A macro level of assessment of material circularity

Aguilar Hernandez, G.A.

Author: Aguilar Hernandez, G.A.
Title: A macro level of assessment of material circularity
Issue Date: 2021-05-06

Summary

A sustainable resource management is an essential aspect to satisfy the current human needs without compromising the needs of future generations. However, there are several challenges for achieving resource use in sustainable way. For example, the increase of resource extraction as well as disruptive events (e.g. natural disasters, or financial crisis) are two of the aspects that affect resource availability and accessibility. Thus, there is a need to provide resource-efficient strategies that enables to decrease the risk of disruptive supply chains while maintaining natural resources for the current and future generations. Within this context, circular economy has been proposed as a paradigm that aims to reduce resource extraction and waste flows by retaining materials into the economy. Furthermore, there are multiple actions or processes that lead material circularity and a sustainable - here called circularity interventions – in which researchers and practitioners have proposed effective strategies to achieve a sustainable resource management.

From global perspective, it becomes crucial to understand whether circularity interventions could lead to macroeconomic, social, and environmental benefits. This has led to a growing body of literature that assess the global material inflows and outflows, providing a global picture of resource use and its economic and environmental implications. However, there is still a lack of understanding on how a global circularity transition might look like, and what would be the magnitude of the potential economic, social, and environmental implications of material circularity on macro scale. These aspects raise the questions: is circular economy a sustainable solution to achieve a global economic and environmental sustainability? And what are the macroeconomic, social, and environmental implications of a transition to a circular economy?

A macro level assessment of material circularity aims to assess whether circularity interventions could contribute to a sustainable resource management, and explore which circularity interventions could contribute to a cost-effective circularity transition on a macro scale. In this matter, environmentally extended input-output analysis (EEIOA) has been used as consistent framework to assess potential macroeconomic and environmental impacts. In contrast with other methods (e.g. life cycle assessment (LCA) and material flow analysis (MFA)), EEIOA method brings the advantage of incorporating the size and structure of an economy, in which circularity interventions can be evaluated in a comprehensive way.

To address the main aim, there are three aspects that require to addressed. First, although EEIOA brings a suitable framework to assess material circularity, it is important to understand how to apply EEIOA in the assessment of circularity interventions. Second, there is a lack of information about the potential materials that can be used for a global material circularity. Third, there is a need to determine what could be the potential macroeconomic, social, and environmental impacts of material circularity. To fulfil the mentioned aspects, Chapter 1 to 5 offered answers to each research question mentioned below, as follows:

> RQ1. *What is the state of the art of environmentally extended input-output analysis on the assessment of circularity interventions?*

To answer RQ1 question, Chapter 2 brought a systematic literature review of EEIOA-based studies on the assessment of material circularity. This Chapter presented over 90 publications

that assess circularity interventions, which were analyzed in terms of the opportunities and limitations of applying EEIOA method. Based on the reviewed literature, a consensus on how to model circularity interventions using EEIOA was established. Likewise, Chapter 2 showed how each circularity intervention requires different ways to adjust intermediate and final demand coefficients, and the integration of multiple data in input-output tables. Overall, general, an effective assessment of circularity interventions would require the use of physical and hybrid-units input-output tables that enable the integration of secondary materials and waste flows in the EEIOA framework.

> RQ2. *How much unrecovered waste is available to be reintroduced into the global economy as secondary materials in a specific period?*

To address RQ2 question, Chapter 3 presented an estimation of the circularity gap of 43 countries and 5 rest of the world regions in 2011, using the global, multiregional, hybrid-units input-output tables (MR-HIOT) EXIOBASE. This Chapter also redefined the circularity gap as waste generation plus waste generated from previous in-use stocks (i.e. stock depletion) minus waste recovery, which represents the amount of unrecovered waste available for recovery or recycling in a specific period. The global material inflows amounted to 77 Gt in 2011, which was constituted of material extraction (74 Gt) and waste recovery (3 Gt). From the global material inflows, 40 Gt were used for energy and food purposes, 30 Gt was added to in-use stocks, and 7 Gt became waste. The total waste was 9 Gt in this period, and the circularity gap was 6 Gt (i.e. total waste minus waste recovery), which represented around 8% share of the global material extraction. Thus, there was only a small fraction of unrecovered waste that can be used for material circularity. Furthermore, the circularity gap varied with respect to the level of economic development, where high income regions presented larger circularity gap per capita compared with middle and lower middle income countries. Finally, Chapter 3 discussed how to implement the circularity interventions described in Chapter 2 to minimize the circularity gap of each country and region.

> RQ3. *Where are the materials accumulated in the global economy that could enable a circularity transition?*

Chapter 4 brought an answer to RQ3 by estimating the global distribution of material added to in-use stocks. This Chapter showed a high geographical, material type, and sectoral distribution of material inflows to in-use stocks across 43 countries and 5 rest of world using the MR-HIOT EXIOBASE. As mentioned in Chapter 3, global material added to in-use stocks amounted to 30 Gt in 2011. Based on the geographical distribution, high income countries and some emerging economies (e.g. China) amounted for almost 70% of material inflows to in-use stocks in 2011, also having the highest stock additions per capita worldwide. For material types, stock additions comprised non-metallic minerals (87.9%), steel (5.2%), wood (4.5%), plastics (0.7%), paper (0.6%), glass (0.5%), other metals (0.4%), and textiles (0.2%). For sectoral distribution, construction sector comprised around 90% of non-metallic minerals, which highlights the relevance of implementing circularity interventions for the construction sector. Chapter 4 also discussed the application of circularity interventions from Chapter 2 to identify which circularity interventions can be used for a sustainable management of material inflows to in-use stocks in the shortest- and long-term.

> RQ4. *What are the expected macroeconomic, social, and environmental impacts of circularity interventions at national and global level?*

To answer RQ4, Chapter 5 presented a systematic literature review and meta-analysis of publications that analyze the potential changes in GDP, employment, and carbon emissions generated by the adoption of circularity interventions (i.e. circularity transition). Chapter 5 covered over 300 circular economy scenarios (CESs) from 2020 up to 2050, which were reviewed and harmonized to perform a statistical analysis to determine whether circularity interventions could lead to a 'win-win-win' situation in terms of macroeconomic, social, and environmental impacts. Based on the reviewed CESs for 2030, circularity interventions could lead to incremental changes in GDP (median (mdn) = 2.0%; interquartile range (IQR) = [0.4–4.6]%), and job creation (mdn = 1.6%; IQR = [0.9–2.0]%), while changes in CO2 emissions could be more substantial (mdn = -24.6%), but values are largely spread (IQR = -[34.0–8.2]%).Moreover, Chapter 5 discussed the 3 main modelling features applied in CESs (i.e. resource taxes, technological and consumption pattern changes), as well as which additional modelling features are required to enhance the assessment of material circularity at macro scale.

Overall, Chapter 2 to 5 showed that material circularity play an important role for a sustainable resource management. Nevertheless, material circularity by itself will not be enough to address global sustainability issues. For instance, the current amount of waste available for circularity is not enough to satisfy the demand of new goods and services. This is because global material inflows to in-use stocks are higher than the materials removed from in-use stocks. Furthermore, material circularity has a limited contribution to decrease material extraction for food and energy purposes, because food and energy flows cannot be reintroduced into the economy as other durable goods. To address sustainable resource management, it would be required the integration of other existing strategies from other systems (e.g. food and renewable energy) together with circularity interventions.

A macro level assessment of material circularity contributes to bring a better understanding of the opportunities and limitations of applying EEIOA on the assessment of material circularity; how circularity interventions can be used by multiple countries or regions; and a consensus of the macroeconomic, social, and environmental impacts of a circularity transition.

Furthermore, the use of MR-HIOT EXIOBASE provided an important advance on the assessment of material circularity because it avoids the disconnection between monetary and physical values of waste flows and other material flows with the highest level of resolution up to date. Further research on material circularity should focus on improving the MR-HIOT EXIOBASE in terms of data resolution, waste accounts, time series, stock accounts and stock-flow modelling, dynamic modelling, and data uncertainty. These aspects will lead to a more comprehensive information that can be used to support decision makers on implementing circularity interventions in more cost-effective way.