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Digitalization and Growth Independence: Utilizing Technologies for Environmental and Economic Resilience

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Digitalization and growth independence: Utilizing technologies for environmental and economic resilience

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Steffen Lange

Abstract

The past years have recurrently seen crises linked to economic recessions – prominently the Covid-19 pandemic, Russia's war in Ukraine and the impacts of climate change. Economies need to be made resilient to such recurring turmoils and recessions. In parallel, sustainability strategies should not rely solely on decoupling emissions and resource consumption from economic growth. The necessary speed of transformation to limit climate change and biodiversity loss makes it questionable whether decoupling alone can suffice.

This report shows that digital technologies are no game changer in facilitating sufficient decoupling and green growth for a combination of reasons: their low energy efficiency improvements and substantial environmental footprints as well as the limited substitution of digital services for physical goods and rebound and induction effects.

The report further explores how digitalization can be utilized for sustainability, resilience and growth independence. Two aspects are of central importance. First, making growth-dependent institutions independent of economic growth becomes even more essential as digital technologies put pressure on employment and the financing of the welfare state. Second, digital technologies can help in realizing sufficiency strategies such as substitution, sharing, second-hand, repairing and subsistence.

A combination of macroeconomic and sectoral policies could guide digital innovations towards growth-independent, sufficient and resilient economies. Policies need to include a change in the relative prices of resources and energy vs. labour, multiple instruments for each economic sector, a strong welfare state and new actors who develop and design digital technologies.

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1 INTRODUCTION

In November 2019, the newly elected president of the European Commission, Ursula von der Leyen, argued in her inaugural speech for a twin transition in Europe. The two twins are the digital and the sustainability transitions, which need to take place simultaneously over the coming years.

This twin transition is usually regarded as part of a green growth strategy: "Accelerating the twin green and digital transitions will be key to building a lasting and prosperous growth, in line with the EU's new growth strategy" (European Commission, 2022, p. 7). Green growth means that economic growth and environmental sustainability can be reconciled (Ekins, 2017). However, achieving sustainability while continuously growing economically in the countries of the Global North is arguably unlikely to be feasible (Hickel & Kallis, 2019; Parrique et al., 2019) and the efficiency improvements necessary to reconcile economic growth with the rapid decline in greenhouse gas emissions are argued to be unrealistic (Kuhnhenn et al., 2020). In addition, strategies that rely entirely on technological fixes may solve one environmental problem but induce new ones as, for example, electric cars reducing greenhouse gas emissions but requiring copious raw materials (Kallis, 2011).

Digital technologies are often regarded as a game changer in facilitating decoupling and green growth. The central strategy is to improve energy efficiencies by using digital tools: Supposedly, robots make manufacturing more energy efficient (Riazi et al., 2017), smart coordination reduces the energy needed in transportation (GeSI & Deloitte, 2019) and smart farming uses pesticides and fertilizers in a more targeted and, hence, more efficient way (Balafoutis et al., 2020). In addition, digital possibilities are seen as facilitating the replacement of environmentally harmful goods by less harmful digital services – e.g., replacing travel by video-conferencing (Santarius et al., 2022).

However, the question remains, can digital technologies indeed facilitate green growth? Section one covers a debate on the empirical insights as well as theoretical explanations of the relationship between digitalization and sustainability. The result: Empirical evidence suggests that digitalization has led neither to strong economic growth nor to reduced energy consumption or substantially less greenhouse gas emissions. The reasons are complex and manifold. For one, digital tools do not bring about the energy efficiency improvements hoped for and the substitution of digital services for physical goods has so far been limited. At the same time, digital technologies bring additional energy consumption due to the environmental footprint of the digital devices themselves, as well as rebound and induction effects.

If green growth is not feasible, and digital technologies cannot strengthen its feasibility, alternative approaches are needed. The Organization for Economic Co-operation and Development (OECD) has recently published the report Beyond growth, which combines the goals of environmental sustainability with those of well-being and economic resilience (Jacobs, 2020). If green growth is unsure or even unlikely (Parrique et al., 2019), European economies need to be prepared to function without economic growth (Seidl & Zahrnt, 2012;

van den Bergh, 2011). From this argument follow positions around the terms a-growth and growth independence. The a-growth position argues that policy-makers should focus on introducing policies that achieve environmental and social goals – and one should be agnostic regarding whether these policies lead to positive or negative economic growth (van den Bergh, 2017). Building on the a-growth position, the concept of growth independence introduces the proposition that important social institutions also need to work when the gross domestic product (GDP) is in decline. Prominent examples of such institutions are employment and wage income as well as social security systems (Petschow et al., 2020).

The strategy of growth independence can also help to address additional challenges, besides the environmental crisis. The past years have seen recurrent crises linked to economic recessions. The restrictions applied to combat the Covid-19 pandemic reduced both consumption and production. Currently, Russia's war in Ukraine has initiated an energy crisis with serious implications for global supply chains and consumer purchasing power. And the existing impacts of climate change give an idea of what is to come. As crises and their economic consequences are likely to become the new normal, economies need to be made resilient for recurring turmoil and recessions – hence to become independent of continuous economic growth.

Concepts for how to combine the digitalization of economies with sustainability and growth independence are urgently required. Two aspects are central in this regard. First, making growth-dependent institutions independent of economic growth remains essential when taking digitalization into account. As shown in section two, digital technologies currently lead to increases in labour productivity, so that employment needs to be made growth independent. Digitalization also brings a reduced wage share, which makes it harder to finance social welfare systems. However, initiating an environmental transformation may change these relationships. Second, digital technologies can help use the strategy of sufficiency (rather than solely efficiency) to reduce energy and resource consumption. For example, technologies and applications can be used to support substitution, sharing, second-hand, repairing and subsistence (see section two).

A set of policies can help to reconcile digitalization with environmental sustainability and growth independence. Changing the relative prices of energy and natural resources compared to labour, providing a strong welfare state, combinations of specific policies for sustainability transformations in each economic sector, as well as new actors driving digitalization are essential in combining digitalization with environmental sustainability and growth independence (see section three).

2 DIGITAL GREEN GROWTH?

Digitalization is often said to help solve environmental issues such as climate change and material overconsumption while increasing economic growth. So far, it has not lived up to this promise. Figure 1 displays the development of GDP, energy consumption and greenhouse gas emissions worldwide, as well as different phases of digitalization.

It indicates that, in the different stages of digitalization, GDP, energy consumption and greenhouse gas emissions have grown worldwide. As GDP has grown much faster than energy and emissions, a relative decoupling has taken place.

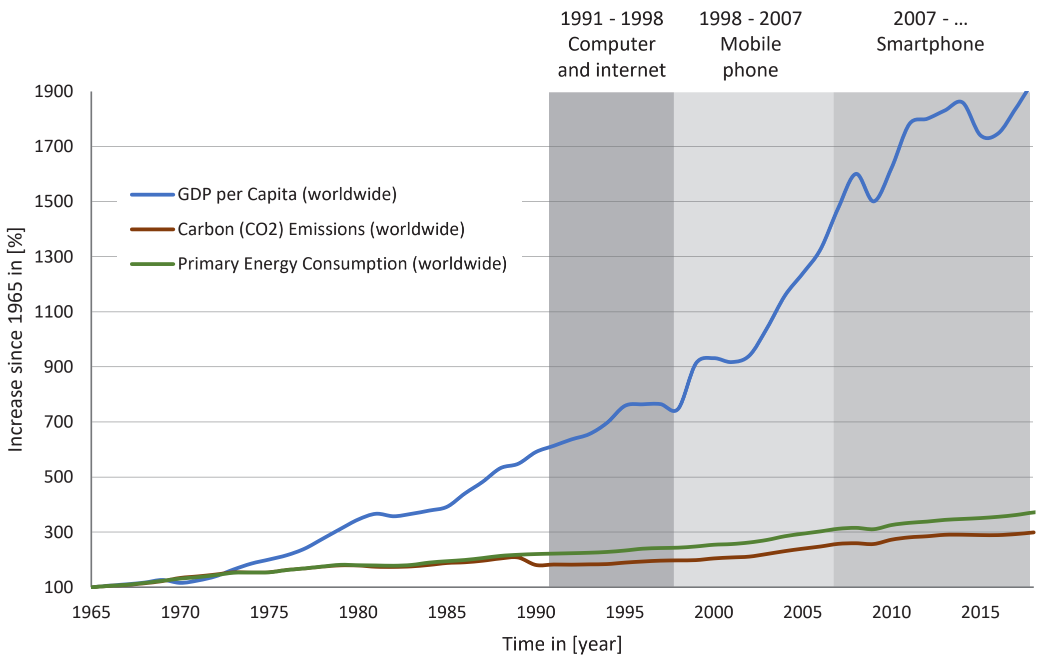

Figure 1: GDP per capita, CO_2-Emissions and energy consumption (BP p.l.c., 2021; World Bank, 2022b, 2022a)

Of course, the strictly descriptive relation displayed in Figure 1 says little about the causal link between digital technologies and economic growth, emissions and energy consumption.

As far as economic growth is concerned, empirical research suggests that digitalization spurs economic growth in high-income countries (Farhadi et al., 2012; Lange et al., 2020; Salahuddin et al., 2016). However, while being statistically significant, the impact is relatively small. Studies on the relationship between digitalization and environmental indicators find differing results for the direction of the relationship, while all find small net effects. The studies estimate the relationship between digitalization and environmental indicators on a country level, so that both positive and negative effects are accounted for, and the net effect is estimated. For energy consumption, the literature identifies a statistically positive correlation with digitalization on a country level: Higher levels of digitalization lead to higher levels of energy use (Haseeb et al., 2019; Salahuddin & Alam, 2015, 2016). For greenhouse gas emissions, studies yield ambiguous results. One group of studies finds a positive relation between digitalization and greenhouse gas emissions (Kopp et al., under review; Salahuddin et al., 2016). Another approach finds that Information and Communications Technologies (ICT) reduces CO2 emissions directly but increases energy consumption, which in turn increases CO2 emissions (Haseeb et al., 2019; Lu, 2018). Not a single study finds a strong reduction in greenhouse gas emissions due to digitalization. For natural resources, there is a lack of studies estimating the net effect of digitalization probably because the large number of natural resources make such estimations methodologically difficult.

In sum, the empirical evidence indicates that digitalization indeed increases economic growth and environmental sustainability, but to a lesser extent than hoped for in political debates.

2.1 Efficiency and substitution smaller than expected

The subsequent question is, why does digitalization not substantially reduce energy consumption and greenhouse gas emissions? This section shows that the potential attributed to digitalization has so far barely materialized – in particular, hopes regarding efficiency improvements and substitution. Further, two mechanisms have detrimental environmental impacts – the environmental footprint of digital devices and rebound and induction effects. The four central mechanisms are displayed in Figure 2.

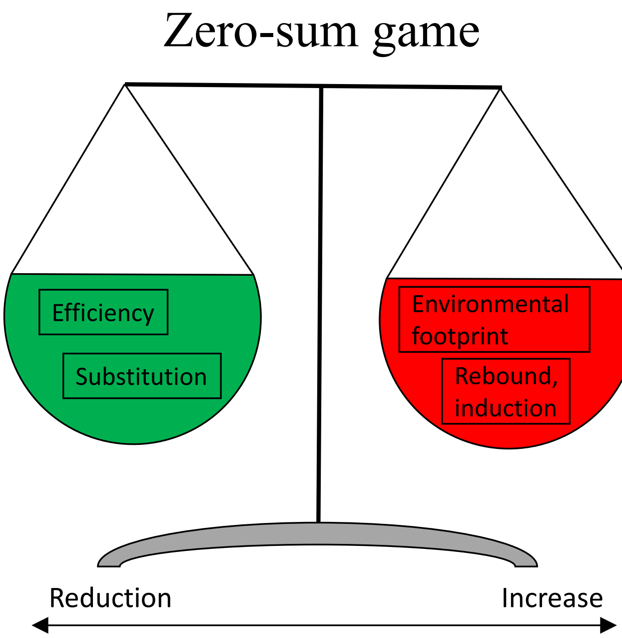

Figure 2: Digitalization as an environmental zero-sum game

2.1.1 Efficiency

Digitalization's greatest potential to reduce energy consumption and greenhouse gas emissions is said to arise in improving energy efficiency in various sectors (GeSI & Deloitte, 2019). However, empirical investigations of efficiency improvements of specific goods and services show a mixed picture. On the one hand, there are energy efficiency potentials for information services. Moberg et al. (2010) find an annual energy-saving potential of electronic invoicing of up to 1400 Terajoule in Sweden. Studies on energy savings in e-commerce, on the other hand, show mixed results (e.g., Horner et al., 2016; Mangiaracina et al., 2015; van Loon et al., 2015). For example, a study of the Japanese book sector found that e-commerce is about as energy-intensive in rural areas but more energy-intensive in urban areas (Williams & Tagami, 2002). According to Horner et al. (2016), decisive factors are population density (based on delivery in the last mile), freight mode, product return rate, trip allocation (share of multi-purpose trips) and type of packaging. A recent estimation of digitalization's effect on energy efficiency in German firms shows a statistically significant but economically irrelevant negative effect (Clausen et al., 2022). In other words: digitalization increases energy efficiency but only a little.

Overall, efficiency improvements seem so far to be existent but are relatively small. The current type of digitalization, therefore, does not substantially contribute to reducing energy consumption, and thereby greenhouse gas emissions, via increasing energy efficiency. Let's turn now to digitalization's second promise.

2.1.2 Substitution and sectoral change

A second way for digitalization to improve the environment could be by it enabling digital services to substitute physical goods – in other words a sectoral change towards services, the so-called tertiarization (European Commission, 2012; OECD, 2015). The idea is that digital services substitute physical goods or other, more environmentally-intensive services, and thereby reduce energy and resource consumption. Most prominent is the example of virtual conferencing, which can substitute for travel (Clausen et al., 2019). More generally, ICT on average leads to higher growth rates of productivity in service sectors compared to those in manufacturing sectors (Sapprasert, 2010). However, the positive effect of ICT on tertiarization may only apply to certain countries, as the mentioned studies regarding European and OECD countries show. Within the ICT sector itself, manufacturing is increasing in countries such as China while ICT services are growing, for example, in European countries (Lange et al., 2020). Hence, the tertiarization experienced in European and OECD countries can lead to increased industrial hardware production in other world regions.

Even if the analysis is limited to countries where digitalization spurs sectoral change towards services, it is still questionable whether this effect is combined with environmental improvements. The reasoning is based on a general criticism of the explanation for tertiarization. The increasing share of services might be the result of a statistical construct related to the so-called Baumol's cost disease: As prices of industrial and agricultural goods fall (due to increases in labour productivity), the share of services rises. However, the amount of industrial and agricultural goods can still rise in total terms (Kümmel, 2011). Applied to the case of digitalization, this means: Even if the share of digital services rises, the total amount of other goods and services and their total environmental impact does not necessarily have to fall.

In addition, a question is whether digital services are indeed environmentally friendly. Investigations show the worldwide energy intensity in industrial production as 0.12kgoe/$ (kilogram oil equivalent per dollar), in agriculture 0.036kgoe/$ and in services 0.016kgoe/$ (EnerData, 2016). Clearly, a shift from the industrial towards the service sector would decrease the economy's energy intensity. However, services derived from applying ICT are relatively energy intensive, compared to other human-based services (such as art, education, etc.). The increasing role of ICT in services is therefore a major factor in the increased energy intensity of services (Mulder et al., 2014). This intensity further diminishes the prospect that digitalization could contribute to reducing energy consumption via a sectoral change.

2.2 Digital footprint and rebound effects

Digital efficiency improvements and digitally introduced tertiarization do not yet help reduce the environmental footprint as hoped for. In addition, two effects associated with digitalization help to explain its lacking ability to improve environmental sustainability: the environmental footprint of digital devices and the rebound and induction effects.

2.2.1 Environmental footprint of digital devices

The production, use and disposal of digital devices are associated with substantial environmental throughput. Three important dimensions of this environmental footprint are energy, greenhouse gas emissions and natural resources.

The ICT sector's electricity consumption constitutes a rising and significant share of global electricity consumption. Estimations of this sector's share of total electricity consumption vary between 3.8% and 7.4% (Corcoran & Andrae, 2013; Malmodin et al., 2010; Malmodin & Lundén, 2018; Van Heddeghem et al., 2014). Estimations of greenhouse gas emissions come to mixed results. A recent study comparing different estimations reckons that ICT's share of global greenhouse gas emissions lies between 2.1% – 3.9% (Freitag et al., 2021). Of the natural resources being used, the ICT sector only accounts for a small part of global consumption (Malmodin et al., 2018). However, the sector accounts for a large part of the consumption of certain materials. For example, much of the lithium held in batteries worldwide is to be found in portable electronics (Melin, 2019). Several essential materials for the production of digital devices are already scarce or are expected to become scarce in the future (Marscheider-Weidemann et al., 2021). Therefore, the crucial question is whether substitution of natural resources will become feasible – if not, limited resources might restrict further expansion of the number of devices (Santarius et al., 2020).

Explaining the environmental footprint of digital devices boils down to a mixture between efficiency increases and growth of the sector. On the one hand, digital devices have experienced an impressive increase in energy and material efficiency over the past decades. On the other hand, the number of devices and the computing power of these devices have grown, explaining the sector's high footprint.

2.2.2 Rebound and induction effects

Digital technologies contribute to environmental pressures not only via the environmental footprint of digital devices but also through several additional effects.

A well-known debate concerns the rebound phenomenon. The phenomenon describes and explains how energy efficiency improvements do not reduce energy consumption to the extent anticipated (Sorrell, 2007). Efficiency improvements lead to additional energy consumption via various channels – rebound effects (Lange et al., 2021). Digital technologies are particularly prone to rebound effects (Coroama & Mattern, 2019), and thus, the efficiency improvements discussed above will reduce energy consumption less than expected. This effect can happen both on the supply and the demand side. For example, digitalization can save energy in industry by making production more energy efficient. However, the same digital technologies usually also bring an increase in labour productivity and thereby lead to increased production (Lange & Berner, 2022). For example, a new machine for production is commonly more energy efficient but at the same time also increases labour productivity. The impact of the expansion of production on energy demand countervails or even outweighs the energy savings due to higher energy efficiency – preventing a reduction in energy demand.

Perhaps even more important are digital induction mechanisms. These describe mechanisms stemming from increasing options due to digital technologies. For example, the immense increase in online shopping has been facilitated by digital devices such as the smartphone (Lange & Santarius, 2020). Online shopping also allows new types of commercials, inducing people to consume more (Frick et al., 2020). Other examples include navigation systems or autonomous car applications, which make it more convenient to drive – inducing additional mileages (Friedrich & Hartl, 2017).

3 DIGITAL ECONOMIES BEYOND GROWTH

The analysis in section one has shown that, so far, digitalization is not a game changer for the prospects of green growth. Digitalization has not substantially improved environmental sustainability – in terms of reduced energy consumption and greenhouse gas emissions.

However, the environmental potentials of digitalization would play out differently under macroeconomic policies geared towards a sustainability transformation (see Section three for a detailed discussion). Such policies are likely to bring about lower economic growth or a reduction in economic output. Most important for this aspect is a central environmental policy that changes the relative prices of natural resources and energy compared to those of labour. Using natural resources and emitting pollution need to be limited by them becoming more expensive. At the same time, human labour can be made less expensive by reducing taxes on low incomes and switching the financing of social security systems towards revenues from taxing natural resource use. Such changes would redirect technological change by incentivizing firms to invest in innovations that increase energy and resource efficiency, rather than in labour productivity. The result would probably be reduced economic growth (Ayres et al., 2019).

This relation between macroeconomic policies and the redirection of technological change also holds true for digital technologies. Therefore, policymakers need to develop and implement concepts that lead to growth independency for several institutions that currently depend on economic growth – on top of initiating policies for a sustainability transformation. Such growth-independent institutions are covered in the next section.

3.1 Growth independent institutions in the digital age

It is unclear whether strict environmental policies will lead to a positive economic growth or a reduction in output (Petschow et al., 2020; van den Bergh, 2017). The position of a-growth argues that neither the discussion nor the policy-making should focus on the level of output (van den Bergh, 2011). However, several essential societal institutions depend on economic growth (see Box 1). The relation between digitalization and these growth dependencies are explained in the following. This report concentrates on two growth-dependent institutions: Employment and social welfare systems.

Box 1: A-growth and growth independence

The concept of a-growth has been put forward as an intermediate position. A-growth states that environmental strategies should target environmental goals and be agnostic as to whether these strategies lead to economic growth or not (Jackson, 2016; Lange, 2018; van den Bergh, 2011, 2017; P. A. Victor, 2019). However, the position of a-growth does not sufficiently account for economic and societal dependencies on economic growth. Several important societal institutions – such as employment and social welfare programs – depend on growth (Seidl & Zahrnt, 2012). Since strict environmental policies might lead to less growth or even reduce production and consumption (Ayres, 1999), implementing those policies requires growth-dependent institutions to become growth independent (Petschow et al., 2020; Strunz & Schindler, 2018).

3.1.1 Employment

A central reason for policymakers to support economic growth is to guarantee a high level of employment (Rivera et al., 2016): First because unemployment brings hardships for the people affected, and second, high unemployment figures lead to loss of taxes and contributions to social security systems as well as high public expenditures via payments for the unemployed. The central reasoning of the relationship between economic growth and employment is as follows. Technological change increases labour productivity so that fewer workers are needed to produce a given level of goods and services. Only if production increases can the same level of employment be guaranteed. Therefore, growth of production – i.e. economic growth – is needed to guarantee high levels of employment (Lange, 2018).

Digitalization includes the introduction of important technological change currently taking place. It is said to have immense rationalization potential, making many jobs, and hence many employees, obsolete (Brynjolfsson & McAfee, 2014). Early studies estimated that a substantial share – more than 40% – of employed people could lose their job (Frey & Osborne, 2017). However, more recent research comes to far lower estimates of jobs being rationalized as well as a substantial number of new jobs being created due to digitalization (Acemoglu & Restrepo, 2020; Arntz et al., 2017, 2018; Autor, 2015; Huws et al., 2016). Several reasons are given for these lower estimates. First, jobs are difficult to rationalize because they often entail not only tasks that can be done by algorithms and robots but also tasks that cannot, and second, the supply of new goods and services creates new jobs.

Hence, in the current economic framework, digitalization increases the growth dependency of employment. However, as the recent studies suggest a lower potential to rationalize jobs than that identified in earlier studies, this increase in growth dependency of employment may be smaller than feared. At the same time, the more optimistic studies that predict a lower impact of digitalization on unemployment assume a positive effect of digitalization employment through producing new goods and services, thereby depending on economic growth again.

Setting the impact of digitalization on employment into a broader concept shows that unemployment is likely to be less of an issue than often feared. For one, many European countries are experiencing an ageing population, leaving an ever-decreasing share of people in the work force. The beginnings are visible today in the form of a shortage of skilled workers. In the future, we will see increasing labour shortages in many sectors.

In addition, the ecological transformation will be accompanied by incentives to use more labour and fewer resources in production, which will further increase demand for labour. Against this background, it seems likely that, even in non-growing economies, overall demand for labour will be higher than supply.

3.1.2 Social welfare system

Digitalization dampens social security payments, as these primarily come from wages (Adler, 2001). Social security payments are put under pressure – in addition to the increasing unemployment – due to two additional developments related to automation. First, automation changes production structures in a way that decreases demand for certain qualifications while increasing the demand for others (Frey & Osborne, 2017). Those changes in demand hit low-skilled workers particularly hard because new jobs tend to be created in higher-skilled areas. Newly created jobs for low-skilled workers are relatively often not subject to social insurance contributions (Schor et al., 2020). Hence, contributions to social security tend to decline. Second, wages make up a smaller part of overall income while the share of capital income rises (Brynjolfsson & McAfee, 2014). As income from capital does not contribute to social security payments under current systems in Germany and many other countries, further pressure is put on financing social security.

3.2 Sufficiency Potentials of Digitalization

Efficiency alone will not suffice to achieve environmental sustainability (Kuhnhenn et al., 2020). Therefore, sufficiency measures are needed if planetary boundaries are to be respected (O'Neill et al., 2018). Sufficiency measures involve a behavioural change that aims for absolute reduction in energy and resource consumption. Sufficient behaviour includes a change in consumption towards environmentally friendly goods and services – for example switching from travelling by car to travelling by train. Sufficiency also includes reducing the environmental impact by consuming less – for example by travelling fewer kilometres per year (Princen, 2005).

Digital technologies offer a wide variety of possibilities to support sufficient lifestyles as well as sufficiency-oriented business cases. The following sections provide cases for six strategies where digital technologies can be used for sufficiency (see also Jaeger-Erben et al., 2017): (1) substitute physical goods for digital services, (2) foster sharing, (3) increase the share of second-hand consumption, (4) support repairing, and (5) enable prosuming and subsistence (see figure 3). Each case contains an explanation of how digital technologies can support the respective strategy. Examples are given of how each strategy is already being implemented and its potential is discussed.

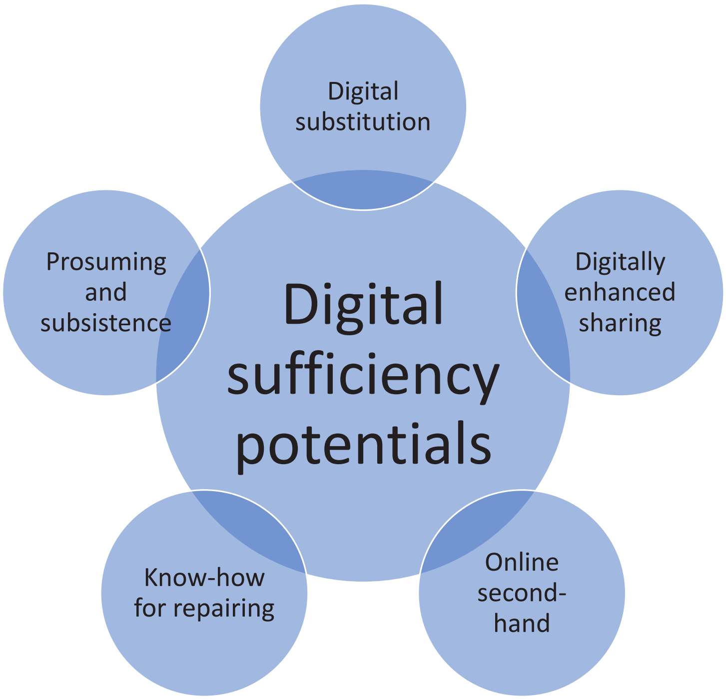

Figure 3: Five digital sufficiency potentials

3.2.1 Digital substitution

Digital tools can replace a variety of non-digital products, thereby reducing resource consumption. This phenomenon is also known as dematerialization, which describes a shift from material products to non-material ones.

Map apps make physical maps obsolete. E-books can store innumerable virtual books that, in a physical form, would have taken up rows of shelf space. Online newspapers and blogs are increasingly replacing physical newspapers. Online music and movie platforms such as Spotify and Netflix have registered increasing user numbers as sales for CDs and DVDs are plummeting, and previously ubiquitous movie rental chains such as Blockbuster, which once owned over 9000 video rental stores in the United States, are going bankrupt. However, not only individual products are becoming less resource-intensive due to digitalization. In the banking sector, entire branches have been closed since most services are now offered via online banking and cash withdrawal is conducted at small ATMs (Automatic Teller Machines).

Replacing resource-intensive goods and services by digital ones has substantial potential to reduce environmental throughput. Realising this potential requires two aspects. First, the digital alternative needs to actually substitute the old good or service – rather than coming on top. Videoconferences need to replace flights rather than be done additionally. And the digital subscription to a newspaper has to substitute the old, printed subscription – rather than having both. Second, the digital alternative needs to be environmentally friendly. The digital devices need to be used for a long time and the server and computation capacities have to be kept at bay (Santarius et al., 2022).

The example of video-conferencing during the Covid-19 pandemic shows the important role of resolute policies to achieve digital substitution. The large-scale adoption of video-conferencing that actually replaced travels was only possible in a politically induced lock-down (Clausen et al., 2022). The quest for future-oriented policymaking is how to introduce policies that support digital substitution without harmful effects on well-being.

3.2.2 Digitally enhanced sharing

Certain digital platforms can reduce the transaction costs of sharing and thereby connect people with a demand for certain goods with those who own those goods.

There are numerous examples of digital sharing tools. Prominent examples can be found in the mobility sector. Apps and sharing platforms allow car owners to privately rent out their cars to strangers. Digital tools also make professional providers more attractive due to convenient booking or free-floating systems. Other examples are the sharing of holiday apartments or sharing household tools such as lawnmowers, drills etc. These sharing tools work best when connected to a neighbourhood app that connects people living nearby. However, such examples also show that sharing is not always environmentally and socially desirable, as is often the case for sharing platforms owned by large profit-oriented firms, with prominent examples such as Uber and AirBnB (Loske, 2015).

Clearly, digital tools could be used for even more sharing. Numerous products in every household are seldom used and could therefore potentially be shared. However, even with time-efficient digital communication tools, at some point transaction costs will make sharing inconvenient as certain transaction costs – such as bringing a device from A to B – will remain. Nevertheless, many goods in a household are no longer used, and many cellars and attics are overflowing with objects not used but still intact. This is where second-hand markets come into play.

3.3.3 Online second-hand

Many goods are just no longer needed by their owners even though they are still in perfectly good shape. These goods can be sold or given away on second-hand markets. While such markets existed long before the arrival of the internet, online platforms make exchanging second-hand goods much easier since it can now be done from the comfort of one's couch.

Given these reduced transaction costs, the internet now hosts the largest flea markets in the world: online trading platforms such as eBay allow users to buy and sell used goods across the world. On platforms such as Vinted, used clothes can be bought and sold, and via Freecycle almost everything is given away for free or traded. Other more local platforms such as craigslist facilitate neighbourly exchanges of no longer needed items. This exchange not only reduces the need for new products but also strengthens neighbourhood ties and communal togetherness.

Second-hand consumption allows products to be used longer and can reduce the resource needs substantially. Even though environmental costs still arise – such as operating the online platforms or transporting the goods – those costs also apply to consuming new goods. Hence, more – and in particular more local – second-hand trade can reduce environmental throughput. Given the enormous amounts of goods that are either thrown away or stored in homes, the potential is huge (Lange & Santarius, 2020).

3.3.4 Know-how for repairing

Digitalization enables knowledge transfer that was not conceivable 20 years ago. Not only is information publicly available, digital tools can also ease the learning processes and make it much easier to adopt this knowledge, for example in the form of online courses and video tutorials. In principle, this allows anybody to gain the knowledge to repair a wide range of artefacts – from household appliances to clothing, from cars to furniture, smartphones, computers, toys – the list goes on.

Online websites such as Rebuy buy used (mostly electronics) products, repair them and then sell them to customers at a discount compared to new products. The online how-to platform iFixit sells repair parts and publishes free online repair guides primarily for consumer electronics and gadgets but also for a variety of other products such as clothing, old typewriters and books, to name but a few. Instead of offering guides on how to repair products yourself, other online platforms such as TaskRabbit connect customers with people who offer to perform small repair tasks around the house, such as fixing a dripping drain.

The potential of repairing to save resources is substantial – and digital tools can help to utilize it. While repairs can be done by individuals, the market could still grow strongly as a large business market.

3.3.5 Prosuming and subsistence

Subsistence means the production of goods and services for one's own needs. Digitalization helps to provide the necessary information and could help develop technologies for subsistence production. Prosuming is similar – here consumers also produce but not necessarily only for their own consumption but also for selling.

For example, with the help of online platforms, allotment gardeners can sell their homegrown products to people they do not personally know. A second prominent example is people who install solar panels on the roof of their homes. They can then use the generated electricity to fulfil the energy demand of their home appliances, store excess energy in batteries, convert it into heating or cooling with the help of a heat-pump or feed excess energy into the grid. The decentralized connection of energy prosumers to the electricity grid is made possible by the digitalization of the energy grid. A smart-grid allows energy to flow both to and from households, whereas in most old grids power flows to consumers in only one direction. Integrating households into the energy grid allows individuals to take part in the energy transition as prosumers.

Implementing sharing and prosuming platforms on a large scale would increase peoples' independence of large corporations and market fluctuations. Homeowners who have a self-sufficient energy supply are less likely to be negatively affected by energy price fluctuations, as are currently happening in Europe. In addition, sharing and prosuming take place locally and thus decrease emissions created by long-distance transport.

In sum, digital technologies can support various sufficiency strategies and are often already used for them. However, making more use of this potential necessitates changing the framework within which substitution, sharing, second-hand, repairing and prosuming take place. Only under substantially different circumstances can the digital potentials be made use of, as is argued in the next section.

4 POLICIES FOR REDIRECTING DIGITAL TECHNOLOGIES

Digital technologies do not themselves automatically either improve or deteriorate the relationship between human activity and the environment. Rather, the potential for those technologies to improve things or lead to a deterioration is related to the circumstances under which they are built and the actors (and their objectives) who build them.

Transforming economies to become more sustainable and resilient includes a wide range of different policies. In the following, I focus on those that are crucial regarding the relationship between digitalization, economic growth, growth dependencies and sustainability.

Changing the relative prices of resources and labour: On the macroeconomic level it is important to change the relative prices of input factors – natural resources and energy relative to human labour. The prices of inputs are decisive for which technologies are used, which new technologies are developed and which products and services are supplied and consumed. Hence, 'getting the prices right' has always been the most important policy advice from environmental and ecological economists. This advice means, concretely, increasing the prices of resource consumption and emissions while reducing the costs of labour – in particular taxes on labour. In this manner, firms would be incentivised to implement other production technologies and to develop different types of technologies throughout economic sectors.

Strong social welfare systems to facilitate transitions: A second macroeconomic field of policies concerns the distribution of wealth and the role of social welfare systems. Transforming economies towards sustainability will bring many changes for numerous people: employees will lose jobs and gain opportunities for new jobs elsewhere. Regions with strong fossil industries will either experience industrial transformation or job loss and a loss of incomes and public revenues, while other regions will see new businesses flourish. An important role in organizing the transformation in a socially acceptable way is for the state to support those experiencing hardships from the transformation. Possible strategies are to redistribute income and wealth and to strengthen social welfare systems, from the provisioning of basic goods and services to supporting unemployed.

Sectoral policies: In addition to macroeconomic policies on prices and the welfare system, individual policies are relevant for each sector. In the energy sector, policies need to aim at switching from fossil to renewable energies. In the mobility sector, private car travel needs to be replaced to a large degree by public transport and the overall kilometres travelled need to be reduced. Important regarding the issue of digitalization and growth independence is that concepts for sectoral transformations often entail ingredients of sufficiency – such as fewer kilometres travelled per person, fewer square meters of housing per person or replacing animal products with plant-based diets. And, in particular, economies need to prepare to cope without economic growth.

Digital actors: Finally, it is decisive who develops digital technologies. Currently, the growth-dependent design of prevailing peer-to-peer platforms and the dominance of shareholder-oriented players (such as Alphabet, Meta, Amazon, Apple, Microsoft etc.) counteract digitalization's potential to support sufficiency-oriented lifestyles. The underlying reason is that such players aim at maximizing profits. The dominant players either focus on growth of sales or on advertisements – both directly countervailing sufficiency strategies (Ferreboeuf, under review). This point is where cooperative business models can offer solutions. Platform cooperatives are cooperatively owned: a democratically governed business that establishes a computing platform and uses a website, mobile app or a protocol to facilitate the sale of goods and services ('Platform Cooperative', 2021). Their aims are geared towards goals different to those of stakeholder-oriented players. Instead of maximizing profits, they focus on social and/or environmental goals. Platform cooperatives subscribe to conditions such as decent pay and income security for employees, co-determined work, transparency and data portability as well as the right to log off (Scholz, 2016). Making them the central actors in digitalization is therefore a crucial aspect in improving social and environmental conditions in the digital economy, as well as facilitating the sufficiency potential of digitalization as described in section two.

These policies would change the use of digitalization. The following shows how these policies can alter digitalization's role regarding the four aspects discussed in section one – efficiency, substitution, ICT's environmental footprint and rebound effects – as well as the two aspects discussed in section two, sufficiency and growth dependencies.

Efficiency: The development and application of digital tools would be focused on increasing environmental efficiencies, rather than on labour productivity, throughout economic sectors. That focus is, in particular, due to the change in relative prices of natural resources vs. labour, as described above. In addition, sectoral regulation could foster the effect. The result would be, for example, that in agriculture, the focus of digitalization in farming could be on minimizing fuel, pesticides and fertilizers and improving biodiversity rather than on increasing labour productivity. Industrial production would focus on resource and energy reductions rather than on rationalizing labour.

Substitution: If physical goods become more expensive, if sectoral regulation supports environmentally sustainable production and if the actors who drive digitalization strive to support environmental behaviour, digital services could substitute energy and resource-intensive goods where possible. For example, videoconferencing will replace more travel if travelling becomes more expensive.

ICT's environmental footprint: Computers and smartphones with longer longevity would be developed as the resources used to produce them become more expensive and developers are oriented towards making these devices environmentally sustainable. And they would be designed to be made from recycled content, easily repairable and recyclable, in order to reduce the costs of new products. In other words: The incentives would make firms and consumers find ways to reduce the footprint of digital devices.

Rebound and induction effects: Preventing rebound and induction effects is a complex task as these are indirect effects and therefore difficult to measure. Prevention of such effects is closely related to organizing economies beyond growth, as rebound effects usually occur with additional production or consumption, i.e. economic growth (Lange & Berner, 2022). Therefore, it is the combination of policies described above that lead to economies beyond growth and to preventing rebound and induction effects, for example, online shopping currently increasing consumption, as described above. Those effects could be counteracted if producing physical goods and travel became more expensive, if digital platforms supported consumers in choosing second-hand and sustainable products and if purchasing power was redistributed.

Sufficiency: The use of digitalization for sufficiency would be fostered by changed relative prices, by sectoral regulations that foster sufficient behaviour and by digital actors who provide the platforms and software to support sufficient lifestyles. For example, sharing becomes more attractive when the price of resource-intensive goods – such as cars or household tools – rises and apps conveniently facilitate sharing. Second-hand consumption is likely to grow immensely when the price of new products rises, and a rise in the difference in prices between new and second-hand items will often outweigh disadvantages such as transaction costs. Repairing will become much more attractive and most likely a growing business case. In particular, when costly products such as laptops or smartphones, but also furniture or expensive clothes, become more expensive, repairing or refurbishing could constitute an increasing share of consumer spending.

Growth dependencies: The policies described above are likely to reduce growth dependencies of digitalized economies in the 21st century. A change in relative prices would increase demand for labour, leading to rising employment, higher wages and a higher labour share. Because firms are exposed to an incentive to introduce technologies that save on resources and energy rather than on labour, employment is likely to increase, despite low or negative economic growth. Low employment and high wages would also help finance social security systems, as expenditures on the unemployed decrease and contributions (which are a share of wages) increase. Additionally, policies to strengthen the social welfare state would support those who lose their job during a transformation.

5 CONCLUSION

A combination of macroeconomic and sectoral policies can guide digital innovations towards supporting growth independent, sustainable and resilient economies. This guiding is necessary as digital technologies have so far not enabled green growth and there is little reason to believe they will do so automatically in the future. A change in the relative prices of resources and energy vs. labour, multiple policies for each economic sector, a strong welfare state and new actors who develop and design digital technologies are decisive changes. They would help make use of digitalization's potential to increase energy and resource efficiencies, to substitute physical goods with digital services, to reduce ICT's environmental footprint and to prevent rebound effects. These policies would also support using digital technologies for sufficiency purposes and reduce growth dependencies in the digital economies of the future.

The focus of this discussion paper has been on the relationships between digitalization, economic growth, growth dependencies and environmental sustainability. Setting this issue in the broader context of how to organize economies environmentally sustainably and socially just in the digital age would bring about numerous additional aspects and policies not covered in this report. Issues of gender equality, workers' rights, precarious jobs and fair international trade relations are only some of them. Further research and discussions need to be included to develop a comprehensive roadmap for just and sustainable economies in the digital age.

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