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Catalonia's energy metabolism: Using the MuSIASEM approach at different scales ☆

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ABSTRACT

This paper applies the so-called Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM), based on Georgescu-Roegen's fund-flow model, to the Spanish region of Catalonia. It arrives to the conclusion that within the context of the end of cheap oil, the current development model of the Catalan economy, based on the growth of low-productivity sectors such as services and construction, must be changed. The change is needed not only because of the increasing scarcity of affordable energy and the increasing environmental impact of present development, but also because of the aging population. Moreover, the situation experienced by Catalonia is similar to that of other European countries and many other developed countries. This implies that we can expect a wave of major structural changes in the economy of developed countries worldwide. To make things more challenging, according to current trends, the energy intensity and exosomatic energy metabolism of Catalonia will keep increasing in the near future. To avoid a reduction in the standard of living of Catalans due to a reduction in the available energy it is important that the Government of Catalonia implement major adjustments and conservation efforts in both the household and paid-work sectors.

1. Introduction

In recent years, interest on the links between energy consumption and economic development has seen a revival outside the academic world, especially because of these three factors: (a) the spike in oil prices that started in 2007, (b) the continuous growth in oil demand by emerging economies and (c) the emergence, of the peak oil hypothesis (Hubbert, 1956; Campbell and Laherrere, 1998) by the media. The period analysed (1990 through 2005) was characterised mainly by economic growth, not a recession like the one we are facing nowadays. However, we would like to remind the reader that oil prices during that period were always lower than oil prices we had in May 2009, over 60 dollars per barrel. This means that the recent downturn in oil prices and other commodities from their maximums of over 140 dollars per barrel in July 2008 does not compromise the main conclusions drawn here, due to the fact that economic structures of most economies have not changed, yet. Therefore, in the near future as the main economies start to recover, we may see again rising industrial production in developed and developing countries, driving up demand and prices for oil and raw materials.

Providing this will be the context, national and provincial governments interested in their dependence on oil will need to commission studies on the matter. Examples of this need can be given as of the case of the so-called Hirsch Report (Hirsch et al., 2005) by the Department of Energy of the USA, which alerted the consequences of Peak Oil in America's GDP. Another case is the study by the Irish government on oil dependency (Forfás, 2006), which introduced a 'vulnerability index' to oil price increases with Ireland as the fifth most vulnerable economy in the world, followed by Spain. Lastly, a document by the Office of the Prime Minister of Sweden (Comission on Oil Independence, 2006) where the road map to achieve an economy independent from oil by the year 2020 was outlined.

Most of the work done relies mainly in economic variables, with energy intensity as the main one. However, such an approach, which links GDP growth to energy consumption only explains partially how economies evolve by consuming energy. Attempts at using different methodologies to approach the issue

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abound, for instance, Alcántara and Duarte (2004) use structural decomposition analysis to compare energy intensities of EU countries, showing how different sectors affect the aggregate indicator.

Another study analysing the energy consumption in Spain, Roca and Alcántara (2001), showed how there was no environmental Kuznets curve for energy intensity in Spain and highlighted the importance of both the residential and the transport sector in driving the high energy demand in Spain. Alcántara and Padilla (2003) used input–output analysis to identify "key" sectors in final energy consumption, where they highlighted, among other results, the importance of the domestic or residential sector. Llop and Pie (2008) also used input–output to analyse the effect of energy policies such as energy taxing and improving efficiency. Climent and Pardo (2007) used multivariate cointegration analysis to investigate different decoupling factors affecting the relationship between GDP and energy consumption, and showed a positive unidirectional causality from energy consumption to GDP. Another suggesting area of research is that of analysing energy balances from a historical perspective, as was done by Cussó et al. (2006) for an agrarian region in Catalonia, for which they calculated the energy return on investment (= EROI calculated in biophysical terms—that is: energy investment and energy return).

We believe standard economic analysis of energy intensity and consumption should be complemented by analyses as the ones mentioned above. However, to better understand exosomatic energy metabolism we suggest introducing the human time variable into the equation. Exosomatic metabolism is a term introduced by Georgescu-Roegen (1975) to indicate the conversion of energy input to perform human activities, which is under human control, but that is taking place outside the human body. In contrast, endosomatic energy metabolism refers to the physiological conversion of food energy into human activity. By introducing human time, we can find some benchmark values in terms of energy consumption per hour of activity, which can also be coupled with labour productivity in order to inform decision makers about the different outcomes of development options. In fact, when considering the exosomatic metabolism, it is the level of technical capital supporting an hour of labour – the ratio exosomatic energy consumption per hour – that will determine labour productivity. This type of analysis is what we are presenting in this work.

The research that led to this paper was a project commissioned by the Generalitat de Catalunya, a regional government in Spain with competences in energy policy among other issues due to the high degree of devolution currently in place in Spain. In that project, we applied the so-called Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) approach (Giampietro and Mayumi, 1997, 2000a, 2000b; more systematically investigated by Giampietro, 2003) to study energy consumption by different compartments of the economy at three hierarchical levels. The case study is Catalonia, a region in the north-east of Spain, and focuses on the period of 1990–2005. The approach, an application of Georgescu-Roegen's fund-flow model (Georgescu-Roegen, 1971, 1975), combines demographic (total and working population), economic (added value generation) and biophysical (exosomatic energy consumption) information at three different hierarchical levels to generate a number of intensive variables that can be used for characterising the exosomatic energy metabolism of the system and therefore for comparison with other economies. There have been some applications of this methodology for countries such as Ecuador (Falconí-Benítez, 2001), Spain (Ramos-Martín, 2001), Vietnam (Ramos-Martín and Giampietro, 2005), China (Ramos-Martín et al., 2007), Chile, Brazil and Venezuela (Eisenmenger et al., 2007), the UK (Gasparatos et al., 2009), Romania, Bulgaria, Poland and Hungary (Iorgulescu and Polimeni, 2009).

However, focusing at the national level does not allow seeing the particular characteristics different regions may have. As Hernández et al. (2004) point out for Spain, there is a strong asymmetry across regions in regard to CO_2 emissions due to their energy systems and we would defend the same occurs in terms of primary energy consumption. This is why our paper is the first attempt at using MuSIASEM at a sub-national level. It is true, however, that focusing at sub-national level has its own limitations. The most important being the different metabolic profile shown by a particular region may be the result of the role that region plays at national level. This fact could explain why certain regions are more specialised in financial services, whereas others are in industrial production or information technologies' services, and so on. Despite this shortcoming, we believe the application of this methodology at the sub-national level has many advantages.

The framework of the analysis is based upon what is called 'Societal Metabolism'. The economic process implies the transformation of both materials and energy into final goods and services. This process means the parallel generation of wastes be it material or in the form of heat. By energy metabolism we understand the study by which energy is used by society to keep it running and to allow further development. The concept of social metabolism has been used in different fields of analysis, such as ecological economics (for instance, Martínez-Alier, 1987); industrial ecology (Ayres and Simonis, 1994); material and energy flow analysis (Adriaanse et al., 1997; Fischer-Kowalski, 1998; Matthews et al., 2000); economic structural analysis (Duchin, 1998) and social ecology (Schandl et al., 2004), and goes back to the basic rationale of energy analysis (Cottrell, 1955), or to the concept of metabolic flow, introduced by Georgescu-Roegen (1971). As Haberl (2006, p. 96) mentions "ecological problems associated with socio-economic energy metabolism are central for sustainable development", this is so because not only energy metabolism determines land use (for growing food, fiber and fuels), but also because the current "temporary emancipation from land" (Mayumi, 1991) that fossil fuels are providing may end in a foreseeable future, therefore constraining human activities and also future options.

The analysis shows how economic growth is linked to exosomatic energy consumption, with a correlation over 90%. We also see how structural change in the economy (with reduced activity in primary and secondary sectors) has implied a change in the metabolism of the society, although new 'diffuse' sectors, such as households or transportation have increased their metabolism faster than the average. At the same time, energy controlled by workers – during an hour of work across the different sectors – remained more or less stable through the period, leading to stagnation in the economic labour productivity – the amount of added value generated per hour of work across the different subsectors – whereas energy per hour of 'non-working time' has been increasing above the average, as a result of the increase in the material standard of living, converging to EU-15 values.

The conclusion is that within a context of the end of cheap oil, it seems clear that a change in the economic growth model is necessary, not only because of the increasing scarcity of affordable energy carriers, but also because of the increasing environmental impact that the present development model represents. Moreover, since the level of energy consumption per worker will remain high in order to increase productivity of labour (due to the reduced work supply determined by an ageing society) and therefore competitiveness, one can conclude that major conservation efforts have to be implemented in both the household and transport sectors, if a huge increase in energy consumption wants to be avoided or in alternative, a sensible reduction of the existing level of material standard of living.