Chapter 12
Biophysical Approaches to Food System Analysis in Latin America

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12.1 Introduction

The Barcelona School of Ecological Economics provided the students not only with the basics of heterodox economic theory, but also insights from other disciplines, such as biology and ecology, demography, geography, politics, and international relations. Moreover, we learned about the problems of monetary valuation and were introduced to multi-criteria decision aid methods, that allow tackling the issue of incommensurability of values (Martinez-Alier et al., 1998), therefore including different valuation languages. We also learned about post-normal science (Funtowicz & Ravetz, 1994), requiring peer-evaluation and democratizing decision-making, and about the need to use non-equivalent descriptive domains in our analysis (Giampietro et al., 2001) to be able to grasp the complexity involved in describing the economic system.

Biophysical analysis complements the usual economic interpretation of the phenomena of society. Table 12.1 shows the different perspectives (or toolboxes) for examining food systems:

Generally, agricultural systems are analyzed in terms of yields (tons/ha) or economic productivity (USD/ton). However, this can lead to obscuring the interpretations of reality and to mistakes in the design, management, and implementation of public policy. A peasant agricultural system, which is carried out on a small

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Table 12.1 A toolbox for the analysis of food systems: conventional approach vs. biophysical analysis

Conventional approach	Biophysical analysis
Yield (ton/ha)	Yield (ton/ha)
Economic productivity (USD/ton)	Economic productivity (USD/ton)
Labor productivity (ton/h)	Labor productivity (ton/h)
Market price	Energy accounting (conversion efficiency of agriculture, including inputs)
Unequal exchange (prices)	Unequal exchange (prices)
Cost-benefit analysis	Ecologically unequal exchange (tons)
	Caloric unequal exchange (calories)
	Analysis of metabolic profiles
	Land-time budget analysis
	Multi-criteria decision methods

extension of land (a smallholding) could be more efficient than a large one, because it uses fewer fossil energy inputs (machinery, fertilizers, etc.) and more energy from the sun, in addition to its diversification and rotation in various crops. Similarly, biophysical analysis broadens the perspective of international food trade. The ECLAC and Latin American dependency schools, which have been minimized in the international debate nowadays, proposed unequal exchange in prices as a result of asymmetries in international insertion and power relations. The Barcelona School has proposed ecologically unequal exchange (Muradian et al., 2002; Muradian & Giljum, 2007; Muradian & Martinez-Alier, 2001a, b; Pérez-Rincón, 2006; Samaniego et al., 2017; Vallejo, 2010) and caloric unequal exchange (Falconí et al., 2017; Ramos-Martin et al., 2017).

12.2 Food Sovereignty and Complementarity in Latin America

Latin America and the Caribbean are regions with abundant arable land and water, which accounts for 14% of global food production and 23% of the world's exports of agricultural and fisheries commodities (OECD/FAO, 2019). This fact is coupled with the prevalence of obesity and malnutrition in the region. In general terms, malnutrition affects poorer quintiles of population, while obesity is transversal to all income levels of the population (Freire et al., 2014).

The focus of the region as food exporter comes with impacts attached. Ceddia et al. (2013) analyze the intensification of agriculture in South America, concluding that the region would face a "Jevons´ Paradox" like situation; that is, improvements in efficiency would not lead to lowering the use of the resource (land), but the opposite would be true. More efficient techniques of production will use more land to

export more. In the case of intensification of agriculture, at the expense of more deforestation occurring.

In sum, although the region is a net exporter, its citizens are not eating enough and properly, and export-oriented food production is having social and environmental impacts that need to be analyzed. This analysis of food systems needs to be multi-faceted, so a single discipline would never be able to cover the different angles involved.

Because of the problems and challenges mentioned above, food self-sufficiency can be considered as one of the main attainments for countries, as exemplified by the European Union, which still nowadays allocates a large fraction of the budget to the Common Agricultural Policy and has reached that goal (Guinea, 2013). South America produces all the food needed to satisfy the caloric requirements of its population and to maintain a balanced diet. However, the region experiences a systematic loss in food self-sufficiency (more imports in relation to domestic consumption, measured in volume) in the period 1961–2011 (Falconi et al., 2015). This result is because food production is ever more oriented to exports, so food exports are increasing dramatically and also changing consumption patterns in the region (see Sect. 12.3).

To see if this move towards export-oriented food production pays or not, we need to introduce the concepts of unequal exchange and ecologically unequal exchange.

The concept of unequal exchange has been critical in the modern economic history of Latin America. The concept focused on the unequal relationship found in traded goods between countries in terms of embodied labor time, which reflected in prices being higher in products coming from developed countries than in products coming from developing countries, that is, showing deteriorating terms of trade for Latin America when compared to the USA or European countries. Unequal exchange obeys asymmetric power relations between the center and the periphery (Amin, 1976; Emmanuel, 1972; Furtado, 1964, 1970; Prebisch, 1950, 1959).

Later, researchers gave a twist to the concept of unequal exchange by including the environmental variable. The exports of developing countries would be intensive in natural resources. However, their prices would not account for the value of environmental externalities involved, implying a de facto transfer of wealth from poor to rich countries. Externalities would not be seen as market failures, but rather as 'cost-shifting successes' in the words of Martínez-Alier (Muradian & Martinez-Alier, 2001a).

When analyzing food production, consumption and related trade patterns under the biophysical approach is very easy to realize that the loss in self-sufficiency driven by export-oriented food production represents a non-desired development path for the region. Population and GDP per capita continue to grow in the region, therefore domestic demand will keep increasing in the long term. One way out is encouraging agricultural complementarity, defined as the contribution each country of the region can make to achieve self-sufficiency as a block (Cango et al., 2023). In this way, not only more food is available at lower costs, but this common goal encourages economic cooperation and integration. Among the potential benefits of this increased integration, one can find: (a) improvements in transport and

communications networks; (b) mutual assistance in case of emergencies; (c) improvements in economies of scale; and (d) improvements in food security (Hubbard et al., 1992). One could also add that external vulnerabilities are reduced, and outward flows of currency are also reduced, a critical aspect for economies characterized by lacking access to financial markets and having periodic liquidity problems.

In 2018, South American countries imported 24.8 million tons of food from other regions of the world. 74.1% of the imports belong to just three products: maize (39.1%), wheat (24.6%), and soybeans (10.3%). Should there be agreements in place to encourage intra-regional trade, none of those products would need to be imported, as the region exports even larger quantities of those same products to third countries. Only 19.8% of those 24.6 million tons would need to be imported, mainly wheat, beverages (no alcoholic), beer of barley, potatoes (frozen), feed and meal (gluten), etc., which is surprising, being South America the origin of potatoes. The result is indeed very humble in monetary terms, as trade diversion would only imply about four billion dollars (constant dollar 2015) per year (FAO, 2020), but the benefits of improving self-sufficiency should prevail (Falconi et al., 2015).

12.3 Caloric Unequal Exchange in Latin America

The analysis of food systems in Latin America over the years has evolved and has brought new concepts like that of caloric unequal exchange (Falconí et al., 2017; Ramos-Martin et al., 2017), which builds on the concepts of unequal exchange and ecologically unequal exchange presented in the previous section. Caloric unequal exchange means the deterioration of the terms of trade when calories of food, instead of volume, are used. That is, we calculate the cost in dollars of the calorie exported, versus the cost of the calorie imported.

We tested the hypothesis of Latin America and the Caribbean increasingly exporting food products to the rest of the world at a lower cost to the calorie, expressing a new form of unequal exchange (Falconí et al., 2017; Ramos-Martín et al., 2017). Figure 12.1 presents the cost of one million kcal exported and imported in real terms (left axis) and the ratio between the cost of the exported calorie and the imported calorie (right axis), that is, an approximation to the terms of trade measured in calories.

The hypothesis was proven right, as we found that, even though the terms of trade were still favorable to Latin America, there was a deterioration with a decrease of more than 47.7% in the period 1986–2018. Exports in volume and calories increased by 6.6 times their original size in the period, whereas its monetary value increased by 4.4 times. In the case of imports, they increased by 3.9 times in terms of volume and 3.7 in calories, while they increased by 4.7 times in monetary terms. The surplus had increased fivefold in the 28 years analyzed. Thus, the region was not only increasingly feeding the rest of the world, but it did so at a lower cost over time.

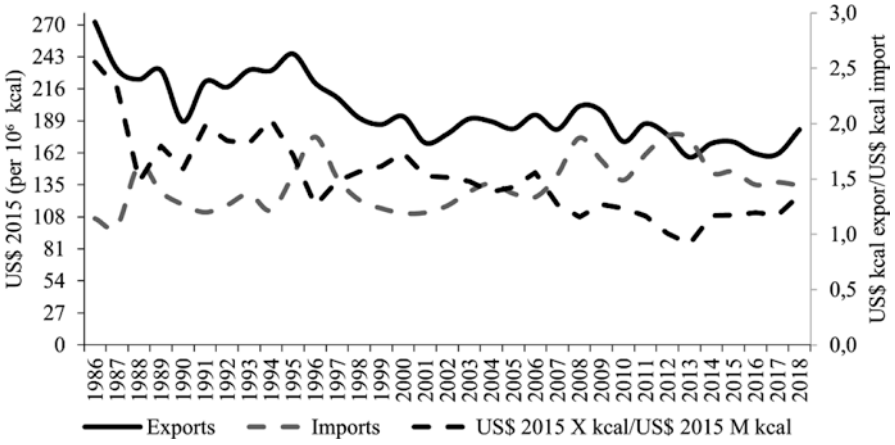

Fig. 12.1 LAC exports, imports, and terms of trade, 1986–2018. (Source: FAO, 2020)

Using calories to measure unequal trade allows us to link food trade with dietary diversity and malnutrition, food sovereignty, and environmental concerns. Volume allows us to link the monetary value of food exports with production and therefore with land use and environmental impacts, as in ecologically unequal exchange. Calories allow us to link the former with nutrition.

The analysis shows how the increase in the volume of exported food products is inducing changes in domestic consumption, towards those export-oriented products. So, not only the dietary diversity is decreasing, with 10 products accounting for 80% of the calorie intake, but also the composition is changing. Cereals, pulses, roots, and tubers are contributing less to the diet, whereas vegetable oils (soybean oil and palm oil) are increasing rapidly, impoverishing the diet (Falconí et al., 2017). More research is needed that links international trade, food production and consumption, nutrition, and health.

12.4 Bottom-Up Approaches: Using Household Types to Assess Sustainable Livelihoods

Biophysical approaches to food production can also be conducted at the level of the farmer, that is, by using bottom-up approaches, that allow to focus on the sustainability of livelihoods and allow for comparison of different production systems. This kind of approach is particularly relevant in the case of developing economies, where a large fraction of domestic demand is covered by small farmers, very often in agroecological systems (Altieri, 2009; Altieri & Nicholls, 2010, 2012; Padilla & Guzmán, 2009; Sevilla Guzmán & Soler Montiel, 2010).

This approach is found, for instance, in a livelihood sustainability assessment of coffee and cocoa producers in the northern Amazon region of Ecuador (Viteri Salazar et al., 2018). This work, built on previous work on a land-time budget analysis (Giampietro, 2003; Gomiero & Giampietro, 2001; Grünbühel et al., 2003; Grünbühel & Schandl, 2005; Pastore et al., 1999), and led by Oswaldo Viteri, another member of the Barcelona School, represents an application of societal metabolism to farming systems, following the work of other members of the School (Gomiero, 2017; Scheidel et al., 2013, 2014). This approach allowed identifying the socioeconomic and environmental restrictions implicit in different land-use patterns, the analysis of how these different land-use patterns improve livelihoods in terms of income, and the identification of how certain public policies have an impact on the income of small-scale producers as well as on the environment.

The information that is generated in this kind of analysis is very easily understood by the participants, which allows for using it with participatory methodologies for a better understanding of the complexities the communities face. It also helps policy-makers with the design of policies addressing the complex realities of rural households, not just focusing on increasing yields, but making explicit the trade-offs involved in production patterns in terms of generation of income and terms of the intensity of use of resources, and therefore the impact upon the environment.

12.5 Conclusion: The Contribution of the Barcelona School

Particularly important for the analysis of economic systems, their surrounding environment, and their evolution over time, is the application of the biophysical approach *a là* Georgescu-Roegen, that is, to describe and analyze the metabolic profiles of activities and sectors so that the trade-offs involved can be discussed in informed debates regarding public policies.

The biophysical perspective on societal metabolism is key for the Barcelona School of Ecological Economics. This means analyzing the economic process, or a particular sector, considering the physical constraints of the availability of resources, but also analyzing the consequences of the process of production and consumption (i.e., waste and pollution) also from a biophysical perspective. In this chapter, we have introduced research conducted by the authors, some with third author members as well as from the Barcelona School, focused on the study of food systems in Latin America. We have also introduced the newly coined concept of caloric unequal exchange, which follows the tradition of the ecologically unequal exchange, and we have also pointed out bottom-up research of food systems, using household categories, which fall under the land-and-time budget analysis tradition within societal metabolism studies.

We believe that the biophysical approach to societal metabolism presented in this chapter is one of the main contributions from the Barcelona School of Ecological Economics, under the leadership of and inspiration from Joan Martínez-Alier.

This work, along with that on water and energy metabolism, sustainable livelihood analysis of farming systems, and the like, are also aligned with international efforts such as the work by the International Resource Panel (IRP, 2019) or the UN System of Environmental Economic Accounting – Ecosystem Accounting, adopted officially by the 52nd United Nations Statistical Commission, on March 2021.

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