortality rate and increase life expectancy. Moreover, several institutional initiatives have showcased digitalization’s potential in advancing health outcomes. The WHO launched “Be He@lthy, Be Mobile”, using messaging services to spread awareness about non-communicable diseases, while DYNAMIC is an AI based solution that provides healthcare workers in Tanzania with devices and clinical algorithms-based software – ever improving as more data becomes available – to support their medical decision making.

Notably, AI in healthcare needs diverse and exhaustive data. ITU (2021) highlights the lack of capacity to collect and store this data, especially in developing countries. This is a key obstacle to the broader adoption of healthcare technologies. Additionally, the report states that missing information about health among members of marginalized communities reduces accuracies of AI solution and increases inequality in access to healthcare.

Stronger educational outcomes (SDG 4) have also been linked with higher digital penetration. Indeed, Tay (2015) and UNCTAD (2022) provide evidence that digital tools and internet platforms like online universities and MOOC (Massive Open Online Course) services have a strong positive impact on access to education. For instance, international certifications from platforms like Edx, Coursera or university websites are widely recognized and available, providing students with a flexible learning environment and education at a lower cost.

However, ITU (2022) highlights that the share of internet users is higher in high income countries, urban areas, among younger and educated people. Specifically, Chamberlin and Parish (2011) show that this disparity in digital access translates to unequal opportunities in access to online education across all demographic groups. In fact, Christensen et al (2013) and Emanuel (2013) confirm that individuals who engage in MOOCs often share specific traits, such as being well educated and young.

On the other hand, ITU (2022) and Chu and Li (2022) demonstrate that considerable amounts of time spend online by students and youth, impacts their health and wellbeing due to lack of physical activity and increase in stress.

Mixed evidence regarding digitalization’s role in promoting gender equality (SDG 5) has emerged. On the one hand, Sorgner et al (2017) have found that digitalization can lower entry barriers for female participation in the work force – either via regular

employment or self-employment – and thus become an engine for financial independence.

Additionally, several studies have highlighted a persistent digital gender divide that threatens to heighten existing inequalities. Indeed, the ITU (2022) found that only 57% of women, compared to 62% of men, use the internet. Zhou (2014) showcased that women exhibit comparatively lower performance and interest in ICT-related skills compared to men. As the OECD (2018) highlights, this can result in displacement in the workforce, unless appropriate adult ICT upskilling is undertaken. The same report also warns against online security and privacy threats, which are especially relevant for women. Indeed, studies by EIGE (2017) and Pew Research Center (2014) state that one in ten women from the age of 15 have experienced cyber harassment and are more likely to experience online sexual harassment than men.

Lastly, higher digital trade and digitalization have been mostly linked with reducing inequality (SDG 10). In particular, Graham et al (2017) highlight the role of digital platforms like Uber and Grab (ridesharing and delivery services) or Fiverr and Upwork (freelance services) in granting individuals' access to more distant, lucrative, or otherwise unavailable markets in the gig-economy. However, studies by Stanford (2017), Rani and Furrer (2020) and Kaine and Josserand (2019) have also highlighted the labor market challenges associated with the digital gig-economy. In most countries, these platforms usually offer ambiguous self-employment service agreements that leave workers without social and labor protections, such as a set minimum wage, paid holiday and sick leave, or the ability to collectively bargain for better working conditions.

Another important channel for inequality alleviation lies on individual remittance flows, which are extremely important for developing countries that rely on earnings from abroad. Notably, a World Bank (2021) report uses the remittance prices worldwide database to demonstrate that average cost of sending and receiving cross border remittances is lowest through mobile money (i.e., digital wallets and payment platforms).

Environmental SDGs (6, 7, 11, 12, 13, 14, 15)

Environmental SDGs comprise of goals 6 (Clean Water and Sanitation), 7 (Affordable Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action), 14 (Life Below Water), and 15 (Life on Land). Overall, the literature points towards the facilitating role of digital technologies in transitioning towards carbon neutrality and sustainable modes of living. However, heavy energy consumption, e-waste and the

use of non-renewable commodities are among the key drawbacks to be considered. Below we deepen the discussion for each individual environmental SDG.

Digital technologies have been at the heart of improving resource management. In particular, Jozefowicz & Michniewicz-Ankiersztajn (2023) demonstrate that the use of digital web-based applications, social media, and IoT reduced water wastage through better user awareness and sewage management (SDG 6). Likewise, Tompos (2020) reports that web platforms, smart grids, AI and blockchain enable more energy trading, promoting efficiency in commercial energy usage (SDG 7). Similarly, a World Bank report (2022) indicates that Energy as a service (EaaS) and smart water management are effective at promoting sustainable consumption of both resources.

In its comprehensive report on Enhancing the Contribution of Digitalization to Smart Cities of The Future (2019), the OECD exhaustively explores the role of digital tools in building sustainable and resilient communities (SDG 11). The report highlights that transformative technologies tackling existing issues on everything from health, education, mobility and security to the government and the environment are rapidly emerging around the world. While the authors identify potential privacy concerns and consumer protection risks to be aware of in highly digitized cities, it sees digitalization has a key factor in achieving SDG 11.

When it comes to responsible consumption and production (SDG 12), Chauhan et al (2022) propose that circular economy goes hand in hand with digitalization. Indeed, IoT sensors and other technologies provide data for predictive analysis for efficient resource utilization. Furthermore, Wilts et al (2021) shows that using robots with AI in municipal waste management to automate waste sorting improves recycling rates.

Regarding SDG 13, digitalization in trade potentially minimizes the environmental footprint associated with conventional trade. Fu et al (2022) study that increase in trade in digital deliverables services lowers carbon emissions. The authors also highlight how the fintech sector uses climate data to allocate credit to projects targeted towards reducing carbon emissions. Lazarevi et al (2020) confirm that providing nighttime deliveries for e-commerce platforms dramatically reduces fuel consumption and CO2 emissions. Duval and Hardy (2021), UNESCAP-UNCTAD-UNEP (2021) find that promoting paperless trade – i.e., using e-contracts, digital records, and electronic document transfers – is a tangible way of reducing trade's environmental footprint.

Finally, environment and climate monitoring systems using satellite imagery, big data analytics and AI have provided key tools to identify and reduce the depletion of natural resources and wildlife both below water (SDG 14) and in land (SDG 15). For instance, WWF (2022) reports that earth observation is used to track wildlife migration and human-wildlife conflict/interaction. In addition, it can distinguish where human

interference should be limited. The report also states that eCDT (electronic catch, documentation, and traceability) systems use digital tools and services to ensure legal fishing and ultimately, prevent depletion of the oceans via overfishing.

In contrast, some evidence regarding digitalization's potentially harmful impacts to environmental SDGs has also emerged. On the one hand, the production and consumption of ICT goods is characterized for being especially damaging in terms global greenhouse gases (GHG) emissions. In fact, Freitag et al (2022) suggest that a sizable 2.1%-3.9% of total GHG emissions can be attributed to the production and consumption of ICT products directly. This is both due to the large amount of energy it consumes and to the specific materials necessary for its production. Interestingly, Vries et al (2022) provide evidence that bitcoin mining alone is responsible for an annual footprint of 65.4 megatons of CO2. Furthermore, as the global E-waste monitor report (2020) highlights, ICT products generate a considerable amount of e-waste. Current estimates put this figure at 53.6 million tons of e-waste produced annually with as much as 83% of it currently not being recycled. Finally, e-commerce logistics have a notable carbon footprint on the environment. For instance, Muñoz-Villamizar et al (2021) warn that parcel trade requires packaging and transportation that contribute to harmful emissions and the consumption of non-recyclable materials.

Governance and Global Partnerships (SDG 16, 17)

Global Governance and Partnerships SDGs comprise of goals 16 (Peace, Justice, and Strong Institutions) and 17 (Partnerships for the Goals). The impact of digitalization and digital technologies on these SDGs is largely thought to be ambivalent. On the one hand, digital technologies have brought governments closer to the public, widening access and efficiency. Multilateral engagement has also been fostered as digital economy issues require international coordination. On the other hand, cyber security issues have raised significant challenges for institutions. The rapid spread and weaponization of misinformation are among the leading challenges. Below we deepen this discussion for each individual governance and global partnerships SDG.

The potential impact of higher internet penetration and digitalization on the strength of government and institutions (SDG 16) remains unclear. On the one hand, the use of digital tools allows government to implement e-governance and e-government solutions that can raise accountability and inexpensively democratize access to many institutional services. In fact, Ouedraogo and Sy (2022) have seen that digital adoption is positively correlated with a reduction of corruption, increase in tax compliance and a significantly increase in trust in government officials.

On the other hand, the rise of social media platforms has accelerated the spread of disinformation with potentially far reaching political and social consequences (ITU, 2022). In fact, Amorin et al (2022) have identified that for each new internet service provider that becomes available in a location – a proxy for broadband penetration – the probability of protests occurring is 1-3 percentage points higher. Moreover, as Reuters (2021) has reported, blocking internet access has increasingly become a tool to suppress social unrest and curb freedom of speech and association.

Lastly, booming digital trade and digitalization have been an effective engine in promoting international engagement for stronger partnership for the goals (SDG 17). Indeed, there is widespread evidence of trade facilitation initiatives relying on the digitalization of customs procedures and regulations. For instance, the UN's ASYCUDA or the 'E-bill of lading' smoothen trade flows and reduce cross-border costs. In Thailand, CustomsConnect allows traders to pay customs duties and related fees online. In Rotterdam, smart infrastructure automatically determines if a ship is allowed to enter the port, while in Australia robots and AI automate boat to quay operations – increasing handling capacity. Initiatives like eTrade alliance and Nextrade support private public partnerships to promote digital trade and allow small businesses in developing nations to access global e-commerce. Notably, these initiatives encourage LDCs and DCs involvement in global trade. Furthermore, Wirjo & Calizo Jr (2022) report that e-payment solutions, blockchain enabled platforms coupled with technologies like AI and sensors ensure better business connectivity and resilience. Overall, the authors point to these technologies'' role in strengthening cross border connections, enhance data eco-systems and reduce corruption and sabotage.

Additionally, the rise in digital trade has played a significant role in reviving international engagement over international regulations that can fairly and safely process this type of trade. The OECD (2018) indicates that in recent years, the number of RTAs including specific provisions on digital trade have sharply increased. The scope of these provisions is diverse covering data security, taxation, privacy, and promotion of paperless trade.

3. Empirical Approach

To understand the intricate relationship between digital trade and the Sustainable Development Goals (SDGs), a series of country fixed-effects regression models were built. In these models several digital trade variables (DTVs), digital provision variables (DPVs) and controls were interacted with 32 SDGs targets, spreading across the 17 SDGs and grouped in 4 clusters: Economic (SDGs 1, 2, 8 and 9), Environmental (SDGs 6, 7, 12, 13, 14, 15), Social (SDGs 3, 4, 5, 10) and Governance and Global Partnership (SDGs 11, 16, 17).All data spanned from 2010 to 2021.

Digital Trade Variables (DTVs) and Digital Provision Variables (DPVs)

In this paper, digitally deliverable services data – as identified in IMF-UNCTAD-OECD-WTO (2023) – was retrieved from the OECD-WTO Balanced Trade in Services Statistics (BATIS) database and further aggregated across pairs and sectors to fit our country-year panel data structure.

In addition to the Digital Trade variable — Log(DT) — which was log transformed for ease of interpretation and for data smoothing purposes, a Digital Trade per capita variable — Log(DT.pc) — (also log transformed) was built. This variable allowed us to gain a deeper understanding on how digital trade concentration – as opposed to simply its overall level – might impact SDGs differently.

Finally, to assess the role of Digital Trade Provisions (DTPs) on SDG targets development, we extracted data from UNESCAP's Regional Trade Agreement (RTA) text analyzer 1.0 (see Semenova et. al, 2023) to build DT.CH, denoting the number of chapters in trade agreements containing digital provisions.

It was verified that the Digital Trade Variable (DTV) coefficients remained stable – and largely unchanged – across models with and without the DPV. This means that while digital trade provisions might have an impact in the level of digital trade itself, the studied specifications successfully isolate the impacts of digital provisions per se on SDGs developments. Descriptive statistics and performed transformations for each of the DTVs and DTPs used can be found in Annex 1.

Sustainable Development Goals

As previously explained, the Sustainable Development Goals (1-17) are composed of concrete targets, which are, in turn, measured via specific indicators. As such, the existing 17 SDGs have been translated into 169 targets and 241 indicators, for which data is regularly collected and made available by the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs) via the UN-STATS portal.

Drawing from our extensive literature review and guided by varying data availability, a sub-set of 32 indicators, spread across the 17 SDGs, were selected to be regressed in our models. Several aspects were considered to arrive at the final sub-set of 32 indicators, where an iterative process aimed, when possible, for at least one significant relationship between a goal and digital trade. After several trial regressions, 18 indicators across 13 SDGs (all except SDGs 2, 11, 14, and 16) yielded statistically significant results.

Owing to diversity of final indicators, final SDG data was treated on a case-by-case approach, with several indicators being treated for outliers and extreme outliers. Log transformations were also applied whenever deemed beneficial. The complete list of 17 SDGs, 169 targets and 241 indicators can be found at the UN-STATS Portal. The list of 32 indicators specifically chosen and their respective descriptive statistics and performed transformations can be found in Annex 1.

Control variables

Two control variables — Log(GDP) and Int.%, corresponding to log of GDP and the percentage of households with internet access in a country — were employed. These variables have been identified as major drivers of SDG development (Zhang et al, 2022; Fu et al, 2022; Khera et al 2022). On the one hand, controlling for GDP allows us to consider how the level of economic advancement and resource availability might be concomitantly correlated with both digital trade and SDGs development. On the other hand, internet penetration – a pre-requisite for participating in digital trade – controls for the intrinsic benefits of enjoying higher digitalization levels, irrespective of the level of digital trade. These variables were applied to all models run. Descriptive statistics and performed transformations for each of the control variables used can be found in Annex 1.

The regression model

Borrowing from Zhang et al (2022) and Fu et al (2022), we developed a series of regression models interacting several digital trade variables (DTVs), digital provision variables (DPVs) and controls with the 32 SDGs targets selected. Our models leverage country-year panel data from 2010 to 2021 characterized by a fair number of observations and variability (Annex 1), thereby promoting the derivation of robust estimations (Baltagi, 2008).

To enhance the precision of our estimates and identify the variation of interest, we used a country Fixed Effects strategy. This is especially important owing to the impact that unobservable country-specific time-invariant characteristics like institutional strength, historical developments, geographic location, or cultural and social norms have on the SDGs (Greene, 2017). Finally, we adopted the Ordinary Least Squares (OLS) inference method to compute our regression coefficients.

Thus, our basic model can be described as follows:

$$SDG_i^y = \beta_0 + \beta_1 DTV_i^y + \beta_2 DPV_i^y + \beta' A'^y_i + \beta'' FE'_i + \varepsilon_i^y \qquad (1-2)$$

Where DTV_i^y represents the set of digital trade variables $\{Log(DT)_i^y; Log(DT.pc)_i^y\}$ used alternatingly in equations (1) and (2), DPV_i^y represents the digital trade provision variable $DT.CH_i^y$, A'^y_i represents the vector of controls $[Log(GDP)_i^y, Int.\%_i^y]$and β' the corresponding vector of coefficients. FE'_i represents the vector of country fixed effect dummies and β'' the corresponding vector of coefficients. The superscript y stands for 'year', while the subscript i stands for 'individual economy'. Together, these denote the country-year panel data structure present across all our models.

Furthermore, to better understand how digital trade might impact SDGs differently across different levels of digitalization, an additional model interacting each DTV with the internet penetration variable (Int %) was run. This model can be described as:

$$SDG_i^y = \beta_0 + \beta_1 DTV_i^y + \beta_2 DPV_i^y + \beta_3 Int.\%_i^y * DTV_i^y + \beta' A'^y_i + \beta'' FE'_i + \varepsilon_i^y \quad (3-4)$$

Where $Int.\%_i^y * DTV_i^y$ corresponds to the interacted variable. Similarly, to equations (1-2), equations (3-4) pertain to regressions alternatingly through the DTV_i^y set.

The results of this exploratory study, complemented with the knowledge gathered throughout the whole exercise, are summarized in the next section.

Limitations

A main limitation of the models above is the absence of target-specific regression specifications, which were not built owing to paper's wide SDG scope. Naturally, as each SDG target interacts with digital trade and other variables via differing channels, individual specifications – e.g., with target-curated control variables – should be employed to account for this heterogeneity. This would help limit the potential impacts of an omitted variable bias and thus better isolate the impact of the explanatory variable. We strongly encourage future research can build on it to further investigate each relationship of interest.

Another limitation of the current model is the understanding that a two-way interaction between the dependent and independent variables is likely. Naturally, as digital trade influences SDGs improvement, higher SDGs can also entice higher digital trade, as countries become more involved in high-value addition activities related with technology. While the selection – and exclusion – of specific indicators in this paper aimed to limit the potential hindering impact of such interaction, an instrumental variable approach could be a powerful strategy to further strengthen the model. We encourage this exploration for future research.

4. Results

Among all areas of intervention, Social targets – covering SDGs 3 (Good Health and Well-Being), 4 (Quality Education), 5 (Gender Equality), and 10 (Reduced Inequality) –, recorded the most consistently positive results, with all 6 targets measured revealing a positive linkage with digital trade.

Moreover, encouraging results on the role of digital trade on development in several Environmental SDGs was observed. In particular, SDGs 6 (Clean Water and Sanitation), 7 (Affordable Clean Energy), 12 (Responsible Consumption and Production), 13 (Climate Action) – for developing economies –, and 15 (Life on Land) reacted positively to increasing digital trade. However, a negative connection with SDG 13 (Climate Action) – for developed economies – and no connection with SDGs 11 (Sustainable Cities and Communities) and 14 (Life Below Water) were also found.

Some evidence was found regarding digital trade's enhancing role on policy-driven Governance and Partnership SDGs, such as SDG 17 (Partnerships for the Goals). Yet no linkage emerged with SDG 16 (Peace, Justice, and Strong Institutions).

Strong linkages between digital trade and improvements in Economic SDGs such as 8 (Decent Work and Economic Growth) and 9 (Industry, Innovation, and Infrastructure) could be observed. However, a negative influence on 1 (No Poverty) and no significant relationship on 2 (Zero Hunger) were also found.

Finally, digital trade provisions were seen to almost always be associated with an improvement in SDG progress across all areas of development.

Social SDGs (3, 4, 5, 10)

Higher overall digital trade was found to be linked with an average improvement in health and well-being (SDG 3). In particular, a 1% increase in Digital Trade was associated with a 0.01pp average decline in the mortality rate from various diseases (Table 1 and Figure 6).

These results are in line with Zhang et al (2022), who presented evidence that an increase in digitally delivered healthcare services reduced mortality rate and increased life expectancy in China. Moreover, it supports the many ongoing digital health initiatives aimed at widening healthcare access and improving health outcomes with digital technologies (WHO, 2021a). As such, trade in digital services, digital enablers, and transformative technologies are thought to be the most promising promoters of health and well-being outcomes.

Nevertheless, this positive impact could only be verified for countries with moderately high levels of internet penetration (at least above 32%), as is, for instance, the case of China explored in Zhang et al (2022). Naturally, shifting healthcare services' provision from modes 2, 3, 4 (physically delivered) to mode 1 (virtually delivered) relies on a strong widespread ICT infrastructure. In addition, this impact was found to be continuously enhanced as internet penetration grows: the more digitized an economy is, the more technologies can be seamlessly integrated, and synergies harnessed (Figure 6). Thus, fostering digital trade can also boost healthcare outcomes by paving the way for a better connectivity infrastructure. This insight is also supported by the positive (i.e., lower mortality rate) influence that internet penetration alone has been found to have.

A robust relationship between higher digital trade and better education outcomes (SDG 4) was also identified. Indeed, a 1% increase in digital trade is associated with an average 1.15pp increase in the participation rate in both formal and non-formal education. As with healthcare, educational outcomes improve substantially due to wider access to educational tools. More specifically, higher digital trade facilitates the

rise of e-education, online training, and MOOCs (Massive Open Online Courses) – digitally ordered and delivered services –, which evidence indicates can reduces costs by as much as 32% (Gibbons and Fairweather, 2000).

Table 1: Impact of digital trade variables on social targets: regression coefficients across models

Variables	3- Mortality rate (from disease)	4 - Participation rate in education	4 - Participation rate in organised learning	5- % women in managerial positions	10 - Return on assets	10 - Remittance costs
Digital Trade Coefficients - Simple Models (1 & 2)						
(1) Log(DT)	-0.01**	1.15*		2.06***		-1.28*
(2) Log(DT.PC)				1.63***	0.22*	
Digital Trade Coefficients - Interaction Models (3 & 4)						
(3) Log(DT) (3) Int % : Log(DT.PC)						
(4) Log(DT.PC)	0.01***		1.28***			
(4) Int % : Log(DT.PC)	-0.0002		-0.03***			
Policy Variable Coefficients - All Models (1 - 4)						
(1-4) DT.CH	Negative			Positive	Positive	Negative
Control Variables Coefficients - All Models (1 - 4)						
(1-4) Log(GDP)	Negative		Positive	Negative		
(1-4) Int %	Negative	Positive	Negative	Positive		

Source: Authors.

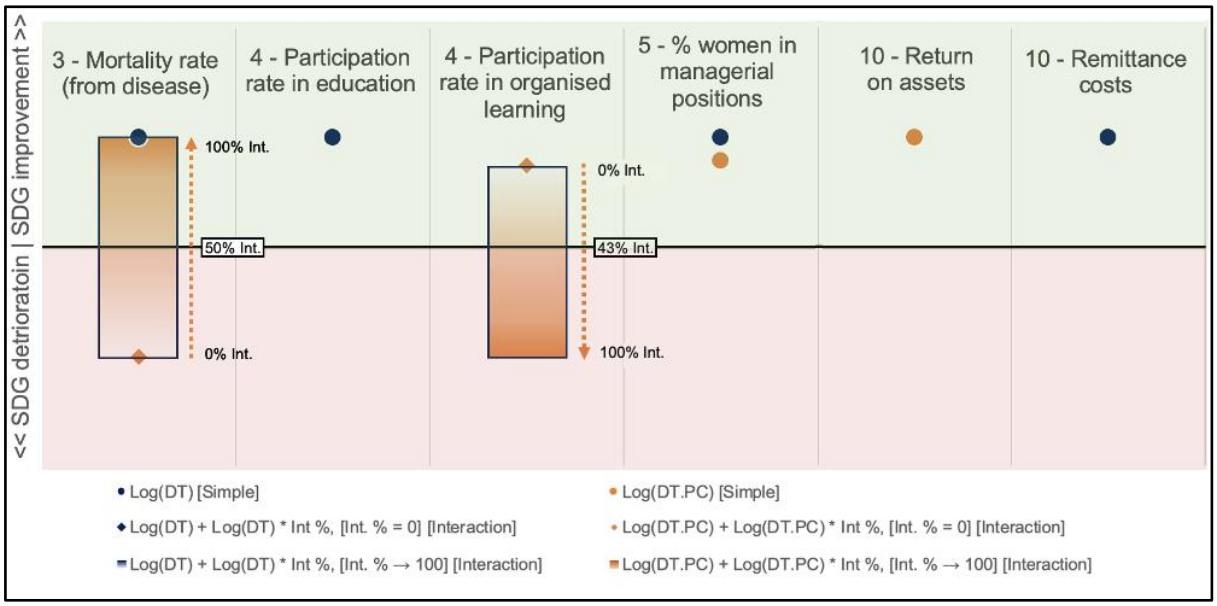
Notes: Values shaded in Green denote that the coefficients sign is consistent with our ex-ante expectation. Values shaded in Red denote that the coefficients sign is inconsistent with our ex-ante expectation. Missing shading for cells with specific values denote that no ex-ante sign expectation was defined. Blank cells denote no significant coefficient.

Yet, while overall impact of digital trade per capita was found to be positive – contributing to a 1.28pp increase in the participation in organized learning – this effect seems to be diminishing as internet penetration deepens, subsiding for moderate internet penetration levels (above 43%). This insight is in line with several studies that have pointed out the potential role of e-learning in exacerbating existing educational disparities in already well digitalized environments. This is mostly since remaining disadvantaged groups have significantly more difficulties in getting all the necessary equipment to connect and benefit from e-learning (Coleman, 2021; Schulz and Robinson, 2022). Hence, digital trade policy should be accompanied with an effective accessibility policy that can guarantee enough resources for disadvantaged groups to be able to connect.

Higher digital trade also seems to be positively contributing towards reducing inequalities. For instance, the percentage of women in managerial positions, a target of SDG 5, was associated with a 2.06pp and 1.63pp increase for every 1% rise in the level of digital trade and digital trade per capita, respectively. Apart from increased female participation in the work force via online and remote jobs, as well as stronger economic growth, welcoming trade in digitally delivered and ordered services like

social media and mobile platforms tends to expedite social awareness and corporate accountability towards social inclusion. Furthermore, digital trade can also help empower minorities through promoting financial inclusion and efficiency, for instance via cross-border online money transfers which directly reduce remittance cost. Indeed, we found that targets of SDG 10, the return on assets and remittance costs were both 0.22pp higher and 1.28pp lower for every percent rise in digital trade per capita and digital trade level, respectively.

Figure 6: Standardized impact of digital trade variables on social targets: standardized regression coefficients across models



Source: Authors.

Notes: The graph presents normalized coefficients for each digital trade variable – Digital trade (DT), Digital trade per capita (DT.PC) – across two model specifications – a simple model (no interacted variables) [Simple] and an interaction model [Interaction]. For [Interaction] models, a diamond represents the direct digital trade variable coefficient (i.e., Int % = 0); gradient bars represent the total (from both the direct and interacted coefficients) average digital trade impact for each level of internet penetration between 0 and 100%. On the X-axis next to crossing

Environmental SDGs (6, 7, 11, 12, 13, 15)

A positive and consistent association between higher digital trade and better resource management was observed. Water use efficiency, a target of SDG 6, was seen to rise by 1.57 US$/cubic meter of water with every percent increase in the level of digital trade (Table 2). The tonnage of municipal waste recycled, a target of SDG 12, increased by 2.18T for every percent increase in both digital trade and digital trade per capita. However, this impact saw diminishing returns with increasing internet

penetration. In fact, at very high levels of internet penetration (upward of 73%) this positive impact subsided (Figure 7).

The share of renewable energy, a target of SDG 7, and the total metric tonnage of CO2 emitted by non-developed countries, a target of SDG 13, also recorded positive associations with digital trade. Indeed, for internet penetration levels above 22% digital trade per capita is associated with a higher share of renewable emissions. This impact rises steeply with higher internet penetration, peaking at 1.56pp increase in the share of renewables for every percent increase in digital trade per capita. Similarly, digital trade per capita was only found to contribute to fewer carbon emissions in developing economies from moderate internet penetration levels and above (43%), with impacts ranging from an additional +0.13 to -0.17 fewer metric tons of CO2 per 1% increase in the level of digital trade per capita. Contrastingly, a negative connection between digital trade and carbon emissions in developed economies was found. This relationship likely translates the outsized role that developed economies have in global CO2 emissions, paired with the fact that higher digital trade is also associated with higher industrial activity.

Table 2: Impact of digital trade variables on environmental targets: Regression coefficients across models

Variables	6 - Water Use Efficiency	7 - % of renewable energy	12 - Municipal waste recycled	13- Greenhouse gas emissions for developed countries	13- Greenhouse gas emissions for non-developed countries	15- Legally established protected forest area
Digital Trade Coefficients - Simple Models (1 & 2)						
(1) Log(DT)	1.57**			0.1**		0.46*
(2) Log(DT.PC)				0.12***		0.47*
Digital Trade Coefficients - Interaction Models (3 & 4)						
(3) Log(DT)			2.18***			
(3) Int % : Log(DT.PC)			-0.03***			
(4) Log(DT.PC)		-0.44***	2.15***		0.13**	0.61**
(4) Int % : Log(DT.PC)		0.02***	-0.03***		-0.003	-0.005
Policy Variable Coefficients - All Models (1 - 4)						
(1-4) DT.CH	Positive	Positive	Positive	Negative		Positive
Control Variables Coefficients - All Models (1 - 4)						
(1-4) Log(GDP)	Positive	Negative	Negative		Positive	
(1-4) Int %		Positive	Unclear		Negative	Positive

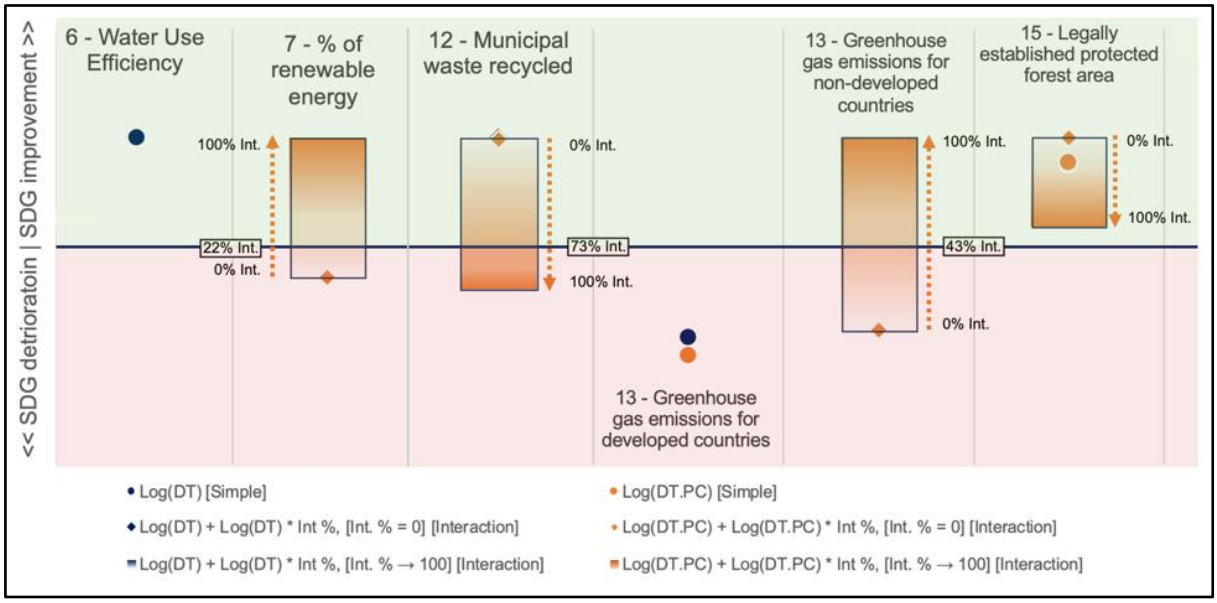
Source: Authors.

Notes: Values shaded in Green denote that the coefficients sign is consistent with our *ex-ante* expectation. Values shaded in Red denote that the coefficients sign is inconsistent with our *ex-ante* expectation. Missing shading for cells with specific values denote that no *ex-ante* sign expectation was defined. Blank cells denote no significant coefficient.

The share of legally established protected forest area, a target of SDG 15, saw a consistently positive, but slightly diminishing, association with digital trade. Indeed, higher levels of both digital trade and digital trade per capita were seen to contribute to an average increase of 0.46pp and 0.47pp in this target, respectively. Yet, considering digital trade per capita's impact across internet penetration levels, it is

possible to identify this impact can be as high as 0.61 (for 0% internet penetration) or as low as 0.11 (for 100% internet penetration).

Figure 7: Standardized impact of digital trade variables on environmental targets: Standardized regression coefficients across models



Source: Authors.

Notes: The graph presents normalized coefficients for each digital trade variable – Digital trade (DT), Digital trade per capita (DT.PC) – across two model specifications – a simple model (no interacted variables) [Simple] and an interaction model [Interaction]. For [Interaction] models, a diamond represents the direct digital trade variable coefficient (i.e., Int % = 0); gradient bars represent the total (from both the direct and interacted coefficients) average digital trade impact for each level of internet penetration between 0 and 100%. On the X-axis next to crossing gradient bars, the precise internet penetration level at which the total average digital trade impact switches sign is displayed.

Digital trade's encouraging association with environmental goals can be understood through its role in facilitating the implementation of Transformative Technologies, such as in IOT, Big Data, Robotics, among others, that can be particularly productive in tackling environmental challenges. Indeed, initiatives like PlantSight or SIWA (working on efficient water and waste management), CoolCrop in India (supporting efficient crop cold storage efforts), DBS's solutions (for tracking products' provenance), or the many projects monitoring everything from flood risks to agricultural yields (WaPOR), overfishing, wildlife migration or the supply of renewable energies, all rely on complex digital products and infrastructure to which energetic digital trade is fundamental (Wilts et al, 2021; Leslie & Lugo-Mulligan, 2021; Jozefowicz & Michniewicz-Ankiersztajn, 2023). Exceptions to these positive impacts are SDGs 11 (Sustainable cities and communities) and 14 (Life Below Water) for which no significant relationship was found.

Global Governance and Partnerships (SDG 16, 17)

No evidence on the impact of Digital Trade on SDG 16 (Peace, Justice, and Strong Institutions) could be observed. Naturally, as a policy driven SDGs, the impact of digital trade can be limited in these areas and result in insignificant or inconsistent relationships.

Nevertheless, convincing statistical evidence pertaining to a positive and consistent linkage between higher digital trade and an improvement in SDG 17 (Partnership for the goals) targets was found. Indeed, higher digital trade (both in total and per capita) was seen to consistently increase a country's share of services trade with Developing Countries (DCs) and Least Developed Countries (LDCs) by 0.05pp (Table 3). This impact only grew stronger as internet penetration rose, increasing at a rate of 0.0003pp per percentage point increase in internet penetration (Figure 8).

Higher digital trade in DCs and LDCs directly, via e-commerce websites, blockchain, on-line database services etc., or indirectly, via enabling digital products, encourage these countries to participate in trade facilitation initiatives and international trade agreements. Initiatives like the UN's ASYCUDA, Thailand's Customs Connect or US-AID's Nextrade, alongside with the many ongoing regional digital trade-related initiatives and launched e-government solutions are signs of increased prominence of DCs and LDCs engaging in multilateral partnerships and global governance programs.

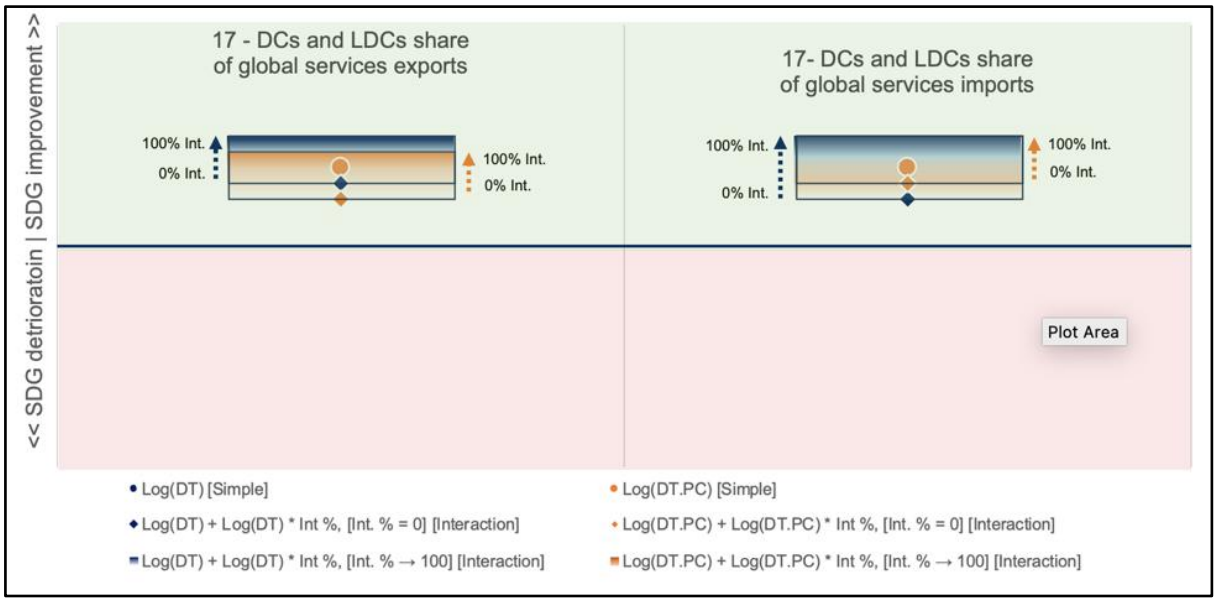
Table 3: Impact of digital trade variables on governance and global partnership targets: Regression coefficients across models

Variables	17 - DC and LDCs share of global services exports	17-DC and LDCs share of global services imports
Digital Trade Coefficients - Simple Models (1 & 2)		
(1) Log(DT)	0.05***	0.05***
(2) Log(DT.PC)	0.05***	0.05***
Digital Trade Coefficients - Interaction Models (3 & 4)		
(3) Log(DT)	0.04***	0.03*
(3) Int % : Log(DT.PC)	0.0002**	0.0004***
(4) Log(DT.PC)	0.03***	0.04**
(4) Int % : Log(DT.PC)	0.0004***	0.0003*
Policy Variable Coefficients - All Models (1 - 4)		
(1-4) DT.CH		Positive
Control Variables Coefficients - All Models (1 - 4)		
(1-4) Log(GDP)	Positive	Positive
(1-4) Int %	Negative	Negative

Source: Authors.

Notes: Values shaded in Green denote that the coefficients sign is consistent with our ex-ante expectation. Values shaded in Red denote that the coefficients sign is inconsistent with our ex-ante expectation. Missing shading for cells with specific values denotes that no ex-ante sign expectation was defined. Blank cells denote no significant coefficient.

Figure 8: Standardized impact of digital trade variables on governance and global partnership targets: Standardized regression coefficients across models



Source: Authors.

Notes: The graph presents normalized coefficients for each digital trade variable – Digital trade (DT), Digital trade per capita (DT.PC) – across two model specifications – a simple model (no interacted variables) [Simple] and an interaction model [Interaction]. For [Interaction] models, a diamond represents the direct digital trade variable coefficient (i.e., Int % = 0); gradient bars represent the total (from both the direct and interacted coefficients) average digital trade impact for each level of internet penetration between 0 and 100%. On the X-axis next to crossing gradient bars, the precise internet penetration level at which the total average digital trade impact switches sign is displayed.

Economic SDGs (1, 2, 8 and 9)

Digital trade's influence on economic SDGs has produced mixed evidence. While strong linkages between digital trade and improvements in SDG 8 and 9 could be observed, a negative influence on SDG 1 and no significant relationship with SDG 2 were also found.

Indeed, on the one hand, a country's GDP growth rate per capita – a target of SDG 8 – was found to increase on average by 0.36pp for every percent increase in the level of digital trade per capita or 0.8pp for every percent increase in the level of digital trade (Table 4). This is consistent with the understanding that digital trade channels are becoming a primary conduit of trade, serving as a significant engine for economic growth. Specifically, digital platforms enable firms to broaden both their source and destination markets, stimulating job creation, enhancing productivity, and contributing to poverty alleviation through the various channels already discussed. Nevertheless,

this positive impact was verified to be strongest for lower levels of internet penetration, subsiding for very high penetration levels (above 70-80%) (Figure 7). This finding highlights digital trade's especially transformative impact in transitioning economies, where initial rises in internet penetration can greatly enhance the benefits of digital trade.

On the other hand, the two targets under SDG 1 (No Poverty) revealed a negative relationship with digital trade. A percent increase in digital trade and digital trade per capita was associated with declines of 0.49pp and 0.35pp, respectively, in the share of the population with access to basic sanitation. Additionally, the share of the population above the international poverty line declined by 1.67pp and 2.29pp for the same variables, respectively. A possible explanation for these results is tied with digital trade's potential relationship with increased job displacement, especially in economically vulnerable demographics. Indeed, as economies transition towards more complex and productive activities, as explored just above, unskilled workers in labor-intensive sectors tend to be replaced (ILO, 2016; UNIDO, 2020; Fan et al., 2018). Since exposed demographics are already the most economically vulnerable – and are most prominent in low-income countries –, a situation of job displacement can quickly lead to poverty and worse sanitation conditions. Accordingly, while digital trade is seen as a positive engine for economic growth at the aggregate level, it might also contribute to worsen economic security among the most vulnerable, as digitally excluded groups face the challenges related to a changing economic landscape.

Table 4: Impact of digital trade variables on economic targets: Regression coefficients across models

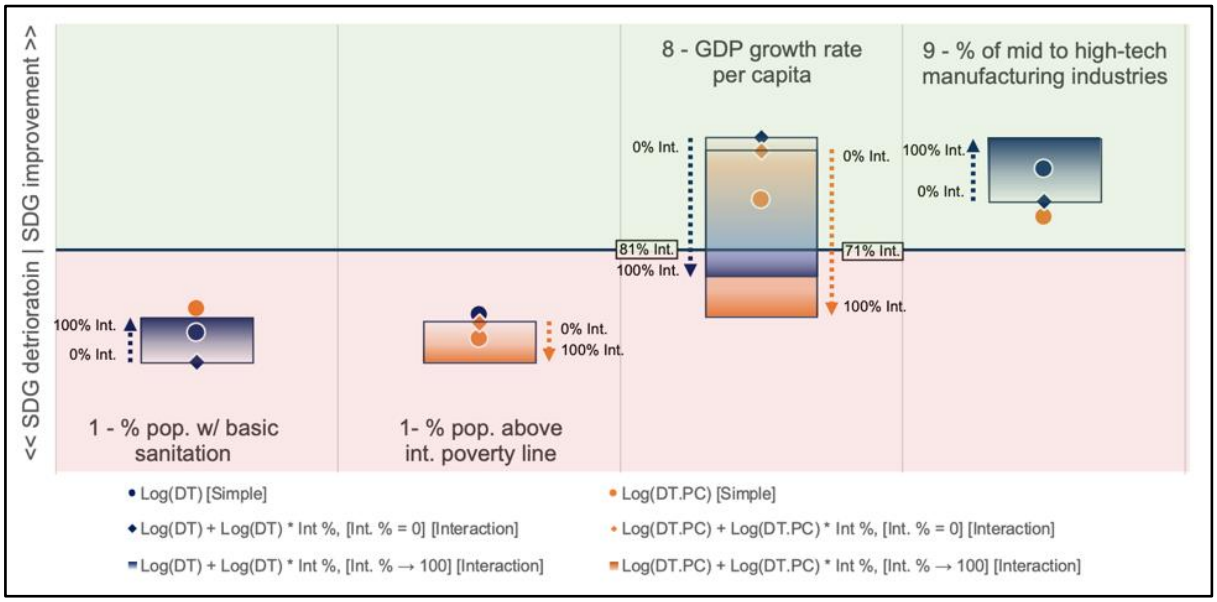
Variables	1 - % pop. w/ basic sanitation	1- % pop. above int. poverty line	8- GDP growth rate per capita	9 - % of mid to high-tech manufactuing industries
Digital Trade Coefficients - Simple Models (1 & 2)				
(1) Log(DT)	-0.49***	-1.67***		0.05***
(2) Log(DT.PC)	-0.35***	-2.29***	0.36*	0.02**
Digital Trade Coefficients - Interaction Models (3 & 4)				
(3) Log(DT)	-0.66***		0.81**	0.03**
(3) Int % : Log(DT.PC)	0.004***		-0.01**	0.0004**
(4) Log(DT.PC)		-1.89***	0.71**	
(4) Int % : Log(DT.PC)		-0.01***	-0.01**	
Policy Variable Coefficients - All Models (1 - 4)				
(1-4) DT.CH	Negative		Positive	Positive
Control Variables Coefficients - All Models (1 - 4)				
(1-4) Log(GDP)	Positive	Positive	Positive	
(1-4) Int %	Positive	Positive	Negative	Negative

Source: Authors.

Notes: Values shaded in Green denote that the coefficients sign is consistent with our ex-ante expectation. Values shaded in Red denote that the coefficients sign is inconsistent with our ex-ante

expectation. Missing shading for cells with specific values denote that no ex-ante sign expectation was defined. Blank cells denote no significant coefficient.

Figure 9: Standardized impact of digital trade variables on economic targets: Standardized regression coefficients across models



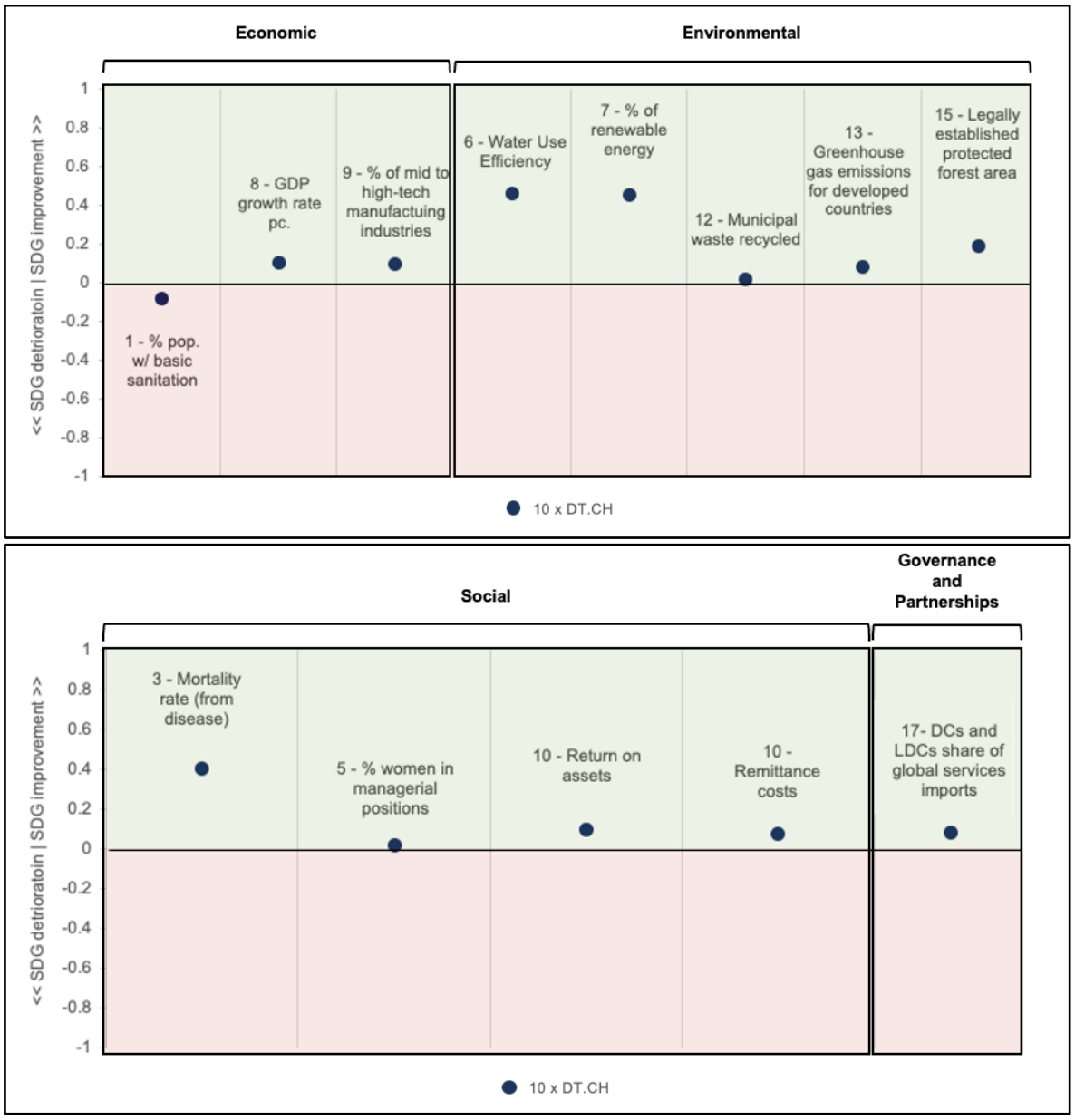
Source: Authors.

Notes: The graph presents normalized coefficients for each digital trade variable – Digital trade (DT), Digital trade per capita (DT.PC) – across two model specifications – a simple model (no interacted variables) [Simple] and an interaction model [Interaction]. For [Interaction] models, a diamond represents the direct digital trade variable coefficient (i.e., Int % = 0); gradient bars represent the total (from both the direct and interacted coefficients) average digital trade impact for each level of internet penetration between 0 and 100%. On the X-axis next to crossing gradient bars, the precise internet penetration level at which the total average digital trade impact switches sign is displayed.

Digital Trade Provisions – all areas of intervention

Additional digital trade provisions in international agreements, specifically measured via the number of trade chapters with digital trade provisions (DT.CH), were consistently found to have a positive impact on all areas of SDG development (Figure 9 and Tables 1-4). In particular, adding trade chapters with digital provisions to international agreements was linked with the highest positive impact on environmental targets, such as 'Water Use Efficiency' (SDG 6) and 'Share of renewable energy' (SDG 7), as well as on the social target 'Mortality Rate (from disease)' (SDG 3). These results likely translate the positive impacts of infrastructure and regulatory readiness in harnessing the benefits from the digital revolution.

Figure 10: Trade chapter with digital provisions variable (DT.CH) coefficient results across SDGs, normalized — by area of intervention.



Source: Authors.

Notes: The graph presents normalized coefficients for DT.CH. The coefficients range from 1 to -1, where 1 represents the highest positive impact recorded across all DTVs within an SDG and -1 is its opposite.

5. Conclusion

In this paper, we empirically examine the potential impact of digital trade and digital trade provisions on the SDGs. Our exploratory findings point towards substantial links between digital trade and several SDGs, particularly within the areas of social and environmental targets. All 6 social targets and 5 out of 6 environmental targets revealed a positive link with digital trade, at least at certain levels of digital penetration. Yet, the results related to economic development and governance and global partnerships present a more varied picture, with limited or mixed evidence emerging. Such results underscore the complexity and variety of relationships between digital trade and the SDGs, highlighting the need for further research in this area.

Crucially, our research has underscored the importance of addressing the digital divide to maximize digital trade's potential benefits. As digital trade continues to expand, it is imperative to prioritize the development of ICT infrastructures, digital skills, and digital regulation that can ensure an affordable, efficient, and safe digital trade environment. This will ensure that the benefits of digital trade can be widely accessed. Moreover, our findings emphasize the significant role of digital trade provisions in international agreements in enhancing sustainable development. As observed, digital trade provisions may play a crucial role in furthering sustainable development. This underlines the opportunity to leverage regional trade agreements as effective platforms for enhancing regulatory cooperation in the area of digital trade, a key factor in achieving sustainable development.

While we endeavored to provide a comprehensive overview of the potential links between digital trade and all the 17 SDGs, further work in this area is strongly encouraged. Indeed, to better understand the potential causation pathways between digital trade and the SDGs, we strongly encourage more in-depth research on specific indicators – rather than on a wide range of goals – that can more robustly model specific relationships. Different identification strategies, such as an instrumental variable approach, would also be a potential way forward to better understand the research question at hand and verify the robustness of the results.

In conclusion, this paper serves as a steppingstone towards a deeper understanding of the potential of digital trade in advancing the SDGs. As digital trade continues to grow and evolve, policymakers have a crucial role in shaping its impacts. Ultimately. we hope that this exploratory study provides a useful resource for policymakers and researchers to find ways to harness digital trade to achieve the SDGs.

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Annex 1: Sustainable Development Goals and chosen Targets and Indicators

Sustainable Development Goals	
Targets	**Indicators**
Goal 1. End poverty in all its forms everywhere	
1.1 By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day	1.1.1 Proportion of population below the international poverty line, by sex, age, employment status and geographical location (urban/rural)
1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property, inheritance, natural resources, appropriate new technology and financial services, including microfinance	1.4.1 Proportion of population living in households with access to basic services
Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture	
2.c Adopt measures to ensure the proper functioning of food commodity markets and their derivatives and facilitate timely access to market information, including on food reserves, in order to help limit extreme food price volatility	2.c.1 Indicator of food price anomalies
Goal 3. Ensure healthy lives and promote well-being for all at all ages	
3.4 By 2030, reduce by one third premature mortality from non-communicable diseases through prevention and treatment and promote mental health and well-being	3.4.1 Mortality rate attributed to cardiovascular disease, cancer, diabetes or chronic respiratory disease
	3.4.1 Number of deaths attributed to non-communicable diseases, by type of disease and sex (number)

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all	3.8.1 Coverage of essential health services (defined as the average coverage of essential services based on tracer interventions that include reproductive, maternal, newborn and child health, infectious diseases, non-communicable diseases and service capacity and access, among the general and the most disadvantaged population)
Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	
4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes	4.1.2 Completion rate (primary education, lower secondary education, upper secondary education)
4.2 By 2030, ensure that all girls and boys have access to quality early childhood development, care and pre-primary education so that they are ready for primary education	4.2.2 Participation rate in organized learning (one year before the official primary entry age), by sex
4.3 By 2030, ensure equal access for all women and men to affordable and quality technical, vocational and tertiary education, including university	4.3.1 Participation rate of youth and adults in formal and non-formal education and training in the previous 12 months, by sex
4.4 By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship	4.4.1 Proportion of youth and adults with information and communications technology (ICT) skills, by type of skill

4.c By 2030, substantially increase the supply of qualified teachers, including through international cooperation for teacher training in developing countries, especially least developed countries and small island developing States	4.c.1 Proportion of teachers in: (a) pre-primary; (b) primary; (c) lower secondary; and (d) upper secondary education who have received at least the minimum organized teacher training (e.g. pedagogical training) pre-service or in-service required for teaching at the relevant level in a given country
Goal 5. Achieve gender equality and empower all women and girls	
5.5 Ensure women's full and effective participation and equal opportunities for leadership at all levels of decision-making in political, economic and public life	5.5.2 Proportion of women in managerial positions
5.b Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women	5.b.1 Proportion of individuals who own a mobile telephone, by sex
Goal 6. Ensure availability and sustainable management of water and sanitation for all	
6.4 By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity	6.4.1 Change in water-use efficiency over time
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all	
7.2 By 2030, increase substantially the share of renewable energy in the global energy mix	7.2.1 Renewable energy share in the total final energy consumption

Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	
8.1 Sustain per capita economic growth in accordance with national circumstances and, in particular, at least 7% gross domestic product growth per annum in the least developed countries	8.1.1 Annual growth rate of real GDP per capita
8.9 By 2030, devise and implement policies to promote sustainable tourism that creates jobs and promotes local culture and products	8.9.1 Tourism direct GDP as a proportion of total GDP and in growth rate
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	
9.3 Increase the access of small-scale industrial and other enterprises, in particular in developing countries, to financial services, including affordable credit, and their integration into value chains and markets	9.3.1 Proportion of small-scale industries in total industry value added
9.b Support domestic technology development, research and innovation in developing countries, including by ensuring a conducive policy environment for, inter alia, industrial diversification and value addition to commodities	9.b.1 Proportion of medium and high-tech industry value added in total value added
Goal 10. Reduce inequality within and among countries	
10.1 By 2030, progressively achieve and sustain income growth of the bottom 40% of the population at a rate higher than the national average	10.1.1 Growth rates of household expenditure or income per capita among the bottom 40% of the population and the total population
10.5 Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations	10.5.1 Financial Soundness Indicators [1]

10.c By 2030, reduce to less than 3% the transaction costs of migrant remittances and eliminate remittance corridors with costs higher than 5%	10.c.1 Remittance costs as a proportion of the amount remitted
Goal 12. Ensure sustainable consumption and production patterns	
12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses	12.3.1 Global food loss index
12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse	12.5.1 National recycling rate, tons of material recycled
Goal 13. Take urgent action to combat climate change and its impacts[a]	
13.2 Integrate climate change measures into national policies, strategies and planning	13.2.2 Total greenhouse gas emissions per year [2]
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development	
14.6 By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation[b]	14.6.1 Progress by countries in the degree of implementation of international instruments aiming to combat illegal, unreported and unregulated fishing

Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss	
15.1 By 2020, ensure the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains and drylands, in line with obligations under international agreements	15.1.1 Forest area as a proportion of total land area
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	
Finance	
17.11 Significantly increase the exports of developing countries, in particular with a view to doubling the least developed countries' share of global exports by 2020	17.11.1 Developing countries' and least developed countries' share of global merchandise imports
	17.11.1 Developing countries' and least developed countries' share of global services imports (%)
Systemic issues	
Policy and institutional coherence	
17.14 Enhance policy coherence for sustainable development	17.14.1 Number of countries with mechanisms in place to enhance policy coherence of sustainable development
Multi-stakeholder partnerships	
17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships	17.17.1 Amount of United States dollars committed to public-private and civil society partnerships
[a] Acknowledging that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change. [b] Taking into account ongoing World Trade Organization negotiations, the Doha Development Agenda and the Hong Kong ministerial mandate. [1] Return on Assets (%) [2] Two separate datasets available for GHG emissions for non-annex 1 and annex 1 parties. Indicator 12.2.1 is identical to 8.4.1	

Annex 2: Descriptive statistics for all variables used

Variable	***Meaning***	***Data Transformation***	***Mean***	***Std. Dev***	***Min***	***Max***
Independent Variables						
Log(DT)	Logarithm of Total Digital Trade	Logarithm transformation	7.31	2.84	-2.3	13.71
Log(DT.PC)	Logarithm of Total Digital Trade Per Capita	Logarithm transformation	-8.28	2.91	-23.03	-1.1
Control Variables						
Log(GDP)	Logarithm of gross domestic product (current value in $)	Logarithm transformation	24.14	2.44	17.28	32.2
Int %	The percentage of households with internet access in a country		46.51	32.17	0.15	100

Dependent Variables						
SDG 1						
1 - % above international poverty line	100 - Proportion of population below international poverty line (%)		86.1	19.68	8.5	100
1 - % using basic sanitation services	Proportion of population using basic sanitation services (%)		74.69	29.18	3	100
SDG 2						
2 - Food price anomalies	Indicator of Food Price Anomalies (IFPA), by Consumer Food Price Index	Outliers removed	-0.09	0.63	-1.78	1.58
SDG 3						
3 - Deaths from non-communicable disease	Number of deaths attributed to non-communicable diseases (number)	Logarithm transformation and outliers removed	7.68	1.63	2.94	14.16

3 - Deaths from non-communicable disease (categorical)	Same indicator as above disaggregated by sex (Male and Female)	Logarithm transformation and outliers removed	7.24	1.77	2.2	15.28
3 - Universal health coverage index	Universal health coverage (UHC) service coverage index		57.18	18.12	14	89
3 - Mortality rate (from certain diseases)	Mortality rate attributed to cardiovascular disease, cancer, diabetes, or chronic respiratory disease (probability)	Logarithm transformation and outliers removed	2.96	0.38	1.99	3.77
SDG 4						
4- youth and adults with ICT skills	Proportion of youth and adults with information and communications technology (ICT) skills (%)		32.98	22.35	0.01	100
4- teachers with minimum qualifications	Proportion of teachers with the minimum required qualifications (%)		78.2	24.34	0	100

4 - Completion rate (categorical)	Completion rate, disaggregated by sex (Male and Female) (%)		65.06	32.86	0	100
4 - Participation rate in education	Participation rate in formal and non-formal education and training, by sex (%)		52.4	15.13	0.6	100
4 - Participation rate is organized learning	Participation rate in organized learning (one year before the official primary entry age), by sex (%)		71.26	28.02	0	100
SDG 5						
5 -% individuals owning mobile phones	Proportion of individuals who own a mobile telephone (%)		82.59	17.17	7.27	100
5- % women in managerial positions	Proportion of women in managerial positions - 19th ICLS (%)		31.25	9.98	4.36	63.3
SDG 6						
6 - Water Use Efficiency	Water Use Efficiency (United States dollars per cubic meter)	Logarithm transformation	37.26	92.87	0.13	1294.91

SDG 7						
7 - Share of renewable energy	Renewable energy share in the total final energy consumption (%)		28.5	29.31	0	98.34
SDG 8						
8 - Tourism direct GDP by total GDP	Tourism direct GDP as a proportion of total GDP (%)		5.45	8.25	0.18	58.58
8 - GDP growth rate per capita	Annual growth rate of real GDP per capita (%)		1.99	6.05	-54.87	96.96
SDG 9						
9- proportion of small-scale manufacturing industries	Proportion of small-scale manufacturing industries in total manufacturing value added (%)	Outliers removed	9.82	5.28	0.12	23.69
9- Proportion of med-high tech manufacturing industries	Proportion of medium and high-tech manufacturing value added in total value added (%)	Outliers removed	2.78	0.96	-1.35	4.2

SDG 10						
10 - Growth rate of household expenditure	Growth rates of household expenditure or income per capita (%)	Outliers removed	2.26	3.02	-6.11	10.66
10 - Return on assets	Return on assets (%)		1.58	1.69	-20.69	12.16
10 - Remittance costs	Average remittance costs of sending $200 for a sending country as a proportion of the amount remitted (%)		7.97	4.54	1.59	27.92
SDG 12						
12 - Food waste per capita	Food waste per capita (KG)	Logarithm transformation	4.82	0.17	4.11	5.56
12- Food waste per capita (categorical)	Same indicators as above disaggregated by sector (Retail, households, and food service)	Logarithm transformation	3.45	0.77	1.14	5.24
12 - Municipal waste recycled	Municipal waste recycled (Tones)	Logarithm transformation	10.58	6.48	-6.91	17.61

SDG 13						
13 - GHG emissions for non-annex 1 parties	Total greenhouse gas emissions without LULUCF for non-Annex I Parties (Mt CO2 equivalent)	Logarithm transformation	2.48	2.28	-3.99	5.3
13 - GHG emissions for Annex 1 parties	Total greenhouse gas emissions without LULUCF for Annex I Parties (Mt CO2 equivalent)	Logarithm transformation	3.95	1.99	-2.49	6.85
SDG 14						
14 - Implementing instruments combating un-regulated fishing	Progress by countries in the degree of Implementation of international instruments aiming to combat illegal, unreported, and unregulated fishing (level of implementation:1 – lowest; 5 - highest)		4.06	1.14	1	5

SDG 15						
15- Legally established protected forest area	Proportion of forest area within legally established protected areas (%)		21.68	19.26	0	100
SDG 17						
17- USD committed to public private partnerships for infrastructure	United States dollars committed to public-private partnerships for infrastructure, million USD nominal	Logarithm transformation and outliers are removed	-1.72	6.37	-6.91	10.33
17 - Enhance policy coherence for SDGs	Mechanisms in place to enhance policy coherence for sustainable development (%)		78.35	14.29	42.5	100
17 -DC and LDCs share of global services imports	Developing countries and least developed countries share of economies' services imports (%)		0.48	1.27	0	11.89
17 - DC and LDCs share of global services exports	Developing countries and least developed countries share of economies' services exports (%)		0.47	1.36	0	15.39

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