Circular Economy and 4.0 Industry: From the Emergence of Concepts to Practical Application in Brazil Steelmaking

This article examines the evolution of circular economy concepts derived from the economic theory of externalities, emphasizing their critical role in the Fourth Industrial Revolution. It highlights the importance of accurately interpreting these concepts when developing technological solutions to transition from a linear to a circular production system. The focus is on the steel industry, providing practical examples from steel mill operations, demonstrating how circular economy principles can be effectively integrated into industrial processes to foster sustainable production.

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Introduction

Economic growth demands increased production of goods, services and materials, consequently generating more waste. The environment is no longer capable of absorbing the generated residues, just as easily extractable material sources have become increasingly scarce. This article examines the evolution of technological advancements and production systems in parallel with the improvement of information asymmetries among agents, leading to the emergence of circular economy concepts and their fundamental role in the Fourth Industrial Revolution.

A Brief History of Circular Economy: "From the Concept of Externality to the Four Pillars of Circular Economy"

Economic science studies the decisions of agents and their consequences. Economic models have been developed based on the assumption of information symmetry, meaning that all agents have access to complete information for decision-making. However, while these models approximate reality, they do not fully reflect it. Extrapolating them involves incorporating information asymmetry, i.e., considering the effects of unanticipated information. These considerations, introduced through statistical tools, created the first suboptimal analytical models, in which asymmetries are addressed using probabilistic distributions of choices, the available level of information and decision outcomes.

In analyzing agents' choices, asymmetry can be approached in two ways: (i) as transaction costs (the cost of obtaining the maximum amount of information before a transaction — avoiding externalities), or (ii) as externalities, which are the unanticipated effects of this information asymmetry. In the second case, once the agents have made their decisions, the established asymmetry or externality can then be measured.

Ronald Coase[1] references the case presented by economist George J. Stigler, in which a company (originally a steel plant) pollutes a watercourse, leading to the death of fish. From the perspective of externalities, this reduction in fish, affecting fishermen, is seen as an inherent byproduct of steel production that impacts fishing. The core issues studied in externalities are: what is the limit of agents' freedom, and how can the costs of the externality be measured?

The First Industrial Revolution occurred between 1760 and 1840, transitioning from preindustrial manufacturing to the establishment of factories, introducing new means of transportation such as railroads and