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Analysis of regional economic metabolism through modeling

Afonso Silva^{a,*}, Bruno Augusto^a, Sandra Rafael^a, Johnny Reis^a, Myriam Lopes^a,
Sérgio Costa^b, Carlos Borrego^a

^a CESAM & Department of Environment and Planning, University of Aveiro, 3810-193, Aveiro, Portugal

^b Simbiente - Engenharia e Gestão Ambiental, 4000-486, Porto, Portugal

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Abstract

A linear economic model has proven to lead society into an unsustainable situation. Current policies have been promoting the transition for a circular economy across Europe. Portugal's Action Plan for Circular Economy foresees the development of regional agendas, which include the characterization of regional economic metabolism. Taking resources inputs, extractions and imports into account, as well as the generated outputs, such as exports and emissions to the environment are a fundamental need for an efficient resources management. Indicators associated with regional economic metabolism allow the identification of inefficient use of natural resources and energy, and opportunities for circularity, which can promote new business models and investments. In this context and to fulfill the current need of evaluating the regional economic metabolism, this work describes the development of the REMET-UA (REgional METAbolism) model. This model was developed to take into account the specificities of Portuguese regions, allowing an analysis with a high-resolution level.

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Keywords: Circular economy; Regional agendas; Regional metabolism; REMET-UA model; Sustainability

1. Introduction

International treaties and pacts about sustainable development have united countries into rethinking about the viability of their economic system, in particular the usage of resources in a linear way. Recently, circular economy has been promoted worldwide as a sustainable alternative to the current economic model. In the end of 2017, Portugal approved an Action Plan for Circular Economy (PAEC) which can be described as a strategic model of growth and investment based on the efficient use of resources and in the mitigation of environmental impacts. The origin of this action plan is based on international agreements and deals like the Paris Agreement, Sustainable Development Goals and of course, the constant commitment with the European Union and with national policies. The plan presents three levels of actions, which included the development of regional agendas, adapted to the

* Corresponding author.

E-mail address: afonsosilva@ua.pt (A. Silva).

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socio-economic specificities of each region. The regional agendas for the circular economy aim at the outgrowth of transition and acceleration strategies that best suits the socio-economic profile of every region [1].

The elaboration of the regional agendas for the circular economy has the purpose to create and promote conditions to identify potentialities and for the implementation of territorially based actions adapted to their specificities. These agendas must be supported in three areas: (i) characterization of the regional economic metabolism and the specificities and valences of the territory; (ii) the definition of a model of governance that allows the effective accomplishment of the goals and actions of the agenda; (iii) the identification of the most relevant transition sectors at the regional level, which can serve as catalysts for the implementation of the agenda [2]. The concept of regional economic metabolism is supported by the analogy between the consumption of resources and the production of waste by the socioeconomic system (economic metabolism) and the metabolism of living beings and ecosystems (ecological metabolism). This means that the metabolism is characterized by a set of inflows and outflows of materials, energy and water as well as consumption, use and storage. The quantification and subsequent analysis of these flows allows the identification of synergies between the consumption needs of economic activities and the availability of materials to integrate productive cycles, identifying economically profitable opportunities for regional development [3]. Taking resource inputs, extractions and imports into account, as well as analyzing outputs, such as exports and emissions to the environment, is a fundamental need in an efficient resource conservation planning. Indicators associated with the regional economic metabolism allow to identify the inefficient use of natural resources and energy. These indicators are important tools in monitoring and developing measures to improve resource management, the development of a circular economy and to promote territorial and industrial symbiosis. In addition, they provide an integrated view of the movement of materials through the economy, important for regional socio-economic development. In this context, REMET-UA model, version 1.0, was developed by the authors at the Department of Environment and Planning of the University of Aveiro. The model allows to identify feasible and logistic opportunities for the efficient use of resource between regional agents based on the knowledge of quantities of material and sub products in each location. The main goal of this work is to present the conceptual approach of REMET-UA model as a tool to assess the regional economic metabolism. REMET-UA also has the potential to evaluate synergies of materials in terms of fluxes between regions maximizing the amount of information available at this scale for municipal councils and enterprises to use having into account the purpose of circular economy.

2. Regional metabolism model – REMET-UA – and methodological approach

Action plans for circular economy created a recent need of characterization the regional economic metabolism to be included in the new regional agendas without giving regional communities proper means to develop this work. There are few models available to calculate and represent the material flows for a region, however, they either do not allow the inclusion of more than one region or they are not prepared to account for a large number of material categories. In this context, answering to the Commission for Regional Coordination and Development of Alentejo (CCDR-Alentejo) request and in partnership with the companies Simbiente — Environmental Engineering and Management and Quarternair Portugal a model was developed to assess the urban metabolism of the Alentejo Region, except Lezíria do Tejo, with the main objective of supplying information that allows to: (i) promote the circular economy of the region; (ii) promote a “smart” region (i.e. resource efficient) and (iii) promote investment.

The REMET-UA model provides an economic analysis of material flows based on the methodology defined by Eurostat [4], and has been developed according to three prerequisites: (i) scale, the model can be adapted to any spatial scale (region, city, municipality, etc.); (ii) supported by Microsoft Excel format, in order to guarantee the application of the model through an intuitive, user friendly and linear interface for the user (interoperable model); and (iii) interregional interactions, this means that the model quantifies the interactions between NUT (Nomenclature of Territorial Units for Statistics) III sub-regions, representing them according to the user’s needs.

Six principles were fundamental while developing the REMET-UA model: (a) Focused (Specific material flow analysis to seek opportunities of circularity) (b) Scalable (capable of adapt to any territorial scale and flexible to alterations according to user needs); (c) Participative (implement with help from regional agents); (d) Evolutionary (though to allow its evolution since the first phase of development); (e) Interpolated (Developed in Microsoft Excel allowing ease of use and integration with other tools); (f) Regionalized (Ready to have into account interactions between NUT III subregions);

In addition, the model was developed in a participatory way, allowing, in one hand, the involvement of regional actors in the collection of information, and on the other, the dissemination of concepts and the promotion of the collaborative spirit for future developments.

This model allows to represent graphically the inputs and outputs of the economy of a region and to gauge basic indicators set from the Eurostat methodology, calculating the materials that are stored or wasted and which can lead to new opportunities. The general categories divide themselves between biomass (including 34 sub-categories), metal ore (including 13 sub-categories), nonmetallic ore (including 10 sub-categories), fossil fuels (including 8 sub-categories), industry (including 15 sub-categories), health (including 2 sub-categories), waste (including 9 sub-categories), water (including 1 sub-category) and others (including 2 sub-categories). Each of these general categories include various sub-categories adapted to the information obtained providing a more detailed data about the general categories. The model is flexible and allows adaptation to any territorial scale and for the user to add new categories according to the need and availability of data. The first phase of approaching the development of a regional economic metabolism is to collect, treat and operate data of activities and products. The categories and themes of collection were identified according to the information available. In detail, the base categories of materials used in the model are based on the Eurostat categories, adapted to the Portuguese reality according to the Portuguese Institute of Statistics (INE) and other statistical databases (PORDATA). The model is developed in a way that the categories can be altered and adapted by the user to attend to its specific demands and availability of the input data.

The data collection technique to feed the database consisted of a general and comprehensive documentary analysis applying expeditious and intuitive research tools, using as an instrument of online data collection the analysis of the main clusters, regional management entities, companies in the region and annual statistical and economic reports. It is also worth noting and anticipating the difficulty of obtaining data for feeding the model, that it was developed to be applied according to available information, allowing its constant updating (evolutionary model); however, the quality of the results are proportional to the quantity and quality of the input data of the model. In Portugal, as in the rest of the world, systematized data collection is a difficult process to reconcile with research. If on the one hand the compilation of data is scarce and difficult to access, on the other hand the existing data is not in quantity and quality necessary for the purpose for which it is intended.

Analyzing and promoting spatial disaggregation is essential to define the average reference values and origins of goods and products, internal flows in the various production and processing chains, internal consumption and outputs of goods and products of the region, as well as to identify the relevant sectors in terms of consumption and the strategic sectors for the development of the region.

In a case where the approach is to be made in a European region, member states can use the geocode standard of the Nomenclature of Territorial Units for Statistics (NUTS), specifically NUTS III because at this level large areas are subdivided mostly into subregions, districts or provinces. The main constraints of this phase are that the available information is very scattered, not detailed, with variable degrees of confidence, few data available at the NUTS III level (or with more detail) and the high time required for the collection of information (not systematized) in different entities. The model considers as inputs imports and domestic extractions, the respective exports, environmental emissions (that includes landfill waste, wastewater, atmospheric emissions) and internal resource consumptions, calculating the materials in stock inside the system boundaries/domain. Fig. 1 shows the conceptual scheme of the material flows that are in the basis of the REMET-UA model.

The model, in its current version, uses a mass balance to calculate inputs and outputs of a study area (Fig. 1), and allows to calculate and represent the interactions between sub-regions in an intuitive way for the user. At this stage, the model does not yet include processes, so the way the input data is organized its crucial for a good functioning. In this sense, the quality and quantity of necessary data to feed the model is very important to obtain trustworthy results.



Fig. 1. Conceptual scheme of material flows considered in the REMET-UA model.

The model provides a quantitative and qualitative analysis aiming to offer an integrated vision about the movements of material flows between economies, relevant for the development of a socioeconomic regional metabolism. For the quantitative analysis, the model calculates the base indicators considered in Eurostat methodological guide. The indicators allow to identify the inefficient use of natural resources and energy with measures to improve the management of resources. These indicators, both in total value and per capita, are:

- Direct Material Input (DMI) - Represents the direct input of materials to the economy;
- Domestic Material Consumption (DMC) - Represents the total quantity of material used directly in the economy;
- Domestic Processed Output (DPO) - Measures the total quantity of materials released into the environment after use. Includes waste for landfill and atmospheric emissions;
- Net Additions to Stock (NAS) - Measures the physical growth rate of an economy by the difference between new materials added and material removed after their use;
- Physical Trade Balance (PTB) - Defines the difference between physical imports and physical exports

3. Case study application: Alentejo

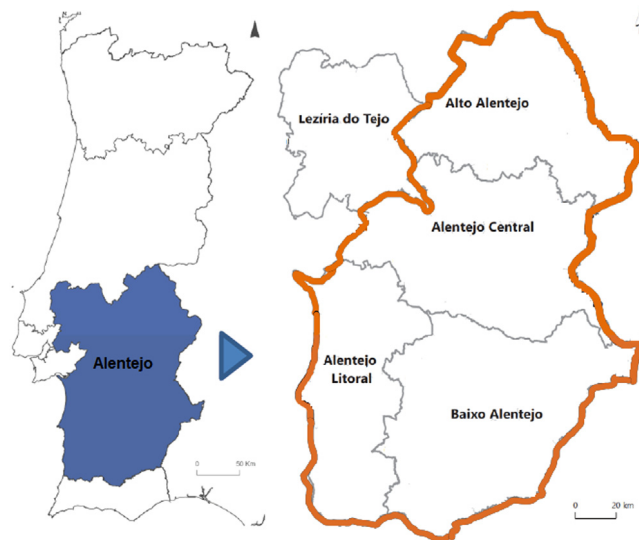


Fig. 2. Location of the case study in the Portuguese mainland. The four NUT III regions in the case study are highlighted (PT181 — Alentejo Litoral, PT184 — Baixo Alentejo, PT186 — Alto Alentejo and PT187 — Alentejo Central) [3].

Alentejo is the largest region of Portugal, corresponding to about a third of the continental area. This region is bordered to the east by the Spanish border and to the west by the Atlantic Ocean (Fig. 2). This region is characterized by many natural, scenic, heritage and cultural advantages. The geographical location of the region also offers strategic potential for external imports through the port of Sines, the largest harbor of Portugal in terms of merchandise movement and the main gateway to the country's energy supply, good road accessibility and proximity to Spain, Algarve and the Metropolitan Area of Lisbon [3]. Despite the recognized potential of Alentejo, several factors still contribute to the low representation of the region in production and national jobs. The causes are, in particular, the low population density, the weak retention capacity of the young population, a not very dynamic innovation system, small urban agglomerations, disparity and weak cohesion between the intermunicipal communities and the lack of raw material processing companies. In addition to these socio-economic constraints, the region also faces other challenges, such as the consequences of climate change in terms of water availability and crop adaptation. In fact, the region has suffered several episodes of drought in recent years, being one of the European regions most affected by climate change [2].

4. Results and discussion

The model represents the results in various graphical forms, allowing for an immediate and intuitive qualitative analysis that will provide visual representations about the distribution of inputs, outputs and stock of each region and information by material category for region's inputs and outputs (Fig. 3). REMET-UA further allows to represent all the results for all of the material categories and/or for one category, chosen by the user in this way all graphical representations can be altered to accommodate the user's needs.

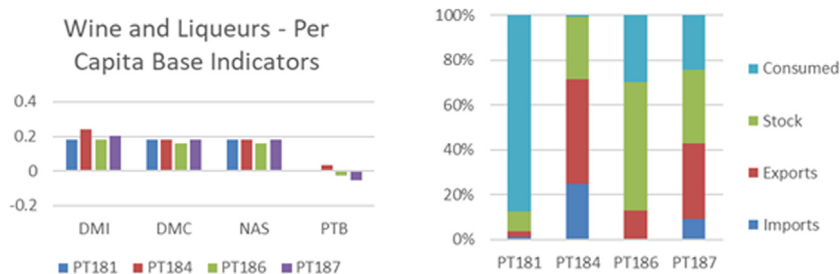


Fig. 3. Examples of graphic representations produced by REMET-UA model.

Fig. 3, on the left, shows the indicators DMI, DMC, NAS and PTB, per capita, for PT181 (Alentejo Litoral), PT184 (Baixo Alentejo), PT186 (Alto Alentejo) and PT187 (Alentejo Central), for the category “Wine and liqueurs drinks”, chosen by the user. On the right, Fig. 3 shows the economic distribution ratio of the category “Wine and liqueurs drinks” for each NUT III. These types of graphics provide a lot of information about the economic status of a product. Regional entities or enterprises can utilize this type of information to make more reasonable decisions about the production or sale of their products and to seek market opportunities in the region or for the export of a product.

Fig. 4 shows an innovative way to graphically present the results, allowing a vision over the international imports of a NUT III region promoting an integrated view of more specific flows of materials for this region. The same can be done to national imports, domestic extraction and exports and to other regions. This graphics were specially made for policymakers because it allows in a simple format to understand the majority of products that contribute to that type of economic relation.

This graphical adaptability presented by REMET-UA model can be a useful tool for administrative services and policy makers since it offers them an easier and simplified overview of economic flows between small scale territories offering a unique functionality that distinguishes it from other models.

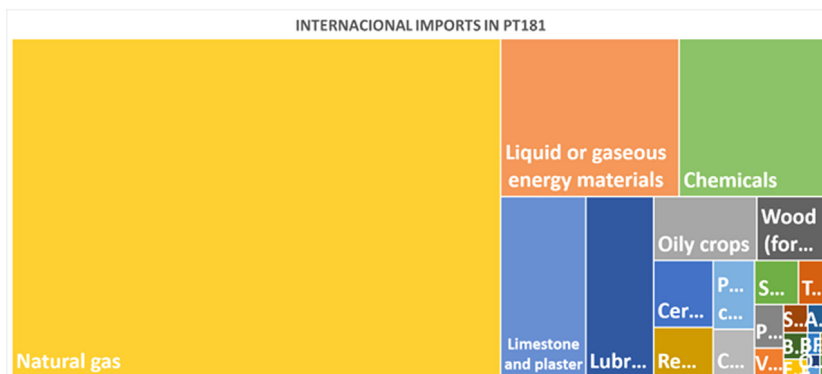


Fig. 4. Graphical representation of the international imports in PT181 calculated by REMET-UA model.

5. Conclusions

REMET-UA model allows, through a mass balance, a quantitative and qualitative evaluation of the interactions between sub-regions and the estimation of the indicators considered in Eurostat. Made in an accessible format allows

users to develop a regional economic metabolism to the region of its choice. It is adaptable to changes according to the user needs and the model is responsive even without being totally filled with the default categories of data. The results are mostly displaced in graphics for an easier interpretation of the results by stakeholders. The most recent version of REMET-UA does not yet include processes in its calculations but nevertheless is fully operational and allows users to identify flag sectors, business opportunities and circularity potential making it an important tool for regional policy makers and governance services.

The main limitations of REMET-UA are related to the time consumed and the lack of regional data, especially at the NUT III level as the case study proved. Using the accessible information only 10% of the data needed were found, proving that some conclusions could not be made. Most data found was dispersed, little detailed and with variable confidence. However, REMET-UA has proved to be able to support decision makers in the finding circular opportunities complying with the objectives in which he was created and developed. Also, in this way, it was able to design a unique model able to include interregional interactions in terms of metabolism, answering to a gap in terms of metabolism models contributing therefore for this theme.

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