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REVIEW ARTICLE

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The circular economy's closed loop and product service systems for sustainable development: A review and appraisal

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Abstract

This review paper examines relevant regulatory guidelines, policies, and recommendations on sustainable development, where it traces the origins of circular economy (CE). Afterwards, it sheds light on key theoretical underpinnings on CE's closed loop and product service systems. The findings suggest that the CE's regenerative systems minimise the environmental impact as practitioners reduce their externalities, including waste, emissions, and energy leakages through the use and reuse of resources. Therefore, this contribution offers a critique on CE's inherent limitations and discusses about the implications of having regulatory interventions that are intended to encourage responsible consumption and production behaviours. This contribution implies that CE is creating value to business and the environment. The closed loop and product service systems can unleash a new wave of operational efficiencies through increased throughput in production processes, as practitioners repair, reuse, remanufacture, refurbish, and recycle resources, whilst safeguarding the natural environment.

KEYWORDS

circular economy, closed loop, environmental policy, product service systems, recycling resources, reducing resources, resource efficiency, restoring resources, reusing resources, sustainability, sustainable consumption, sustainable production

1 | INTRODUCTION

Prior to the industrial revolution, business and industry would hardly throw away their by-products. The waste or unusable material that was generated from craftsmanship or from other manual processes was usually reutilised or recycled (Barnes, 1982). However, the industrial revolution has changed the businesses' approaches on the use of materials and resources. This period has introduced disposable products with the explicit purpose of being discarded after use (Lieder & Rashid, 2016). Such irresponsible behaviour has probably stimulated a throwaway mindset which has become widely pervasive in the consumption patterns of many societies. Today, business and industry are customarily following a linear model that is built on the premise of "take-make-consume and dispose" actions (EU, 2014). This economic model assumes that resources are abundant, available, and cheap to dispose of, as every product is usually bound to reach its "end of life" at some stage or another. When products are no longer useable or required, they are often discarded as waste. Consequently, their improper disposal in landfills may cause inconvenience and can pose serious health risks to nearby communities. In addition, land degradation is constantly impacting on the natural environment, as arable land continues to disappear. Furthermore, the warming of the earth's climate, which is one of the outcomes of carbon emissions from fossil fuels, is yet another serious problem facing today's society. Industrial and mining activities are also causing pollution problems as well as exhausting the world's resources. The world's growing populations and their increased wealth are inevitably leading to greater demands for limited and scarce resources. Notwithstanding, it is envisaged that the reserves of some of the globe's key elements and minerals shall be depleted within the next 50 years or so (Shrivastava, 1995).

Boulding's (1966) famous paper, "The economics of the coming spaceship Earth," had anticipated that human beings will need to find their place in a cyclical ecological system where the resources are reduced, reused, or recycled. He described the econosphere as a material process involving the discovery and mining of fossil fuels. Boulding (1966) went on to suggest that the ecological environments should not be appropriated, as the effluents of industrial systems are passed out into noneconomic reservoirs, including the atmosphere and the oceans. However, today's economic models are relying too much on resource extraction and depletion. If solutions are to be found, the business, industry, and the general public must be encouraged by to alter a number of irresponsible behaviours.

Arguably, there is scope in using resources more efficiently, as better ecodesigns, responsible waste management and prevention, and the reuse and recycling of materials can possibly bring net savings to businesses and consumers, and also reducing their environmental impact (Pearce & Turner, 1990; Porter & Van der Linde, 1995; Stahel, 2016; Stubbs & Cocklin, 2008). Manufacturing companies could benefit from the circular economy's (CE) regenerative systems that reduce resource inputs, waste, emissions, and/or energy leakages by slowing, closing, and narrowing material and energy loops (Stål & Jansson, 2017; Liu, Qu, Lei, & Jia, 2017; EU, 2014; Srour, Chong, & Zhang, 2012; Yuan, Bi, & Moriguichi, 2006; UNEP, 2005, 2006; Japanese Act 110/2000, 2002; Butler & Hooper, 1999; Hediger, 1998). In a nutshell, closed loop systems can be achieved through long-lasting designs, maintenance, repair, reuse, remanufacturing, refurbishing, and the recycling of resources (Geissdoerfer, Savaget, Bocken, & Hultink, 2017). The circular (closed) flows of materials and resources will ultimately result in more economies and efficiencies whilst reducing externalities (Yuan et al., 2006). CE necessitates a complete reform in terms of sustainable production and responsible consumption patterns. In plain words, the recovery processes and the recycling of resources are aimed at reducing our reliance on new resources (Hu et al., 2011). Therefore, this contribution suggests that CE is a sustainable development strategy as it creates economic and environmental value to society (EU, 2014; UNCSD, 2012; UNEP, 2005, 2006; WSSD, 2002; Agenda 21, 1992; WCED, 1987).

2 | RESEARCH QUESTION

CE and its practical application to the industrial processes have evolved to incorporate different aspects from the sustainable business models, including closed loop (Geissdoerfer et al., 2017; Geng, Sarkis, Ulgiati, & Zhang, 2013; Murray, Skene, & Haynes, 2017; Peeters, Vanegas, Tange, Van Houwelingen, & Duflou, 2014; Zhang, Ren, Liu, & Si, 2017) and product service systems (PSS; Catulli, Cook, & Potter, 2017; Piscicelli, Cooper, & Fisher, 2015; Tukker, 2015; Gaiardelli, Resta, Martinez, Pinto, & Albores, 2014; Mont, 2002). Nevertheless, there are other theoretical influences from the sustainable development literature. Hence, this review paper is structured as follows: First, it traces the origins of the CE as it examines the intergovernmental guiding principles, policies, and recommendations for sustainable development. Second, it critically evaluates key theoretical underpinnings relating to the CE agenda. Third, the researcher analyses CE's closed loop and PSS as intergovernmental organisations and policy makers are encouraging sustainable production and responsible consumption behaviours in different contexts.

3 | TRACING THE ORIGINS OF THE CIRCULAR ECONOMY

3.1 | Guiding principles, policies, and recommendations

The Brundtland Report (WCED, 1987) defined sustainable development as; "development that meet the needs of the present without compromising the ability of future generations to meet their own needs" (p. 43). Its underlying assumption is that the world's physical resources are not finite; therefore, they have to be managed responsibly to sustain future generations. Subsequently, the United Nations (UN) Conference on Environment and Development has put forward Agenda 21 that dedicated a chapter that was focused on unsustainable patterns of production and consumption. This document recommended that the UN's member states ought to intensify their efforts to reduce the use of scarce resources during production processes, whilst minimising the environmental impacts from generation of waste and pollution (Agenda 21, 1992).

In 2002, the UN Report of the World Summit on Sustainable Development also made reference to unsustainable patterns of production and consumption. The UN's member states were urged to manage their natural resources sustainably and with lower negative environmental impacts, by promoting the conservation and sustainable use of biodiversity and ecosystems, whilst reducing waste (WSSD, 2002, p. 13). Moreover, in another resolution, entitled; "The future we want," the General Assembly at the UN Conference on Sustainable Development has reaffirmed its commitment to implementing green economy policies in the context of sustainable development. The heads of state and government or their representatives have agreed to continue promoting the integrated and sustainable management of ecosystems, whilst facilitating their conservation, regeneration, and restoration of resources (UNCSD, 2012). Furthermore, during the UN's General Assembly Resolution of September 25 2015 entitled "Transforming our world: the 2030 Agenda for Sustainable Development," the world leaders have agreed to adopt the Sustainable Development Goals that replaced the previous millennium development goals that were established in the year 2000. Specifically, the Sustainable Development Goal 12 of the 2030 agenda, namely, "Sustainable Consumption and Production" explained that there is an opportunity for business and industry to reap economic gains through resource and energy efficiencies. It also raised awareness on the use of sustainable infrastructures and urged the UN member states to address air, water, and soil pollution to minimise their environmental impact (UNDP, 2015). Moreover, the Paris Climate Agreement (COP 21) and Resolutions 1/5 and 2/7 on chemicals and waste, and 2/8 on sustainable production and consumption, as adopted by the first and second sessions of the United Nations Environment Assembly (that was held in Nairobi, Kenya, on the June 27, 2014 and the May 27, 2016), are also considered as important policy instruments for many stakeholders, as they have paved the way for the transition towards the CE strategy.

These intergovernmental policy recommendations on sustainable consumption and production have led to increased regulatory pressures on business and industry towards controlled operations management and environmentally responsible practices. In 2014, the European Union (EU) Commission anticipated that "new business models, eco-designs and industrial symbiosis can move the community toward zero-waste; reduce greenhouse emissions and environmental impacts" (EU, 2014:4). Eventually, in March 2017, the EU Commission and the European Economic and Social Committee organised a Circular Economy Stakeholder Conference, where it reported on the delivery and progress of some of its action plan. It also established a Finance Support Platform with the European Investment Bank and issued important guidance documents to Member States on the conversion of waste to energy.

Other EU Communications on this subject comprised: "Innovation for a sustainable future—The Eco-innovation Action Plan"; "Building the Single Market for Green Products: Facilitating better information on the environmental performance of products and organisations"; "Green Action Plan for SMEs: enabling SMEs to turn environmental challenges into business opportunities"; "Closing the loop—An EU action plan for the Circular Economy" and the report on its implementation, and "Investing in a smart, innovative and sustainable Industry - A renewed EU Industrial Policy Strategy," among others (EU, 2017). Recently, the EU commission has adopted a set of measures, including a "Strategy for Plastics in the Circular Economy" that specified that all plastics packaging will have to be recyclable by 2030; it released a communication on the interface between chemical, product, and waste legislation, as it explains how they relate to each other. Moreover, the commission launched a monitoring framework that may be used to assess the progress of its member states towards the implementation of the CE action plan. This framework is composed of a set of 10 key indicators, comprising (1) EU self-sufficiency for raw materials, (2) Green public procurement, (3a–c) waste generation, (4) food waste, (5a–b) overall recycling rates, (6a–f) recycling rates for specific waste streams, (7a–b) contribution of recycled materials to raw materials demand, (8) Trade in recyclable raw materials, (9a–c) private investments, jobs, and gross value added, and (10) patents. Furthermore, EU (2018) published a report on the supply and demand of critical raw materials that are used in mining, landfills, electrical and electronic equipment, batteries, automotive sector, renewable energy, defence industry, and for chemicals and fertilizers.

3.2 | Theoretical underpinnings from academic literature

The CE reduces the reliance on resource extraction and raw materials (Cooper, 1999). Therefore, it restores any damage in resource acquisition by ensuring that little waste is generated throughout the production process and during the products' life. Liu, Li, Zuo, Zhang, and Wang (2009) explained that CE aims at minimising the generation of waste, as it involves environmental conservation. Similarly, Su, Heshmati, Geng, and Yu (2013) contended that the CE strategy involves efficiency-oriented control systems at all stages of production, distribution, and consumption during the closed loop flows of materials. They made reference to energy efficiency and water conservation, land management, and soil protection, among other issues. Hence, this circular model can lead to resource and energy efficiencies as well as economic development. The CE's closed loop systems could minimise the cost of dealing with pollution, emissions, and environmental degradation (Geissdoerfer et al., 2017; Geng et al., 2013; Geng & Doberstein, 2008; Jayaraman, Guide, & Srivastava, 1999; Peeters et al., 2014; Stubbs & Cocklin, 2008).

Hu et al. (2011) argued that the basic philosophy behind the CE approach is to enhance the emergence of an industrial and economic system that relies on an increased cooperation among actors. These authors contended that there is scope for stakeholders to use each other's externalities as sustainable resources. This way they could minimise the use of virgin materials and energy inputs. Such closed loops in industrial ecosystems can turn unwanted goods and materials that are at the end of their service life into resources for others (Bocken, de Pauw, Bakker, & van der Grinten, 2016; Murray et al., 2017; Stahel, 2016). Hence, circular systems could change economic logic as production is replaced with sufficiency and the used resources can be reused through long-lasting designs, recycled, repaired, refurbished and/or remanufactured. Thus, CE is a regenerative system in which resource input and waste, emission, and energy leakage are minimised by slowing, closing, and narrowing material and energy loops (Geissdoerfer et al., 2017; Su et al., 2013). In sum, the CE's regenerative design and its closed loop systems can enable resource efficiency through the sustainable consumption and production of resources, whilst minimising the environmental impact. Table 1 presents a nonexhaustive list of constructs that have emerged from the sustainability agenda.

4 | CLOSED LOOP SYSTEMS

The CE approach reduces externalities and resource depletion as small improvements in sustainable product design can result in resource efficiencies in production processes (Cooper, 1999). Hence, this concept focuses on the redesign of manufacturing and service systems. Closed loop systems reduce resource throughput in industrial production and consumption (Ghisellini et al., 2016). The recycling of resources has been a significant part of sustainability practices for many years (Barnes, 1982; Butler & Hooper, 1999; Geyer et al., 2016). For instance, the formation of interfirm clusters at supply chain level that are promoted in ecoindustrial parks (EIPs) in various contexts are leading to industrial symbiosis as firms use each other's waste as resources (Chertow, 1998; Dong et al., 2013; Geng et al., 2009). The unwanted outputs of one industrial process may be used as raw materials in another industrial process. Redesigned manufacturing systems within the industry can improve resource utilisation as opposed to natural resource depletion and environmental degradation (Liu et al., 2009). As a result, the CE and its closed loop systems may lead to the sustainable development of the economy, environment, and society (Camilleri, 2017; Murray et al., 2017). The EMF (2013) has described the CE's closed loop systems as an industrial economy that is restorative or regenerative by intention and design. This latter perspective suggests that the circulation of resources could regenerate the organisations' operational performance, whilst ensuring the protection of our environmental resources. Lieder and Rashid (2016) also reiterated that the concept of CE was considered as a solution

TABLE 1 Concepts that were drawn from the sustainable development agenda

Circular economy	Geissdoerfer et al. (2017); Murray et al. (2017); Bocken et al. (2016); Lieder and Rashid (2016); Ghisellini, Cialani, and Ulgiati (2016); Stahel (2016); Tukker (2015); Geng et al. (2013); Su et al. (2013); Hu et al. (2011); Liu et al. (2009); Geng and Doberstein (2008); Yuan et al. (2006); UNEP (2005); Pearce and Turner (1990).
Closed loop systems	Murray et al. (2017); Zhang et al. (2017); Geissdoerfer et al. (2017); Peeters et al. (2014); Geng et al. (2013); Bocken, Short, Rana, and Evans (2014); Stevens (2010); Wang, Wang, and Zhao (2008); Geng and Doberstein (2008); Stubbs and Cocklin (2008); UNEP (2006); Mont (2002); Jayaraman et al. (1999); Shrivastava (1995).
Ecological economics	Liu et al. (2017); Daly and Farley (2011); Hediger (1998).
Environmental economics	Liu et al. (2017); Pindyck (2007); Cropper and Oates (1992); Pearce and Turner (1990).
Industrial ecology	Liu et al. (2017); Catulli et al. (2017); Martens, Gutscher, and Bauer (2011); Hertwich (2005); Cooper (1999).
Product service systems	Catulli et al. (2017); Tukker (2015); Piscicelli et al. (2015); Mont (2002).
Recycling	Geyer, Kuczenski, Zink, and Henderson (2016); Peeters et al., 2014; Srour et al. (2012); Butler and Hooper (1999); Barnes (1982).
Regenerative design	Gou and Xie (2017); Lyle (1996).
Resource efficiency	Ghisellini et al. (2016); Tukker (2015); *Piscicelli* et al. (2015); Dong et al. (2013); Geng, Zhang, Côté, and Fujita (2009); Tukker and Tischner (2006); Chertow (1998); Porter and Van der Linde (1995).
Sustainable consumption and production	Yan and Spangenberg (2018); Stål and Jansson (2017); Catulli et al. (2017); Pollex (2017); Liu et al. (2017); Armstrong, Niinimäki, Lang, and Kujala (2016); Hanss, Böhm, Doran, and Homburg (2016); Lee, Levy, and Yap (2015); McDonald, Oates, Thyne, Alevizou, and McMorland (2009); Stevens (2010).

to the series of challenges such as waste generation and resource scarcity. The adoption of closed loop systems would increase the firms' operational efficiency of resource use in production (Bocken et al., 2014; Mont, 2002; Shrivastava, 1995; Zhang et al., 2017).

Industrial operations can be improved through redesigned processes, the elimination of some of them, the modification of certain systems, and/or by introducing new technology. Prakash (2002) suggested that the businesses could adopt management systems that create the right conditions to reduce their negative impact on the natural environment. He posited that this could take place in the following ways: (a) repair—extend the life of a product by repairing its parts, (b) recondition—extend the life of a product by significantly overhauling it, (c) remanufacture—the new product is based on old ones; (d) reuse—design a product so that it can be used multiple times; (e) recycle—products can be reprocessed and converted into raw material to be used in another or the same product, and (f) reduce—even though the product uses less raw material or generates less disposable waste, it could still deliver benefits that are comparable to its former version. These preventative and restorative practices are related to the CE.

The biological and/or technical nutrients that are used for the production of goods and resources are either designed to re-enter the biosphere "safely," or to recirculate at high quality, without entering the biosphere (UNEP, 2006). Murray et al. (2017) suggested that sustainable production is optimised via biomimetics, wherein the structure and function of natural systems would inform responsible industrial processes. Therefore, closed loop systems emit lower emissions of pollutants and will result in high efficiencies for a sustainable industrial economy which is, by design or intention, restorative in nature. Similarly, in industrial symbiosis, EIPs use each other's waste as resources, where CE models would increase the longevity of products through better manufacturing and maintenance. Hence, the rate of replacement decreases, and the use of resources is considerably reduced.

Firms of all sizes could engage in the CE's closed loop systems to extend the producers' liability, life-cycle analyses, material-use, and resource flows, for eco-efficiencies. Cooper (2012) pointed out that individual consumers would prefer using longer lasting products. Notwithstanding, such durable products would appear to provide added value for money to customers. The businesses as well as their consumers bear mutual responsibility on their consumption patterns and on the collection of resources before their recycling or disposal. The consumers are also be expected to do their part in terms of sustainable consumption (EU, 2018). However, the targeting of consumers seems much more complicated than regulating the industrial production of goods and services (McDonald et al., 2009; Pollex, 2017).

5 | PRODUCT SERVICE SYSTEMS

Many academic commentators claim that PSS are moving society towards a resource-efficient, CE (Tukker, 2015; Piscicelli et al., 2015; Yuan et al., 2006). PSSs shifts the businesses' focus from designing and selling only physical products, to selling a marketable set of products, services, supporting networks, and infrastructures, by including repair and maintenance, updates/upgrades, help desk, training and consultancy, and disposal-services such as recycling and take-back (Gaiardelli et al., 2014). Therefore, PSS consists of tangible products as well as intangible services that are combined so that they are jointly capable of satisfying the consumers' demands (Hockerts & Weaver, 2002).

PSS providers are in a position to design need-fulfilment systems with lower impacts to the environment, by either replacing an alternative product-service mix or by influencing the customers' activities to become more eco-efficient. Tukker (2015) suggested that firms have an incentive to prolong the service life of their products and to make them as cost- and material-efficient as possible. Moreover, PSSs would typically extend beyond purchase, affecting the use and disposal of resources. Hence, these systems could lead to the minimisation of material flows in the economy whilst maximising the businesses' service output and their users' satisfaction.

Tukker (2015) suggested that there are three types of PSS that prescribe different product-service components and ownership packages: (a) a product-PSS adds extra services but the ownership of the product(s) is transferred to the consumer(s); (b) the results-PSSs would involve both parties agreeing to achieve target results, as they recast product(s) as utilised materials, (c) and in a use-PSS, the provider(s) lease, share or pool their product(s); however, they retain the ownership of the product(s). For instance, Koninklijke Philips N.V. (Royal Philips, commonly known as Philips), a diversified technology company utilises the use-PSS approach, as it provides a lighting service to customers and is responsible for its technology risk. The Dutch company installs its lighting equipment (including street lighting), maintains it, and ensures that it runs for a very long time. Eventually, it reclaims back its equipment when it is the right time to recycle materials. This property rights are distributed amongst Philips and its clients, over the life time of the products. Philips has recognised an untapped opportunity to retain ownership of its products, as it has committed itself to dispose of the infrastructure and its constituent parts at their end of life. At the same time, customers (including the government) do not have to pay high upfront costs for their lighting equipment. Interestingly, Philips is also adopting a similar PSS within health care environments where it has established leasing relationships with clients for its medical infrastructure. Again, the company will eventually reclaim back its equipment and upgrades it when necessary. When the medical equipment is refurbished with the state-of-the art technology, the multinational firm will reuse it for another customer; it provides a warrantee cover and guarantees its products as new.

The idea of shared ownership is conspicuous with the results- and use-PSSs. These systems have led to upstream effects (through sustainable designs) and increased throughput. As a result, they are sustainable in the long run, as there are less externalities, in terms of waste and emissions (Tukker & Tischner, 2006). On the other hand, critical commentators argue that the ownership of the product(s) may represent intangible value to consumers as they may concerned on issues such as control, self-identity, intimacy, and hygiene, if the products they use are shared rather than owned by them (Piscicelli et al., 2015; Gaiardelli et al., 2014; Catulli et al., 2017; Tukker, 2015).

6 | CONCLUSIONS AND IMPLICATIONS

National governments, intergovernmental organizations, and NGOs have formulated a number of policy levers and recommendations on sustainable development and on the responsible consumption and production (UNCSD, 2012; UNDP, 2015). Yet there are potential challenges and opportunities for the implementation of the CE's closed loop and PSS. The CE approach can be criticised for its over-simplistic goals as well as its unintended consequences. Moreover, there are macroenvironmental factors, including political, economic, social, and technological issues that could also impact on the businesses' responsible and sustainable behaviours. For example, government legislation has led to a higher rate of recycling in Texas (see Srour et al., 2012). However, the transition towards a zero-waste model could prove to be a costly, long-term investment for business and industry. Although financial investments in new technologies could possibly improve operational yields and efficiencies (Porter & Kramer, 2011), there could still be a low demand for them, particularly if these new systems require behavioural changes by their users (Porter & Van der Linde, 1995). Notwithstanding, business practitioners would probably resent any mandatory changes that may be imposed on them by institutions and policy makers. It is very likely that they would opt to remain in their status quo, where they are “locked-in” to their traditional linear models (Bocken et al., 2016). Developed and developing countries may not follow the international recommendations for sustainable development. These jurisdictions may not enforce their respective legislation. Other constraints may include the shortage of advanced technology, weak economic incentives, poor leadership and management of corporations, and the lack of performance assessments of sustainability models, among other matters. Technology is a key factor in the development of a CE model. However, businesses may not be in a position to invest in economic and efficient infrastructures, and they may not be incentivised to conduct “green activities” in terms of their waste management, because changing or updating equipment is usually both time- and money-consuming, whereas the potential economic benefit is limited. Many governments may not provide economic instruments, such as subsidies and tax incentives to support businesses and clusters in their closed loop systems (Camilleri, 2017; Stevens, 2010; Wang et al., 2008).

On the other hand, the governments' hard legislation could have an impact on the businesses' bottom line. Similarly, financial services institutions, including banks, may not finance sustainable and environmental-friendly technologies. Therefore, practitioners may see little economic incentives to save energy, material, and water. Arguably, an active engagement of the marketplace stakeholders, including suppliers and distributors, is indispensable to the development of the CE. Eventually, regulatory authorities will probably introduce intelligent, substantive, and reflexive regulations for performance assessment (Camilleri, 2015). National governments may consider setting up region-specific indicators, rather than using the same national standards, so that even the poorer regions would have incentives to pursue CE targets (Su et al., 2013).

For the time being, the CE perspective is focused on the economic and environmental dimensions through the redesign of closed loop manufacturing and service systems that are intended to reduce the use of finite resources (Murray et al., 2017). It is virtually silent on the social dimension that is inherent within the sustainability development literature (Camilleri, 2017; Elkington, 1998), although the transition towards CE can be facilitated through stakeholder engagement and the formation of clusters at supply chain level. The main challenge is creating the right environment where businesses collaborate together to benefit from resource efficiency and increased throughput. The development EIPs would help them turn their unwanted externalities into useable materials for others. Therefore, local institutions and governments should support closed loop or PSS. Perhaps, a more direct and effective route to ensuring the sustainable development is to regulate, tax, or subsidise producers to comply with the regulatory policies and guiding principles. The intergovernmental organisations, including the EU, among others, has already put forward a Monitoring Framework and a set of indicators to encourage its member states to adopt the CE strategy.

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CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

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