Ecological Economics 96 (2013) 51–61

Contents lists available at ScienceDirect

Ecological Economics

journal homepage: www.elsevier.com/locate/ecolecon

Analysis

Economic growth and the evolution of water consumption in Spain: A structural decomposition analysis

Ignacio Cazcarro [a,1], Rosa Duarte [b,*], Julio Sánchez-Chóliz [b,2]

[a] Department of Economics, Rensselaer Polytechnic Institute (RPI), School of Humanities and Social Sciences, 110 8th Street, Troy, NY 12180, USA
[b] Department of Economic Analysis, Faculty of Economics and Business, University of Zaragoza, Gran Vía, 2, 50005 Zaragoza, Spain

ARTICLE INFO

Article history:
Received 26 March 2013
Received in revised form 12 August 2013
Accepted 17 September 2013
Available online 26 October 2013

Keywords:
Environmental analysis
Input–output model
Water consumption
Technological change
SDA
Spain

ABSTRACT

The aim of this paper is to examine how technology, processes of input substitution, and changes in final demand, all of which underlie economic growth, influence water consumption. This analysis is undertaken for Spain during a significant socio-economic period, from 1980, the beginning of the democratic era, to 2007, the onset of the current economic crisis.

To this end, we construct water consumption series linked to a time series of input–output tables generated for the Spanish economy, and we develop a structural decomposition analysis to study mainly changes in water consumption embodied in final demand.

We find that the growth in Spanish demand (all other things being constant) would have implied an increase in water consumption almost three times the growth actually observed. However, this demand effect is largely offset by technology and intensity effects, mainly due to changes in agricultural crops. Given the importance of the demand growth, the final demand effect is also analyzed in detail, broken down by categories as well as level and composition. Household demand and the increase of exports appear as key explicative factors.

1. Introduction

Economic growth is influenced by changes in technologies, processes of input substitution, and changes in final demands. These technological, structural and demand factors also influence the patterns of resource consumption. The aim of this paper is to examine the impact of these factors on the evolution of water consumption. This analysis is undertaken for a Mediterranean country, Spain,[3] and for a period of time, 1980 to 2007, in which the current configuration of the Spanish economic structure has become settled. During these three decades, the Spanish economy experienced an economic, productive, and social transformation without precedent. From the beginning of the democratic period, in the late 1970s, until the recent and severe economic crisis in 2008, Spain was regarded as one of the most dynamic EU countries. Sustained growth rates that were higher than the European average during the 1990s (particularly since the economic crisis of 1992[4]). They allowed the Spanish economy to reduce, in part, the significant gap in per capita income that had long differentiated it from the rest of Europe. Integration into the European Union, in 1985, launched a process of economic openness that enabled a higher level of trade. It also allowed for the progressive adoption of technologies and production methods then common in neighboring advanced countries. This process transformed markets and productive activity, increased the per capita income of Spain, and expanded and changed patterns of consumption. The 1990s attracted significant amounts of foreign investment, and low interest rates facilitated a boom in the real-estate sector, with construction – during the first decade of the 2000s – accounting for more than 15% of GDP and employment growth.

Moreover, during this same period, funding from the EU contributed significantly to the economic empowerment of Spain. Agricultural funds from the Common Agricultural Policy of the EU, along with structural and cohesion funds, drastically transformed the rural and urban landscape. This contributed to a rapid and widespread access to irrigation

---

* Corresponding author. Tel.: +34 876554787.
E-mail addresses: cazcai@rpi.edu, icazcarr@unizar.es (I. Cazcarro), rduarte@unizar.es (R. Duarte), jsanchez@unizar.es (J. Sánchez-Chóliz).
[1] Tel.: +1 5182763639.
[2] Tel.: +34 976761826.

[3] Despite having areas such as the north-west, with an oceanic (rainy) climate, the semi-arid and Mediterranean dry climates provoke irregularities and droughts, with few lakes, and rivers with low flow (the largest of these discharging into the Atlantic Ocean).

[4] According to Eurostat. http://epp.eurostat.ec.europa.eu/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tec00115, last access June 2013, average real GDP growth rate for the period 1995–2007 was 3.5 for Spain, 2.5 for EU27 and 2.3 for the Euro-area.

0921-8009/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.ecolecon.2013.09.010

and cultivation technologies, a significant improvement in transport and energy networks, a broad access to the knowledge society (R&D, innovation, information), and notable agricultural and rural development.

These profound economic and social transformations have also modified the patterns of consumption and use of resources, particularly of water. Changes in the size and composition of final demand, a greater share for the industrial and service sectors, structural and technological changes, and a significant transformation in agriculture (with a major focus on industrial and high-value-added products, and adoption of new irrigation technologies) drove – or coexisted with – an increase of about 30% in the direct consumption of (essentially green) water, from 1980 to 2007, according to our estimations presented here.

The study of water use and its evolution is particularly important in Spain, where a combination of spatial and time irregularity of precipitation, together with an inefficient hydrological planning regime, has caused permanent imbalances between resources and requirements. This situation has been made worse over time by a model of economic growth based on a major extension of water-intensive crops in the agricultural sector, weak water-saving tendencies in industrial activity, and urban and tourism development (in many cases uncontrolled) that was highly intensive in the use of water.

In this general context, our objective is to analyze the role played by demand, and by the structural and technological changes underlying Spain's economic growth. More specifically, we want to go further in the study of the determinants of economic growth (mainly demand growth, structural change, and technological change). Offering insights into how much the pressure on natural resources, specifically water, has changed during almost thirty years. Sectoral and temporal perspectives are important in understanding the nature of this evolution.

In our view, the relevance of the analysis goes beyond the specific case studied, showing how economic dynamics have an environmental impact, and how these interrelated dynamics and impacts can be studied and interpreted. The analysis might be especially interesting for other arid or semi-arid regions, where water is scarce and there are severe rainfall and climatic irregularities.

Input–output models are suitable tools to examine the direct and indirect requirements of inputs, and the impact of economic growth on natural resources. More concretely, the extension of the traditional Leontief's input–output economic model to environmental indicators, explained by Leontief and Ford (1972) and Miller and Blair (1985), opened the field to much greater use of extended input–output models. In the case of water, works in line with the early contributions of Lofting and McGauhey (1968) and Carter and Irei (1970) can be found, with new applications of the input–output methodology to assess the water uses of different economies, e.g. Lenzen and Foran (2001), and Guan and Hubacek (2007, 2008) among others. For Spain, studies such as Duarte et al. (2002), Sánchez-Chóliz and Duarte (2003) and Velázquez (2006) use the input–output model to estimate the water embodied in economic production at the national or regional levels, while Dietzenbacher and Velázquez (2007) focus on the virtual water trade in a regional context. More recently, Cazcarro et al. (2012) calculate the water flows embodied in Spanish international trade, and simulate the water impacts associated with different scenarios of household consumption in Spain.

From the temporal perspective, Structural Decomposition Analysis (SDA) will be applied in our study to analyze the evolution of direct and indirect water consumption. SDA has been widely used to study the evolution of economic variables and the role played by demand, technology, and intensity in environmental analysis (see Rose and Casler, 1996; Hoekstra and Van der Berg, 2002, for a review of these issues; and Wood and Lenzen, 2009, on the methodological approaches to the study of sustainable consumption).

Through our interest in linking the pressure on water resources to the structural and technological changes that occurred in Spain, we apply an SDA to a set of Spanish input–output tables estimated for the period 1980–2007, and we obtain different components that explain the evolution of water consumption. To the best of our knowledge, this is the first attempt to analyze the evolution of water consumption over time, looking at the contribution of different sectors and growth components to this evolution.

The rest of the paper is structured as follows: Section 2 presents the methodological aspects of the SDA applied; Section 3 is devoted to the construction of the database; Section 4 presents our results, and Section 5 reviews our main conclusions.

2. Methodology

2.1. Basic Model

We begin with the equilibrium equation for an economy, based on a Leontief model: $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}$, where $\mathbf{x}$ is a vector of sectoral outputs, $\mathbf{A}$ is the matrix of total technical coefficients, and $\mathbf{y}$ the vector of final demands. In what follows, denoting by ˆ the diagonalization of a vector (i.e., a diagonal matrix with elements of the vector only in the main diagonal) and by ′ the transposition of a vector. We denote by $\mathbf{e}$ a summation vector (i.e., a column vector of 1s). The economic equilibrium $\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y}$ can also be expressed in terms of the Leontief inverse:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{L}\mathbf{y}.$$

Let $\mathbf{d} = (d_j)$ be a vector of direct sectoral water consumption and $\mathbf{w} = (w_j)$ a vector of water intensities with $w_j = d_j / x_j$. Then, the direct water consumed in the economy is $\mathbf{w}'\mathbf{x} = \mathbf{d}'\mathbf{e}$ and we can also obtain the matrix $\mathbf{H} = \hat{\mathbf{w}}\mathbf{L}\hat{\mathbf{y}}$, capturing all water flows in the economy directly and indirectly consumed, to obtain their final demands (the embodied water or virtual water). In this way, we estimate the water consumed in the economy to produce the final demand, including net exports and adopting the domestic technology assumption. A matrix element $h_{ij} = w_i L_{ij} y_j$ shows water consumed to obtain the inputs i directly and indirectly used by sector j to obtain its final demand. The transposed vector of water embodied in final demand can also be obtained as $\mathbf{m}' = \mathbf{e}'\mathbf{H} = \mathbf{e}'\hat{\mathbf{w}}\mathbf{L}\hat{\mathbf{y}}$. Note that, for the whole economy, direct and embodied consumption of water are coincident, that is to say, $\mathbf{m}'\mathbf{e} = \mathbf{e}'\mathbf{d}$.

2.2. Structural Decomposition Analysis

Given that we are interested in analyzing the evolution of direct and embodied water, and the sources of changes in sectoral water consumptions and water footprints, Structural Decomposition Analysis (SDA) is used to decompose the changes in matrix $\mathbf{H}$. This technique, defined by Rose and Chen (1991) as "the analysis of economic change through a set of (static and comparable) changes in key parameters of an input–output table", has been used to study variations in impacts and resource use (see Rose and Casler, 1996 and Hoekstra and Van der Berg, 2002, for a review). Broadly speaking, SDA techniques aim to break down a time trend of a variable into a group of driving forces that act as accelerators or retardants (Dietzenbacher and Los, 1998; Hoekstra and van der Berg, 2002; Lenzen et al., 2001; de Boer, 2009).

As stated in Hoekstra and van der Berg (2003), Structural Decomposition Analysis (SDA) is, together with Index Decomposition Analysis (IDA), one of the most common tools to describe the changes in a variable over time and to identify driving factors for these changes. In both cases, the analysis is of a static-comparative nature. The main difference between these methods is established in terms of the model used. While IDA uses aggregated sector level or country-level data, SDA builds on the input–output framework. In this regard, data requirements for IDA are significantly lower than for SDA, since SDA captures a more detailed decomposition of the economic structure. The main advantage of SDA, given the underlying the IO model, is the possibility to assess changes