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Structural change and digitalization in developing countries: Conceptually linking the two transformations

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ABSTRACT

In the wake of digitalization it is increasingly debated whether developing countries can achieve economic prosperity through industrialization in the same manner as developed countries did. At the same time, developing countries have high hopes for digital technologies to drive the transformation of the economy towards prosperity. Literature on structural change views technology as one driver of employment shifts between economic sectors, but underlying mechanisms are often overlooked. Similarly, evidence on digitalization highlights its impacts on employment, but the causes and effects require further investigation. As a consequence, both strands of literature benefit from an integrated perspective on structural change and digitalization, which has largely been lacking. Hence, we pose the following research question: *What are potential linkages between structural change and digitalization?* Based on a review of the existing literature we identify the drivers of structural change as well as the economic impacts of digitalization on these drivers. We then elaborate on linkages between both strands of literature, showing that digitalization impacts the drivers of structural change in various ways. Evidence suggests that digitalization is likely to affect relative sectoral productivity, but it is questionable whether destinations of subsequent labor movements (e.g. towards traditional services) will equally benefit from technological progress. Moreover, the skill bias of digital technologies may be a risk not only for equitable income gains, but also for inter-firm linkages. Our review further implies that digitalization fosters the servicification of manufacturing and presents opportunities for developing countries to diversify in traded goods and services. However, it is contested if digitalization facilitates better positioning of developing countries in global markets, or if it narrows the scope for their participation and upgrading opportunities in global value chains due to relatively larger benefits for developed countries. We thus highlight various differences between developed and developing countries in the ability to benefit from digitalization. Future studies can empirically test the proposed linkages to reveal technology-, country- and industry-specific interactions between processes of structural change and digitalization.

1. Introduction

It is contested whether or not developing countries[1] can achieve economic prosperity through shifting from agricultural to industrial societies, i. e. through structural change, in the same manner as developed countries did. Since the 1990s, countries have reached peak manufacturing employment at incomes that are at around one third of the levels experienced before the 1990s [1]. Although there are many countries striving for income growth through structural change, there is only a very limited amount of countries that have become 'developed' in terms of GDP and per capita income [2]. In the face of uncertainty surrounding economic and technological development, policy makers in many developing countries formulate ambitious goals for digitalization and its positive impacts on accelerating structural change. For instance, many African digital policies expect digitalization to lead to productivity growth, job creation, environmentally-friendly digital transformation in industry and transforming countries into knowledge-based economies. However, the envisioned impacts of digitalization are rarely grounded in theoretical or empirical evidence [3,4] and it is still unclear how digitalization will impact structural change in the long run.

A comprehensive body of literature investigates different drivers of structural change, such as technology-related productivity growth or

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[1] We use the term "developing countries" to refer to low and middle income countries according to World Bank Classification.

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income growth [5–8]. However, current literature largely lacks an integrated perspective of studying various drivers and the connections between them at once. With regards to digitalization, a wealth of studies investigates the relationship between digital technologies and their economic impacts, e.g. on productivity [9], employment [10], or servicification of manufacturing [11]. Hence, the scientific literature on digitalization provides evidence that would be able to inform the discussion on structural change. Reversely, scientific literature on structural change, being concerned with labor movements and employment developments across sectors [7], facilitates the investigation of mechanisms through which digital technologies may impact economic development and affect changes in the structures of economic sectors. Both topics, however, are being discussed in separate strands of literature, and direct connections between structural change and digitalization are rarely being investigated. Therefore, we pose the following research question: *What are potential linkages between structural change and digitalization?*

The aim of our study is to review the literature on drivers of structural change and the economic impacts of digitalization in order to identify and discuss linkages between both research fields providing a theoretical basis for further empirical investigations. This can contribute to a better understanding of the connectedness of both fields and underpin how insights from each field may benefit from one another. We aim to overcome existing disciplinary and thematic separations in the scientific debates in order to contextualize insights on both phenomena of structural change and digitalization on a broader scope.

Besides the scientific relevance of broadening and connecting insights in both fields, there is also a policy relevance to investigating this question. Many developing countries are still at early stages of structural change and exhibit low degrees of digitalization in the economy. Awareness of potential linkages is important in order to create consistent policy measures for cross-cutting themes, applying to both industrialization and digitalization. Evidence suggests that there are gaps between the envisioned use and impacts of digital technologies in developing countries' policies and actual conditions on the ground [12]. For instance, studies suggest that policies are overly optimistic concerning the employment effects of technology [13].

Our study is structured as follows: We first highlight the context of structural change and digitalization before outlining our methodological approach. We then review the literature on the drivers of structural change as well as on the economic impacts of digitalization. This is followed by a conceptualization of potential linkages between both research fields and concluding reflections.

2. Methodological and conceptual approach

In order to integrate evidence on different phenomena and conceptualize their connections [14], we structure our paper around the investigation of evidence regarding structural change and digitalization. In this chapter, we first define and contextualize both structural change and digitalization to reflect upon trends influencing developing countries. This is followed by a description of our approach to the review of scientific evidence on both phenomena, and our approach to conceptualizing the perceived linkages which emerge when bringing both strands of literature together.

2.1. Structural change: definition and context

Structural change describes the reallocation of labor across the economic sectors, i.e. agriculture, manufacturing, and services [7]. Historical evidence on today's developed countries (e.g. Ref. [6] shows that agriculture contributed a large portion of employment opportunities at early development stages before industrialization took place. In the following stages, the share of employment in manufacturing rose, before peaking at a certain level, and then declined. Hence, manufacturing employment over time is characterized by a hump-shaped curve [15]. Whereas employment in services was relatively low in earlier development stages and at lower levels of average income, the sector absorbed an increasing amount of workers in later stages, exhibiting ongoing growth potential in terms of employment for the countries observed in North America and Europe [6].

Regarding today's developing countries, recent evidence (see Table 1) suggests that there are noticeable differences in comparison to developed countries, as well as heterogeneous trajectories of structural change between global regions [7]. Many Asian countries display similarities with developed countries from Europe and North America concerning their pathways of structural change. Relative employment in agriculture in Asia declined from 48% in 1960 to 21% in 2010. Moreover, employment in manufacturing increased between 1960 and 1990, but showed a slight decline in recent years. Simultaneously, employment in the service sector in Asian countries increased steadily and reached 56% in 2010. However, in the same time span, many African and Latin American countries deviated in their trajectories of industrialization from what was formerly observed in North America, Europe, and parts of Asia. That is, peak manufacturing employment happens at much lower levels of relative employment and at significantly earlier levels of average income, known as the phenomenon of "premature deindustrialization" [1]. Hence, there is a growing uncertainty surrounding the future of "manufacturing-led" development [16].

Furthermore, Table 1 includes additional information that hints at some characteristics of structural change in developing countries. Agriculture employed more than 70% of the African workforce in 1960, and still 51% in 2010. It has often been voiced that low agricultural productivity and high agricultural employment are two important aspects that contribute to the differences in living standards between rich and poor countries, hampering structural change [17,18]. Indeed, agricultural productivity in many African countries is the lowest when compared to other sectors, at only 35% of average productivity [19].

With regards to the service sector, employment growth needs to be looked at from a more nuanced perspective. The service sector typically grows in two waves. At lower levels of income, traditional services (e.g. lodging, housekeeping) expand, whereas at higher levels of income, modern services (e.g. banking, computing, communication) expand [20]. This is in line with trends in employment in Africa. Although the service sector reached an employment share of 37% in 2010, up from 18% in 1960, the share of workers being employed in the services that have the potential to create higher value and contribute more to economic growth has increased insignificantly, as indicated, for instance, by the low employment share in financial services (Table 1).

Still, there are varying insights regarding the prospects of the service sector in developing countries [21] and whether service industries represent opportunities to "catch-up" with developed countries [22]. There has been an increase in the global trade of services, and there are considerably less logistical barriers to trading services, as there are in the case of manufactures [22]. Services today account for 70% of global GDP and 60% of global employment [23]. Hence, it remains to be seen if industrialization continues to be the main engine of economic development, or if developing countries increasingly deviate in their paths towards economic prosperity.

2.2. Digitalization and its economic impacts: definition and context

We refer to digitalization as the proliferation and application of digital technologies in the economy. Digital technologies[2] are used for the creation, processing, transmission and analysis of digital data and include a broadening range of technologies such as broadband, cloud computing and mobile telephony [24]. Although there is no commonly agreed definition, Yoo et al. [25] propose three characteristics that

[2] We use the term „digital technologies" synonymously with the term "Information and Communication Technologies" (ICT).

Table 1
Employment shares in different regions between 1960 and 2010.

	Africa				Asia				Latin America			
	1960	1975	1990	2010	1960	1975	1990	2010	1960	1975	1990	2010
Agriculture	**73**	**66**	**62**	**51**	**48**	**43**	**32**	**21**	**47**	**34**	**25**	**14**
Industry	**9**	**13**	**14**	**13**	**19**	**23**	**26**	**23**	**21**	**24**	**24**	**22**
Mining	2	1	2	1	1	1	1	0	2	1	1	1
Manufacturing	5	8	9	7	15	18	19	15	14	15	15	12
Other industry	3	4	4	4	4	5	6	8	5	7	7	9
Services	**18**	**21**	**24**	**37**	**33**	**34**	**42**	**56**	**32**	**42**	**51**	**64**
Market services	9	10	13	23	20	21	28	37	16	21	27	40
Trade and distribution	8	9	11	20	18	18	23	28	13	17	22	31
Finacial services	1	1	1	3	2	3	5	9	3	4	5	9
Non-market services	9	10	11	13	13	13	15	18	17	21	24	25

Notes: 'Other industry' included construction and infrastructure deployment. 'Non-market services' consist of government services, and social and community services.
Source: Table adapted from Timmer et al. [7]; based on the GGDC Sector Database.

distinguish digital technologies from earlier technologies: a) the physical body of information and communication technology (ICT) is distinct from its functional logic allowing re-programmability, b) data can be transmitted through homogenized methods allowing communication between devices and networks, c) positive network externalities can arise by building on and extending existing parts of the digital system [25,26].

The degree of digitalization in a country or industry can be assessed according to various indicators. Regarding the digital development of a country, the International Telecommunication Union [27] proposes the ICT development index (IDI) [28] based on ten indicators: Fixed-telephone subscriptions, international internet bandwidth, households with a computer, households with internet access, individuals using the internet, fixed-broadband subscriptions, active mobile-broadband subscriptions, mean years of schooling, secondary gross enrolment and tertiary gross enrolment. The IDI allows assessing changes in the development of ICT across countries over time [27]. A world map of countries' IDI is shown in Fig. 1. The figure reflects a north-south divide in ICT Development, with African countries largely showing low IDI levels.

The degree of digital development is heterogeneous not only across economies but also across and within industries. Calvino et al. [30] calculate a digital intensity index for 36 industries identified by the ISIC revision 4 using 5 indicators, i. e. investment in ICT equipment and in software and databases, purchase of ICT goods and services, robot use, ICT specialists and online sales. The results are based on 2001 to 2015 data from OECD countries covered in several databases such as the OECD Annual National Accounts and EU-KLEMS. A selection of industries, their prevalence at certain development stages and their respective digital intensity are summarized in Table 2. While the primary sector, including agriculture, shows low digital intensity, various industries from the tertiary sector, i. e. services, depict high digital intensity. These are mostly modern services such as telecommunications or finance and insurance, as compared to traditional services such as accommodation and food services.

Within industries, digital technology use varies across firms depending on firms' characteristics. For instance, Forman [32] shows that more geographically dispersed firms are more likely to adopt internet technologies as they can benefit more from reductions in communication costs. Thus, firms with higher coordination costs, e. g. due to size or complex network infrastructure, may adopt new technologies more rapidly, while smaller firms with lower coordination costs may have less incentive to adopt, creating a within-industry heterogeneity of digital development.

2.3. Review approach and identification of linkages

We performed a two-step literature review on both structural change and digitalization. Various reviews compile the evidence regarding one particular driver, such as changes in productivity growth [6] or changes in the composition of demand [33]. However, given our broader interest in linking the phenomena of structural change and digitalization, we consulted recent literature that allows an assessment of multiple possible drivers. In a recent study, van Neuss [15] highlights evidence on four drivers of structural change. Whereas 1) changes in relative sectoral prices, and 2) changes in real aggregate income have already received substantial attention in the scientific debate, 3) changes in input-output linkages, and 4) international trade are also increasingly being investigated as drivers of structural change [15]. Thus, we included all four drivers in our review. We used Google Scholar to find relevant literature in English language, using search strings containing keywords and synonyms for the drivers previously identified, for instance, "((('productivity' OR 'technolog*' OR 'price*' AND ('structural change' OR 'structural transformation')) for the driver 'changes in relative sectoral prices'".

Our review on the economic impacts of digitalization builds on the identified drivers of structural change. We followed the rationale of "How do the economic impacts of digitalization influence the drivers of structural change?". In accordance with our definition of digitalization, we proceeded similar to the review of structural change, but used synonyms for both the general phenomenon of digitalization (e.g. "digital transformation") as well as specific technologies in combination with key words of the drivers of structural change. For instance, "digitalization" AND "productivity" could yield relevant studies on how digitalization impacts technology-related growth (first driver). This resulted in a set of combined keywords for all four drivers of structural change. Additionally, we included different levels of analysis in our review. Although structural change is assessed on a national level, we also deemed firm-level evidence important for an initial conceptualization of the linkages.

Once we reviewed the literature on the economic impacts of digitalization, we had an overview of the scientific evidence concerning the drivers of structural change and how these drivers are affected by digitalization. This helped us to identify recurring insights from the literature on digitalization, which was the basis for the formulated linkages. This approach is shown in Table 3 by exemplifying stylized insights from the reviews and how the formulated linkages are connected to them. As the right column indicates, we did not separate the discussion of linkages for the drivers of input-output linkages and trade. As our review will show, that is in part because not all impacts of digitalization can easily be subsumed under one specific driver of structural change. As a consequence, we combined the discussion on linkages between digitalization and the latter drivers (input-output linkages, trade). This resulted in a total of six linkages, which will be discussed in chapter 5.

Fig. 1. ITU ICT Development Index 2017.
Source: ITU ICT Development Index [29].

Table 2
Sector and development stage, industries (selection) and digital intensity.

Sector and development stage		Industry	Digital intensity
Primary		Agriculture, forestry, fishing	Low
		Mining and quarrying	Low
Secondary	early	Food beverages and tobacco	Low
		Textiles, wearing apparel and leather	Medium-low
		Wood products; publishing;	Medium-high
	middle	Coke and refined petroleum	Medium-low
		Basic metals and fabricated metals	Medium-low
	late	Rubber and plastics	Medium-low
		Chemicals	Medium-low
		Machinery and equipment	Medium-high
		Electrical machinery and apparatus	Medium-high
Tertiary		Accommodation and food service activities	Low
		Real estate	Low
		Residential care and social work activities	Medium-low
		Telecommunications	High
		IT and other information services	High
		Finance and insurance	High

Note [31]: classifies industries into early, middle and late industries if an industry's share in GDP is estimated to peak before $6500 at constant 2005 PPP, between $6500 and $15,000, and after $15,000, respectively [31].
Source: Own elaboration based on Calvino et al. [30]; UNIDO [31].

3. State of the art: drivers of structural change

In this chapter, we review literature on the four drivers of structural change described in chapter 2. The main insights regarding each separate driver of structural change are summarized in Table 4.

3.1. Changes in relative sectoral prices: 'technology-driven structural change'

One driver of structural change refers to changes in relative sectoral prices. Changes in relative sectoral prices, in turn, are the outcome of sectoral differences in the use of technology and technological progress and the subsequent change in sectoral productivities. The higher the relative sectoral productivity, the lower the relative sectoral price [34]. Baumol [35] coined the term "cost disease", and hypothesized that labor would move from technologically progressive sectors to sectors which are characterized by low degrees of technological dynamism. Empirical findings corroborate the hypothesis of this so-called 'technology-driven structural change'. Baumol et al. [36] find that the technologically stagnant service sector largely absorbed employment growth in the US between 1947 and 1976. Similarly, Herrendorf et al. [6] find that agriculture had the highest total factor productivity (TFP)[3] in many of today's advanced economies, whereas TFP in services grew the slowest. Hence, the assumption that sectoral differences in technological progress drive structural change is underpinned by evidence that labor movements occurred from technologically progressive sectors to sectors with slow growth in TFP.

Besides sectoral differences in TFP, changes in relative sectoral prices can also be caused by other factors. For instance, Caselli and Coleman [37] find that a decline in education cost increased the supply for skilled workers, leading to a decrease in the relative price of non-agricultural goods (being more skill intensive), which resulted in labor movements out of agriculture towards industry and services. Changes in relative sectoral prices can also be related to sectoral differences in the elasticity of substitution between capital and labor [38]. If labor costs increase in relation to cost of capital, the sectoral input relation between capital and

[3] Total factor productivity is defined as output per unit of labor and capital combined [132]. Cross-country differences in TFP can be explained by differences in technologies used or the efficiency with which technologies are used [133].

Table 3
Potential linkages between structural change and digitalization.

Drivers of structural change	Economic impact of digitalization	Potential Linkages between structural change and digitalization
Technology	• Positive impact on economic growth • Positive impact on labor productivity • Internationally heterogeneous productivity gains	• Raising agricultural productivity (in early development stages) • Expansion of low productivity services
Preferences	• Skill bias of digital technologies • Variegated income effects between skilled and unskilled labor • Mixed insights regarding poverty alleviation	• Contribution to the appropriation of knowledge and skills • Driving structural duality of national economies
Input-output linkages	• Vertical disintegration and trade of services	• Enabling trade diversification
Trade	• Reduction of transaction costs	• Limiting convergence prospects for developing countries

Table 4
Drivers of structural change.

Drivers of structural change	Main mechanisms	Exemplary studies
Technology	Use of technology affects productivity and thus sectoral prices.	Ngai & Pissarides [34]; Baumol [35]; Herrendorf et al. [6]; Bauml et al. [36]
	Technologically stagnant traditional service industries absorbed large parts of labor movements.	
	Rising supply of skilled labor impacts price of skill-intensive goods and services.	Caselli & Coleman [37]
	Labor movements towards sectors in which labor cannot easily be substituted by capital.	Alvarez-Cuadrado et al. [38]
Preferences	Non-homothetic demand drives the production of goods and services.	Kongsamut et al. [39]; Echevarria [40]
	Goods and services displaying high income elasticity are more intensive in skilled labor inputs.	Caron et al. [41]
Input-output linkages	Unbundling of manufacturing processes is related to increasing shares of intermediate inputs.	[42,43]; Jones [44]
	Increasing share of service in value added.	Crozet & Milet [45]; Thangavelu et al. [46]
Trade	Specialization according to comparative advantage	Baldwin [42]; Matsuyama [8]; Uy et al. [47]
	Specialization in Global Value Chain (GVC) trade.	
	Lack of diversification related to stagnating incomes.	Wade [2]; Felipe et al. [48]
	Power imbalances in GVCs negatively influence upgrading opportunities.	Cattaneo et al. [49]; Morris and Staritz [50]

labor may tilt towards the former. Against this backdrop, Herrendorf et al. [51] find the highest degree of substitutability between capital and labor in agriculture, followed by manufacturing, and the lowest elasticity of substitution in services.

3.2. Changes in real aggregate income: 'preference-driven structural change'

The second driver of structural change is changes in real aggregate income. Changes in real aggregate income lead to structural change through changes in the structure of demand (e.g. Refs. [39]). Consumption preferences are non-homothetic. That means that an individual's relative demand for different products is affected by their income [52]. With rising income, the relative demand for goods and services serving higher hierarchical needs increases [40]. As a consequence, economic activity adapts to changing needs and demands, reallocating labor accordingly. Whereas agriculture is supposed to provide goods that satisfy the more basic and urgent needs, the service sector satisfies more luxurious needs, with manufacturing being in between the two [5].

Empirical studies confirm sectoral differences in the income elasticity of goods. Comin et al. [53] find that there are differences in income elasticities across sectors which are stable over time and with increasing income. They find that the income elasticity in agriculture was lower than in manufacturing, and that the income elasticity in manufacturing was lower than in services [53]. Moreover, other studies find that goods which show a relatively strong growth in increased demand due to rising incomes – i.e. those with a high income elasticity – are more intensive in skilled labor [41]. Similarly, Buera et al. [54] find a positive association between GDP per capita growth and structural change towards sectors which are intensive in high-skill labor.

3.3. Input-output or sectoral linkages

The third driver of structural change are changes in input-output or sectoral linkages. Input-output linkages concern the composition of final and intermediate goods and services in the production process and inter- and intra-firm linkages, i.e. whether a produced good or service serves as an input for the production of another good or service.

Changes in input-output structure in recent decades were triggered by two mutually influencing processes: a) vertical disintegration and specialization, b) outsourcing and "servicification". Firstly, from 1970 onwards firms began to increasingly vertically disintegrate their production processes, i.e. labor on one product was more granularly divided into tasks and shared among various firms. Baldwin [42] calls this the "unbundling" of manufacturing processes (e.g. in automotive, aerospace, or textile manufacturing). Firms specialized in stages of the production process and competed in specific tasks rather than products [43]. For instance, within the manufacturing sector, intermediates began to make up a significant part of production, approx. half of gross total output in 35 OECD countries analyzed by Jones [44]. Specialization led to shared risks among firms but also made coordination of the production process more difficult, risky and costly [55].

Secondly, the contribution of services, particularly "modern" services such as financial and communication services (see chapter 2) to value added rose in the course of the fragmentation of production processes. This process happened on the producer and the user side. On the producer side, manufacturing process steps were outsourced and replaced by service intermediate inputs, i.e. business-to-business service trade increased [46,56]. On the user side, manufacturing companies offered additional services to customers, i.e. business-to-customer service trade increased. Function-oriented business models, i.e. product–service systems, emerged offering tangible products along with product-related services such as maintenance or product-related consultancy [57,58]. This two-sided "servicification" of manufacturing shifted employment statistics towards the services sector and led to increased interest in the role of services for structural change [15,45,59,60].

3.4. International trade

The fourth driver of structural change is trade. The role of trade in directing structural change has not been integrated in the majority of studies employing a multi-sector growth model [15]. Neo-classical economic theory suggests that in an open economy model countries specialize in those industries and sectors in which they have a comparative advantage. These national specialization processes lead to structural change [61]. For instance, Matsuyama [33] shows that a country with relatively high productivity gains in manufacturing can lessen the effect of deindustrialization in a bilateral trade scenario. Similarly, Uy et al. [47] show that a country with comparative advantage in manufacturing can have both increasing labor shares and the largest productivity gains in a scenario of trade between two countries. However, other authors argue that a lack of diversification of exports in line with specialization in sectors of high comparative advantage is one cause for stagnating incomes in middle income ranges [2]. There is evidence for stronger per capita income growth with more diversified exports, depending on the current per capita income [48,62] and choosing the "right" industries to diversify in, e.g. those which experience high growth rates in their share in world trade [63]. The general question remains as to what the "latent" comparative advantages[4] of a country are, and how far these advantages can be changed (e.g. by policy interventions) over time [2].

In the 1980s the concept of comparative advantage was challenged by the emergence of a new organizational form of international trade: Global Value Chain (GVC) trade [64]. Before the globalization of production processes, industrialized nations contributed the major part of manufacturing production, the G7 countries accounting for 52% of global manufacturing value added in 1991 [65]. Then, North-South trade began to accelerate. Firms from developed countries used managerial and manufacturing know-how in foreign markets to profit from lower wages in developing countries. Specialization began to happen on the level of particular stages of the production chain instead of on the country or sector level [66], entailing a "denationalization" of comparative advantage [65]. In this regard, Hidalgo [67] finds that the availability of capabilities (both tangible and intangible) that a country possesses determines the range of products it is being able to produce. A broader range of capabilities facilitates increasing the complexity of a country's productive structure. Globalization enables the specialization in tasks and product parts, which reduces the individual capabilities needed to fulfill these tasks in global trade [67].

However, trade gains were distributed unequally. The contribution of developing countries to manufacturing trade rose significantly for a few countries (China, Korea, India, Indonesia, Thailand, Turkey and Poland) but remained low for all other countries, i. e. less than half a percentage point rise in manufacturing value added from 1990 to 2010 according to an analysis by Baldwin and Lopez-Gonzalez [65]. Today, GVCs are concentrated in three regional clusters, sometimes called Factory Asia (China, Japan, and surrounding countries), Factory Europe (Germany, Poland, and other EU countries) and Factory North America (US, Mexico, Canada) [68]. Furthermore, the geographic concentration of GVCs reflects differences in the relative comparative advantage of regions. Whereas East Asian countries have developed comparative advantage in large parts of the electronics, textile and garments industries, comparative advantage of many sub-Saharan African countries are limited to industries producing less sophisticated products [69].

In an ideal-typical scenario, trade is expected to foster technology transfer and technological learning between firms, sectors and national economies [70]. However, today's polycentric trade order with asymmetries in trade balances and power relationships in GVCs can render technology transfer, upgrading of production and achieving positions of higher value added production more challenging for developing countries [49,50]. For instance, organization of manufacturing processes in GVCs allows international firms to keep control over intellectual property and only passively integrate local firms into labor-intensive parts of regional value chains with little or no technology and know-how transfer [2]. This is also important against the backdrop that economic development in terms of employment growth and income growth not only requires a more efficient production, but also increasing the variety and quality of output [71].

4. Economic impacts of digitalization

In this chapter, we review the literature on economic impacts of digitalization. These are summarized in Table 5.

4.1. Impact of digital technologies on productivity and growth

A plethora of studies investigate the relationship between digitalization and productivity related effects. On an aggregate level, many studies report a positive correlation between the use of or the access to digital technologies and the growth of national economies. For instance, Qiang et al. [9] find that broadband penetration substantially contributed to per capita GDP growth in 120 countries between 1980 and 2006. Similarly, Vu [72] and Farhadi et al. [79] find positive associations between ICT penetration and GDP growth. Irawan [80] corroborates these findings by emphasizing the positive relationship between ICT use and GDP growth. Moreover, Manyika et al. [81] find significant contributions of internet-enabled activities to GDP in a variety of countries. Likewise, Donou-Adonsou et al. [82] find that in sub-Saharan African countries, internet and mobile phone use are positively correlated with economic growth. Adopting an even broader perspective, Strohmaier et al. [83] investigate the relationship between socioeconomic performance and digitalization (including indicators such as access and quality of broadband) in Asian and Western countries between 2007 and 2016, and find a positive impact of digitalization on socioeconomic performance in almost all countries. Furthermore, Banga and te Velde [73] find that a doubling of internet penetration rate increases labor productivity by 10% on average between a variety of high- and low-income countries.

Numerous studies investigating the relationship between digitalization and productivity on a national scale include comparisons between developed and developing countries, high- and low-income countries, highly digitalized economies and thinly digitalized economies, questioning who benefits the most from digitalization. For instance, Farhadi et al. [79] hold that the effect of ICT penetration on GDP growth is higher in high-income countries than in low-income countries. Dedrick et al. [84] further state that the positive relationship between IT investment and productivity growth for upper-income developing countries only materialized once they increased their IT capital stocks and gained experience in the use of new technology. Vu [72] hold that the positive effect of ICT penetration on economic growth diminishes with increasing penetration rates. Qiang et al. [9] also find that a 10% increase in broadband penetration leads to a higher (1.38%) GDP increase in developing economies than in high-income economies (1.21%).

The literature on productivity effects on a firm level confirms the positive role that digitalization plays (e.g. Ref. [77]. For instance, Banga and te Velde [73] find that Kenyan firms with internet access are more productive than their offline counterparts. Likewise, a World Bank [24] report finds that labor productivity is 3.7 times higher in African firms using the internet, as opposed to firms without internet access. Moreover, the use of cloud computing was found to disproportionately foster the productivity of young firms through reduced costs of learning about IT needs [85]. Furthermore, there are gender-specific results regarding firm leadership. Whereas ICT access was found to increase business growth in microenterprises owned by women [86], computer and cell

[4] The "latent" comparative advantage applies to sectors where a country has low factor costs by international standards according to its endowments but competitiveness is undermined by transaction costs [121].

Table 5
Summary of results from empirical literature of economic impacts of digitalization on drivers of structural change.

	Productivity and growth	Employment and income	Input-output linkages	Trade
ICT indicators (infrastructure, use, skills)	Broadband penetration Inidvidual ICT use IT investment Firm-level ICT use, e. g. cloud computing and internet access	Broadband adoption & expansion IT investment	Costs for ICTs Business-to-business trade E-commerce	Costs for ICTs Internet access e-commerce Type of use of ICT (e.g. communication vs. strategic)
Main mechanisms	(Sectoral) Productivity effects in low- vs. high-income countries	Skill bias of digital technologies Variegated income effects along skill levels	Vertical disintegration Trade in services	Integration into international trade; share in value added in international trade
Exemplary studies	Qiang et al. [9]; Vu [72]; Banga and te Velde [73]	Autor et al. [74]; Sachs and Kotlikoff [75]	Murphy et al. (2014) [76],	Hjort and Poulsen [77]; Clarke and Wallsten [78]

Note: The results are clustered along the categories of drivers of structural change (productivity and growth, employment and income, input-output linkages and trade) shown in the first row. The reviewed studies largely use the ICT indicators proposed in chapter 2.2 to measure the economic impact of digitalization on each of the drivers as indicated in the second row.

phone use as well as general technology adoption was also found to increase value added per worker by 49% in female-run businesses [87].

4.2. Impact of digital technologies on employment and income

Autor et al. [74] find that in the U.S., the relative demand for college graduates persistently increased between 1940 and 1996, and that the increased demand can be explained by rapid skill upgrading. Skill upgrading has been higher in industries with higher computer use of employees, higher computer capital per worker, and higher rate of computer investment. Hence, they link computerization to changes in demand for skilled labor [74]. Following studies built on this and found that computerization leads to job polarization. That is, in many developed countries, negative correlations between computerization and employment in middle-skill occupations were found, whereas positive correlations with low- and high-skilled occupations were found [88,89]. In addition, other studies find that industries experiencing the fastest growth in ICT also experienced the fastest decrease in demand for middle-skilled labor and concomitant growth in high- and low-skilled labor [10,90]. Furthermore, Sachs and Kotlikoff [75] develop a model which shows that smart technologies substitute for unskilled labor of young adults, leading to lower wages of unskilled youth and subsequent disadvantages in acquiring skills [75].

In the developing country context, Maloney and Molina [91] find different results, indicating that in least developed countries, automation and trade have not yet led to the polarization of job markets. Still, the impact of technology adoption on employment is more likely to be positive for skilled labor and for lower middle income countries as opposed to unskilled labor and lower income countries [13]. Against this backdrop, in a study on 12 African countries [77], find that broadband increases the share of skilled jobs. Furthermore, Banga and te Velde [73] find that employment growth is not significantly different for firms with and without internet, implying that digitalization did not lead to substitution of labor in Kenya.

With regards to income effects, DiMaggio and Bonikowski [92] investigate the relationship between internet use and earnings. They find that in the U.S. between 2000 and 2001, both internet use at home and at work were positively associated with earnings growth [92]. Linking skill-biased technology with income effects in the U.S., Atasoy [93] finds that the impacts of broadband expansion on payrolls is higher in counties with larger shares of college-educated workers. Similarly, Forman et al. [94] find that investment in internet is correlated with an exacerbation of wage inequality in the U.S., because wage growth only occurred in counties which already had high wages. Furthermore, Kolko [95] finds that in the U.S., in areas in which broadband expanded more rapidly, neither greater employment increases nor greater increases in average wages were found. In a study investigating the skill complementarity of broadband in Norway, the authors find that broadband adoption positively affects wages of skilled labor, but negatively impacts the wages of unskilled labor. It is estimated that in 2007 wages were 1.8% higher for skilled workers, but 0.6% lower for unskilled workers, than they would have been without broadband expansion [96].

Studies also investigated the relationship between digitalization and poverty eradication. Kenny [97] adopts a more skeptical attitude with regards to the often proclaimed leverage effect of internet connectivity on poverty eradication. He holds that benefits of internet roll-out would be low in relation to costs, emphasizing the limited potential of poor countries to absorb these technologies and fully reap the benefits without proper knowledge and skills [97]. However, Katz and Callorda [98] find that broadband deployment in Ecuador has led to an increase in average income of 3.67%, noting the positive impacts of digitalization on poverty eradication. Heeks [99] further conceptualizes the linkages between ICT and poverty eradication and concludes that more profound impacts, such as the benefits of ICT innovation for capabilities, are likely to be limited to a small size of the poor population [99].

4.3. Impacts of digital technologies on input-output linkages

Technology can be considered a prerequisite and accelerator for what drives changes in input-output linkages, namely: vertical disintegration and specialization, outsourcing and “servicification” [15]. With respect to vertically disintegrated production processes, reductions in communication and coordination costs have enabled accounting in terms of value added and production stages rather than final products [42]. Particularly through the industrial applications of digital technologies, e.g. the industrial internet of things and automated data assessment, cost of fragmented production across firms, industries, and economies is expected to decline further [16]. This opens up opportunities for firms to move into new industrial activities.

However, this opportunity may depend on the level of sophistication of digital technologies on firm and industry level. Murphy et al. (2014) hold that positive impacts of digitalization for SMMEs in South Africa and Tanzania are rather incremental or supplemental. They do not facilitate industrial transformation, neither do they change how SMMEs access and process information (Murphy et al., 2014). A study on the tea, tourism and business processes outsourcing sectors in Kenya and Rwanda finds that the digital integration of surveyed firms is marginal. Although there are efficiency gains and better networks, digitalization of respective firms did not improve their positioning in terms of upgrading the production process and executing tasks with higher value added [100].

With respect to outsourcing and “servicification”, two trends can be

observed. On the one hand, due to decreased coordination costs it becomes easier and less risky to hire subcontractors for information-related tasks [76]. Services become more efficiently tradable online. On the other hand, there might also be a tendency to reverse servicification and outsourcing trends and vertically re-integrate production processes. Digital technologies provide individual workers with tools to execute more tasks, e.g. by operating a computer-aided manufacturing machine or interacting with suppliers and customers on platforms, increasing the variety of tasks that can be performed by a worker and potentially reducing the need to focus solely on one specific production step [55]. However, Foster and Graham [101] highlight context dependency with regards to how technology is absorbed in a specific country or sector. Focusing on the Rwandan tea industry, they find that while the introduction of digital technologies can remove intermediaries, it also forced sellers to adapt software systems, limiting their flexibility and adaptability [101].

4.4. Impacts of digital technologies on trade

Digital technologies lower cost of communication, coordination, transportation and information procurement, i. e. transaction costs which in turn facilitates trade [16,42]. For instance, Meijers (2014) finds that internet use positively affects openness to trade and that this effect is stronger in non-high income countries (Meijers, 2014). Clarke and Wallsten [78] come to a similar conclusion, finding that internet access increases the exports of developing countries to developed countries, but not the other way around [78]. Focusing on digitalization and trade in Africa, Hjort and Poulsen [77] find a positive relationship between broadband access and export in Ghana, Kenya, Mauritania, Nigeria, Senegal, and Tanzania. In a similar context, telecommunication structure, coupled with institutional quality, was also found to have a positive impact on intra-African trade efficiency, with regards to input use (Bankole et al., 2015).

A fall in transaction costs is also presumed to enable economic integration of isolated areas [102]. However, the empirical evidence is mixed, indicating geographic differences in profiting from technological opportunities. Zanello et al. (2014) find that using mobile phones to gain market information does not lead to increased selling to distant markets. Instead, the information is used to increase the bargaining power in closer markets (Zanello et al., 2014). Likewise, Hortacsu et al. (2009) find a proximity effect on selling platforms, as more distant buyers are less likely to engage in a purchase and as commerce is concentrated within city boundaries. In a survey of businesses in South Africa, Molla & Heeks [99] find that the benefits of e-commerce are limited to basic communication between firms, but do not extend to strategic effects, such as market access, or more profound changes to linkages with customers and suppliers. While platforms such as eBay are found to significantly reduce trade costs with potential benefits for firms in remote countries (Lendle et al., 2012), UNCTAD [103] emphasizes the discrepancy of e-commerce participation between developed and developing countries. Although the size of the global e-commerce market was estimated at $23 trillion, 32% of global GDP, only 5 developing countries were placed in the top 50 among a ranking of e-commerce activity in countries [103].

5. Linkages between structural change and digitalization

Our review shows that digitalization impacts structural change beyond technology-related productivity gains. We reviewed studies that highlight the relationship between digital technologies on the one hand and income, sectoral linkages, and trade on the other hand. In this chapter we link the discussions on structural change and digitalization by proposing six linkages. As our review suggested tight connections between changes in sectoral linkages and globalization, we jointly discuss the linkages regarding sectoral linkages and globalization in chapter 5.3.

5.1. Digitalization and sectoral productivity growth

5.1.1. Agricultural productivity in early development stages

One reason for structural change is inter-sectoral differences in productivity growth leading to changes in relative sectoral prices, which can be connected to the findings of relatively strong TFP growth in agriculture in early development stages in today's developed economies. By contrast, agricultural productivity in many of today's developing economies grows slower than aspired. Chapter 2.1 highlights low agricultural productivity and high agricultural employment as an inhibiting factor for structural change, especially in many African countries.

Although there is no evidence of digitalization having a stronger relative impact on the productivity of a specific sector, studies emphasize the positive effect of digital technologies on productivity in agriculture [104]. For instance, it has been shown that ICTs increased agricultural productivity in Zambia [105]. Even the use of relatively simple mobile technology has resulted in higher agricultural productivity in Kenya [106].

Moreover, it is important to understand at which stage of economic development technology-driven productivity growth will have a bigger impact on structural change as compared to the other drivers of structural change [107]. We infer that countries should be encouraged to consider the leverage effects of digitalization on agricultural productivity, especially at early stages. This is in line with the notion that countries which have low income per capita and which are still specialized in low productivity activities are more likely to experience sustained industrialization. Hence, raising productivity of low-skilled labor by using simple digital technologies [31] might help to accelerate the transition out of agriculture into other labor-intensive, better paid sectors. Focusing on relatively simple digital technologies may be fruitful given that capital costs are high in a variety of developing economies [108], rural areas tend to be disadvantaged in terms of infrastructure, and the fact that the use of more sophisticated digital technologies in agriculture has been shown to require other complementary factors for the effective use, such as knowledge and technical skills [109].

5.1.2. *Expansion* of low productivity services

A potential risk of the impact of digitalization on productivity may arise when considering other possible destinations of labor movements. Hence, we caution against outcomes of early structural change that would perpetuate the observed labor movement out of agriculture towards low productivity services. This may have both general as well as digitalization specific downsides. We have highlighted the growth of traditional services at early development stages, and the growth of modern services at higher income levels. The critical issue is that traditional services are neither tradable nor technologically dynamic [110]. This is underpinned by the low digital intensity of traditional services (see chapter 2.2). As a consequence, the positive impact of digitalization in one sector (agriculture) could attenuate its impact in another sector (traditional service industries), because it cancels out both the productivity impact (due to technological stagnancy of traditional service industries) and the globalization effect (due to low tradedness of traditional services). This can be underscored by findings which show that labor productivity grew the slowest in services in all but one out of 29 countries studied by [111]. Moreover, the low tradedness of traditional services is evidenced by the fact that domestic demand was the main reason for the early growth of service sectors in many African countries. Thus, growth enhancing structural change was accompanied by declining labor productivity growth in non-agricultural industries of these countries [19].

Still, the plurality of insights regarding the role of services in economic transformation [21] need to be kept in mind. Hence, we agree that policy needs to ensure that developing countries do not try to be a "one-trick-pony" by focusing on either manufacturing or service sector development [22] and instead pursue productivity growth in different

sectors and industries.

5.2. Digitalization and the skill required to perform work

5.2.1. Appropriation of knowledge and skills

The scientific debate suggests a confirmation of the skill bias of digital technologies and thus emphasizes the knowledge and skill requirements to benefit from their use. Hence, it is doubtful whether there are major opportunities of digital technologies with regards to human capital and structural change in developing economies, especially at early stages of development. Still, we believe it is important to not just view the rising skill requirements that come with the introduction of digital technologies, but to consider the possibility that they may also help to attain higher levels of education and job-related skills.

The evidence of the relationship between digital technologies and appropriation of skills is mixed [102]. Some positive connections can be drawn. For instance, the introduction of digital technologies also leads to an increased likelihood of on-the-job training from which all workers may benefit, regardless of their skill level [77]. Moreover, the impacts of digital technologies are not limited to on-the-job learning. Computerization is also positively associated with (ICT) skill improvements through private use [92,112]. However, it should be kept in mind that digtal technologies are more suitable for certain types of information exchange and knowledge appropriation. Whereas codified data-based knowledge can be transferred more easily, acquiring tacit knowledge still requires human interaction [113]. The relative benefit of digital technologies then largely depends on the type of tasks fulfilled and the requirements for certain types of knowledge.

Given the general ambiguity regarding the income effects of digital technologies as well as the differential gains found between workers due to their skill level, we argue that changes in the composition of demand for different goods and services driven by rising income (i.e. non-homothetic preferences) may not be the important mechanism trough which digitalization can induce structural change in early stages of economic development. Instead, we argue that it is more likely that the effects of digital technologies on human capital pay off in later stages of development. This represents the opportunity of reaping relatively large benefits at income levels at which the importance of skill-intensive service industries and the demand for highly skilled labor starts to accelerate [114].

5.2.2. Structural duality of developing economies

Considering the impact of digital technologies on human capital formation also raises the question of relative gains. We have prominently discussed this with regards to skill-biased technological change and subsequent income effects, but also highlighted the distributional effects of digitalization concerning productivity and trade. Elaborating on this cross-cutting issue seems especially fruitful against the backdrop of structural duality within developing economies. In a traditional sense, structural dualism describes the situation in which a modern sector which is highly productive, innovative, technologically dynamic, and a traditional sector with the opposite characteristics exist [115]. This is still relevant given that it resembles the situation in many developing countries today [19]. There is also a duality within industries in many developing countries. Whereas a lot of firms operate at low levels of productivity, there are a few larger firms which are highly productive and more capable of effectively using new (digital) technologies [116]. This is not least important for structural change because smaller firms have created large parts of employment opportunities both in developing and developed countries, especially in manufacturing [117].

This notion of structural dualism can be broadened by considering the impacts of skill-biased technological change, especially with regards to digitalization. It is evident that effective appropriation of digital technologies requires human capital and organizational assets such as innovative capacity [102,118]. Studies highlight the consequences when these requirements are lacking. For instance, an increasing amount of firms lamenting an inadequately skilled workforce indicates an increasing skills mismatch in Kenya [73]. Regarding trade in services, Foster [100] and Mann et al. [119] note that a skills gap concerning digitalization and other technical skills weakens the links into global markets and reduces the competitiveness on digital work platforms.

We argue that the deepening of these dualistic structures due to digitalization both within and across sectors of developing economies can be of relevance in terms of structural change. For instance, it has been acknowledged that dualistic structures do not promote trickle-down in terms of income [52]. However, the widening of the gap regarding the beneficial effects of technological progress between firms and industries can have more impacts. We raise the issue of what happens when there is a small amount of firms being able to quickly move up the ladder of value added activities, while the disadvantage of the majority of firms to achieve productivity (and income) convergence increases. Arguably, this will weaken the linkages between firms within and across industries, also regarding spillovers and learning opportunities, an aspect that is positively associated with successful industrialization in Asian countries [120].

5.3. Digitalization, input-output changes and globalization

5.3.1. Increase of diversification in trade

Jointly assessing the effects of digitalization on input-output-changes and trade, we suggest that a linkage between structural change and digitalization lies in the increasing possibility to diversify in tasks, products, and sectors. We argued that reduced transaction cost through digitalization is a driver of input-output changes, i.e. how industrial activity is organized (firm level) and labor allocated to (manufacturing and services) sectors on the country level. Moreover, input-output changes enabled by digitalization led to changes in trade patterns with firms competing in tasks internationally and being able to coordinate fragmented production processes through cheap information and communication technology. Hence, input-output-changes enabled by digitalization were a prerequisite for the emergence of GVC trade.

We argue that digitalization is positively linked to the creation of intermediate input and services trade, particularly modern services trade. Some of the emerging tasks, products and services could be provided by developing countries, e.g. via online trading platforms and mobile connectivity. This may help overcoming a lack of diversification in trade in developing countries, having been identified as one reason for stagnating incomes. For instance, “telecommunications, computer and information services” and “other business services”, identified as “potentially ICT-enabled services” by the WTO, experienced the highest growth rates in global trade between 2005 and 2016 [23]. The share of developing countries’ services imports and exports of total trade also experienced an increase by roughly 11 and 8% points to 39,4% and 32%, respectively, from 2005 to 2015 [70].

Moreover, we suggest that digitalization might facilitate harnessing latent comparative advantages to diversify trade. Digitalization reduces transaction costs which have been identified as one impeding factor to exploiting latent comparative advantages. Hence, it might be valuable for developing countries to re-assess latent comparative advantages related to digitalization-enabled tasks, products and sectors which exhibit higher growth rates compared to traditional tasks, products and sectors (e.g. due to network and scale effects). Technological upgrading might require targeted governmental measures such as training programs, infant industry protection and the manipulation of relative factor prices under the assumption that markets fail to provide appropriate (infrastructure) conditions [121,122]. For instance, the factor endowment of a young, English-speaking workforce in the Philippines and India was supplemented by government investment in education and training enabling the development of a competitive software industry [123].

However, there are several limits to applying these strategies in order to diversify trade. Hopes for professional business services outsourcing

to developing countries raised in the early 2000s [124,125] did not materialize for many developing countries. Participation in services trade concentrated largely on only a handful of developing countries (China, Hong Kong, India and the Philippines) [126]. With respect to new forms of (online) trade, there is a lack of globally competitive internet companies from developing countries. For instance, only 2 out of the 100 most valuable online platforms worldwide are from Africa [127]. Unless infrastructural (electric, broadband, physical transport) weaknesses are overcome, it seems unlikely for developing countries to gain major market shares in global (online) service provision.

5.3.2. Limited convergence prospects for developing countries

Due to the discussed limitations, we argue that developing countries profit relatively less from digitalization in manufacturing and services trade compared to developed countries. This might hinder convergence of economic development prospects. Although the positive impact of digitalization in trade in services is strong [23] its positive impact on income convergence between developing countries and developed countries and the positioning of developing countries in international trade has been limited so far [128]. We identify three main reasons as to why developed countries profit relatively more from digitalization: Firstly, developed countries are on average relatively more endowed with high-skilled labor, capital and intangible assets whose productivity increases relatively more than for land, low-skilled labour, energy and material. Thus, following comparative advantage, while labor intensive manufacturing services can more easily be outsourced overseas, technology intensive services tend to be provided domestically, depending on infrastructure, skilled labor supply, intellectual property protection and connectivity [46].

Additionally, ongoing digitalization is likely to reduce costs of automation of low-skilled, labor-intensive routine tasks in manufacturing industries in high-income countries. This might reduce the incentive to outsource labor-intensive tasks and carries the potential benefit for developed countries to produce close to the domestic markets. In effect, high-wage locations maintain and, in some parts, increase competitiveness despite skill premia for workers.

Secondly, with ongoing automation and digitalization relative wages of unskilled workers are affected negatively and employment intensity of trade decreases. Reductions in trade costs have been shown to have a negative impact on manufacturing employment (Cravino & Sotelo, 2019). One reason could be that developing countries compete globally for labor-intensive industries with in part increasing workforces, driving prices (wages) down. Additionally, less employment is created in developing countries per unit of value added in trade and thus outsourced production facilities are less likely to create high amounts of low-skill employment in developing countries.

Thirdly, technology transfer and domestic learning as well as power relations in GVCs can be shaped by technology-leader companies in developed countries to the disadvantage of developing countries. Companies with high financial resources, able to adapt to digital technologies more easily, can "cherry pick'" high value added tasks/production stages, for instance R&D and after sales activities, and choose low value added tasks to be performed in developing countries. Durand and Milberg [129] speak of lead firms building “intellectual monopolies”. Technology transfer and domestic learning is impeded in such a setting with specific technology intensive task not being embedded in the national (industrial) context. Furthermore, digitalization entails new technical standards introducing barriers to trade integration of new companies. Companies might experience technological lock-in once investments are made.

In conclusion, digitalization increases the quantity of trade in developing countries but does not raise the quality of trade enough for a catch-up: Thin digital integration of firms may reinforce a “technology-bias” in favor of developed countries, limiting learning opportunities and upgrading capabilities for developing countries. Industrial policy measures could target industries in which countries with similar endowments have made good experiences but should avoid trying to leapfrog into excessively capital- and knowledge-intensive industries at early development stages where there is a high risk of skill-mismatch [130,131]. Moreover, Imbs et al. [61] argue that developing countries specialize according to regional, rather than global comparative advantage, because in earlier development stages regions within developing countries tend to be more heterogeneously economically developed. Exploring regional advantages such as a shared language and geographic proximity [23] could help creating regional niches in global trade.

6. Concluding remarks

The literature on structural change recognizes a variety of reasons for the reallocation of labor across sectors. Whereas the impacts of technology-driven changes in relative sectoral prices and changes in real aggregate income have been investigated extensively, the role of changes in sectoral linkages and the role of trade received less attention [15]. Thus, there is still a lot to be learnt about the evolving nature of structural change.

With the ongoing digitalization of national economies around the world, the socio-economic impacts of applying digital technologies have attracted substantial interest in the scientific debate. Several mechanisms through which digitalization may impact economic processes and structures have been discussed. More specifically, it can be shown that digitalization influences the process of structural change not only through its contribution to technology-driven productivity increases but also through its impact on employment and income, input-output linkages, and on trade.

Although there is a lot of evidence that suggests linkages between digitalization and structural change, this is often not done in an explicit manner. However, valuable insights can be gained by connecting evidence on both topics. For instance, even though digitalization can foster agricultural productivity in early stages of economic development, it is also worth considering that technology-driven structural change can cause labor movements towards industries that are not technologically dynamic [110]. Moreover, the skill-bias of digital technologies casts doubt upon their widespread effect on structural change caused by rising incomes.

Instead, potential outcomes of unevenly distributed benefits from digitalization might reinforce, given that firm and industry linkages and learning opportunities arising from digitalization are non-linear and path-dependent. Furthermore, reduced transaction costs related to digitalization enable fragmented production and present the opportunity for countries to diversify through the increasing tradedness of services and the servicification of manufacturing. However, evidence also suggests that even though digitalization is positively associated with the quantity of trade, it does not necessarily increase the quality of trade with regards to the tasks that developing countries can fulfill in GVCs. Differences in the ability to benefit from digitalization between developed and developing countries can thus result in rising barriers for entering and upgrading in global trade amplifying the technology bias.

Our paper shows that an integrated perspective on structural change and digitalization can be fruitful for future studies, especially for empirically testing the described phenomena. Whereas technology has been traditionally regarded as one specific driver of structural change, the review of the economic impacts of digitalization serves as an example to highlight the connectedness to other drivers of structural change. Likewise, although studies on digital technologies investigate their impacts on employment, insights on structural change offer explanations regarding the possible mechanisms through which this may occur, such as changing trade patterns and power relations.

Current trends show that the digitalization of economic activities as well as structural change happen very differently across and within regions. Thus, having chosen a broad scope of investigation in this paper we necessarily omitted differentiations in the specific interactions

between processes of structural change and digitalization. Rapid technological advancements and the variety of application contexts of digital technologies need to be investigated in detail. Further theoretical and empirical contributions, e.g. regarding the effect of policies fostering the use of specific digital technologies in an industry field to accelerate structural change in a given country context, can yield specific policy advice on whether digitalization is expected to lead to the expected employment effects. However, we provided a starting point for the investigation of linkages between structural change and digitalization. Given the uncertainty of industrialization in developing countries and their endeavors to utilize digital technologies to transform the economy, it is a crucial point in time to investigate associated risks and opportunities.

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