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## THE PRODUCTION FUNCTION IN THE CIRCULAR ECONOMY

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### FUNKCJA PRODUKCJI GOSPODARKI ZAMKNIĘTEGO OBIEGU

**STRESZCZENIE:** W systemach naturalnych odpady czy emisje włączane są w naturalne obiegi materii i energii poprzez ich wykorzystanie na różnych poziomach troficznych. Tymczasem, powstające odpady czy emisje w procesach gospodarczych częstokroć nie tylko przekraczają pojemność ekosystemów naturalnych w zakresie ich przetwarzania, ale również stanowią rozwiązania technologiczne, które bez ingerencji człowieka trudne są do utylizacji w długim okresie czasu. W niniejszej pracy wskazuje się na pojawiające się w tle rozważań ekonomicznych koncepcje gospodarki obiegu zamkniętego, która jest formą przebudowy technologicznej i społeczno-gospodarczej w zakresie podejścia do odpadów i emisji. W pracy oferuje się nie tylko szerokie podejście do gospodarki obiegu zamkniętego, ale również zmianę w zakresie funkcji produkcji zgodnie z tymi zasadami wskazując na nową formę kapitału antropogenicznego – kapitał wtórny. Ten rodzaj kapitału nie jest celem produkcji, ale nie jest również ujmowany w kategoriach kosztów stając się zasobem surowcowym. Dopóki nie może być włączony bezpiecznie w naturalne obiegi materii i energii powinny być nieustannie wykorzystywane w obiegu gospodarczym, jako kapitał antropogeniczny wtórny. Dopiero jego transformacja zgodna z obiegiem materii i energii w przyrodzie może się wiązać z przekształceniem tego kapitału w zasoby kapitału naturalnego.

**SŁOWA KLUCZOWE:** gospodarka zamkniętego obiegu, odpady, emisja

## Introduction

In natural systems waste, excrement or other kinds of physiological products of some organisms are at the same time a valuable capital resource for other organisms (for example, as a building material for their nests or hiding places, or as a food base). A good example here is the earth-boring dung beetle (*Geotrupes stercorarius*) feeding on excrement<sup>1</sup>. Similarly, problematic municipal wastewater is a valuable source of energy for heating homes and sidewalks in cities, while PET (polyethylene terephthalate) caps are used as a raw material in the textile industry (for the production of knitwear) or the pharmaceutical industry.

However, the traditional approach to production processes did not consider waste and emissions generated in the economic process, and focused strongly on the volume of production. Waste and emissions have been accounted for as production costs if they could be traded, or as social costs that were shifted to the environment and the sector of non-economic social activities.

This paper presents the concepts of the circular economy emerging on the background of economic considerations. In the light of this discourse attempts are made to change the approach to the problems of waste and emissions, which are a valuable source of anthropogenic capital. The cost of all forms of the safe disposal of waste and recycling that do not take into account the possibility of their reuse or safe inclusion in the natural cycles of matter are shifted onto the natural environment or society. The best examples of problems associated with this type of activity are numerous public protests and studies that indicate the burden caused by this strategy to both the environment and local communities<sup>2</sup>.

The key issue in this approach involves the huge resources of matter and energy which can be effectively utilised in business, reducing the burden on the environment and at the same time generating additional resources for production processes. This, however, requires not only rethinking the nature

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<sup>1</sup> B. Glass (eds), *Survey of Biological Progress*, New York 2013, pp. 168.

<sup>2</sup> M. Biesiada, *Ocena ryzyka zdrowotnego mieszkańców Wiślinki związanego z oddziaływaniem hałdy fosfogipsu*, Sosnowiec 2006; L. Budek, M. Wardas, A. Kasprzyk, *Rozprzestrzenianie się metali ciężkich w środowisku wód powierzchniowych wokół wysypiska odpadów komunalnych w Baryczy*, „Inżynieria Środowiska” 2000 Vol. 5, No. 2, pp. 397–413.

of waste<sup>3</sup> as a by-product of human activity, but also economic analysis considering its generation in categories other than costs. This does not imply that creating waste is the purpose of manufacturing processes, but waste is an inevitable element, which should be treated as capital resources.

Nevertheless, the issue of a zero waste economy seems to be a political and business practice taken into account to only a small extent in theoretical deliberations by economists. This paper points out the theoretical assumptions of these transformations and at the same time proposes a change in the approach to the production function, which in mainstream economic discourse ignores these precious natural resources and assumes linear models of management.

### The origin and definition of the circular economy

The concept of the zero waste economy initially appeared in practice and politics. In business this term was first used by Paul Palmer in 1973 as the name of his company, which recovered resources from chemicals used in industry and science<sup>4</sup>. In a wider sense this concept appears, however, only in the 1990s, mainly in the context of waste management indicating the need for a holistic change in the approach to the problem of the storage or disposal of waste.

Today the concept of zero waste economy is strongly identified with the term circular economy, which has been addressed in much more numerous publications. A. Murray et al.<sup>5</sup> and F. Qiao et al.<sup>6</sup> when referring to the circular economy point to the writings by K. Boulding<sup>7</sup> and assume that this term was coined in opposition to the one-way, linear concept of the 'cowboy economy', inadequate for modelling the closed earth ecosystem which has become a single spaceship. In the linear economy resources are extracted, turned into products, and waste and emissions are removed. Both input and output in

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<sup>3</sup> J. Birkeland, *Ecological waste: rethinking the nature of waste*, „BEDP Environment Design Guide” 2007 Vol. 1, No. 6, pp. 1–9.

<sup>4</sup> A. Uz Zaman, *A Comprehensive Review of the Development of Zero Waste Management: Lessons Learned and Guidelines*, „Journal of Cleaner Production” 2015 No. 91, p. 13.

<sup>5</sup> A. Murray, K. Skene, K. Haynes, *The Circular Economy: An Interdisciplinary Exploration of the Concept and Application in a Global Context*, „Journal of Business Ethics” 2015 No. 3.

<sup>6</sup> F. Qiao, N. Qiao, *Circular Economy: An Ethical and Sustainable Economic Development Model*, „Prakseologia” 2013 No. 154, p. 254.

<sup>7</sup> K.E. Boulding, *The Economics of the Coming Spaceship Earth*, in: H. Jarrett (ed.), *Environment Quality in a Growing Economy: Essays from the Sixth RFF Forum*, Baltimore 1966, pp. 3–14.

such an economic model are problematic in the context of limited resources and space to accommodate waste.

The economic discourse also emphasizes the strong involvement of Chinese researchers who popularized the principle of closed loop production, not only in scientific discussions, but also in business practice and legislation, in the development of the concept of the circular economy. The above-mentioned A. Murray et al. also points to the papers of environmental economists or deliberations in the field of industrial ecology which present similar approaches to the problem of waste<sup>8</sup>.

However, as recently as in 2007 P. Glavič and R. Lukman analyzed the key concepts related to the issues of sustainable development and indicated that actually the definition of zero waste production has not been presented in any documents released by organizations dealing with the protection of the environment, such as the United Nations Environment Programme, the European Environment Agency, and the US Environmental Protection Agency<sup>9</sup>. In fact, even today, in spite of the development of programmes already based on the concept of zero waste economy in the European Union<sup>10</sup>, most sources refer to the definition used by the *Zero Waste International Alliance*<sup>11</sup> established in 2002. According to the definition proposed in 2009 by ZWIA, "Zero Waste is a goal that is ethical, economical, efficient and visionary, to guide people in changing their lifestyles and practices to emulate sustainable natural cycles, where all discarded materials are designed to become resources for others to use. Zero Waste means designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, conserve and recover all resources, and not burn or bury them. Implementing Zero Waste will eliminate all discharges to land, water or air that are a threat to planetary, human, animal or plant health"<sup>12</sup>.

This definition is very broad and indicates the holistic nature of changes in ethical, economic and environmental aspects. F. Qiao et al. even compares

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<sup>8</sup> A. Murray, K. Skene, K. Haynes, op. cit., p. 4.

<sup>9</sup> P. Glavič, R. Lukman, *Review of Sustainability Terms and Their Definitions*, „Journal of Cleaner Production” 2007 No. 15(18), p. 1880.

<sup>10</sup> European Commission, *Towards a circular economy: A zero waste programme for Europe*, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (Brussels: European Commission, 2014).

<sup>11</sup> J. Zwier et al., *The Ideal of a Zero-Waste Humanity: Philosophical Reflections on the Demand for a Bio-Based Economy*, „Journal of Agricultural and Environmental Ethics” 2015 No. 2(28), p. 13.

<sup>12</sup> ZW International Alliance, „ZW Definition”, *ZW Definition*, 2009, [www.zwia.org](http://www.zwia.org) [05/02/2016].

it to the Copernican change<sup>13</sup>, J. Birkeland indicates the shift of the paradigm in product design<sup>14</sup>, while S. Lehmann has a similar approach to cultural transformations in urban development<sup>15</sup>. On the other hand, A. Gillespie stresses that the emphasis is on avoiding not just the management of waste, since preventing the generation of waste is much more beneficial<sup>16</sup>. Consequently, it is vital to take actions in all areas of human activity, from the production process to change of lifestyle and consumer behaviour.

The zero waste concept is today linked with many other terms and concepts in waste management, such as clean production<sup>17</sup> or cleaner economy<sup>18</sup>, low emission economy<sup>19</sup> or low carbon economy<sup>20</sup>, bioeconomy<sup>21</sup> or bio-based economy<sup>22</sup>, circular economy<sup>23</sup>, as well as sustainable development<sup>24</sup>. Clean production or a bio-based economy are narrower concepts. The first one refers only to the aspects of zero waste economy from the perspective of production process (although in a very broad sense), while zero waste economy covers a wide range of activities, even in the area of consumption or the general transformation of communities. P. Glavič and R. Lukman define cleaner production (cleaner economy) as “a systematically organised approach to production activities, which has positive effects on the environment. These activities encompass resource use minimisation, improved eco-efficiency and source reduction, in order to improve the environmental protection and to reduce risks to living organisms”<sup>25</sup>.

<sup>13</sup> F. Qiao, N. Qiao, op. cit., p. 253.

<sup>14</sup> J. Birkeland, op. cit., p. 1.

<sup>15</sup> S. Lehmann, *Resource recovery and materials flow in the city: Zero waste and sustainable consumption as paradigms in urban development*, „Sustainable Development Law & Policy” 2010 No. 11, p. 28.

<sup>16</sup> A. Gillespie, *Waste Policy: International Regulation, Comparative and Contextual Perspectives*, Waikato 2015, p. 34.

<sup>17</sup> F. Qiao, N. Qiao, op. cit., p. 261.

<sup>18</sup> P. Glavič, R. Lukman, *Review of Sustainability Terms and Their Definitions*, „Journal of Cleaner Production” 2007 No. 15(18), p. 1879.

<sup>19</sup> O. Davidson et al., *The development and climate nexus: the case of sub-Saharan Africa*, „Climate Policy” 2003 No. 3, pp. 97–113.

<sup>20</sup> K. Shimada et al., *Developing a long-term local society design methodology towards a low-carbon economy: An application to Shiga Prefecture in Japan*, „Energy Policy” 2007 No. 9(35), pp. 4688–4703.

<sup>21</sup> K. McCormick, N. Kautto, *The Bioeconomy in Europe: An Overview*, „Sustainability” 2013 No. 5/ 6, pp. 2589–2608.

<sup>22</sup> S. Nebe, *Bio-Based Economy in Europe: State of Play and Future Potential, Summary of the position papers received in response of the European Commission’s Public on-line consultation, Studies and Reports*, Brussels 2011.

<sup>23</sup> A. Murray, K. Skene, K. Haynes, op. cit.

<sup>24</sup> F. Qiao, N. Qiao, op. cit., p. 261.

<sup>25</sup> P. Glavič, R. Lukman, op. cit., p. 1879.

On the other hand, the concept of bio-economy (*bio-based economy*, BBE) is related to the philosophy of G. Bataille<sup>26</sup>, who in response to the criticism of the mainstream economy developed his own 'general economy' and indicated that in the latter, "resources, production, circulation, growth and value are thought of not just in relation to the societal or private economy, but also in relation to the economy of nature and the universe"<sup>27</sup>. The key process here is the circulation of energy that is restricted by human communities, which rely on the concepts of mainstream economics, appropriating nature and leading to a significant depletion of global resources. Restricted economy treats energy as a purely economic commodity and ignores its relevance to biological processes. The European Commission defines the concept of bio-economy as "the production of renewable biological resources and the conversion of these resources and waste streams into value added products such as food, feed, bio-based products and bioenergy"<sup>28</sup>. The concept of clean production, low emission (low carbon) economy, and zero waste economy also encompass broader actions with respect to products that do not have to be biodegradable. The concepts of low emission and low carbon economy (containing the previous concept) have been coined mainly with reference to climate policy and the need to reduce greenhouse gas emissions. They have a very broad meaning for the regulation of production and consumption, but from the perspective of the concept of zero waste economy they must be considered as complementary and more focused on emissions rather than on waste. Each of these concepts can be used as a sustainable development strategy, which involves intergenerational respect for resources and a holistic approach to the relationship between the economy, community and nature.

The concept of circular economy is presented in the European Union and other documents as a zero waste strategy. The key document addressing this problem is *Towards a circular economy: a zero waste programme for Europe*<sup>29</sup>. This concept has been defined rather vaguely, as "closing the loop of product lifecycles through greater recycling and reuse, and bring benefits for both the environment and the economy"<sup>30</sup>. A report by the United Nations Environmental Programme defines the circular economy in a very similar way as an economy that balances economic development with environmental and

<sup>26</sup> J. Zwier et al., op. cit.

<sup>27</sup> A. Sorensen, *On a Universal Scale: Economy in Bataille's General Economy*, „Philosophy & Social Criticism” 2012 No. 2(38), p. 172.

<sup>28</sup> European Commission, *Innovating for Sustainable Growth: A Bioeconomy for Europe, Research & Innovation*, Brussels 2012, p. 9.

<sup>29</sup> European Commission, *Towards a circular economy: A zero waste programme for Europe*.

<sup>30</sup> U. Pisano et al., *The role of stakeholder participation in European sustainable development policies and strategies*, ESDN Quarterly Report, Vienna 2015, p. 20.

resources protection, and puts emphasis on the most efficient use and recycling of resources. The term also features low energy consumption, low emission of pollutants and high efficiency<sup>31</sup>. On one hand, it is a broader approach than the zero waste concept, as it also covers emissions, but on the other hand, the emphasis is on the reduction of resource use and their management, unlike in the more restrictive approach of zero waste presented in EU documents.

Nevertheless, in many documents and discussions the concept of the zero waste economy is identified with the restricted circulation economy. For example, according to the Ellen MacArthur Foundation, a circular economy is one that is restorative and regenerative by design and aims to keep products, components and materials at their highest utility and value at all times, distinguishing between technical and biological cycles<sup>32</sup>. In China, 'the world's largest factory', the circular economy was already put into practice in 1998<sup>33</sup> and is defined in legislation as a term for reducing, reusing and recycling activities conducted in the process of production, consumption and circulation<sup>34</sup>. It is difficult, therefore, to speak of a universally accepted definition, and additionally most analyses are carried out in the form of practical, political, or theoretical discourse.

## Calculation of the production function in the circular economy

In this paper, the production function is calculated based on the broad definition of the circular economy, similar to the one presented in the United Nations Programme. In this sense, it is assumed that in the economic process all cycles of matter must be closed in line with the generally accepted principles of the zero waste economy, but also taking into account emissions. Therefore, matter and energy in a broad sense, generated during economic activities, should be included in the cycle, not only to avoid the storage and disposal of waste, but also to prevent emissions in the perspective of climate change and energy management mentioned in the concept of the bio-economy.

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<sup>31</sup> UNEP, *Circular Economy. An Alternative Model for Economic Development*, Paris 2006, p. 1.

<sup>32</sup> Ellen MacArthur Foundation, *Towards A Circular Economy: Business Rationale For An Accelerated Transition*, 2015, p. 2.

<sup>33</sup> Z. Dajian, *Plan B: Rescuing a planet under stress and a civilization in trouble*, „Chinese Journal of Population, Resources and Environment „, 2003 No. 6(4), p. 4.

<sup>34</sup> F. Preston, *A global redesign? shaping the circular economy*, „Energy, Environment and Resource Governance „, 2012 No. 2, p. 3.

Winpenny pointed to the special role of some natural capital in sustaining biological and socio-economic processes<sup>35</sup>. Consequently, it is necessary to distinguish the natural capital and fundamental natural capital, which is difficult to assess in economic terms due to its significant role in the functioning of all living organisms.

In view of the above classification and postulates put forward by ecological economists, D. Pieńkowski proposed a definition of the production function, in which the goal of every economic process is also to improve the quality of fundamental natural capital<sup>36</sup>. In reference to these considerations, a traditional production function has the form of equation (1).

$$f(K, L) = Q \quad (1)$$

where: K – capital, L – labour, Q – volume of production.

Following the concept of J. T. Winpenny the production function can be extended to include the role of natural capital, as in equation (2).

$$f(k, P, \acute{S}, L) = Q \quad (2)$$

where:  $K = k + P + \acute{S}$ , k – man-made capital, P – natural capital,  $\acute{S}$  – fundamental natural capital.

Finally, if we consider the postulate proposed by D. Pieńkowski, the production function can be described by equation (3).

$$f(k, P, L) = Q + \acute{S} \quad (3)$$

As we can see in the latter case, the goal of every economic process is, in addition to production utilising man-made capital, labour and natural capital (natural resources), the improvement of the quality of fundamental natural capital such as air, water or the landscape. This approach requires that the improvement of the environment is taken into account whenever economic activities are designed and undertaken in line with the previously mentioned postulate by the European Commission “to bring benefits for both the environment and the economy”. However, in view of the objectives of the circular economy, there is no direct reference to the secondary man-made capital, which is the key element necessary to change the approach to the process of production.

According to the objectives of the circular economy, two key assumptions have to be adopted here. Firstly, we have to add to the current discussion an

<sup>35</sup> J.T. Winpenny, *Wartość środowiska. Metody wyceny ekonomicznej*, Warszawa 1995, p. 20.

<sup>36</sup> D. Pieńkowski, *Kapitał naturalny w teoretycznych analizach czynników produkcji*, „Ekonomia i Środowisko” 2002 No. 1(21), p. 15.

element obvious to all economists, but from the perspective of the production function treated as waste or emissions, more or less shifted onto nature. Due to the limited analyses in terms of the market value of these production effects, they were ignored in the formula for the production function, which should be expressed as follows (4).

$$f(K, L) = Q + W = Q_w \quad (4)$$

where:  $W$  – matter and energy generated in the process of production but not being the main goal of this process,  $Q$  – the volume of primary production representing market value.

Secondly, we have to consider postulated changes in the paradigm in terms of the approach to matter and energy generated in the process of production and not being the main goal of this process. In this sense, any waste or emissions form the secondary man-made capital and should be retained in the circulation of man-made capital as long as its inclusion in the circulation of matter and energy in the natural system does not create a risk to the balance of natural ecosystems. Following this assumption, the production function is expressed in formula (5).

$$f(k_a, k_w, P, L) = Q_w + \dot{S} \quad (5)$$

where:  $k = k_a + k_w$ ,  $k_a$  – primary man-made capital,  $k_w$  – secondary man-made capital.

As we can see, the volume of production ( $Q$ ) is expressed as the sum of the classically expected volume of production from equation 1, i.e. the goal of production ( $Q$ ) and the amount of generated matter and energy ( $W$ ). The inclusion of secondary man-made capital ( $k_w$ ) in the economy does not eliminate the need for undertaking measures or considering the effects of business operations on the quality of the fundamental natural capital ( $\dot{S}$ ). Of note is that the secondary man-made capital is a factor of production. It may be consumed and/or may be part of the fundamental natural capital if this does not deteriorate the quality of the environment. In the latter case, the secondary man-made capital can be assumed as an element of bio-economy.

Although in environmental economics the internalization of external costs (including those related to the generation of waste and emissions) is widely discussed, both with respect to political (the Pigou tax) and market solutions (the Coase theorem)<sup>37</sup>, from the perspective of the concept of the circular economy such measures are temporary and must lead to a change in the approach to secondary man-made capital, particularly in situations

<sup>37</sup> A. Graczyk, *Ekologiczne koszty zewnętrzne*, Białystok 2005.

where business operations are very burdensome for the environment and people, or all the possible consequences of undertaking these operations are associated with a high level of risk and uncertainty.

But the key problem is rethinking the process of management and shifting the core considerations from the category of cost to the category of valuable man-made resources. In this aspect also the technological development will not be perceived in opposition to biological processes, especially when it is associated with the inclusion of man-made capital in the natural capital without upsetting the balance of the global ecosystem.

## Summary

A specific feature of waste and emission management is the anthropogenic origin of this capital and its secondary character with respect to the major goal of business. However, in the process of closing the loop of man-made matter and energy modelled on the cycling of natural capital in the environment the deliberate and full utilisation and management of this capital has to be designed at the stage of production planning. The existing practices put a stronger emphasis on the safe and effective disposal of waste rather than its reuse. In this sense, production should be launched only if each of the products of the process (including secondary products) can be reused by the producer or sold or handed over to another producer who has a suitable technology for the reuse of this secondary product. Disposal of waste implies the expectation that nature, over a long time, can more or less safely return these resources into the cycle of matter and energy. However, because of the scale of matter and energy transformation in economic activity and the specific nature of these transformations, modern society is forced to adopt an integrated approach to the management of business operations by closing cycles of man-made matter and energy, or by including them in the natural processes, without upsetting the balance of local and global ecosystems.

Waste and emissions are resources that can be largely utilised in business operations if the consequences of their generation, and at the same time the possibility of their reuse, are planned in advance and included in the cycling of matter and energy between the economic and natural environment. The old approach to the economic process, focused only on the efficient use of resources, including restricted consumption and production, requires a broader look at business processes from the perspective of the inclusion of emissions and waste in business operations as value added elements in business.

## Authors' contributions to this article:

prof. Dariusz Pieńkowski, PhD – 50%

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