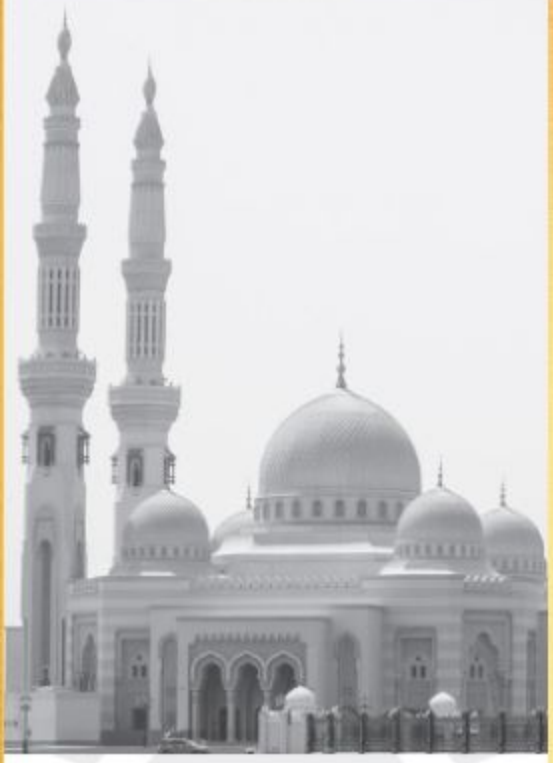
AL QASIMIA UNIVERSITY JOURNAL OF ISLAMIC ECONOMICS



Bi-annual Refereed Journal

Vol.3, No. 1
Dhu al Qadah 1444 A.H. / June 2023 A.D.

ISSN: 2788-5542

AQU Journal of Islamic Economics, Vol. 3 No. 1, pp.33-48 (June 2023)
DOI:10.52747/aqujie.3.1.230
E-ISSN 2788-5550 / ISSN 2788-5542

دور التكنولوجيا الرقمية في تحويل الاقتصاد الخطي إلى الاقتصاد الدائري

ROLE OF DIGITAL TECHNOLOGY IN TRANSFORMING LINEAR TO CIRCULAR ECONOMY[1]

ناظم شاه شيرازي

جامعة حمد بن خليفة، قطر

Nazim Shah Shirazi
Hamad Bin Khalifa University, Qatar

الملخص

لم يعد نموذج الاقتصاد الخطي قابلاً للتطبيق، فهو يُثقل كاهل الأرض، ويستنزف الموارد بما يتجاوز قدرة الطبيعة. ويكمن الحل في التحول إلى الاقتصاد الدائري، الذي يحسن استخدام الموارد، ويضمن مستقبلاً مستداماً للأجيال المقبلة. وتلعب التكنولوجيا الرقمية دوراً حاسماً في تمكين الدائرية والاستدامة؛ حيث تربط منصات المشاركة بين مقدمي الخدمات والمستخدمين، مما يحقق أقصى استفادة من الموارد، دون الحاجة إلى موارد إضافية. إذ تتيح التطورات التكنولوجية فرزًا وصيانةً وإعادة تدوير فعالة للمنتجات. ومع ذلك، يتطلب تحقيق التبني على نطاق واسع معالجة الحواجز من خلال التوعية العالمية، والتعليم، والقوانين المعينة، والمؤسسات، ودعم الحكومة.

Abstract

The linear economy model is no longer viable, overburdening the earth and depleting resources beyond nature's capacity. The solution lies in transitioning to a circular economy, which optimizes resource use and ensures a sustainable future for future generations. Digital technology plays a crucial role in enabling circularity and sustainability. Sharing platforms connect service providers and users, maximizing resource utilization without the need for additional resources. Technological

[1] Article received: April 2023; article accepted: May 2023.

advancements enable efficient sorting, maintenance, and recycling of products. However, achieving widespread adoption requires addressing barriers through global awareness, education, supportive laws, institutions, and government backing.

الكلمات الدالة: التكنولوجيا الرقمية، الاقتصاد الخطي، الاقتصاد الدائري

Keywords: Digital technology, linear economy, circular economy

1.0 Introduction

The global economy has long been characterized by a linear model of production and consumption, where resources are extracted, processed, and eventually discarded as waste. However, this linear economy model is inherently unsustainable, leading to resource depletion, environmental degradation, and social inequalities. In response to these challenges, there has been a growing recognition of the need to transition towards a circular economy, which aims to decouple economic growth from resource consumption and waste generation. The circular economy is an alternative economic model that seeks to maximize the value of products, materials, and resources by circulating them for as long as possible. It emphasizes the reduction, reuse, and recycling of materials and the regeneration of natural systems. Adopting a circular economy approach can create a more sustainable and resilient economic system that minimizes waste, reduces environmental impact (McKinsey & Company,2016), and promotes social and economic inclusivity.

Digital technology has emerged as a critical enabler in transitioning from a linear to a circular economy. CE transition goes hand-in-hand with digitalization transformation. The rapid advancements in digitalization, including the Internet of Things (IoT), artificial intelligence (AI), blockchain, and data analytics, have revolutionized how we produce, consume, and manage resources. These technologies offer unprecedented opportunities to optimize resource utilization, improve supply chain efficiency, and foster stakeholder collaboration (Hoosain, M. S., Paul, B. S., & Ramakrishna, S.,2020).

One of the key contributions of digital technology to the circular economy lies in its ability to enable more efficient resource management and utilization. IoT devices, for instance, can be deployed to monitor and track the usage of resources in real time, allowing for better decision-making and resource allocation. This real-time data can help identify inefficiencies, optimize processes, and reduce waste throughout the value chain. Additionally, AI and data analytics can analyze vast amounts of data to uncover patterns, identify opportunities for resource recovery, and enable predictive maintenance, thereby maximizing the lifespan and value of products and materials (see Lacy and Rutqvist, 2015; Hoosain, M. S., Paul, B. S., & Ramakrishna, S.,2020).

Furthermore, digital technology facilitates the creation of interconnected ecosystems and platforms that encourage collaboration and resource sharing. Through digital platforms, businesses, organizations, and individuals can connect and exchange underutilized resources, enabling the development of new business models such as sharing economies and product-as-a-service models. These platforms promote resource efficiency and reduce overall consumption, as they enable access to goods and services rather than ownership. With its decentralized and transparent nature, blockchain technology can enhance trust and traceability in supply chains, ensuring the authenticity and quality of products throughout their lifecycle.

Moreover, digital technology is crucial in raising consumer awareness and driving behavioural change. Mobile applications, social media platforms, and online marketplaces provide consumers with information on the environmental impact of products and services, enabling them to make more informed choices. Digital platforms can also empower consumers to participate in circular economy initiatives, such as recycling programs or product take-back schemes, by providing convenient and accessible channels for engagement. Nevertheless, while the role of digital technology in advancing the circular economy is promising, several challenges and considerations must be addressed. These include data privacy and security issues, the digital divide, e-waste management, and the need for policy and

regulatory frameworks to support integrating digital technologies into circular economy strategies (see Chauhan et al. (2022).

In short, transitioning from a linear economy to a circular economy is essential for achieving sustainability and resilience in resource constraints and environmental degradation. Digital technology offers transformative solutions to accelerate this transition by optimizing resource utilization, fostering collaboration, and driving behavioral change. However, it is crucial to address the challenges and ensure that digitalization is implemented in a way that is inclusive, secure, and aligned with the principles of the circular economy. By harnessing the potential of digital technology, we can unlock new opportunities and pave the way toward a more sustainable and regenerative economy.

In this paper, we opted for a simple methodology involving a literature review of relevant research, providing examples from real case studies and integrating current trends and insights on circular economy practices and digital technology advancements.

The rest of the paper is organized as follows. The following section will discuss the need to shift the linear economy to a circular economy. The third section will highlight the role of digital technology in transforming the circular economy, and the fourth section will conclude the paper.

2.0 Literature Review

The interconnectedness of the entire universe is evident through the example of COVID-19. This phenomenon highlights the importance of sustainability, which is a global concern. Consequently, numerous writings and discussions on various platforms delve into environmental challenges, the consequences of population growth, ecosystem destruction, resource utilization, and the well-being of future generations.

Human exploration and economic activities have a profound impact on the environment. Any detrimental effect on the environment hinders its ability to meet human consumption needs. The Living

Planet report (2020) identifies the top five risks for the upcoming year, all linked to environmental issues such as climate change, biodiversity loss, and extreme weather events. The manifestation of these risks could lead to significant disruptions that are challenging to manage, as the world's economic activity relies on nature and its resources. The report for 2022 further reveals a staggering 69% decline in monitored wildlife populations between 1970 and 2018, with Latin America experiencing a particularly pronounced decline of 94%. Additionally, the report highlights a sharp decrease in monitored freshwater species, with an 83% decline.

The world's population is steadily increasing, posing further challenges to sustainability. The United Nations projects a rise from 7.6 billion to 8.6 billion people by 2030 and 9.8 billion by 2050. As the population expands, the demand for goods and services will surge, necessitating increased resource exploitation for manufacturing and service delivery. Eventually, non-renewable resources will be depleted, and renewable resources will not replenish quickly enough to meet global needs. Consequently, international prices will rise, impacting demand and compromising the economy, ultimately affecting the well-being of future populations. Renowned naturalist Attenborough (2020) emphasizes the unsustainability of activities that damage ecosystems, warning that the accumulation of such damage can lead to the collapse of the entire system.

Climate change poses a significant threat to economies. Unsustainable human activities contribute to greenhouse gas emissions, intensifying climate change risk and natural disasters. These disasters, in turn, jeopardize social well-being by destroying infrastructure, disrupting supply chains, threatening food security, and pushing more people into poverty. The ramifications of such events are extensive, and the recovery process is often protracted.

The prosperity of the agricultural sector is crucial for human survival as it provides food and represents the livelihood of 65% of the global poor. Unfortunately, this sector is also highly vulnerable to climate-related risks.

The generation of waste without sustainable disposal practices is another pressing issue. According to the World Bank's 2018 report, only 33% of the 2 billion tonnes of municipal waste generated globally in 2016 was disposed of in an environmentally friendly manner. Furthermore, waste generation is expected to increase to 3.4 billion tonnes by 2050, surpassing population growth. Inadequate solid waste management negatively impacts the environment and human health and disproportionately affects low-income communities by increasing disease rates. It pollutes the air and water, disrupts biodiversity, accelerates climate change through greenhouse gas emissions, and incurs significant costs for management. Global waste management expenses are estimated to reach $375 billion by 2025.

The socioeconomic and environmental challenges faced by the world today, and potentially in the future, stem from the linear paradigm. The linear economy focuses on short-term resource usage without considering its long-term preservation. It follows a "take, make, and waste" model, where resources are extracted, converted into products, consumed, and discarded at the end of their lifecycle. This linear approach undermines the well-being of future generations.

Currently, the rate of resource consumption is alarming, resulting in higher prices, reduced demand, and a shrinking economy, ultimately compromising the welfare of future generations. The Global Footprint Network's 2019 report estimates that the planet exhausts its resources within 209 days each year, while it takes 365 days for the earth to regenerate them.

A shift from a linear to a circular economy is necessary to ensure the ability to meet the needs of present and future generations without compromising resources. This transition addresses population growth, environmental concerns, and social inequalities. Embracing a circular economy revolutionizes production and consumption practices, reorganizes the relationship between markets, customers, and natural resources, and presents significant opportunities for companies to develop competitive advantages through innovative business models, digital technologies, engineering, and supporting infrastructure.

Embracing circularity is a fundamental shift toward sustainable development.

In the early 1970s, stakeholders recognized the need to address environmental concerns and promote sustainable consumption practices. They advocated for reducing the consumption of virgin materials, reusing existing products to extend their lifecycle, and recycling waste to prevent it from ending up in landfills or nature. The motto "Reduce, Reuse, Recycle" became popular in promoting sustainable manufacturing, consumption, and disposal. Moreover, the concept of ownership shifted, especially after the 2008 financial crisis, leading to increased utilization of unused assets for economic benefits (Ravenelle, 2019)). This gave rise to the sharing economy, which combines technology and sharing principles to create a new model for sustainable value creation. The subsequent section of this discussion will explore the sharing economy in greater detail.

3.0 The Role of Digital Finance in Enabling the Circular Economy

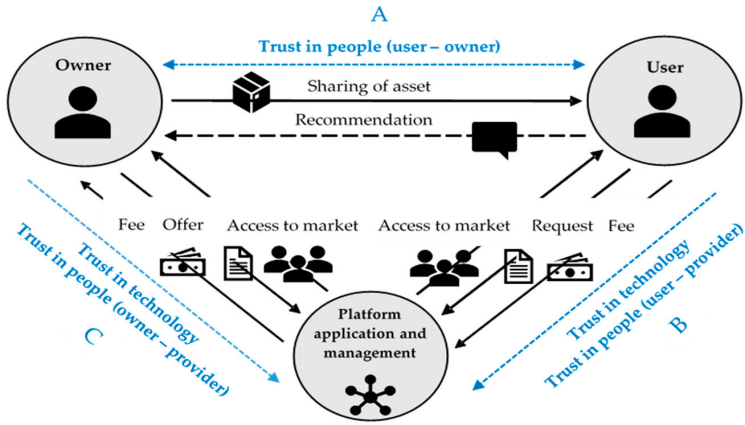
Resource constraints, technological development, and socioeconomic opportunity are the driving force for the circular economy. Digital financial services help businesses and consumers by making operations and transactions easier and helping developing economies grow over time. By increasing productivity, efficiency, and cost savings, digital financial services can help reduce environmental impact; reduce resources, chemicals, and waste; and keep track of, analyze, and measure progress. Digital technology is significant in the circular economy's Reduce, Reuse, Recycle, and Sharing models.

3.1 The Sharing Model and Sharing Platform

The foundation of this innovative economic model revolved around the idea of "consumer to consumer," also referred to as "peer-to-peer," "business to consumer," or "business to business" interactions that allow access to services and resources in a sharing context. These transactions can take on a formal or informal nature. Informal arrangements involve close-knit networks of individuals sharing assets

and providing services to one another either for a fee or free of charge. In the case of formal sharing relationships, an intermediary company facilitates the sharing process through an organizational and technological framework.

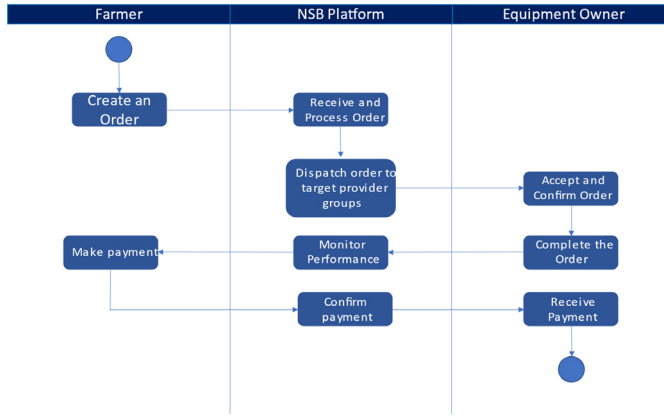
The sharing platform serves as a nexus, bringing together service providers (owners of the assets) and service users, thereby creating a new source of income. This sharing business model enhances resource utilization by enabling the use of assets without requiring additional resources, thereby fostering a circular economy. Digital technology, facilitated by the internet, empowers the service enablers or sharing platforms to provide the necessary infrastructure for these sharing services. Customers, such as travelers, guests, or consumers, place service orders through mobile applications and platforms like Uber, Cream, Airbnb, and Luxe, then connect with the owners who can fulfill these service requirements, such as car/driver, host, or valet (see Figure 1). This entire process is completed swiftly through the mobile application. The platform or service enablers receive a commission for facilitating the sharing process. In China, local online ridesharing services like Didi and Shenzhou have emerged, following a similar pattern to Uber (Shouxiang et al., 2021).



Source: Wagner Natalia et al. (2019)

Figure 1: Sharing Economy

In China, an agriculture machinery-sharing platform called NSB connects numerous small farmers and owners of agricultural machinery for economically efficient cultivation. Farmers requiring various farm services such as "sowing, fertilizing, plant protection, harvesting, pruning, picking, primary processing, and transportation" can order these services. On the other hand, agriculture machinery owners can receive these orders and provide the required machinery and services to fulfil the farmers' needs (Shouxiang et al., 2021). A visual representation of the sharing process within NSB can be observed in Figure 2.



Source: Shouxiang Qiu, Zhejing Xu, and Babita Bhatt (2021)

Figure 2: The Case of NSB

Sharing models is now a universal trend accepted generally and successfully. Sharing in many settings worldwide allows others access to material and non-material items and services, including food, clothes, tools, and services, primarily labor and knowledge" (Widlok, 2016). The sharing economy is becoming popular and increasing rapidly. In the USA, PwC (2015a) underlines the possibility for growth in the sharing economy among the five important sharing

sectors "automotive, hospitality, finance, staffing, and media streaming." About $14 billion in revenue was made in 2013 and was expected to increase to $335 billion in 2025. These projections are based on the fast growth of Uber and Airbnb as indicative (Niam and Shamika,2017).

China has prioritized the sharing economy (Larmer, B. 2017) and has been recognized in the 13 Five-Year Plan (2016–2020) as an encouraging aspect of the new digital, service-based economy. Consequently, the Chinese sharing economy sector exceeded $ 229 billion. In 2015. In 2016, the sharing economy reported more than $500 billion in transactions involving approximately 600 million people. The government predicted it to be 10 per cent of its GDP by 2020 and 20 per cent by 2025 (Zhong, N. & Zheng, Y. 2017).

In its special report of October 2016, McKinsey & Company mentioned that in Europe, adopting the circular economy and business models will provide an opening to boost the productivity of resources, cut costs, reduce dependence on them, less waste, and increase employment and growth. It reported the expected impacts of the digital and technology revolution on many sectors. For example, driving average cost per car-kilometer could drop by up to 75 per cent due to "car sharing, autonomous and driverless driving, electric vehicles (EVs), and better materials." Due to precision agriculture, the efficiency of fertilizers and water can improve by 20 to 30 per cent in the food sector. Furthermore, with no tillage, farming could reduce inputs and machinery costs by about 75 per cent. Similarly, in the construction sector, building costs could be reduced by 50 per cent by the industrial and modular process, and with passive houses, energy consumption could decrease by 90 per cent. However, it all depends on the integration of new technology effectively and meeting other regional or zoning requirements.

Regarding "growth within the model," it would generate annual benefits of about €1.8 trillion by 2030. The CE will increase welfare by increasing the European household disposable income, GDP, and employment. By 2030, CE, compared to the current development path, the household disposable income will be higher by

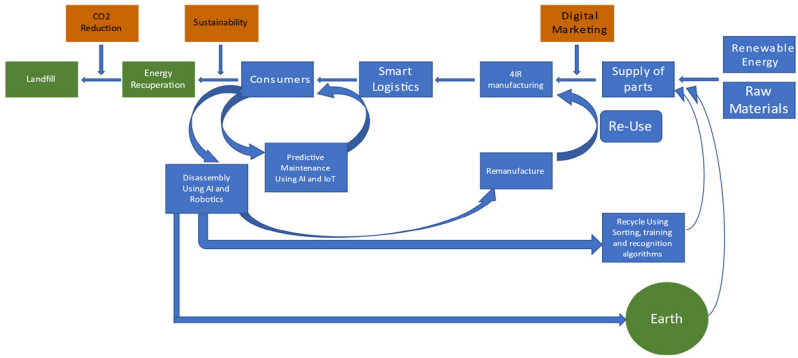
about 11 percentage points and GDP by 7 percentage points, positively impacting employment. The report further revealed that following the principle of CE, decoupling economic growth from resource use would benefit the environment, raising competitiveness and resilience. Following the principles of CE, the carbon-dioxide emissions would drop by about 48 per cent from 2012 levels by 2030 and 83 per cent by 2050 in the three sectors mentioned above. This reduction would come from using electric, shared, and autonomous vehicles; a reduction in wastage of food; regenerative and healthy food chains; passive houses; urban planning; and renewable energy.

3.1 The Use of Digital Technology in Reuse and Recycling for Remanufacturing

The end of the life cycle of the products is a big challenge worldwide. But due to technology, the end-of-life cycle products are reused, recycled, and remanufactured. Some companies have managed to take back the discarded products and use them for upgradation or remanufacture after disassembling these used products. Disassembling is also needed for repair and maintenance. Desired components, parts, and materials from used products are extracted and separated (S. Parsa and Saadat,2019,2003). This is a very labour-intensive job. However, due to the development of Robotic technologies over the last few decades, disassembly can be achieved with minimal human intervention or collaboration between machines and human operators. Combining robotics with human activities effectively increases productivity (Gerbers et al., 2018). Once the used products are disassembled, some components are recycled using sorting, training, and recognition algorithms. Some parts are remanufactured and used as input for the finished goods.

Digital technology like Artificial intelligence (AI) and the Internet Of Things (IoT) is also used for predictive maintenance (Figure 3). In the past, producers used to sell their equipment and products to users and did not know how the tool was used. The users used to inform the producers regarding any fault in the tool if it

occurred during the use of the equipment. That leads to a lot of loss to the user due to downtime or waiting for the repair of the tool. The IoT-connected equipment can easily be monitored, and identifying faults in equipment can be done by remote monitoring. Changes in the parameters, like vibration or temperature, indicate a failure is developing. As a result, the manufacturer can do timely maintenance to save the breaking of the tool and its use. For example, Caterpillar uses digital technology in its "Product Link" interface to track components and machinery locations with the dealer or the customers. The wireless system helps manage preventive maintenance to preserve the equipment's value (Lacy and Rutqvist, 2015).



Source: Hoosain, M. S., Paul, B. S., & Ramakrishna, S. (2020)

Figure 3: Use of Technology in Circular Economy

4.0 Conclusion

The linear economy model of take make and waste is no more viable. It has overburdened the earth, and today we are using a stock of resources more than what nature can produce in a year. Human activities are responsible for all that waste and destruction. The world has to move very fast towards a circular economy to save the earth, use the resources optimally and provide living standards for the present and future generations. The resource constraints, digital technological

development, and socioeconomic opportunities provided the driving force for the shift toward the circular economy. However, it depends on the change in the thinking behaviour of the people to move towards CE. The use of digital technology can make it possible to reap all the benefits of circularity and sustainability. This is the technology that connects all stakeholders for their help and the benefit of the earth.

The sharing platform brings together the service providers (owners) and the service users, thus creating a new income stream. The sharing business model increases resource utilization and the use of assets without additional resources. The service enablers or sharing platforms through the digital technology facilitated by the internet perform the sharing services. Technological advancement enabled the sorting end of life products for reuse, recycling, and remanufacturing. Digital technology facilitates an early warning system for the maintenance of the tools, whether in the hands of dealers or employed in the field. The world can benefit from the accelerated spread of adoption. However, this requires the removal of the barriers in transforming the linear economy to the circular economy, which needs awareness and education programs at the global level, favourable laws, supportive institutions, and the full support of the governments at the country level.

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