UNIVERSIDAD DEL CEMA
Buenos Aires
Argentina

Serie
DOCUMENTOS DE TRABAJO

Área: Economía

UNDERSTANDING THE CIRCULAR ECONOMY: OVERVIEW OF THE ISSUES

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Septiembre 2021
Nro. 809

https://ucema.edu.ar/publicaciones/doc_trabajo.php
UCEMA: Av. Córdoba 374, C1054AAP Buenos Aires, Argentina
ISSN 1668-4575 (impreso), ISSN 1668-4583 (en línea)
Editor: Jorge M. Streb; asistente editorial: Valeria Dowding <jae@cema.edu.ar>

Understanding the Circular Economy: Overview of the Issues

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Abstract

This essay tries to synthesize a recent discussion on circular economics, aiming to clarify the concept, its relationship with the notion of "decoupling", and how technology, business, and economic policy influence it. In essence, circular economy means turning waste into something valuable. The concept encompasses some previous notions, such as bioeconomy. Technology of Fourth Industrial Revolution helps to decoupling growth from resource use. The reach of decoupling is disparate between growth optimistic and growth pessimistic thinkers. Business models comprehended in circular economy vary from eliminating waste, maximizing use extension of capital and durable consumption goods, until recovering materials and energy from process and products, turning goods into services by sharing, and replacing property by lease or pay-per-use models. Policies to induce or incentivize circular economy includes fiscal incentives through taxation and subsidization, command and control measures, and voluntary coordination efforts at the international level.

Resumen

Este ensayo procura sintetizar una discusión reciente sobre la economía circular, apuntando a clarificar ese concepto, su relación con la noción de "desacople" y cómo es influenciada por la tecnología, los negocios y la política pública. En esencia, la economía circular significa tornar desperdicios en algo valioso. El concepto abarca y supera algunas nociones previas como bioeconomía. La tecnología de la Cuarta Revolución Industrial aporta al desacople entre el crecimiento y los recursos. El alcance del desacople enfrenta a los optimistas con los pesimistas del crecimiento. Los modelos circulares de negocios incluyen eliminar desperdicio, maximizar la vida útil de los bienes durables, recuperar materiales y energía de procesos y productos, transformar bienes en servicios a través de su uso compartido y reemplazar su propiedad por alquiler o pago por el uso. Las políticas para inducir o incentivar la economía circular incluyen medidas fiscales, regulatorias y esfuerzos internacionales de coordinación voluntaria.

Keywords: Circular economy, Fourth Industrial Revolution, Business, Public policy

JEL Codes: Q20, Q50

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1. Introduction

This essay tries to synthesize a recent discussion on circular economics, and aims to clarify the concept, its relationship with the notion of "decoupling", and the role that technology, business, and economic policy play in going circular. Transition costs from traditional to circular economy is not discussed, deserving another study.

Following Conte Grand (2020) as well as Gallaud and Laperche (2016), the concepts that led to "circular economy" started with "sustainable growth" (at the United Nations Conference on Environment, Stockholm, 1972), continued with "sustainable development" (from Brundtland Report, 1987), "green economy" (in the United Nations Environmental Program, March 2009), "green growth" (OECD, July 2009), followed with "inclusive and green growth" (at the Annual Report of the World Bank, 2012), "bioeconomy" and finally the newest definition of "circular economy".

Sustainable development stands for "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*". In its weak form, it means that if depleted natural capital is being replaced with more valuable physical and human capital, thus the aggregate stock of human, physical, and natural capital is increasing over time; however, in its strong forms, physical or human capital cannot substitute consumed environmental depletable resources at all, and if renewable sources, only partially per time unit (Brears, 2018). The term *Sustainability* comes from forestry and means maximizing the proceeds from a stock or natural capital (as the forest) while conserving it (Stahel, 2019).

For Sillanpää and Ncibi (2017), "*bioeconomy means the sustainable extraction, exploitation, growth, and production of renewable resources … and their eco-friendly conversion into --- [goods] ... to be consumed and recycled in a sustainable manner*." The bioeconomy focuses on a more efficient industrial use of natural capital, but "*its economic characteristics resemble more the linear than the circular industrial economy. Most of its products cannot be reused, and molecules can only exceptionally be recovered […] once appropriate technologies are developed*" (Stahel, 2019). This fact gave rise to the circularity concept. According with Ellen McArthur Foundation (2013), "*A circular economy is based on … designing out waste and pollution, keeping products and materials in use, and regenerating natural systems.*" Thus "circular economy" concept encompasses "bioeconomy", in fact, adds to all the former concepts (Conte Grand, 2020). As Lacy et al. (2019) establish, beyond reducing or avoiding waste, "*The fundamental concept of circularity … [consists in turning] … all waste into something valuable*."

The "circular" economy transforms traditional or "linear" ways of doing business[2], rejecting the "take resources, make products, waste residues" approach in favor of keeping products and resources in use for as long as possible and, at finally in "looping" back their components and materials. Thus, circular economy *decouples* economic growth from resource usage (Lacy et al., 2019). The linear model acts as if resources were abundant, available, and easy to dispose of. This leads to human and physical capital accumulation and natural capital depletion. Nevertheless, natural resources are mostly exhaustible, and since their use faces externalities, they are undervalued. In the absence of an owner, the former can lead to the "Tragedy of the Commons", because of overexploitation (Brears, 2018).

The relevance of the discussion is clear. The humanity is consuming about 175 percent of the natural resources that can be regenerated each year. A "one-planet economy" would imply using only those resources that can be replenished in a single year. Globally, over 80 percent of the world's wastewater is released to water courses without treatment. The world generates around 1.3 billion tons of

[2] The point of sale separates the linear from the circular economies. Traditionally, at the point of sale, ownership and liability are transferred from producer to buyer, and the waste collection and disposal is delegated to the state; waste management destroys value and utility of stocks, and this happens because for individuals, the reuse or remarket option costs effort, time, and money (Brears, 2018).

municipal solid waste annually (1.2 kg/person/day), and it is expected to increase up to 2.2 billion tons per year by 2025 (1.42 kg/person/day) (Brears, 2018). For the past three decades the share of fossil fuels in the total primary energy supply has remained stable at about 80 percent. Around 8 percent of the world's oil production is used to produce plastic, expected to rise to about 20 percent by 2050. In that year it is estimated that there will be more tonnage of plastics in the oceans than fish. More than 400 million tons of hazardous wastes are produced annually by the chemical industry. Air pollution kills annually a similar number of people than smoking tobacco (Brears, 2018). The world generates around 50 million tons of electronic waste annually (70 percent of landfilled hazardous waste), while only 10 million are recycled.

Interestingly, in 1970, the world consumed a total of 26.5 billion tons of materials. By 2017, that total had risen to 41.7 billion tons (a 57 percent increase). Real GDP grew more in the same period (a 183 percent increase), thus the difference implies that certain relative decoupling was achieved between GDP growth and resource use. In 1970, 1.95 kg of materials were required per dollar of GDP, which dropped to 1.08 kg per dollar by 2017, at comparable prices (Lacy et al., 2019). Absolute decoupling implies that the environmental damage remains stable or decreasing while the economy grows. Instead, relative decoupling involves that the environmental damage is increasing, but at a lower rate than the economy. Resource decoupling or 'dematerialization' involves reducing the rate at which natural resources per unit of economic output are used; on the other hand, impact decoupling seeks to increase economic activity while decreasing environmental impact[3].

Global warming has been characterized as the greatest market failure in history, resulting from the emission to the atmosphere of greenhouse gases (GHG) which capture the sun heat. The generalized increase of temperatures provokes global climate change (McDonough and Braungart, 2003). One half of GHG emissions is explained globally by the production and consumption of energy; the other half relates with manufacturing and use of products, of which half (or one quarter of total) is due to agriculture, forestry, and food productive chains. Global warming at the current rate will likely increase average temperatures by 1.5°C between 2030 and 2052, and the planet could potentially be 3 to 5ºC warmer by 2100. To date, 185 parties have ratified the Paris Agreement, which aims to keep global warming this century 2°C above the pre-industrial levels and to pursue efforts to limit the temperature increase further to 1.5°C. The Paris Agreement goals implies achieving for 2050 zero net emissions of GHG (Lacy et al., 2019).

According with Conte Grand (2020), three points of view on the relationship between growth and environment can be identified: pessimistic, optimistic, and agnostic. Growth-pessimistic can be traced until Malthus (1798), Georgescu-Roegen (1971), Meadows et al. (1972, 2004), Daly (1997), Daly and Farley (2010). Because there is a limit to the planet capacity to bear human activity (holding technology advances and population growth as constants), they propose a degrowth strategy, until to a new steady state, compatible with nature limits. However, human impact depends also on population and technology, beyond production. If technology progress or population control are considered, the human impact can be controlled or reduced without decreasing production. Growth-optimistic consider that it is possible to achieve an absolute decoupling between pollution and production, based on Kuznets (1955) environmental curve. As Conte Grand (2020) states, it is not clear that this relationship does exist for all pollutants, particularly for GHG. The Growth-agnostic (a-growth) challenge the idea of measuring social welfare through GDP and employ different metrics for human welfare and/or evaluate societal achievements with different utility functions. They use several measures, but do not arrive to consensus in choosing one.

[3] By introducing absolute decoupling indicators, governments can make the impact of changes visible to policymakers, economic actors, and consumers. Two absolute decoupling indicators are: value per weight, in monetary units per kilogram ($/kg); labor input per weight, in hour per kilogram (hour/kg), which can be used to compare the sustainability of different products (Brears, 2018).

Decoupling implies a virtuous relationship of technological change, new business models, and policies. In the section 2 we refer to technology achievements which help decoupling, in section 3 we present new and renewed business models, in section 4 we discuss policies to go circular and in section 5 we conclude. Transition from linear to circular models, nonetheless, deserves a deeper examination, since creation of value added or employment in recycling activities, for instance, imply closing establishment and destroying jobs in traditional industries, among other complex interactions. We leave aside this discussion which for its complexity deserves another essay.

2. Technology achievements which help decoupling

The characterization of the technologies in each industrial revolution (IR) is as follows:

1) The First IR used water and steam power for mechanization.
2) The Second IR applied electricity to create mass production.
3) The Third IR employed electronics and information technology for automation.
4) The Fourth IR combined physical, digital, and biological technologies in disruptive ways.

The Fourth Industrial Revolution has the potential to decouple growth from resource use, because it enables greater efficiencies, helps drive innovation, increases available information, and moves beyond resource intensiveness in its biological technologies (Lacy et al., 2019).

The Table 1 presents schematically how business go circular. First, business models vary from eliminating waste, maximizing use extension of capital and durable consumption goods, recovering materials and energy from process and products, turning goods into services by sharing, and replacing property by lease or pay-per-use models. Wastes are generated in resource use, capacity underutilization, shortened life cycles of capital and durable goods, and at molecular scale. The introduction of circularity implies new forms of consumption, redesigning products to be looped, creating reverse logistic to help closing the loops, accelerating changes through disruptive technology, and generating practices, regulation, culture and knowledge generation and diffusion. Technologies which allow going circular combines digital, physical, and biological features. They can be applied to reshape operations, rethink products and services, redesign institutions, and to introduce collaboration and partnerships.

Disruptive technologies of the three realms (digital, physical, and biological) include (according Lacy et al, 2019) artificial intelligence[4], machine learning[5], cloud and edge computing[6], machine vision[7], big data analytics[8], Internet of the things (IOT)[9], machine-to-machine communication[10], mobile devices[11], blockchain[12], digital anchors[13], and digital twin[14] (among the first category); 3D printing[15], robotics[16],

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[4] Machines which can simulate human intelligence at big scale and react autonomously.
[5] Machines which can perform new tasks after algorithms learning from historical datasets.
[6] Shared web-based (cloud) content and applications hosted in remote servers or on devices (edge).
[7] Which can extract, acquire, process, analyze and understand images automatically from real world.
[8] Analysis of huge databases to detect patterns, trends, and causalities.
[9] Wireless devices with sensors, which interact and operate remotely vehicles, appliances, and machinery.
[10] Sensors and actuators which connect data, analytics, and machines.
[11] Hardware, operating systems, networks, and software combined to provide real time access to content.
[12] They record digitally transactions by parties participating in a computer network.
[13] Tiny computers which monitor, analyze, communicate, and act on data
[14] Virtual models of processes, products, or services which pair the virtual and physical worlds.
[15] 3D objects are created by layers of material under computer control.
[16] Machines programmed to automatically carry out a complex series of repetitive actions.

energy storage[17], energy harvesting[18], nanotechnology[19], spectroscopy[20], physical markers[21], virtual / augmented reality[22] (between the second category); and carbon capture[23], materials science[24], bioenergy[25], bio-based materials[26], genetic engineering[27], DNA marking[28], cellular and tissue engineering[29] and hydroponics and aeroponics[30] (within the third category).

Table 1: Business going circular

What business models to go circular?	Where is the waste?	Where to go circular?	Which technologies to go circular?	How to go circular?
Eliminate waste by input circularity through renewable resources, energy, bio-based and man-made materials.	Resources	Engaging consumers	Digital	Reshaping operations (energy, emissions, water, and waste)
Maximizing use extension through redesign, repairs, reconditioning, upgrades, and resale.	Capacity	Designing to be circular, easy to repair, disassemble and reuse	Physical	Rethinking products and services (usage, waste, and loops)
Recovering resources from materials and energy	Lifecycles	Reversing logistic to close the circle creating takeback loops	Biological	Redesigning institutions (working practices, policies and procedures, culture, and organizations)
Sharing high-value goods through platforms enabled by digital technologies	Embedded value	Accelerating change by disruptive technologies		Collaborating and partnering
Transforming products in services or premium good “servitization” by lease or pay-per-use models		Driving ecosystems by policy, legislation, investment, knowledge sharing, and collaboration		

Source: Author elaboration on Lacy et al. (2019)

3. New and renewed business models

[17] Long-life batteries, with enhanced storage or organic material based.
[18] Small amounts of energy otherwise lost, captured by specialized materials.
[19] Matter manipulated on an atomic, molecular, or supramolecular scale.
[20] Electromagnetic radiation analyzing a material based on its molecular composition.
[21] Help authenticate a product by a direct link to a database.
[22] VR provides interactive digital reality in a computer-generated or video-enabled environment; AR superimposes text, sounds, and graphics on real physical world via wearable devices.
[23] Waste carbon dioxide captured from large sources, transports, and store to avoid entering the atmosphere.
[24] Applies chemical engineering and knowledge from other fields to material innovation.
[25] Derives energy from biomass (vegetable, animal, forestry, and municipal organic waste).
[26] Plant-based compostable and recyclable materials used as substitutes for less-sustainable resources.
[27] Manipulates an organism’s genome directly through use of biotechnology.
[28] Marks items in undetectable to the eye ways, to differentiate among genuine ones from counterfeits.
[29] Applies the principles of cell and tissue growth to replace or modify materials.
[30] Deploy organic, ecologically responsive, and sustainable approaches to gardening.

Going circular includes changing products, its production, and its consumption. Circular opportunities may also blur industry lines. A completely circular product would be designed for reuse, created only with looped or sustainable materials, kept useful for as long as possible, and be disassembled into materials or components that returns as valuable inputs. Companies can build circular product and services by focusing on design, use, use extension, and end of use (Lacy et al., 2019). By extending the service life of goods through reuse, repair, remanufacture and upgrading, the circular economy substitutes with energy and materials with labor-intensive service activities, probably at small and local scale (Stahel, 2019).

Producers of manufactured materials and objects can rent or lease their molecules and goods, in combination with efficient return logistic loops. The performance economy sells results instead of objects. It redefines the role of the supply and demand side, which goes from ownership to user-ship of objects. By renting objects, users gain flexibility in use. In selling goods as a service, producers retain ownership and liability (Brears, 2018).

Within the circular industrial economy, there are differences between maintaining the value and utility of stocks of manufactured buildings, vehicles, machines, and other durable objects ('R' activities)[31], by the use-focused performance economy[32], and maintaining the value and quality (purity) of stocks of molecules and atoms ('D' activities)[33] 'as good as virgin'. By extending the service-life of objects and materials, the circular economy reduces the speed of resource flows through the economy (Brears, 2018).

Companies implement circularity through operations (addressing losses in energy, emissions, water, and waste), products and services (redesigning, extending lifecycles and closing loops of wastage), culture and organization (redefining working practices, policies, and procedures) and collaborating and partnering with public sector. Each industry will differ in the level of possible circularity. It is useful to distinguish among consumer-facing (Table 2) and business-to-business industries (Table 3).

Consumer-facing industries have focused on packaging and input waste reduction. Fashion industry has replaced materials and introduced product takeback and reuse. In consumer electronics and household goods, waste occurs during product use (wasted capacity) and premature disposal (wasted lifecycles). In household appliances, regulations are pushing companies to increased recovery of used machines. Consumer readiness to shift to renting or sharing models for goods depends on the perceived value of the product, emotional attachment, and hygienic factors when it comes to reuse. Consumers are most likely to pay a premium for food and beverage packaging, or electronics products and toys designed to be reused or recycled. Both in the information and communication technology and fashion industries, lifespan of goods became shorter for previously longer-lasting devices and clothing, because they become outdated or unwanted prematurely (Lacy et al., 2019).

Business-to-business industries include chemical, metals and mining companies, oil, and gas, and heavy-duty machinery and equipment. Industries such as machinery and industrial equipment and automotive companies have after-sales maintenance and services activities already included into their business models. Therefore, the transition to circularity is natural. Oil and gas companies are entering into the electricity and e-mobility sectors, and chemical companies are participating in textiles and food component innovation. Resource-intensive production industries are focusing on reducing wasted resources as well as machinery wasted capacity (Lacy et al., 2019).

[31] 'R' activities, such as Reuse, Repair, Remarket, Remanufacture, Re-refine, Re-program goods.

[32] Long-life goods, multifunctional goods, selling goods as a service, shared, common and multiple use.

[33] 'D' activities, such as De-polymerize, De-alloy, De-laminate, De-vulcanize, De-coat materials and De-construct buildings and infrastructure.

Table 2: Consumer-facing industries going circular

Possibilities / Industry	What can we do with raw materials?	What can we do for recycling or reusing	What can we do with operations?	What can we do with energy, water, and other basic resources in production	What can we do with otherwise waste capacity?
Fast moving consumer goods	Agriculture, forestry, and land use, accounts for one fourth of GHG emissions. One-third of global food production is wasted. Need to more sustainable packaging.	Only 14 percent of plastic packaging is recycled. The industry employs one fourth of total plastic. Need of less toxic products and recycled or recyclable inputs.	Need of better management of stocks and logistic. Enhance collection, sorting, and waste infrastructure.	Growing use of water resources. Need of creating consumer awareness	Need of planning to reduce energy for logistics. Need of improving efficiency and reducing inputs and waste along production stages.
Fashion industry	Production heavily reliant on virgin materials from non-renewable sources (fertilizers to grow cotton, oil to manufacture synthetic fibers, chemicals to dye)	92 million tons of clothing become waste every year. Less than 1% is recycled. 0.5 million tons of microfiber end up in the ocean every year, equal to over 50 billion plastic bottles.	The typical consumer wears an item for a fraction of its useful life (low recycling and reuse, short life for garments).	"Circular materials" use fashion waste as raw inputs. New business models, including re-commerce, rental, and repair	Need of applying advanced analysis and circular principles to demand forecasting, design, sourcing, and manufacturing
Household industry	Resource-intensive manufacturing process. Lost embedded value of materials from premature disposal.	Due to low reuse and recycling rates, most products end up in landfills.	Waste occurs during product usage. Need for a more established reverse logistics, collection, and recycling infrastructure	Need of circular materials in manufacturing, more efficient, durable, and eco-friendly products. Extension of repairing, reusing, recovering, and "product as a service" models.	Goods with long-term use and relatively expensive, have been replaced by cheap and low-quality items.
Information and communication technology	Valuable inputs are not being recovered. Redesigning for lower material use	Difficulty of recycling or reusing small quantities of inputs and sparse use of each device.	Need of refurbishment and reuse of existing devices.	Need of extended lifecycles. Robotics can help material recovery	Leasing or rental. Reverse logistic
Personal mobility industry	Electrification and digitalization of vehicles have created increased demand for metals and minerals.	In developing countries, there is fragmented and informal recycling. In developed ones, most cars are retired before their full use end.	Manufacturing is resource intensive and disposed vehicles generate millions of tons of waste every year. 110 kg of waste are generated in producing a vehicle.	Partial or full fleet electrification. Tendency to sharing vehicles	Automobiles have low-capacity utilization rates. Vehicles in good shape are disposed.

Source: Author elaboration from Lacy et al., (2019)

Table 3: Business-to-business industries going circular

Industry \ Possibilities	What can we do with raw materials?	What can we do for recycling or reusing	What can we do with operations?	What can we do with energy, water, and other basic resources in production	What can we do with otherwise waste capacity?
Metals and mining	Need of renewable inputs. Mineral and non-mineral material recovery	Extending mines life cycle	Rehabilitation of exhausted mines	Technology highly dependent on energy and water use	Management and procurement of equipment
Oil and gas	Migration to renewable energies	Increase of renewable sources	Waste and unrealized value	Extraction became intensive in water and energy	High investments to develop renewable sources.
Chemical industries	Transition to renewable inputs, and reduction in hazardous content (polymer)	Only 5 percent of plastic packaging is recycled annually.	Better supply chains. Reusing molecules by mechanical or chemical processes	Largest industrial user of energy	Need for long term investments in infrastructure and innovation.
Electricity generation	Transition to clean sources. Need of reducing energy losses	Smart grids permit renewable energy sources diffusion, controlling losses and capping peak capacity needs	Trends to decarbonization, decentralization, and digitalization.	High levels of GHG and air pollutants. Chemical or radioactive waste	Opportunities for reducing losses and maximizing plant and equipment utilization.
Machinery and industrial equipment	Firms can focus on repair, maintain, upgrade, rent and secondary markets of equipment	Need of concentrating in maintenance and long-lasting products and in recovering and reusing valuable parts and metals.	Idle capacity allows machinery and tools "servitization". Regulation of admitted used pieces in manufacturing	Avoiding waste in valuable metals. Reverse logistic to encourage circularity.	Eliminating ownership in favor of renting or leasing.

Source: Author elaboration from Lacy et al., (2019)

4. Policies to go circular

Policy tools for circularity, can be classified into fiscal and command and control ones. The former group includes environmental taxes and charges, subsidies, and other incentives such as tradeable permits, or business support mechanisms through soft loans, public expenditure for innovation such as R&D funds. The latter set, comprehends regulations, information, and awareness campaigns, for business and consumers. A third category of policies can be labeled as coordination ones. These depend on agreements and voluntary participation rather than on mandate. For this reason, we present them separately. All those policies are intended to increase resource efficiency, recycling, and value addition, and to create jobs in circular goods, as well as to develop the markets for circularity activities.

Fiscal policy creates incentives or disincentives by taxation or subsidization. The linear industrial economy is resource- and capital-intensive, with high labor productivity; the circular industrial economy is labor-intensive, with a high resource productivity. In most countries, fiscal policies tax labor effort (a renewable resource) and subsidize or tax moderately the production and consumption of fossil fuels and other non-renewable resources. Reversing this situation, would give incentives to shift towards the circular industrial economy, where individuals and firms manage their goods instead of replacing them with new ones. Human labor is a renewable low-waste low-carbon resource; taxing non-renewable resources instead will induce stock optimization instead of flow optimization. It can be added encouraging for circularity through public procurement policies and setting longer fiscal depreciation periods to extend the service-life of tools, machineries, and vehicles (Brears, 2018). Moreover, taxation to promote circular economy should consider not charging Value Added Tax on activities as reuse, repair and remanufacture, and giving carbon credits for the prevention of greenhouse gas (GHG) emissions to the same degree as for their reduction (Stahel, 2019).

The disassembly of objects into components and materials, and their remarketing, is labor and knowledge intensive. Product-life extension is a strategy to create local/regional jobs and to substitute energy and material with labor. In infrastructure and buildings, about four fifths of the material and energy resources initially spent are embodied in the structure. Refurbishing buildings saves most of them and employs as much labor as the initial construction. Every building is a "material bank".

'R' activities are labor-intensive services; they demand skilled labor and 'silver workers', because of their accumulated knowledge. The era of 'R' of the circular industrial economy creates novel jobs in new professions. The main opportunities for skilled workers in 'D' activities will be commercial, developing new markets of used goods, and in research and development aimed to identify and develop small volume process technologies to recover pure molecules (Brears, 2018).

Depreciation rules influence the service-life of investment goods, or tools. Governments can induce circularity through longer fiscal depreciation periods. There is a strong correlation between the service-life of goods, manufacturers' liability periods and tax depreciation periods. Legislators can use longer tax depreciation and product liability periods (and conditions, such as compensating depreciated value by insurers) as a policy to create jobs and prevent waste (Wijkman and Skanberg 2016).

In the same vein, there are some policy options in the realm of command and control to induce behavior changes: spreading knowledge of circularity opportunities through education and information; banning the use of materials, which cannot be de-bonded, and promoting activities such as de-polymerize plastics, de-alloy metals; de-laminate carbon-fiber composites, de-vulcanize tires to recover rubber and steel; de-coat objects; de-construct high-rise buildings, and extending liability to the end user (Brears, 2018).

In linear economy, at the point of sale, liability is transferred from the producer to the consumer, who passes it to the state as waste. The waste management costs are borne by society at large, thus producers have no economic incentive to control them (Stahel, 2019). By defining waste as 'objects without positive value or ultimate liable owner', policies introducing an Extended Producer Liability at the end of object service life, would create an individual rather than collective accountability for waste. (Brears, 2018). Also, an Extended Producer Liability would give manufacturers financial incentives to change the choice of materials, or to retain ownership of goods renting them and thus be able to recover products after use (Stahel, 2019).

To enable the best value preservation of stocks of molecules, owners of materials embodied in end-of-service-life objects should have a duty to sort and de-link the materials to recover molecules of highest purity. In the case of materials such as plastics in the oceans, objects could be commercialized through rent-a-molecule strategies instead of being sold, or producers forced to accept an Extended Producer Liability. This implies a cultural change in waste management, from volume reduction to value capture. The producers know how the objects were manufactured and what materials were used. Nowadays the recovery of pure atoms or molecules is feasible and established for few materials. For many used goods recycling costs are higher than their scrap value (Brears, 2018).

An Extended Producer Liability will give producers strong incentives to design goods for maximizing end-of-service-life value and to minimize waste. It changes the present collection responsibility and disposal costs with municipalities or recyclers. Nevertheless, it does not solve the problem of molecules wasted in 'free' dumps, such as the atmosphere (CO2 and other GHG emissions), oceans (micro plastic and toxic chemicals) and space (abandoned satellites and space craft) (Brears, 2018).

Table 3: Inventory of policies for going circular

Objective / Instrument	Resource efficiency use	Recycling	Hazardous materials
Fiscal			
Taxation and subsidization	Subsidies and fiscal benefits for producing durable, easy to repair, upgraded, or remanufactured goods. Taxes on nonrenewable resource use. Low taxes or subsidies for labor intensive activities. Extended depreciation rules. Promotion of "servitization" Grants and loans for transition.	Externality pricing and taxation /subsidies, showing hidden costs and benefits. Grants and low interest loans for recycling. Low taxes or subsidies for labor intensive activities by contrast to resource intensive ones.	Tradeable permits
Public investment and procurement	Physical (waste management) and digital infrastructure (reverse logistics)	Invest in infrastructure for waste collection, sorting, and recycling	Creation of a market for waste through procurement. Introduction of reverse logistic facilities and digital tracing of hazardous waste.
Command and control			
Regulation	Waste definition, secondary and export markets for waste definition.	Set recycled content requirement Education and training on recycling	Bans of harmful or pollutant substances Detoxification policies
Dissemination and demonstration	Education and training Eco labels and certification Rewards and penalties Encouraging life cycle analysis Extended producer liability	Promotion of awareness and behavior attitudes through education and training Enaction of eco labels and certifications Rewards and penalties Encourage life cycle analysis Extended producer liability	Education and training Eco labels and certification Rewards and penalties Extended producer liability
Coordination			
Private-Public collaboration	Research and development Information policies Cluster policies	Research and development Information policies Cluster policies	Information policies
International collaboration agreements	Global consensus on targets. Setting performance indicators Monitoring.	Global consensus on targets. Setting performance indicators Monitoring.	Global consensus on targets. Setting performance indicators Monitoring.

Source: Own elaboration on Lacy et al. (2019), Stahel (2019), and Brears (2018).

Under coordination policies, voluntary in nature, two subsets of policies can be grouped: at national level, those which include collaboration between private and public sectors, while at the international level, they are agreements among sovereign states for a common agenda, not yet reaching issues such a global tax on carbon, as suggested by Acemoglu and Robinson (2019). Collaboration at national level between private and public sectors includes sharing information, partnerships for research and development, and cluster policies, important for recycling activities and to incentivize resource efficiency. With respect to the international agenda, in the year 2000, the UN set the Millenium Development Goals (MDG) to be attained in 2015 (8 objectives split into 21 goals, with 60 status indicators). The baseline was set in 1990. In 2015 the MDG were replaced by the Sustainable Development Goals (SDG), to be attained in 2030 (17 objectives, split in 169 goals, with 231 status indicators)[34].

Between the 17 SDG, there are possible interactions of complementarity or substitution. Synergies and interactions can yield better results at lower costs. According with Copenhagen Consensus Center, it is worthwhile to focus on certain goals instead of spreading resources equitably between them. Just 19 goals concentrate the bulk of benefits, concentrating in health, energy, and education (Conte Grand, 2020). International goals are useful to generate global consensus around targets, to devise indicators to measure baselines and progress and to monitor results.

Conclusions

The concepts that led to "circular economy" started fifty years ago with "sustainable growth" and "sustainable development", continued with "green economy", next turn was for "green growth", followed with "inclusive and green growth", afterwards arrived "bioeconomy" and finally the newest definition of "circular economy". "*The fundamental concept of circularity … [consists in turning] … all waste into something valuable*", and it encompasses bioeconomy, as well as the rest of the already mentioned concepts.

The "circular" economy proposes a transformation from the traditional "linear" ways of doing business, in favor of keeping products and resources in use for as long as possible and, at end of use, "looping" their components and materials with zero- or near zero-waste generation. Thus, circular economy decouples economic growth from resource usage. Between 1970 and 2017, the world increased its usage of materials in a 57 percent, enhances its real GDP in 183 percent, and reduced the per capita material requirement to generate one constant dollar of GDP in 45 percent. Nevertheless, the humanity is consuming about 1.7 times the natural resources that are regenerated each year.

With respect to the relationship between growth and environment, the positions can be classified into growth pessimistic, growth optimistic and growth agnostics. The first group emphasizes the limit of the planet to bear human activity (given technology advances and population growth). Growth optimistic, instead, consider that it is possible to achieve an absolute decoupling between pollution and production. The growth agnostics challenge the idea of measuring social welfare through GDP. Absolute decoupling implies that the environmental damage remains stable or decreasing while the economy grows. Instead, relative decoupling involves that the environmental damage is increasing, but at a lower rate than the economy.

Decoupling implies a virtuous relationship of technological change, new business, and policies. The Fourth Industrial Revolution has the potential to decouple growth from resource use, because it enables greater efficiencies, helps drive innovation, increases information transparency, and moves beyond resource intensiveness in its biological technologies.

Business models of circular economy goes from eliminating waste, maximizing use extension of capital and durable consumption goods, until recovering material and energy from process and products, turning goods into services by sharing, and replacing property by lease or pay-per-use models. Going circular includes changing products, its production, and its consumption. Circular opportunities may also blur industry lines. A circular product would be designed for reuse, created only with looped or

[34] SDG are more numerous and detailed than MDG. The latter were concentrated in poverty, while the former is devoted to sustainable growth, including economic, social, and environmental issues. The degree of detail implies that for some countries not enough data is available to monitor them.

sustainable materials, kept useful for as long as possible, and be disassembled into materials or components that returns to production as valuable inputs. Producers of both manufactured materials and objects can rent or lease their molecules and goods, in combination with efficient reverse logistic to generate loops. The performance economy sells results instead of objects. It redefines the role of the supply and demand side, which evolved from object owners to object users.

Companies implement circularity through operations (addressing losses in energy, emissions, water, and waste), products and services (redesigning, extending lifecycles and closing loops of wastage), culture and organization (redefining working practices, policies, and procedures) and collaborating and partnering with public- and private sector for collective transformation.

'R' activities, such as Reuse, Repair, Remarket, Remanufacture, Re-refine, Re-program goods, and 'D' activities, such as De-polymerize, De-alloy, De-laminate, De-vulcanize, De-coat materials and De-construct high-rise buildings and major infrastructure, are part of the circular economy.

Policy tools for circularity, can be classified into fiscal incentives and command and control instruments, the former including environmental taxes and charges, subsidies, and incentives such as tradeable permits, or soft loans, public expenditure for R&D funds, and the latter comprehending regulations, information, and awareness campaigns, for business and consumers. A third category of policies are coordination ones, which depend on agreements and voluntary participation.

Fiscal policy creates incentives or disincentives by taxation or subsidization. In most countries, fiscal policies heavily tax labor and subsidize or tax moderately production and use of fossil fuels and other non-renewable resources. Reversing this situation, would give incentives to shift towards the circular economy. Human labor is a renewable low-waste and low-carbon resource; instead, taxing non-renewable resources wiould induce stock optimization instead of flow maximization.

Taxation to promote circular economy should consider not charging Value Added Tax on activities as reuse, repair and remanufacture, and giving carbon credits for the prevention of greenhouse gas (GHG) emissions. Governments can induce circularity through longer fiscal depreciation periods for durable goods, to extend their lifecycles.

Command and control policies include spreading knowledge of circularity opportunities through education and information, banning products, defining waste, and extending liability to the end user, as a way to internalize the waste costs.

Under coordination policies, voluntary in nature, two families of policies can be grouped: at national level, those which include collaboration between private and public sectors, while at the international level, they are agreements among sovereign states for a common agenda.

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