The circular economy of Robinson Crusoe: exploring the impact of the representative consumer

Danylo Cherevatsky[1], *Roman* Smirnov[2*], *Denys* Lypnytskyi[1], and *Myroslava* Soldak[1]

[1] Institute of Industrial Economics of National Academy of Sciences of Ukraine, 03057, Ukraine
[2] Dalhousie University, Department of Mathematics and Statistics, Halifax, B3H 4R2 Nova Scotia, Canada

Abstract. The circular economy typically addresses waste recycling issues at the micro-level, primarily focusing on individual enterprises, and less frequently at the meso-level, such as regions. This article introduces a novel perspective by examining recycling processes not only at the macro level but also through the lens of the Robinson Crusoe economy (ERC). The ERC concept was originally proposed in the 1930s. In this new paradigm, a representative producer, embodying Robinson Crusoe, establishes a business structure that implements a circular economy mega-project. This project comprises individual mono-projects aimed at maximizing profits derived from waste recycling. On the other hand, a representative consumer (representing the state and society) seeks to maximize its inherent utility, including taxes and fees. Now, the focus shifts to Robinson Crusoe as a consumer, thus defining the objective of this study as identifying approaches to determining the macroeconomic effects associated with such consumption. The recycling of blast-furnace slags in Ukraine serves as a case study for analysis.

1 Introduction

Admittedly, in times of economic turmoil, the ideas of John Maynard Keynes manifest themselves most prominently into reality, which in turn encourages their revision and study [1]. As Robert Rowthorn confessed ‘It would be an exaggeration to say that ‘we are all Keynesians now’, but surveys indicate that many leading economists in the USA and the UK have Keynesian sympathies’ [2]. However, it seems the time of ‘an intellectual potpourri of factoids, partial theories, empirical regularities without firm theoretical foundations, hunches, intuitions and half-developed insights. It is not much, but knowing that you know nothing is the beginning of wisdom’ has come [3].

This quote comes from the paper by Willem H. Buiter. In our opinion, it perfectly describes the current situation, namely while working within the framework of the ideology of “Industry 4.0” is not exactly, so to speak, beating a dead horse yet, we have now the new “Industry 5.0” that becomes widely accepted with its new paradigm [4].

*Corresponding author: roman.smirnov@dal.ca

Its main goal is to transform the current “cowboy economy” [5] into a circular one, that is a regenerating economy that is akin to the economy of a gigantic “space station”. Global economy by definition must be an economy of prosumers because the humankind is bound to consume and recycle what it has produced, including any waste, even of the most toxic kind [6]. In view of the above, the macro-level model of a Robinson Crusoe economy (RCE), which at its essence is an economy of prosumers, appears to be that Buiter’s potpourri that can be used to determine the effectiveness of a circular economy, as well as its value to society at large.

In summary, the study aims to investigate the macroeconomic impact of a representative consumer, Robinson Crusoe, within the context of mass waste recycling. Specifically, it focuses on the Ukrainian industry and the national taxation system as a case study. The paper is organized as follows. First, we generalize and analyze the literary sources relevant to our research to establish and describe the study’s purpose. Next, we develop an economic model for a RCE that aligns with the study’s objectives. In what follows, we introduce a method to calculate the macroeconomic effect of Robinson Crusoe as a representative consumer, considering the specific features of the Ukrainian national tax system. We conclude our study with a calculation of the macroeconomic effect of Robinson Crusoe within the equilibrium of the economic system in question.

2 Literature review

A Robinson Crusoe economy integrates a producer and a consumer operating with two goods, forming a "1×1×2" system. Since the beginning of the 20th century, this development by prominent marginalists has established itself as a university discipline [7, 8] but has not gained practical significance. It is worth noting that scientists from the Institute of Economics of Industry of the National Academy of Sciences of Ukraine have made a certain contribution to the topic of RCE at a micro level. In 2022 the authors conducted a detailed study to find an optimal strategy for a company engaged in a circular economy, specifically in the recycling of blast furnace slag [9].

The RCE is always an economy of a prosumer, but not the other way around. The presence of two commodities, namely the goods produced and leisure time, distinguishes the RCE from the economy of prosumers. This observation is not only original but also crucial for the further development of the theory. It should be mentioned that vertically-integrated structures are not truly RCE models without this clarification, but rather prosumer models.

The Robinson Crusoe economy was considered as aggregated [10], schizophrenic [11], but no one considered the "1×1×2" economy as a macro-level circular economy. While the functioning of the Robinson producer has been extensively studied [9], the indifference curves [12] characteristic of the Robinson consumer remain fragmented. Despite being invented in the 1930s, indifference curves continue to attract the attention of researchers [13].

The next step is to determine the relationship between a properly functioning Robinson Crusoe as a consumer of goods produced within the framework of a circular economy at the macro level. In other words, the main goal of this paper is to quantify this phenomenon.

3 Methods

This study is primarily focused on theoretical investigations and incorporates various general methods such as abstraction, induction, analysis, and synthesis. Additionally, it draws upon ideas from marginalism, specifically the Robinson Crusoe economy.

To illustrate the concepts and ideas presented in this work, a hypothetical case study on the recycling of blast furnace slag is provided. This case study is derived from extensive observations and studies conducted within the Ukrainian industry, offering practical insights into the application of the theoretical framework.

A general illustration of the Robinson Crusoe economy (RCE) is given in Fig. 1 [7].

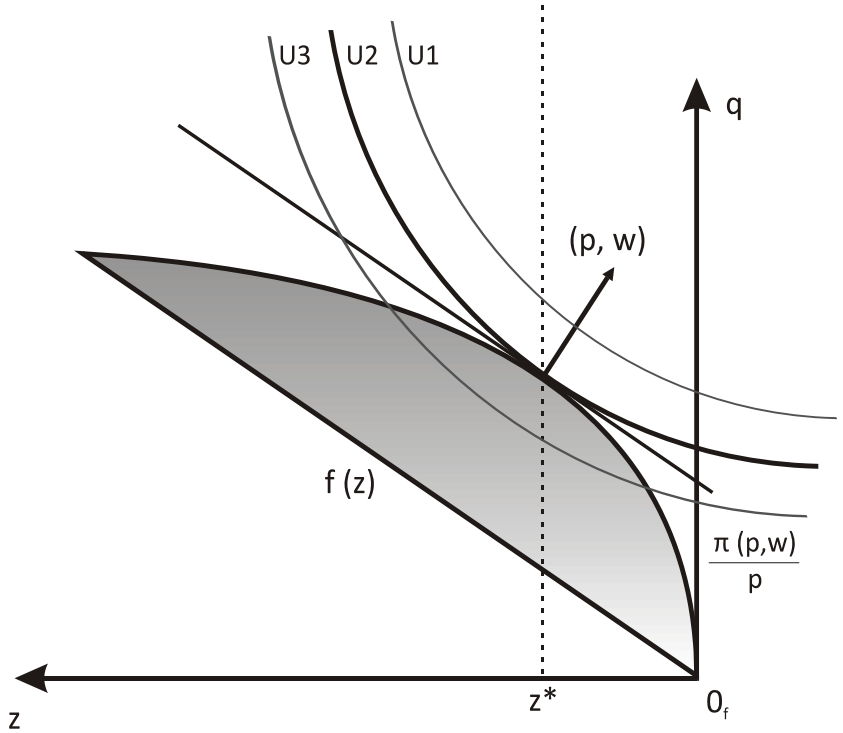

Fig. 1. Options of interrelations between Robinson-prosumer.

The first good, denoted as x_2, represents the useful product, while the second good, denoted as x_1, represents the analogue of Robinson's leisure, which is the difference between the maximum possible resource consumption and the resources spent on the production of commodity x_2. The numerical correlation between the product q and resource z is represented by the function $f(z)$, which is an attribute of the manufacturer. The consumer attribute is represented by the utility functions $U_i(x_1, x_2)$, which are indifference curves. The price of the useful good is denoted as p, and the price of the resource is denoted as w. The outcome of the production activity is the profit π.

The position of the equilibrium in the Robinson Crusoe economy, which represents the Pareto optimum, is determined by the point with coordinates z^*, where the curves $f(z)$ and $U2$ intersect.

In contrast to the classical microeconomic model, the new Robinson Crusoe economy operates at the macro-level, representing a national economy. In this system, Robinson Crusoe serves as both a representative producer and a representative consumer, contributing to the total market value of goods and services produced annually using all available resources. In the context of the circular economy, this implies that the goods and services are derived from slag produced within the metallurgical industry.

The development of a national industry for processing this waste can be seen as a mega-project, consisting of a collection of localized mono-projects that function as individual circular industrial ecosystems.

In the modified "1x1x2" economy model, a representative Robinson Crusoe is currently involved in processing blast furnace slag in Ukraine, resulting in a generalized useful product that contributes to the country's GDP.

4 Results

The representative Robinson Crusoe-consumer of goods represents society, including the state and local communities involved in the slag business, among others. The challenge lies in evaluating the macro effect at the national economy level. The direct income of the representative Robinson Crusoe-consumer consists of tax revenues and fees, which can be divided into two groups – those collected from enterprises and those collected from workers, depending on the number of personnel *M*.

$$\eta_t = \beta_i + \alpha_j, \tag{1}$$

where η_t represents tax revenues in year *t*; β_i represents tax revenues and fees collected from enterprises; α_j represents taxes and fees collected from workers.

According to the Tax Code of Ukraine, all enterprises that have chosen the general taxation system are required to pay basic taxes. Table 1 provides data on the taxes applicable to enterprises involved in slag processing.

Table 1. Taxes and fees are included in the Tax Code of Ukraine.

Taxes	Marking	Base	Marking	Norm, fraction of Unit	Marking
On the profit of enterprises	β_1	Profit	π	0,18	μ_1
For added value (VAT)	β_2	Price	p	0,20	μ_2
Single social contribution	β_3	Remuneration fund	*F(M)*	0,22	μ_3
Taxes and fees from individuals					
Military levy	α_1	Remuneration fund	*F(M)*	0,015	ε_1
Personal income tax (PIT)	α_2	Remuneration fund	*F(M)*	0,18	ε_2

The existing Value Added Tax (VAT) is not specifically a tax on value added; in fact, it is a tax on the total value of the goods. The taxable object is the value of the goods [14]. Although the authors understand the essence and algorithm of value added taxation, it is important to note that not the entire amount calculated based on sales turnover is payable as VAT. Only the difference between the calculated amount and the VAT paid or payable by a specific taxpayer when purchasing raw materials, materials, goods, works, and services is considered. The adopted scheme for VAT calculation is followed during the process, according to which:

$$\beta_2 = p\mu_2. \tag{2}$$

The overall logic of recycling operations is that the main resource of the enterprise is not acquired but rather the existing raw materials are utilized.

The labor remuneration fund of the recycling slag enterprise also depends on the volume obtained during the technological processes of slag masses.

$$F = \frac{q_t}{n} l, \tag{3}$$

where n is the average labor productivity; l is the average annual labor costs for an employee.

In addition to tax and social contributions, enterprises must also pay rent for the land allocated for slag dumps. These payments go to local budgets.

$$\gamma = \Delta\rho, \tag{4}$$

where γ is the revenue to local budgets from leasing land plots; Δ is the area of the landfill for slag disposal; ρ is the rental rate for the land plot allocated for slag dumps.

The area of the processing and storage landfill for slag depends on the volumes of slag material to be stored.

$$\Delta = (z_t - z_{1t})\varphi, \tag{5}$$

where φ is the rate of placement of slag mass on the landfill; z_t is the volume of slag obtained in year t; z_{1t} is the volume of slag subjected to recycling.

The difference between the volume of slag generated in the specified period and the amount that has been processed, i.e., the slag that the Robinson producer did not recycle but sent to the dump, should become a source of replenishing the public good through the collection of fees.

Thus, the aggregated Robinson consumer has revenue based on what the Robinson producer released as a product in terms of slag recycling (taxes), and from not using it as raw material but rather sending it to the landfill and paying for waste disposal on a specific territory (fees). In this way the indifference curve of Robinson the consumer reflects the exchange of goods: more taxes mean fewer fees, and vice versa. If the processed slag z is considered a resource in the production function of the aggregated Robinson the producer, then for the aggregated Robinson the consumer, the argument of the utility function is:

$$x_1 = z_N - z, \tag{6}$$

where z_N is the annual volume of slag based on the full capacity functioning of the recycling complex; z is the volume of slag as the independent variable of the production function.

The maximum satisfaction of the consumer is related to the maximum satisfaction of Robinson as the producer: this is the key point of Robinson Crusoe's macroeconomics, which is depicted on the diagram as the tangent point where the production function meets a certain indifference curve.

In general, the slag recycling industry is capable of providing annually a certain amount of taxes and fees to society, namely:

$$\eta_t = f(z)\left[p(\mu_1 + \mu_2) + \frac{l(\mu_3 + \varepsilon_1 + \varepsilon_2)}{n}\right] - \mathrm{z}w\mu_1 + (z_t - z_{1t})\varphi\rho. \tag{7}$$

Obviously, the economic efficiency of Robinson Crusoe the consumer's functioning primarily depends on the variables p, w, ρ, z_t, and z_{1t}. Based on the experience of functioning of large Ukrainian metallurgical plants, the proportion of blast furnace slag processing did not exceed 70% even in better times, with the rest being disposed of in landfills [15].

Later, due to declining demand for recycling products, low prices for slag as raw material, and the high cost of transportation, the situation worsened, leading to a decrease in slag processing and a significant increase in landfill volume. According to the findings presented in [9]:

$$f(z) = Ns = Nkln(r) + N, \tag{8}$$

where N — the maximum production capacity of the enterprise for processing waste into a useful product for the period t, metric ton; s is the standardized annual output of a useful product, unity fractions; $k>0$ is the coefficient of the production function; r – the standardized volume of waste (slag furnace) recycling, unity fractions.

$$r = \frac{z}{z_N} = e^{(s-1)/k}, \tag{9}$$

where e is the base of the natural logarithm.

$$k = 0{,}3e^{3{,}2r_0}, \tag{10}$$

where r_0 is the normalized value of industrial waste remaining unused during recycling for the period of time t.

$$r_0 = \frac{z_t - z_{1t}}{z_N}. \tag{11}$$

$$r_{opt} = 0{,}3e^{3{,}2r_0}\frac{p_1}{w_1}, \tag{12}$$

where r_{opt} is the value that meets the optimality condition according to the criterion of maximum profit; p_1 – the cost of producing useful products under conditions $s = 1$ (when production is operating at full capacity – the price of a unit of output); w_1 – the cost of the waste recycling under the conditions of operation of production at full capacity, the price of the unit of resource (under conditions $s = 1$).

$$N = z_N(1 - r_0)\omega, \tag{13}$$

where ω – product output rate from waste recycling.

In view of the above, we derive from the equation (12) the following expression.

$$\frac{\eta_t}{p_1} = (0{,}3e^{3{,}2r_0}\ln(r) + 1)\left[\mu_1 + \mu_2 + \frac{Nl(\mu_3 + \varepsilon_1 + \varepsilon_2)}{np_1}\right] - \frac{rw_1}{p_1}\mu_1 + \frac{z_t r_0 \varphi\rho}{p_1} \tag{14}$$

If we accept the performance indicators of the slag processing industry as for the traditional industry "Production of concrete products for construction" (Table 2), then the indicators of a representative Robinson Crusoe consumer will be the values shown in Table 3.

Table 2. Data for calculations of the macro effects of the Robinson Crusoe circular economy of slag processing (dated 2020).

z_N, *Mt*	z_t, *Mt*	z_{1t}, *Mt*	z_t-z_{1t}, *Mt*	p, thousand UAH/t	l, thousand UAH per capita	n, t per capita
11,0	11,0	8,1	2,9	2000	112,0	586
μ_1	μ_2	μ_3	$\varepsilon_1+\varepsilon_2$	w/p	φ, t/m^2	ρ, UAH/m^2
0,18	0,2	0,22	0,195	0,7	18,7	0,59
r_0	k	r_{opt}	s	ω	N, Mt	M, thousand people
0,262	0,700	1,0	1,0	1,43	15,7	26,8
p_1, billion UAH	π/p_1					
31,4	0,51					

The researchers did not specifically include the analysis of Keynesian multiplicative effects in other industries such as cement production, road construction, or the service sector in their study. While these effects could be relevant and provide additional insights into the broader economic impact, they were not within the scope of the researcher's tasks and objectives for this particular study.

Table 3. Results of the functioning of a representative consumer of the circular economy reduced to the cost of useful products produced (under condition s=1).

Indicator	**The given values are fractions of Unit**
Profit tax	0,09
VAT	0,20
Remuneration fund Tax	0,04
Fees for environmental protection	0,02
The total amount of taxes and fees	0,33

5 Conclusions

The characteristics of the modern turbulent flow of economic activity have motivated researchers to explore new models for understanding the underlying regularities. In this study, the researchers utilized the Robinson Crusoe economy, which was initially proposed in the 1930s. The model, represented as "1x1x2", involves one producer, one consumer, and two goods. As a producer, Robinson Crusoe seeks to maximize profit, while as a consumer, he aims to maximize satisfaction.

Despite being taught in leading universities worldwide, traditional model has seen limited utilitarian application. However, the authors of this article suggest that the rise of the circular economy, driven by the ideology of sustainable development, can reinvigorate the RCE. Humanity, by definition, is a prosumer civilization, consuming only what it produces. Currently, the "1x1x2" economy serves as an example of prosumerism.

In 2022, the authors extensively developed the role of Robinson Crusoe as a producer participating in the circular in the circular economy at a micro-level in metallurgical industry. The focus has now shifted to Robinson Crusoe as a consumer of the consequences of circular activities, leading to the goal of this study: identifying approaches to determine the macroeconomic effect associated with such consumption.

The research is based on the concept of a representative producer of useful goods resulting from waste recycling and a representative consumer of circular economy outcomes at the macroeconomic level. Essentially, there exists a macroeconomic mega-project comprising a collection of mono-projects, with specific circular ecosystems acting as implementers. While Robinson Crusoe, as a producer, aims to maximize profit, Robinson Crusoe as a representative of the state and society seeks to maximize taxes and charges related to recycling activities. The article provides an example of slag recycling to illustrate this concept.

Aligned with the research objective, the authors have developed a conceptual framework and calculation formulas to assess the outcomes of the representative Robinson Crusoe consumer's activities. The research has reached a conclusive stage, and its results are ready for implementation in industrial settings. However, it remains pertinent to investigate the impact of environmental charges on the well-being of both Robinson Crusoe as a producer and Robinson Crusoe as a consumer of the consequences of recycling activities.

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