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FULL ARTICLE

Analysis of the social and environmental economic sustainability in the territory of Yucatan (Mexico)

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Abstract

This research focuses on the state of Yucatan, Mexico, and provides evidence of unsustainable performance of the local economy: the local economic structure and income distribution widens the gap between rich and poor households. A constructive policy towards sustainable development would place greater emphasis on productive restructuring the agricultural sector, road transport and electric power generation, in designing actions of technological change and sustainable natural resource management. An exhaustive hybrid environmental social accounting matrix (ESAM) and linear multipliers models are used to analyse the interactions of the local economy with the use of resources, the environment and income distribution.

KEYWORDS

energy, greenhouse gases, groundwater, income distribution, sustainability

1 | INTRODUCTION

The objectives of sustainable development (OSD) include a set of actions that are implemented in an articulated way leading to the overcoming of poverty, reduction of inequality, creation of quality employment opportunities and conservation of natural resources, among other purposes (UNDP, 2016). The challenge for governments of subnational countries and regions is to determine how to implement this set of actions to generate continuous development processes in a complex and dynamic context in the geographical space of a particular territory. In the interaction economy-society-environment, there can be virtuous circles that lead to economic prosperity, reduction of social gaps and conservation of the environment. But it is also possible that there are vicious circles in which economic growth has negative effects such as widening economic gaps between households or some environmental degradation.

In determining the sustainable development strategy to be implemented in a particular territory, it is important to know the direction of the interactions of the economic, social and environmental spheres that are presented in a given geographic space in a dynamic context. That is, the feedbacks are presented in the three dimensions, but bounded to a territory in a continuum of points in time. The set of sustainable development goals implemented in a co-ordinated manner by regional governments can lead to a multiplicity of development processes depending on the economic, social and political structures that make up a particular territory. In a given geographic space the goals may be discordant to each other or conflict with one another and lead to unsustainable development paths. In other territories they can reinforce each other and generate processes of harmonious development.

This research focuses on the state of Yucatan, Mexico, and analyses the sustainability of local development at a point in time (2003) in three dimensions: economic, social and environmental. Sustainability is understood as a process in which the pattern of organization of production, the structure of consumption and accumulation of wealth in the local economy is in harmony with the local and global ecosystem in the satisfaction of the material needs of the population in a continuum of points in time (United Nations, 2003; WCED, 1987). The conceptual framework of sustainability is the basis for the development of the present work in line with the theoretical and methodological approaches of the school of ecological economics and to a lesser extent of environmental economics (Aguilera & Alcántara, 1994; Martínez & Roca, 2006; Pearce & Turner, 1990).

In this sense, it is interesting to elucidate the directions of the interactions of the social, economic and environmental spheres in the geographical territory of Yucatan in Mexico, a territory with wide cultural, environmental and social richness. Also to determine if such interactions trigger sustainable development processes in the region. The state of Yucatan in Mexico possesses vast natural resources with abundant forest, water, coastal and aquatic resources, numerous cultural and tourist destinations and a growing economy that offers a high quality of life for the population (Lutz, Prieto, & Sanderson, 2000; OECD, 2007; SEMARNAT-CONAFOR, 2014). However, sustainable development in the region faces obstacles that if not removed can lead to the widening of economic gaps between households and processes of environmental degradation. In this context, the general objective of this paper aims to determine if the economic structure of the region is compatible with social development and conservation of natural resources in the geographical territory of Yucatan, Mexico in a specific point in time.

Multisectorial models based on input–output (I-O) tables or social accounting matrices (SAMs) are frequently used in regional analysis, covering all kinds of issues: for example, Brandsma, d'Kancs, Monfort, and Rillaers (2015) present the uses of I-O tables in combination with computable general equilibrium (CGE) models to analyse the impact of regional cohesion policies within the European Union; Fuentes-Saguar, Vega-Cervera, and Cardenete (2017) use linear models based on SAMs to analyse the socioeconomic impact in Extremadura (Spain) of the closure of a nuclear power plant and Duarte, Mainar-Causapé, and Sánchez-Chóliz (2017) use SAMs to analyse the regional differences in Spain in reference to and greenhouse gases (GHG) emissions. Regarding environmental regional analysis, Flores and Mainar (2010), Llop and Pié (2011) and Franco Solís and De Miguel Vélez (2017) are good example of the application of this tools.

Input-ouptut, SAMs and linear models have also been used to study the productive structure of Mexico, both at the national level (Beltrán, Cardenete, Delgado, & Núñez, 2016; Núñez, 2018) and regionally: Núñez and Cruz (2009) analyse the economy of Oaxaca through IO analysis. and Chiquiar, Alvarado, Quiroga, and Torre Cepeda (2017) carry out a detailed study of the manufactures exports through regional I-O tables. Specific studies on energy sustainability have also been carried out using I-O (Guevara, Córdoba, García, & Bouchain, 2017).

In recent years, multisectorial models have been widely used to address the issues of climate change, energy issues and water use. The models derived from the input–output framework focus on the analysis of the productive structures of the economies. The models based on SAMs emphasize the processes of distribution and redistribution of the income generated in the economies; and its extension to the Environmental Social Accounting Matrices

(ESAM) allows analysing the implications of productive structures, consumption and accumulation in natural resources and the environment.

To achieve the general objective of the investigation, an ESAM with economic and social accounts in monetary units and environmental accounts in physical units is estimated. The hybrid ESAM serves as the basis for the estimation of a model of accounting multipliers of the economy of Yucatan, Mexico for the year 2003. The accounting multipliers are decomposed in such a way that the articulations of the local economy with the use of resources (groundwater use and energy consumption), the environment (emissions to the atmosphere) and income distribution at the household level can be discerned. In the construction of the hybrid matrix we adopt the methodologies most used in the literature, but adapted to the reality of the regional economy. The estimated hybrid matrix is proposed as a statistical approach to the reality of a local economy and as a first step towards the compilation of an integrated system of regional accounts that brings together the socioeconomic and environmental dimension into a single analysis instrument and avoids the dispersion of data and information.

The literature that addresses environmental pressure and, on the other hand, the generation of income and its distribution, both within a single analytical framework, is of recent development. In the 1990s, the document entitled "System of environmental economic accounts [SEEA]" (United Nations, 1993) offers a methodological proposal for integrating the SNA (system of national accounts) into a new matrix format with social and environmental indicators in physical units giving rise to the ESAMs. The accounting system has been extended and refined in the SEEA 2012. However, the applied developments of the ESAM have been rather scarce. The first work in this line of analysis belongs to Resosudarmo and Thorbecke (1996) who assess the impact on household income of environmental policy in Indonesia, as well as Thorbecke and Jung (1996) who evaluate social policies also in Indonesia. Recent applications of the ESAM approach emerged in the 2000s to address social concerns (Alarcón, Van Heemst, & Jong, 2000; Pieters, 2010) and environmental concerns on three major issues: water, energy and air emissions (Duarte, Mainar, & Sánchez-Chóliz, 2010; Mampiti & Rashid, 2006; Manresa & Sancho, 2004; Rodríguez, Llanes, & Cardenete, 2007; Sánchez-Chóliz, Duarte, & Mainar, 2007).

In this context, this work constitutes an important methodological and empirical contribution to the scientific literature on ESAM and its applications. In this regard, in the literature there are no studies on the construction of hybrid matrices in the context of a regional geographic space like Yucatan and this work makes an original contribution to improve the regional information systems in Mexico that serve as the basis for decision making of sustainable public policy. In addition, an original methodological proposal is presented to integrate the use of groundwater, energy consumption and GHG emission to the monetary social accounting framework. In addition, the proposed decomposition of accounting multipliers allows us to discern the implications of the productive structure of the local economy in the generation and distribution of income among households and their environmental consequences. In this regard, the novelty of the paper is to present an original multiplier decomposition focused on evaluating the (in) sustainable performance of the economy of a particular territory at a given time based on the proposal of Thorbecke and Jung (1996).

The present work is structured as follows. After a brief introduction, section 2 is devoted to the main information about construction and structure of the ESAM and also, the description of the data and sources of information that fed this work. Section 3 presents the methodological proposal for the decomposition of accounting multipliers to estimate the total effects of an exogenous change in the aggregate demand of the local economy on the distribution of household income, use of groundwater, energy consumption and emission of GHG. Next, section 4 discusses the main results of the analysis in the four topics addressed and in the Section 5 a synthesis is presented as a conclusion.

2 | CONSTRUCTION AND STRUCTURE OF THE ESAM

In order to construct the model that allowed analysing the articulations of the social, economic and environmental system, first, a system of regional accounts in monetary terms was elaborated through indirect methods of estimation

(Harris, 2002; Jackson, 1998). The monetary system of regional accounts for the economy of Yucatan (corresponding to 2003) consists of: supply and use tables, input–output domestic matrix (industry by industry) and a monetary SAM.[1] The monetary SAM disaggregates the accounts associated with households by income decile.[2] SAM was balanced using the cross-entropy method (Robinson, Cattaneo, & El-Said, 2001; Robinson & El-Said, 2000).

On the other hand, vectors of natural resources and emissions to the atmosphere, both in physical units, were integrated in the monetary SAM. Information on the use of groundwater was obtained from the database of the Public Registry of Water Rights (REPDA, acronym in Spanish), an information system administered by CONAGUA [National Water Council] (2010). The available data are the volumes of groundwater in m^3 per year allocated for productive use classified by type of use.[3] In 2003, a total of 10,774 titles had been granted for productive use. A reclassification of water uses had to be made to its respective SCIAN (North American Industry Classification System -NAICS) code (INEGI, 2002) in order to integrate the information into the SAM framework. In the integration of the coefficient vector a_w the volumes of gross extraction of granted groundwater are taken.[4]

Coefficients populating matrices of energy consumption and GHG emissions ($\mathbf{A_e}$ and $\mathbf{A_g}$ respectively) were calculated based on information from the State Emissions Inventory of Greenhouse Gases (SEDUMA-CICY, 2013). Information only took the fossil fuel consumption of the *energy* category of the inventory as well as direct and indirect GHG emissions by this source category. Consumption of fossil fuels comprises the stationary combustion (power generation, manufacturing industry and construction), mobile sources (motor transport, air, rail, maritime) and other sources.[5] Fuels reported by the inventory are diesel, fuel oil, natural gas, LP gas, coke, marine diesel, jet fuel and gasoline) in units of terajoules (Tj) and direct GHG emissions: CO_2, CH_4 and N_2O and indirect ones: CO, NMVOC and NO*x* in units of gigagrams (Gg). The classification of inventory activities does not strictly correspond to the SCIAN classification of activities so it had to be reclassified according to the second.

The integration of monetary information regarding the SAM and vectors into physical units of groundwater use, energy consumption by type of fuel and the emission of direct and indirect Greenhouse Gases in the same matrix (ESAM). Information on groundwater use in m^3, energy in terajoules and GHG emission in gigagrams is only available for the productive activities sector, therefore, the ESAM records the use of groundwater and energy consumption as intermediate inputs in the process of production and the emission of GHG as a byproduct of productive activities to the environment. By adding to the monetary SAM the vectors of natural resources and emissions of pollutants the inflows of the natural system are incorporated to the economy (underground aquifer water and energy consumption

[1]The data for the construction of the integrated system of regional accounts came from Mexico's System of National Accounts (INEGI, 2010, 2012), Mexico's input–output framework (INEGI, 2003), National Household Income and Expenditure Survey (INEGI, 2008), National Occupation and Employment Survey (INEGI, 2005b) Public Administration Accounts (Government of the State of Yucatan, 2003; INEGI, 2005a), Ministry of Economy of the Federal Government and Ministry of Finance and Public Credit (SHCP, 2002).

[2]The information on the sources of income of the households, as well as the structure of expenses, was taken from the ENIGH—National Household Income and Expenditure Survey—(INEGI, 2008). The criterion followed for classification by decil of income was to take as reference of analysis the data of total income by household that includes the total current income (monetary and non-monetary) and the total financial and capital (monetary and non-monetary) perceptions according to ENIGH. This criterion corresponds to that used in the System of National Accounts of Mexico in the estimation of the total income of households as opposed to that used in the estimates of the income poverty lines that take as reference of analysis the total current income (monetary and non-monetary) per capita of the home. In addition, income of households in the ENIGH were deflated to the year 2003 and adjusted according to the aggregate regional accounts system as a whole.

[3]Urban and domestic public uses are excluded. Urban public use REPDA (Public Registration of Water Rights) includes the municipal public network, which distributes drinking water volumes (without ruling out their use in productive activities); given the above, drinking water is already considered a different volume of water, so, for the purposes of this study, its use will not be taken into account (Albornoz, García, & Adrián, 2014).

[4]The net volume of discharges is not considered because the volumes for the use and those discharged are volumes with different qualities and incomparable (Duarte, Sánchez-Chóliz, & Bielsa, 2002; Okadera, Watanabe, & Xu, 2006).

[5]Other sources refers exclusively hosting services. In the inventory, consumption of fossil fuels for commercial, residential and agricultural sectors is not reported because those who drew up the inventory did not have sufficient information for integrating the inventory of these sectors.

TABLE 1 Structure of an extended monetary SAM with environmental accounts associated with production

	Factors	Institutions	Production	Exogenous	Totals	Emissions
Factors	0	0	T_{13}	x_1	y_1	
Institutions	T_{21}	T_{22}	0	x_2	y_2	
Production	0	T_{32}	T_{33}	x_3	y_3	g_3
Exogenous	l_1	l_2	l_3	t	y_x	
Totals	$y_1{'}$	$y_2{'}$	$y_3{'}$	$y_x{'}$		
Energy			e_3			
Groundwater			w_3			

Source: Own elaboration from Thorbecke and Jung (1996).

as inputs of production), as well as the flows of output economic system to the natural system (emissions to the atmosphere).

The ESAM is developed for 2003 as the base year[6] and the structure is presented in Table 1. The economic endogenous accounts have been classified as productive factors (18 categories of labour and another account denominated other factors), institutions (10 categories of households stratified by deciles of income, companies, regional government) and production activities (19 productive activities grouped and classified according to SCIAN).[7] In the linear model used, the exogenous accounts are: central government (Public Administration), Savings-investment and Rest of the world.[8] The SAM has a dimension of 53 × 53 rows and columns.[9]

y_i row totals represent the revenues of the endogenous accounts, the values of the exogenous accounts are represented by x_i, system leaks are represented by l_j, and since income (row totals) are equal to expenses (column totals), the expenditure of the endogenous accounts are given by $y_i{'}$. Endogenous accounts are determined by changes occurring in the exogenous accounts and intensity of integration of supply and demand factor, input and product markets of the local economy.

[6]The system of regional accounts was constructed taking 2003 as the base year. This year is the latest in which information became available in all three dimensions identified for the same reference period. Environmental information on energy consumption and emissions comes from the only state emissions inventory for Yucatan (SEDUMA-CICY, 2013) that has been published so far. The inventory information in the category energy and pollutant emissions belongs to the year 2005. The information of groundwater was taken from REPDA [Public Registration of Water Rights] and from a study by Albornoz et al. (2014), with reference to 2003. The social information about income-spending household was obtained from the ENIGH 2008.The survey has national scope and biannual periodicity; for 2008 and 2010, the INEGI prepared a broadening of the sample to ensure the representativeness of the income-expenditure information for Yucatan. Outside the period 2008–2010, ENIGH information is not representative for Yucatan. ENIGH information was deflated to 2003.

[7]The labour account includes information on the payments of industries to labour factor by type of work and its distribution to households. There are 18 categories of work according to the Mexican Classification of Occupations (INEGI, 2005c). On the other hand, the other factors account registers the payment made by the industries of property rents for the possession of natural resources and financial assets to the owners of the factors of production. Includes mixed income. The household account records income from paid, unpaid work, property income and transfers to different types of households, as well as household expenses. The regional government account comprises the units administered by the authorities of the state of Yucatan. The companies account records the income and expenses of local businesses.

[8]The central government comprises entities under the jurisdiction of the central or executive government at the national level. The rest of the world account includes transactions with the rest of Mexico and with other countries. The savings-investment account the flows that are captured by savings concept and their destination to the investment.

[9]The SAM used was constructed in such a way that it was consistent with the System of National Accounts of Mexico, the regionalized supply and use tables and the regionalized symmetric product input matrix. However, because the SAM was developed from information from numerous sources, it was not balanced. A cross entropy method developed in GAMS was adapted to balance the SAM. The linear restrictions incorporated into the estimation are intermediate demand (DI), exports, payments to other factors of production, value added, private consumption, government consumption and transfers from the rest of the world to households. Given that the total column values were considered the most reliable data available, it was taken as a target in the SAM balance process. In this sense, row totals would adjust to the value of the corresponding column during the balance sheet process.

Flows into the endogenous accounts are unbundled and represented by the submatrices $\mathbf{T_{ij}}$. Matrix $\mathbf{T_{13}}$ expresses payment flow of the industries (production activities) to labour and other factors for services provided during the production process; the matrix $\mathbf{T_{21}}$ is the distribution of salaries, wages and other income to different institutions; $\mathbf{T_{22}}$ represents transfers among households, regional government and enterprises (including social benefits, taxes, etc.); $\mathbf{T_{32}}$ is the consumption of goods and services by households and the regional government; $\mathbf{T_{33}}$ is the demand for raw materials by productive activities.

3 | METHODOLOGY

In the general model, the income of the endogenous accounts are equal to the sum of rows so that $y_i = \sum_{j=1}^{n} t_{ij} + x_i$. Based on the matrix of endogenous transactions that includes the accounts of factors, institutions and productive activities (industries), we define a new matrix $\mathbf{A}$ of average expenditure coefficients or average propensity to spend as:

$$a_{ij} = {}^{t_{ij}}/_{y_j}.$$

Since $t_{ij} = a_{ij}y_j$ then we have $y_i = \sum_{j=1}^{n} a_{ij}y_j + x_i$, thus the revenues of an i endogenous account (y_i) are given by multiplying the coefficients of average expenditure (a_{ij}) of the i account and the total cost of the endogenous accounts $y_j \ \forall \ j = 1, \ldots, n$ $(\sum_{j=1}^{n} a_{ij}y_j)$, plus the value of the exogenous injection given by x_i. In the matricial form, $\mathbf{y_n} = \mathbf{A_n}\mathbf{y}_n + \mathbf{x}$, from which $\mathbf{y}_n = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{x}$ is obtained.[10] The matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is called accounting multipliers matrix, that is, it indicates how a unit increase in exogenous demand of the central government, the rest of the world and saving-investment affects household income, companies, regional government, factors and productive activities, that is, $\mathrm{d}\mathbf{y} = (\mathbf{I} - \mathbf{A})^{-1}\mathrm{d}\mathbf{x}$.

Now the procedure is performed with the matrix of average coefficients partitioned in the different endogenous components that integrate it to obtain the breakdown of the accounting multipliers:

$$\begin{bmatrix} \mathbf{0} & \mathbf{0} & \mathbf{A_{13}} \\ \mathbf{A_{21}} & \mathbf{A_{22}} & \mathbf{0} \\ \mathbf{0} & \mathbf{A_{32}} & \mathbf{A_{33}} \end{bmatrix}.$$

The components of the matrix represent submatrices of mean propensities among the different accounts that compose it.[11] $\mathbf{A_{13}}$ represents the average payments of industries to production factors; $\mathbf{A_{21}}$ means the average payments of various factors to institutions; $\mathbf{A_{22}}$ is the average propensities of transfers between institutions; $\mathbf{A_{32}}$ the average expenditure of institutions in locally manufactured products, and $\mathbf{A_{33}}$ is the average spending of industries in intermediate inputs at a local level. The breakdown of interactions at the sub-account level allows us to analyse the importance of each component of the economic system and its impact on the social and environmental systems.

In algebraic terms, the change in the income of the endogenous accounts is given by:

$$\begin{aligned} \mathrm{d}\mathbf{y_1} &= \mathbf{A_{13}}\mathrm{d}\mathbf{y_3} + \mathrm{d}\mathbf{x_1}, \\ \mathrm{d}\mathbf{y_2} &= \mathbf{A_{21}}\mathrm{d}\mathbf{y_1} + \mathbf{A_{22}}\mathrm{d}\mathbf{y_2} + \mathrm{d}\mathbf{x_2}, \\ \mathrm{d}\mathbf{y_3} &= \mathbf{A_{32}}\mathrm{d}\mathbf{y_2} + \mathbf{A_{33}}\mathrm{d}\mathbf{y_3} + \mathrm{d}\mathbf{x_3}. \end{aligned}$$

[10]Regarding the foreign sector, the SAM is expressed in terms of the domestic economy, so the flows of intermediate and final demand do not contain the flows of imports. Therefore, matrix A referred to domestic inputs. In this regard, current developments in multi-regional input output (MRIO) models allow better apply of this assumption, covering in this way an important shortcoming (Wiedmann, 2009, among others).

[11]Matrices and vectors dimensions are described in Table A1.

Factoring common terms:

$$\begin{aligned} d\mathbf{y_1} &= \mathbf{A_{13}}d\mathbf{y_3} + d\mathbf{x_1}, \\ d\mathbf{y_2} &= (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}d\mathbf{y_1} + (\mathbf{I}-\mathbf{A_{22}})^{-1}d\mathbf{x_2}, \\ d\mathbf{y_3} &= (\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}d\mathbf{y_2} + (\mathbf{I}-\mathbf{A_{33}})^{-1}d\mathbf{x_3}. \end{aligned}$$

Given that we want to focus on how the change in the exogenous demand of a good produced by an activity ($d\mathbf{x}_3$) affects the income of households ($d\mathbf{y_2}$), $d\mathbf{y}_3$ is replaced in $d\mathbf{y}_1$ and then this new expression $d\mathbf{y_1}$ in $d\mathbf{y}_2$:

$$\begin{aligned} d\mathbf{y_2} &= (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}[\mathbf{A_{13}}d\mathbf{y_3} + d\mathbf{x_1}] + (\mathbf{I}-\mathbf{A_{22}})^{-1}d\mathbf{x_2}, \\ d\mathbf{y_2} &= (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}d\mathbf{y_3} + (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}d\mathbf{x_1} + (\mathbf{I}-\mathbf{A_{22}})^{-1}d\mathbf{x_2}, \\ d\mathbf{y}_2 &= (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}\left[(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}d\mathbf{y_2} + (\mathbf{I}-\mathbf{A_{33}})^{-1}d\mathbf{x_3}\right] + (\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}d\mathbf{x_1} + (\mathbf{I}-\mathbf{A_{22}})^{-1}d\mathbf{x_2}. \end{aligned}$$

Solving:

$$\begin{aligned} d\mathbf{y_2} = &\left[\mathbf{I}-(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}\right]^{-1}(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}d\mathbf{x_3} \\ &+\left[\mathbf{I}-(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}\right]^{-1}(\mathbf{I}-\mathbf{A_{22}})^{-1}d\mathbf{x_2} + \left[\mathbf{I}-(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}\right]^{-1}(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}d\mathbf{x_1}. \end{aligned}$$

3.1 | Effects on household income

In algebraic terms, the effect of the impulse to local productive activity via exogenous demand ($d\mathbf{x_3}$) for goods produced in the local economy and its impact on household income ($d\mathbf{y_2}$) is given by:

$$d\mathbf{y_2} = \left[\mathbf{I}-(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}\right]^{-1}(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I}-\mathbf{A_{33}})^{-1}d\mathbf{x_3}. \quad (1)$$

If we denote:

$$\mathbf{D} = (\mathbf{I} - \mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}(\mathbf{I} - \mathbf{A_{33}})^{-1} \text{ and } \mathbf{F} = \mathbf{A_{32}},$$

then (1) can be represented as:

$$d\mathbf{y_2} = (\mathbf{I}-\mathbf{DF})^{-1}\mathbf{D}d\mathbf{x_3}, \quad (2)$$

where the matrix **D** represents the effect Thorbecke and Jung (1996) call distributive and the matrix $(\mathbf{I} - \mathbf{DF})^{-1}$ is the interdependency effect here called consumer-production-income integration effect.[12]

Let $m_{ij} = r_{ij}d_{ij}$, where *i* represents the type of household, *j* is the productive sector, *r* the consumption-production-income integration effect, *d* is the distributional effect and *m* is the income-production accounting multiplier. Since m_{ij} *and* d_{ij} have the same dimension, then $r_{ij} = m_{ij}/d_{ij}$, that is, consumption-production-income integration effect. This is done in order to compare the magnitude of the effects and to be able to determine which is the one that contributes the most in household income.

[12]The dynamic of the effects is carried out as follows: to introduce an exogenous change in the demand for a good produced by any industry (represented by $d\mathbf{x_3}$), the industry increases production in response to increased demand and purchase supplies from other industries to produce goods that were required; these inputs in turn require other inputs to those that can be produced; with this, it is created in the economy a chain of inter-industrial consequences given by $(\mathbf{I} - \mathbf{A_{33}})^{-1}$. Labour demand and factors increase ($\mathbf{A_{13}}$) and their payments distributed to institutions ($\mathbf{A_{21}}$). The institutions transfer resources to other institutions and each other, which creates a chain of interinstitutional impact which is represented algebraically by $(\mathbf{I} - \mathbf{A_{22}})^{-1}$. So far the distributive effect concludes. Once the distributive effect concludes, the consumption-production-income integration effect initiates, this happens when institutions demand goods and services ($\mathbf{A_{32}}$) which in turn have to be produced by the activities. The activities increase production in response to increased demand for their products and in turn demand inputs again creating a chain of inter-industrial repercussions$(\mathbf{I} - \mathbf{A_{33}})^{-1}$. Then they demand inputs factors which in turn distribute income to the institutions and these together with inter - chain implications$(\mathbf{I} - \mathbf{A_{22}})^{-1}$. The integration effect is stopped at this point after having repeated indefinitely until the muffling effect will weaken and to extinction after a varied series of rounds.

3.2 | Breakdown effects on productive activity

To assess the impacts of a change in exogenous demand on industries, impact of $d\mathbf{x_3}$ over $d\mathbf{y_3}$ is measured. It is a question of measuring the impact of an exogenous change in demand ($d\mathbf{x_3}$) on revenues of activities ($d\mathbf{y_3}$) to then measure the impacts on the demand of natural resources as inputs (emissions) of production. Then:

$$d\mathbf{y_3} = \left[\mathbf{I}-(\mathbf{I}-\mathbf{A_{33}})^{-1}\mathbf{A_{32}}(\mathbf{I}-\mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}\right]^{-1}(\mathbf{I}-\mathbf{A_{33}})^{-1}d\mathbf{x_3}. \quad (3)$$

Let: $\mathbf{N} = \mathbf{A_{32}}(\mathbf{I} - \mathbf{A_{22}})^{-1}\mathbf{A_{21}}\mathbf{A_{13}}$ **y** $\mathbf{H} = (\mathbf{I} - \mathbf{A_{33}})^{-1}$, then

$$d\mathbf{y_3} = (\mathbf{I}-\mathbf{HN})^{-1}\mathbf{H}d\mathbf{x_3}, \quad (4)$$

where $(\mathbf{I} - \mathbf{HN})^{-1}$ is the income-consumption-production integration effect and $\mathbf{H}$ is the effect on the productive sphere. The effect $(\mathbf{I} - \mathbf{HN})^{-1}$ is similar to the consumption-production-income integration effect; they only differ in the starting point and conclusion of the effects. On the other hand, the effects in production are the Leontief's multipliers that are obtained from the regional input–output table.

3.2.1 | Effects on groundwater use

As the growth of exogenous demand leads to an increase in income from productive activities, there is an increase in the use of groundwater.[13] If $\mathbf{a_w}$ is the vector of *coefficients of direct use of water* by monetary unit of production, and $\mathbf{y_3}$ are the *revenues of productive activities:*

$$w_3 = \mathbf{a_w}\mathbf{y_3}, \quad (5)$$

is the total aggregate use of groundwater (by productive activities).

According to the above, $w_3 = \mathbf{a_w}(\mathbf{I} - \mathbf{A})^{-1}\mathbf{x_3}$, then to estimate the environmental impact of an exogenous change in demand we have $dw_3 = \mathbf{a_w}(\mathbf{I} - \mathbf{A})^{-1}d\mathbf{x_3}$ and the decomposition of accounting multipliers is given by:

$$dw_3 = \mathbf{a_w}(\mathbf{I}-\mathbf{HN})^{-1}\mathbf{H}d\mathbf{x_3}. \quad (6)$$

The above equation shows how an increase in the exogenous demand of the local economy affects the income of productive activities and, therefore, the use of groundwater. And this effect can be decomposed into the part corresponding to the integration effect and that which corresponds to the productive effect.

3.2.2 | Effects on energy and polluting emissions

For the case of energy consumption and emission of gases to the atmosphere we have:

$$d\mathbf{e_3} = \mathbf{A_e}(\mathbf{I}-\mathbf{HN})^{-1}\mathbf{H}d\mathbf{x_3}, \quad (7)$$

$$d\mathbf{g_3} = \mathbf{A_g}(\mathbf{I}-\mathbf{HN})^{-1}\mathbf{H}d\mathbf{x_3}. \quad (8)$$

Where $\mathbf{A_e}$ is the matrix of dimension eight (type of fuel) for nineteen (productive activities) of physical coefficients of energy in *Tj* for every monetary unit produced. An element of this matrix indicates the direct energy consumption in *Tj* by fuel type, by monetary unit produced by every activity sector. Meanwhile, the matrix of physical emission

[13]There is a difference between use and water consumption. Water use refers to the granting of rights of extraction to the concession holder expressed in the maximum volume of extraction of groundwater in m^3 per year. Water consumption refers to actually harvested volumes. It should be noted that the concession volume may not match the actual volume harvested (Dinar, Guerrero, Yúnez, & Medellín, 2008; Rivero & García, 2011) and the recorded use may not match the actual water use. Moreover, for the CONAGUA, concessions are the basis for determining future concessions and to manage the resource.

coefficients is given by $\mathbf{A_g}$ an element of this matrix of dimension six (direct and indirect emissions of GHG) by nineteen (productive activities) indicates the GHG emission in *Gg* by type of gas per monetary unit produced by activity sector.

3.2.3 | Breakdown of effects

As we can see, the consumption-production-income integration effect and the income-consumption-production integration effect close the circuit of effects in the algebraic formulations of total effects. The integration effect is linked to the integration of supply with demand in each of the factor, input and output markets in the economy. One hypothesis of this work is that the greater the integration between demand and supply, the higher the income of households, but the greater the use of natural resources and the emission of GHG. Impacts on the use of natural resources, gas emissions and household incomes are presumably linked by the two types of integration effects, in addition to the distributive and productive effects.

In order to be able to compare the different effects, the multipliers are disaggregated as follows: $m_t = m_p + (m_t - m_p)$ where m_t is the total effect, m_p is the productive effect, and the difference between the first to the second is the income-consumption-production integration effect. So:

$$m_t^w = a_w m_p + a_w (m_t - m_p), \tag{9}$$

$$m_t^e = a_e m_p + a_e (m_t - m_p), \tag{10}$$

$$m_t^g = a_g m_p + a_g (m_t - m_p). \tag{11}$$

4 | RESULTS

4.1 | Effects on household income

The local economy in 2003 is characterized by a high concentration of household income in the upper decile (X) (Table 2). At national level, the situation is similar (Credit Suisse, 2014; Esquivel, 2015). At the national and local levels, a large part of the population is excluded from advancement in economic and social well-being such as the

TABLE 2 Total income of households in Yucatan by income decile. Millions of pesos 2008

Decile	Abbreviation	Income	%
I	Home1	1,321	1.54
II	Home2	2,061	2.40
III	Home3	2,663	3.09
IV	Home4	3,186	3.71
V	Home5	4,331	5.04
VI	Home6	4,406	5.12
VII	Home7	5,731	6.67
VIII	Home8	8,142	9.47
IX	Home9	10,371	12.06
X	Home10	43,761	50.90
Total		85,973	100.00

Source: ENIGH (INEGI, 2008).

TABLE 3 Effect on household income in Yucatan Mexico 2003 by productive activity (pesos)

SCIAN	Distributive	Integration	Total
FARMING	0.66	1.77	1.17
MINING	0.76	1.69	1.29
ELEC&WATER	0.58	1.71	1.00
CONST	0.58	1.81	1.04
MANUFAC	0.52	1.71	0.90
TRADE	0.71	1.71	1.21
TRANSP	0.54	1.79	0.97
INFORM	0.65	1.68	1.09
FINAN	0.81	1.79	1.46
REALESTATE	0.67	1.63	1.10
PROFSERVI	0.73	1.68	1.24
DIRECTION	0.66	1.69	1.13
SUPPORT	0.75	1.82	1.36
EDUCA	0.82	1.65	1.36
HEALTH	0.80	1.67	1.33
RECREATION	0.83	1.80	1.49
ACCOMMOD	0.72	1.82	1.31
OTHERS	0.71	1.95	1.38
GOVERNMENT	0.80	1.76	1.40
Average	0.70	1.74	1.22

Source: Own elaboration based on ESAM 2003.

Mayan indigenous population in Yucatan,[14] being inequality in income distribution extreme and resulting in broad social, political and economic implications. This inequality stems from the high dependence on labour wages of households on the lower decile (therefore more linked to local labour markets), meanwhile in the upper decile, revenues have a greater source of diversification linked mainly to capital.[15]

Interactions included in the SAM model used provide results about household income due to an exogenous change in the final demand by productive activity and type of effect (Table 3). The distribution effect is less than one and has an average value of 70 cents, that is, for each peso that increases the exogenous demand for a good in the economy, household income increases by 70 cents on average. This effect is the result of remuneration for the factors that intervened in the production of the good, the requirements of production and the structure of income redistribution determined by the economic structure and social policy of the federal and state government. On the other hand, the integration effect is greater than one, has an average value of 1.74 pesos, because the income generated is spent on local goods and products that generate new rounds of impacts on factor incomes and households.[16]

The total effect, given by the product of the distribution effect and the integration effect, is dampened by the distribution effect (Table 3). In addition, the distribution effect determines the total effect since the activities whose

[14]In 2008, If the income was evenly distributed among the population, per capita income would rise to $49,449.58 pesos per year, about $135.48 a day per person.

[15]Wages represent 86.56% of the total income in the lower decile, while in the upper decile, wages are 37.38% and payments to capital 46.27%.

[16]The activities with the highest integration effects produce goods and services that are consumed locally (those which effect is greater than the global average of 1.22 units, see Table 3) and whose production use in greater measure local origin inputs. They represent the activities with the greatest impact on local economic system.

TABLE 4 Average effect on household income in Yucatan Mexico 2003 by household decile (pesos)

Home	Distributive	Integration	Total
Home1	0.017	2.030	0.025
Home2	0.013	2.074	0.025
Home3	0.018	2.045	0.033
Home4	0.025	1.930	0.045
Home5	0.032	1.866	0.056
Home6	0.038	1.827	0.066
Home7	0.047	1,793	0.082
Home8	0.067	1,729	0.115
Home9	0.092	1.692	0.150
Home10	0.352	1.845	0.625

Source: Own elaboration based on SAM 2003.

distribution effect is higher than the average are those whose total effect is higher than the average (except for the trade sector). The total effect amounts to 1.22 pesos. The activities with the highest total effects above average are the following[17]: MINING (21), FINAN (52), PROFSERVI (54) SUPPORT (56), EDUCA (61), HEALTH (62), RECREATION (71), ACCOMMOD (72), OTHERS (81) and GOVERNMENT (93).

Table 4 shows the average effect on household income by household decile and type of effect. The distributive effect varies in the opposite direction to the integration effect but since the distributive effect has a greater weight than that it determines the behaviour of the total effect.

A significant finding is that households of the upper decile (Home10) receive 25 times more than the households of the lower decile (Home1) (0.625 and 0.025 respectively) for each peso that increases the exogenous demand of the economy. Main part of this effect is due to the distributive effect, because local productive activities pay poorly to the most disadvantaged households. Moreover, the integration effect indicates that households in the bottom decile spend a significant part of their income in locally manufactured products unlike households in the top decile consuming products imported in greater proportion to those.[18] This is due to the fact that the integration effect is decreasing as the socioeconomic level of households increases.

In Table A2 in the Appendix, the total effect is presented by type of productive activity and by household decile. One can see that the pattern of the total effect is predominantly increased for the same activity as we move deciles of lower to higher income. The activities with the highest total income effects of a wide range of household belonging to deciles II-VIII are ACCOMMOD (72) and OTHERS (81). The sectors of MINING (21), RECREATION (71), PROFSERVI (54), EDUCATE (61) HEALTH (62) and GOVERNMENT (93), have important effects on total household income of the IX–X deciles that far exceed the amounts of the impact on households of lower deciles.

In short, the local economy has minimal impacts on household incomes in the bottom decile and high impacts on income of the top decile. Households in the lower deciles do not benefit from the boost to the local economy through demand and differences exacerbate the gaps between households.

[17]In parentheses, it is indicated the activity key, corresponding to the SCIAN (INEGI, 2002). The Mining sector comprises exclusively non-metallic minerals because there is no activity of metal mining in Yucatan.

[18]In addition, households in the lower deciles consume a greater proportion of their income, that is, they represent a major stimulus to the local aggregate demand unlike households in the upper deciles that consume a smaller proportion of their money in local manufacturing goods. The more money is concentrated at the top, the lower aggregate demand of an economy (Stiglitz, 2015).

4.2 | Effect on the groundwater

Productive activities of the local economy represent a use of 589,115,629 m^3 of groundwater self-supplied to 2003 (REPDA). The main direct user of water is the agricultural sector with 93.80% of the total,[19] followed in importance by the manufacturing sector with 2.75% and the electric power generation sector with 2.48% of the total. The agricultural sector is unquestionably the most important of the local economy to ensure sustainable use of water in productive activities.[20]

Production and consumption perspectives differ regarding the use of self-supplied groundwater for productive use. Two uses are distinguished: direct from the point of view of production and the total from the point of view of final demand. Direct use is determined by the volumes allocated in m^3 for productive use. Total use is determined by the final demand of commodities from exogenous accounts. Total use consists of two effects: the productive one gestating in terms of production and the integration effect reproduced throughout the economic system. The productive use comprises the direct use linked to the production of goods and the indirect one linked to the use of water incorporated in the required production of commodities inputs.[21] Meanwhile integration effect comprises the use of water due to the effects of the distribution and redistribution of income in local economic system that determines the demand for products that incorporate water in their production.

Table 5 shows the results of direct and total use and the breakdown of the latter in the production and integration effects. Direct use of a productive activity is less than productive, integration and overall effect because the last three comprise the first and, additionally, incorporate indirect and induced effects of the economic system. The two activities major direct users of locally self-supplied groundwater are agricultural sector and manufacturing sector (obviously, largest value corresponds to agriculture: 82,123 m^3 of per one million pesos increase in the value of production activity).

Relative to the total use, for some activities, productive effects are greater than integration. The productive effect of the agricultural sector is the most important, followed by manufacturing sector and electric power generation, both far behind the first. It is the main cause of the high demand for the resource in these three activities. For the other sectors, the production effect is marginal.

The integration effect income-consumption-production is higher than the productive effect on activities other than the agricultural, manufacturing and power generation, which use water for production; the integration effect involves the use of groundwater comprising the rebound effect in productive activities of increased remuneration of production factors and of households demanding goods and services for consumption which in turn have to be produced by industries. In Table 5 can see that the range of the integration effect is narrow as it goes up to 7,784 at a minimum of 3,511 m^3.

Relative to the total use, the three activities with the highest total effects on self-supplied groundwater (per million pesos to increase the corresponding exogenous demand) are: agricultural sector (87,145 m^3 per million pesos to increase the exogenous demand for this activity); the electric power generation sector (8,771 m^3) and manufacturing

[19]The water extracted for agricultural usage is mostly used for irrigation. Only a small part is used in livestock activities, aquaculture and other uses and exploitation.

[20]Authors like Rivero and García (2011) or Carabias and Landa (2005) argue that national agriculture makes a little sustainable resource use. The inefficient use of irrigation water is high, over 50% is lost due to leaks and bad technology. Otherwise, the efficient use of water for irrigation is 46%, that is, 54% of granted water for irrigation returns to the hydrological cycle without being exploited in agriculture, but contaminated by the effects of agrochemicals and pesticides. Inefficiencies are not limited to the primary sector; it is also present in other sectors of the economy. Guerrero (2005) presumes that the industry makes a very little productive use of water. These inefficiencies in sectors of the economy, even though representative of the situation nationwide, they also include the problems present in Yucatan.

[21]For example, in maize production, direct use is given by the amount of groundwater used in the production of corn and indirect use is given by the amount of groundwater incorporated in the necessary inputs for the production of corn and the seeds used, in the fertilizers, pesticides, and other supplies as well as water incorporated into the inputs of inputs.

TABLE 5 Direct and total water use by type of effect on the productive activities of Yucatan Mexico. m^3 per million pesos. 2003

Activity	Direct	Productive (direct + indirect)	Integration	Total
FARMING	82,123	82,271	4,874	87,145
MINING	420	727	4,930	5,657
ELEC&WATER	3,176	4,781	3,989	8,771
CONST	0	1,194	4,633	5,828
MANUFAC	339	4,819	3,511	8,331
TRADE	9	926	4,741	5,668
TRANSP	64	660	4,236	4,896
INFORM	1	422	4,272	4,695
FINAN	1	194	7,784	7,979
REAL ESTATE	28	155	3,816	3,971
SERVIPROF	120	555	5,147	5,702
DIRECTION	0	596	4,697	5,293
SUPPORT	73	436	6,677	7,113
EDUCA	77	193	4,719	4,913
HEALTH	96	568	5,485	6,053
RECREATION	852	1,267	6,325	7,593
ACCOMMOD	127	595	5,786	6,381
OTHERS	23	534	7,366	7,900
GOVERNMENT	259	585	6,151	6,736

Source: Own elaboration based on ESAM 2003.

(8,331 m^3). For these activities, the production effect is having greater weight in the total use of groundwater and is the main cause of high natural resource use.

In short, the productive use of water in the agricultural sector accounts for 94.41% of total use in that sector. In the electric power generation sector accounts for 54.51% and 57.84% of the manufacturing total use. Therefore, given the importance of water in the three activities, a sustainable water policy must focus their actions in promoting more efficient use of water in production processes in such activities. If a more sustainable economy is wanted, it should be promoted a more efficient water use in technical terms.

4.3 | Effects on energy consumption

Fossil fuels used in the local economy account for direct consumption of 88,619.17 *Tj* of energy in the local economy in 2005. The main fuel is natural gas with 34.91% of the total energy; secondly, diesel with 30.92% and gasoline with 23.08% as the third most important. Other types of fuels have a marginal participation.

The electric power generation sector directly consumes 60.17% of the total energy, which is based on consumption of natural gas, diesel and fuel oil. The transport sector is the second largest with 34.48% of the total and its main fuels are gasoline and diesel. These two sectors account for 94.65% of total direct energy consumption of the economy. Therefore, the sustainable development of the local economy depends on the efficiency of energy consumption in these two sectors.

Table A3 shows the total effects on energy consumption by production activity and type of fuel. The sector that has the greatest overall impact on diesel consumption, fuel oil and natural gas in the local economy is electric power generation with 5.2184, 0.9303 and 7.9094 *Tj*.[22] Transport is the main sector in the consumption of marine diesel, jet fuel and gasoline. LP gas consumption, to a greater extent, is represented by the accommodation and manufacturing sectors as the activities with greater overall impact on consumption of this fuel in the local economy. Coke consumption is represented by the manufacturing activity as the activity presenting the greatest impact.

The productive effect (Table A4) is the main cause of energy consumption in the economy. In particular, in the sector of electric power generation, the nature of their production processes in which a significant amount of fossil fuels (natural gas, diesel and fuel oil, in that order) is required, which demonstrates the high dependence on this sector on fossil fuels to continue operating and meet the production requirements of other industries. In this sector, the productive effect on the consumption of natural gas, diesel and fuel oil is greater than the integration effect. In the transport sector, the same applies but in relation to consumption of gasoline, jet fuel and marine diesel. The manufacturing and hosting services sector has the same pattern but in relation to the consumption of coke and LPG. All other sectors of the local economy have greater integration effects in all fuel types.

The electric power generation sector is the main source of direct, indirect and induced consumption of energy in the local economy with 14.2957 Tj per million pesos to increase exogenous demand for this sector.

4.4 | Effects on GHG

The other dimension of the problem of fossil fuels is that its combustion emits GHG. Local productive activities use fossil fuels in their production processes generating GHG into the atmosphere and contribute to global warming phenomenon. In 2005, the local economy issued 6,006.28 Gg CO_2 eq representing 1.56% of national GHG emissions in Mexico in units of Gg CO_2 eq by burning fossil fuels.[23]

The CO_2 represents 99.52% of the total of GHG emissions in units of Gg CO_2 eq. The gases CH_4 and N_2O have a marginal share, even though its warming potential is higher than that. The electric power generation sector issues the 57.58% of CO_2 eq. and the transport sector reports the 35.89% of the total. The other industries have marginal units. Regarding the indirect GHG, tropospheric ozone precursors, the transport sector is the largest contributor in this sense with 59.37% of the emissions of NO_x, 99.26% of CO and 98.84% of NMVOC.

Table 6 shows total effect of emissions generated per million pesos to increase the exogenous demand for each activity.[24] Regarding CO_2, main effects correspond to the electric power generation sector (0.9262 Gg CO_2 eq) and transport sector (0.2604 Gg CO_2 eq). In relation to CH_4 emissions, the same two activities stand out with 0.0010 Gg CO_2 eq for both. Relative to N_2O, the highlighting activity is the electric power generation with 0.0024 Gg CO_2 eq. In the emission of NO_x, the electric power generation sector and transport stands out in the first with 0.0036 Gg and 0.0022 Gg, respectively, as the most important.[25] In relation to CO and NMVOC, the transportation sector is the largest source of emissions in the economy (0.0178 Gg and 0.0033 Gg respectively).

Summarizing, the main emission source of direct GHG (CO_2 as the major gas in terms of absolute emissions) on the local economy is the electric power generation sector which represents a significant portion of the emissions from energy fossil combustion. This sector stands out in the emission of direct gases: CO_2, CH_4, N_2O and also in indirect gases: NO_x. Regarding indirect GHG emissions, the most important sector is transport, although this sector is the second largest direct GHG emitter, right behind the electric power generation sector. Transport stands out in direct

[22]The interpretation is as follows: the natural gas consumption in the economy increases 7.9094 *Tj* per every million pesos to increase exogenous demand for electric power generation sector.

[23]At national level, energy sector emissions from burning fossil fuels amounts to 384,500.4 Gg of CO_2 eq (CO_2, CH_4 and N_2O) in 2005 (SEMARNAT-INECC, 2012).

[24]It is noteworthy that the emissions reported in the tables refer to total emissions in the economy due to increase in one million pesos in the exogenous demand for a commodity produced by some activity. Therefore, it refers to the total effects arising from the direct, indirect and induced effects due to an increase in the demand by the federal government, investment and the rest of the world.

[25]NO_x, CO and NMVOC have no equivalent in CO_2, therefore, they are only reported in Gg.

TABLE 6 Total effect. Direct and indirect GHG emission in Yucatan, Mexico. *Gg* per million pesos

NAICS	CO_2	CH_4	N_2O	NO_x	CO	NMVOC
FARMING	0.0566	0.0001	0.0002	0.0003	0.0012	0.0002
MINING	0.0600	0.0001	0.0002	0.0003	0.0014	0.0003
ELEC&WATER	0.9262	0.0010	0.0024	0.0036	0.0019	0.0004
CONST	0.0624	0.0001	0.0002	0.0003	0.0016	0.0003
MANUFAC	0.0635	0.0001	0.0002	0.0003	0.0013	0.0002
TRADE	0.0644	0.0001	0.0002	0.0003	0.0013	0.0003
TRASNP	0.2604	0.0010	0.0008	0.0022	0.0178	0.0033
INFORM	0.0564	0.0001	0.0002	0.0003	0.0014	0.0003
FINAN	0.0728	0.0001	0.0002	0.0004	0.0017	0.0003
REALESTATE	0.0466	0.0001	0.0001	0.0002	0.0010	0.0002
PROFSERVI	0.0593	0.0001	0.0002	0.0003	0.0014	0.0003
DIRECTION	0.0610	0.0001	0.0002	0.0003	0.0016	0.0003
SUPPORT	0.0712	0.0001	0.0002	0.0004	0.0016	0.0003
EDUCA	0.0568	0.0001	0.0002	0.0003	0.0012	0.0002
HEALTH	0.0651	0.0001	0.0002	0.0003	0.0014	0.0003
RECREATION	0.0875	0.0002	0.0002	0.0004	0.0017	0.0003
ACCOMMOD	0.0976	0.0002	0.0003	0.0005	0.0016	0.0003
OTHERS	0.0882	0.0002	0.0002	0.0005	0.0019	0.0004
GOVERNMENT	0.0823	0.0002	0.0002	0.0004	0.0017	0.0003

Notes: CO_2, CH_4 and N_2O are expressed in *Gg* in CO_2 eq. All the other gases are expressed in Gg.
Source: Own elaboration based on ESAM 2003.

GHG emissions: in emissions CH_4 and indirect gases: CO and NMVOC. In the overall economy, the main GHG is CO_2 in terms of absolute emissions and the main emission source is the electric power generation.

The productive effect on both emission sources: electric power generation and transport is the main cause of the emission of gases to the atmosphere (Table A5). That is, both activities generate large amounts of greenhouse gases due to the nature of their production processes based on combustion of large amounts of fossil energy source. In all other activities, the integration effect has greater weight in determining GHG emissions.

5 | CONCLUSIONS

The ESAM is a kind of snapshot in a geographical area (Yucatan) that captures the relations of economic, social and environmental system.[26] The relations of the social and economic system are captured following the path of circular flow of income in monetary units and the relations of the environmental-economic system by the environmental impact of production and consumption activities expressed in physical units. Integration of monetary and physical information in a single accounting framework results in hybrid information that partially satisfies the requirements of strong sustainability approach driven by the school of thought of the ecological economy.

[26]An important consideration should be taken into account: reference to year 2003 as period analysis is a drawback, but it is the only period for which all the information and data necessary for this analysis could be found. In general, many times this lack of data results in an uncertainty in input–output models, concerning to empirical aspects, but, as noted in Peters, Weber, Guan, and Hubacek (2007), data uncertainty, although potentially important, is sometimes difficult to quantify. Also, in this paper we are combining economic and environmental information from different sources, generating additional uncertainty (Wiedmann, 2009).

The integrated information system in ESAM 2003 served as the basis for estimating accounting multipliers to derive the impacts on natural systems (groundwater, energy from fossil sources, emissions pollutants into the atmosphere) and social ones (generation and distribution of income) that sustain the economic system for continuous reproduction. The results obtained here provide evidence of unsustainable performance of the local economy for several reasons: the economic structure widens the gap between rich and poor households; inefficient groundwater use in agriculture and presumably in the electric power generation and manufacturing productive use; economy based on fossil fuels from non-renewable sources that generate greenhouse gases into the atmosphere with global impacts.

In the social dimension, the local economic structure and pattern of income redistribution are the most important variables in household income. The household income determines the spending in the local economy and its level and composition has important implications for economic dynamics. The household income of the lower deciles consists largely of remuneration to the labour, which are characterized by corresponding to a minimum subsistence wage, unlike top decile households, which derived greater extent of income from capital and high salaries. In this sense, the results of this study suggest that the option of establishing a progressive fiscal policy, which taxes at higher rates capital income and to a lesser extent labour income combined with a social policy of transfers to employees households, would contribute to the reduction of economic gaps between households. With these changes in the orientation of fiscal and social policies, they strengthen aggregate demand and economic dynamics lead to reducing gaps between households. Local aggregate demand would be strengthened and the economic dynamics would lead to reducing gaps between households.

Regarding the use of groundwater, the results suggest that the productive use is the major factor in the sustainable management of water resources. Therefore, given the importance of groundwater in the agricultural, manufacturing and electric power generation sectors, a sustainable water policy must focus their actions in promoting more efficient use of groundwater in production processes such as those activities. If it is wanted an economy with sustainable local development, the research results suggest that an environmental policy focused on the most efficient use of water in technical terms (economic) mainly in the agricultural sector, it is needed to ensure management in line with the principles of Sustainable Development Goals.

Moreover, as in the case of groundwater, productive consumption is the leading cause of energy (fossil) consumption in productive sectors in the economy of Yucatan. Particularly, in the sector of electric power generation and road transport sectors, they represent the two largest direct and total energy consumers of fossil energy both determined by the production requirements of the prevailing technology in these sectors. These results provide direction in the general guidelines of a sustainable energy policy aimed at promoting the efficient consumption of energy in the above sectors and according to the availability of fossil fuels on a long-term time horizon sectors. At the same time, sustainable energy management includes the development of alternative sources of renewable energy that can replace the energy consumption of non-renewable sources.

With regard to GHG emissions, the activities of electric power generation and transportation represent the two sectors with the largest GHG emissions into the atmosphere and productive consumption is the most important factor in this situation again. That is, both activities emit large amounts of GHG due to the nature of their production processes based on combustion of large amounts of fossil energy source. Based on the research results, sustainable policy options point to promote efficient production processes in the consumption of fossil fuels and transition to fuel sources that shed less pollutants into the atmosphere.

For the local economy, the sector of electric power generation is the activity that largely determines the little sustainable performance of the local economy, in relation to energy consumption, GHG generation and to a lesser extent the use of groundwater. It is the sector that represents the most important challenge in the dynamics of the transition of the economy along the path of sustainable local development. For its part, agriculture plays an important role in the sustainable management of the economy as a strategic sector in the provision of food, but being little sustainable in its use of groundwater for the abuse and waste of natural resources. A constructive policy towards the sustainable development would place greater emphasis on productive restructuring the agricultural sector and electric power generation, in designing actions of technological change and sustainable natural resource management.

Productive reconversion of activities along with tax policies levied further capital income and income redistribution through transfer mechanisms to households that depend on income from wage labour, would help to set up an economy a less unsustainable performance, at least on a short-term time horizon and in the right direction in the transition to more sustainable development actions. In the short term, they would be taking steps in the right direction, but in the medium and long term these actions are not enough to ensure sustainable natural resource management. The local ecosystem requires action to put in balance the demand and supply of local biocapacity in meeting the needs of the population entity. The biggest challenge is not the short term, the most difficult battle is to co-ordinate development actions in a long-term involving intergenerational co-ordination of actions in line with the Sustainable Development Goals.

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REFERENCES

Aguilera, F., & Alcántara, V. (1994). *De la economía ambiental a la economía ecológica*. Barcelona: ICARIA-FUHEM. URL: http://www.fuhem.es/media/ecosocial/File/Actualidad/2011/LibroEA_EE.pdf

Alarcón, J., Van Heemst, J., & Jong, N. (2000). Extending the SAM with social and environmental indicators: an application to Bolivia. *Economic Systems Research*, *12*(4), 473–496.

Albornoz, L., García, H., & Adrián, D. (2014). La vulnerabilidad de la economía yucateca ante limitaciones en la disponibilidad de agua subterránea. Un enfoque de insumo producto. *Ensayos Revista de Economía*, *23*(2), 77–104.

Beltrán, L., Cardenete, M., Delgado, M., & Núñez, G. (2016). Análisis estructural de la economía mexicana para el año 2008. *Ensayos Revista de Economía*, *35*(1), 1–38.

Brandsma, A., d'Kancs, A., Monfort, P., & Rillaers, A. (2015). RHOMOLO: A dynamic spatial general equilibrium model for assessing the impact of cohesion policy. *Papers in Regional Science*, *94*(S1), S197–S222.

Carabias, J., & Landa, R. (2005). *Agua, medio ambiente y sociedad: Hacia la gestión integral de los recursos hídricos en México*. México DF: UNAM, El Colegio de México and Fundación Gonzalo Río Arronte.

Chiquiar, D., Alvarado, J., Quiroga, M., & Torre Cepeda, L. (2017). Regional input-output matrices, an application to manufacturing exports in Mexico. Banco de México Working Paper 2017–09.

CONAGUA (2010). *Registro público de derechos de agua*. Mérida, Mexico: Comisión Nacional del Agua.

Credit Suisse (2014). Global wealth report 2014. URL: https://publications.credit-suisse.com/tasks/render/file/?fileID=60931FDE-A2D2-F568-B041B58C5EA591A4

Dinar, A., Guerrero, H., Yúnez, A., & Medellín, J. (2008). Políticas en el sector agua, herramientas para la evaluación de sus implicaciones económicas y ambientales: una visión panorámica. In H. Guerrero, A. Yúnez, & J. Medellín (Eds.), *El agua en México: Implicaciones de las políticas de intervención en el sector*. México City: FCE.

Duarte, R., Mainar, A., & Sánchez-Chóliz, J. (2010). The impact of household consumption patterns on emissions in Spain. *Energy Economics*, *32*, 176–185.

Duarte, R., Mainar-Causapé, A., & Sánchez-Chóliz, J. (2017). Domestic GHG emissions and the responsibility of households in Spain: Looking for regional differences. *Applied Economics*, *49*(53), 5397–5411. https://doi.org/10.1080/00036846.2017.1307933

Duarte, R., Sánchez-Chóliz, J., & Bielsa, J. (2002). Water use in the Spanish economy: An input-output approach. *Ecological Economics*, *43*(1), 71–85.

Esquivel, G. (2015). *Desigualdad Extrema en México: concentración del poder económico y político*. México: Oxfam. URL: https://www.oxfammexico.org/sites/default/files/desigualdadextrema_informe.pdf

Flores, M., & Mainar, A. (2010). Análisis del impacto medioambiental derivado de las actividades económicas. Aplicación a una economía regional. *Economía Agraria y Recursos Naturales*, *10*(2), 3–23.

Franco Solís, A., & De Miguel Vélez, F. (2017). Revealing the economic channels of natural impacts: An extended input-output subsystems application to GHG gases and water use. *Journal of Environmental Planning and Management*, *61*(3), 451–473.

Fuentes-Saguar, P., Vega-Cervera, J., & Cardenete, M. (2017). Socio-economic impact of a nuclear power plant: Almaraz (Spain). *Applied Economics*, *49*(47), 4782–4792. https://doi.org/10.1080/00036846.2017.1293793

Guerrero, G. R. H. (2005). Industrial water demand in Mexico: Econometric analysis and implications for water management policy. PhD dissertation, Université des Sciences Sociales, Toulouse I (France).

Guevara, Z., Córdoba, O., García, E., & Bouchain, R. (2017). The status and evolution of energy supply and use in Mexico prior to the 2014 energy reform: An input–output approach. *Economies*, *5*(1), 10. https://doi.org/10.3390/economies5010010

Harris, R. (2002). Estimation of a regionalized Mexican social accounting matrix using entropy techniques to reconcile disparate data sources. TMD Discussion Paper 97, International Food Policy Research Institute (IFPRI), Washington, DC.

INEGI (2002). *Sistema de clasificación industrial de América del Norte México 2002*. Aguascalientes, Mexico, DF: Instituto Nacional de Estadística y Geografía.

INEGI (2003). Mexico's input-output framework. URL: http://www.inegi.org.mx/est/contenidos/proyectos/scn/c_anuales/matrizinsumo/default.aspx

INEGI (2005a). *Estadísticas de Finanzas Públicas Estatales y Municipales*. Aguascalientes, Mexico, DF: Instituto Nacional de Estadística y Geografía.

INEGI (2005b). *Encuesta Nacional de Ocupación y Empleo 2005. Una nueva encuesta para México*. Aguascalientes, Mexico: Instituto Nacional de Estadística y Geografía.

INEGI (2005c). *Clasificación Mexicana de ocupaciones*. Aguascalientes, Mexico, DF: Instituto Nacional de Estadística y Geografía.

INEGI (2008). Encuesta nacional de ingresos y gastos de los hogares. URL: http://www.inegi.org.mx/est/contenidos/Proyectos/encuestas/hogares/regulares/enigh/

INEGI (2010). *Sistema de cuentas nacionales de México. Producto interno bruto por entidad federativa 2003–2008. Año base 2003 (2nd Version)*. Aguascalientes, Mexico, DF: Instituto Nacional de Estadística y Geografía.

INEGI (2012). *Sistema de cuentas nacionales de México: Gobiernos estatales y gobiernos locales cuentas corrientes y de acumulación: Cuentas de producción por finalidad 2007–2011 año base 2003*. Aguascalientes, Mexico, DF: Instituto Nacional de Estadística y Geografía.

Jackson, R. (1998). Regionalizing national commodity by industry accounts. *Economic Systems Research*, *10*(3), 223–238.

Llop, M., & Pié, L. (2011). Decomposition of emission multipliers in a national accounting matrix including environmental accounts. *Journal of Industrial Ecology*, *15*(2), 206–216.

Lutz, W., Prieto, L., & Sanderson, W. (2000). *Population, development and environment on the Yucatán peninsula: From Ancient Maya to 2030*. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Mampiti, M., & Rashid, H. (2006). Integrated ecological economics accounting approach to evaluation of interbasin water transfers: An application to the Lesotho Highlands Water Project. *Ecological Economics*, *60*(1), 246–259.

Manresa, A., & Sancho, F. (2004). Energy intensive and CO_2 emissions in Catalonia: a SAM analysis. *International Journal of Environment, Workforce and Employment*, *1*(1), 91–106.

Martínez, J., & Roca, J. (2006). *Economía ecológica y política ambiental*. Mexico, DF: Fondo de Cultura Económica.

Núñez, G. (2018). Social accounting matrix and analysis of productive sectors in Mexico. *Contaduría y Administración*, *63*(1), 1–28.

Núñez, G., & Cruz, A. (2009). Input-output matrix of Oaxaca and an analysis of its economy. *Revista Mexicana de Economía Agrícola y de los Recursos Naturales*, *2*(3), 105–126.

OECD (2007). *Territorial reviews: Yucatan Mexico 2007*. Paris: OECD.

Okadera, T., Watanabe, M., & Xu, K. (2006). Analysis of water demand and water pollutant discharge using a regional input output table: an application to the city of Chongqing, upstream of the Three Gorges Dam in China. *Ecological Economics*, *58*(2), 221–237.

Pearce, D., & Turner, K. (1990). *Economics of natural resources and the environment*. Baltimore, MD: The Johns Hopkins University Press.

Peters, G., Weber, C., Guan, D., & Hubacek, K. (2007). China's growing CO2 emissions: A race between increasing consumption and efficiency gains. *Environmental Science and Technology*, *41*, 5939–5944.

Pieters, J. (2010). Growth and inequality in India: Analysis of an extended social accounting matrix. *World Development*, *38*(3), 270–281.

Resosudarmo, B., & Thorbecke, E. (1996). The impact of environmental policies on household incomes for different socioeconomic classes: the case of air pollutants in Indonesia. *Ecological Economics*, *17*, 83–94.

Rivero, E., & García, H. (2011). Instrumentos económicos y de política pública para la asignación de agua subterránea para uso agrícola en México. *Revista de Economía Facultad de Economía Universidad Autónoma de Yucatán*, *28*(76), 41–80.

Robinson, S., Cattaneo, A., & El-Said, M. (2001). Updating and estimating a social accounting matrix using cross entropy methods. *Economic Systems Research*, *1*(1), 47–64.

Robinson, S., & El-Said, M. (2000). GAMS code for estimating a social accounting matrix (SAM) using cross entropy (CE) methods. TMD Discussion Paper 64. International Food Policy Research Institute (IFPRI), Washington, D.C.

Rodríguez, C., Llanes, G., & Cardenete, M. A. (2007). Economic and environmental efficiency using a social accounting matrix. *Ecological Economics*, *60*(4), 774–786.

Sánchez-Chóliz, J., Duarte, R., & Mainar, A. (2007). Environmental impact of household activity in Spain. *Ecological Economics*, *62*, 308–318.

SEDUMA–CICY (2013). *Inventario de gases de efecto invernadero. Yucatán 2005*. Mexico, DF: Secretaría de Desarrollo Urbano y Medio Ambiente, Centro de Investigación Científica de Yucatán y Unidad de Energía Renovable. URL: https://www.gob.mx/cms/uploads/attachment/file/41032/2005_yuc_inventario_gei.pdf

SEMARNAT–CONAFOR (2014). *Inventario estatal forestal y de suelos Yucatán 2013*. Mexico, DF: Secretaría de Medio Ambiente y Recursos Naturales y Comisión Nacional Forestal.

SEMARNAT–INECC (2012). *Quinta Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el cambio climático*. México, DF: Secretaría de Medio Ambiente y Recursos Naturales e Instituto Nacional de Ecología y Cambio Climático.

SHCP (2002). *Distribución del pago de impuestos y recepción del gasto público por deciles de hogares y personas. Resultados para el año 2002*. México, DF: Secretaría de Hacienda y Crédito Público.

Stiglitz, J. (2015). Inequality and economic gGrowth. *The Political Quarterly*, *86*, 134–155.

Thorbecke, E., & Jung, H. S. (1996). A multiplier decomposition method to analyze poverty allevation. *Journal of Development Economics*, *48*(2), 253–277.

UNDP (2016). *UNDP support to the implementation of the 2030 agenda for sustainable development*. New York: United Nations Development Programme.

United Nations (1993). *Integrated environmental and economic accounting*. New York: United Nations.

United Nations (2003). *Integrated environmental and economic accounting 2003*. New York: United Nations, European Commission, International Monetary Fund, Organization for Economic Co–operation and Development World Bank.

WCED (1987). Report of the World Commission on Environment and Development: Our common future. URL: http://www.un–documents.net/wced–ocf.htm

Wiedmann, T. (2009). A review of recent multi-region input-output models used for consumption-based emission and resource accounting. *Ecological Economics*, *69*, 211–222.

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APPENDIX

TABLE A1 Matrices and vectors dimensions

y	50 × 1	A_{32}	19 × 12	D	12 × 19	$(I\text{-}HN)^{-1}$	19 × 19
A	50 × 50	A_{33}	19 × 19	F	19 × 12	A_w	1 × 19
A_{13}	19 × 19	y_1	19 × 1	$(I\text{-}DF)^{-1}$	12 × 12	A_e	8 × 19
A_{21}	12 × 19	y_2	12 × 1	N	19 × 19	A_g	6 × 19
A_{22}	12 × 12	y_3	19 × 1	H	19 × 19		

Source: Own elaboration.

TABLE A2 Total effect on household income in 2003 in Yucatan, Mexico (pesos)

SCIAN	Home1	Home 2	Home 3	Home 4	Home 5	Home 6	Home 7	Home 8	Home 9	Home 10
FARMING	0.01	0.04	0.04	0.05	0.06	0.07	0.08	0.10	0.12	0.59
MINING	0.02	0.02	0.03	0.04	0.05	0.06	0.07	0.13	0.17	0.70
ELEC&WATER	0.01	0.02	0.03	0.04	0.04	0.05	0.06	0.09	0.11	0.53
CONST	0.02	0.03	0.04	0.05	0.06	0.07	0.06	0.10	0.12	0.49
MANUFAC	0.01	0.02	0.03	0.03	0.04	0.04	0.05	0.08	0.09	0.49
TRADE	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.11	0.14	0.65
TRANSP	0.02	0.02	0.04	0.04	0.05	0.07	0.07	0.10	0.12	0.46
INFORM	0.02	0.02	0.03	0.03	0.04	0.05	0.07	0.10	0.11	0.62
FINAN	0.08	0.02	0.03	0.05	0.06	0.08	0.11	0.14	0.17	0.71
REALESTATE	0.01	0.02	0.03	0.03	0.04	0.04	0.06	0.10	0.09	0.68
PROFSERVI	0.03	0.02	0.02	0.03	0.04	0.05	0.07	0.11	0.16	0.70
DIRECTION	0.03	0.02	0.02	0.03	0.04	0.05	0.07	0.10	0.14	0.63
SUPPORT	0.04	0.03	0.04	0.06	0.08	0.09	0.11	0.15	0.16	0.61
EDUCA	0.01	0.02	0.02	0.03	0.05	0.06	0.07	0.12	0.19	0.78
HEALTH	0.04	0.02	0.02	0.03	0.04	0.05	0.06	0.11	0.18	0.77
RECREATION	0.02	0.03	0.04	0.06	0.07	0.07	0.12	0.15	0.28	0.65
ACCOMMOD	0.02	0.04	0.05	0.06	0.08	0.08	0.11	0.13	0.16	0.59
OTHERS	0.04	0.04	0.06	0.09	0.10	0.12	0.12	0.13	0.16	0.52
GOVERNMENT	0.03	0.02	0.03	0.05	0.06	0.08	0.10	0.14	0.19	0.69
AVERAGE	0.02	0.03	0.03	0.05	0.06	0.07	0.08	0.12	0.15	0.62

Source: Own elaboration based in ESAM 2003.

TABLE A3 Total effect on energy consumption in Yucatan Mexico in *Tj* per million pesos

	Diesel	Fuel oil	Natural gas	LP gas	Coke	Marine diesel	Jet fuel	Gasoline	Total
FARMING	0.2759	0.0509	0.3457	0.0007	0.0141	0.0067	0.0117	0.1425	0.8483
MINING	0.2890	0.0539	0.3567	0.0008	0.0163	0.0075	0.0131	0.1597	0.8970
WATER&ELEC	5.2184	0.9303	7.9094	0.0009	0.0192	0.0090	0.0158	0.1925	14.2957
CONST	0.2924	0.0552	0.3441	0.0010	0.0199	0.0090	0.0157	0.1913	0.9286
MANUFAC	0.2725	0.0816	0.3425	0.0025	0.0544	0.0072	0.0126	0.1535	0.9268
TRADE	0.3150	0.0585	0.3978	0.0008	0.0161	0.0074	0.0130	0.1576	0.9661
TRANSP	0.9811	0.0499	0.3277	0.0008	0.0155	0.0987	0.1735	2.1087	3.7560
INFORM	0.2677	0.0482	0.3181	0.0007	0.0148	0.0080	0.0140	0.1699	0.8413
FINAN	0.3509	0.0635	0.4287	0.0009	0.0180	0.0094	0.0166	0.2014	1.0894
REALESTATE	0.2269	0.0427	0.2857	0.0006	0.0125	0.0054	0.0095	0.1153	0.6986
PROFSERVI	0.2841	0.0530	0.3469	0.0008	0.0166	0.0077	0.0135	0.1641	0.8868
DIRECTION	0.2889	0.0516	0.3401	0.0008	0.0159	0.0088	0.0155	0.1886	0.9104
SUPPORT	0.3438	0.0633	0.4236	0.0010	0.0185	0.0089	0.0157	0.1909	1.0657
EDUCA	0.2755	0.0517	0.3451	0.0008	0.0153	0.0067	0.0118	0.1434	0.8502
HEALTH	0.3167	0.0600	0.3997	0.0009	0.0177	0.0075	0.0131	0.1597	0.9753
RECREATION	0.4325	0.0793	0.5525	0.0010	0.0199	0.0096	0.0168	0.2045	1.3160
ACCOMMOD	0.5014	0.0891	0.6510	0.0028	0.0179	0.0088	0.0154	0.1872	1.4736
OTHERS	0.4322	0.0789	0.5440	0.0011	0.0207	0.0102	0.0180	0.2185	1.3237
GOVERN	0.4059	0.0733	0.5142	0.0009	0.0178	0.0093	0.0164	0.1990	1.2368

Source: Own elaboration based in ESAM 2003.

TABLE A4 Total, productive and integration effect on primary energy consumption in Yucatan Mexico in Tj per million pesos

SCIAN	diesel			fuel oil			natural gas			LP gas		
	I	II	III	I	II	III	I	II	III	I	II	III
FARMING	0.0298	0.2462	0.2759	0.0053	0.0456	0.0509	0.0418	0.3039	0.3457	0.0000	0.0007	0.0007
MINING	0.0456	0.2434	0.2890	0.0082	0.0457	0.0539	0.0566	0.3001	0.3567	0.0001	0.0007	0.0008
WATER&ELEC	5.0251	0.1933	5.2184	0.8941	0.0362	0.9303	7.6712	0.2382	7.9094	0.0004	0.0006	0.0009
CONST	0.0627	0.2298	0.2924	0.0128	0.0423	0.0552	0.0597	0.2844	0.3441	0.0004	0.0007	0.0010
MANUFAC	0.1002	0.1723	0.2725	0.0494	0.0323	0.0816	0.1305	0.2120	0.3425	0.0020	0.0005	0.0025
TRADE	0.0818	0.2332	0.3150	0.0148	0.0436	0.0585	0.1106	0.2873	0.3978	0.0001	0.0007	0.0008
TRANSP	0.7699	0.2112	0.9811	0.0109	0.0390	0.0499	0.0661	0.2616	0.3277	0.0002	0.0006	0.0008
INFORM	0.0701	0.1976	0.2677	0.0109	0.0373	0.0482	0.0753	0.2428	0.3181	0.0001	0.0006	0.0007
FINAN	0.0411	0.3098	0.3509	0.0060	0.0575	0.0635	0.0439	0.3847	0.4287	0.0001	0.0009	0.0009
REALESTATE	0.0420	0.1849	0.2269	0.0075	0.0352	0.0427	0.0600	0.2257	0.2857	0.0000	0.0006	0.0006
PROFSERVI	0.0572	0.2270	0.2841	0.0101	0.0429	0.0530	0.0668	0.2801	0.3469	0.0001	0.0007	0.0008
DIRECTION	0.0789	0.2100	0.2889	0.0120	0.0396	0.0516	0.0809	0.2592	0.3401	0.0002	0.0006	0.0008
SUPPORT	0.0396	0.3042	0.3438	0.0073	0.0560	0.0633	0.0462	0.3774	0.4236	0.0001	0.0008	0.0010
EDUCA	0.0388	0.2367	0.2755	0.0067	0.0450	0.0517	0.0537	0.2913	0.3451	0.0000	0.0007	0.0008
HEALTH	0.0788	0.2379	0.3167	0.0147	0.0452	0.0600	0.1060	0.2938	0.3997	0.0002	0.0007	0.0009
REACREATION	0.1023	0.3302	0.4325	0.0183	0.0610	0.0793	0.1411	0.4114	0.5525	0.0001	0.0009	0.0010
ACCOMMOD	0.2069	0.2945	0.5014	0.0350	0.0541	0.0891	0.2861	0.3649	0.6510	0.0020	0.0008	0.0028
OTHERS	0.0787	0.3536	0.4322	0.0148	0.0642	0.0789	0.1041	0.4399	0.5440	0.0002	0.0009	0.0011
GOVERNMENT	0.1153	0.2906	0.4059	0.0193	0.0540	0.0733	0.1542	0.3600	0.5142	0.0001	0.0008	0.0009

Notes: I. Productive effect. II. Integration effect III. Total effect.

Source: Own elaboration based in ESAM 2003.

TABLE A4 Continued

	coke			marine diesel			jet fuel			gasoline		
SCIAN	I	II	III	I	II	III	I	II	III	I	II	III
FARMING	0.0006	0.0135	0.0141	0.0003	0.0063	0.0067	0.0006	0.0111	0.0117	0.0071	0.1354	0.1425
MINING	0.0021	0.0142	0.0163	0.0012	0.0063	0.0075	0.0020	0.0111	0.0131	0.0246	0.1351	0.1597
WATER&ELEC	0.0080	0.0111	0.0192	0.0040	0.0050	0.0090	0.0070	0.0088	0.0158	0.0852	0.1074	0.1925
CONST	0.0077	0.0122	0.0199	0.0031	0.0058	0.0090	0.0055	0.0103	0.0157	0.0664	0.1249	0.1913
MANUFAC	0.0444	0.0100	0.0544	0.0027	0.0045	0.0072	0.0047	0.0079	0.0126	0.0573	0.0962	0.1535
TRADE	0.0026	0.0135	0.0161	0.0013	0.0061	0.0074	0.0023	0.0107	0.0130	0.0277	0.1299	0.1576
TRANSP	0.0043	0.0113	0.0155	0.0934	0.0054	0.0987	0.1640	0.0094	0.1735	1.9941	0.1146	2.1087
INFORM	0.0029	0.0119	0.0148	0.0027	0.0052	0.0080	0.0048	0.0092	0.0140	0.0585	0.1114	0.1699
FINAN	0.0012	0.0168	0.0180	0.0016	0.0078	0.0094	0.0028	0.0137	0.0166	0.0346	0.1668	0.2014
REALESTATE	0.0007	0.0117	0.0125	0.0004	0.0050	0.0054	0.0007	0.0088	0.0095	0.0084	0.1069	0.1153
PROFSERVI	0.0030	0.0136	0.0166	0.0018	0.0059	0.0077	0.0032	0.0103	0.0135	0.0384	0.1258	0.1641
DIRECTION	0.0035	0.0124	0.0159	0.0034	0.0054	0.0088	0.0059	0.0096	0.0155	0.0723	0.1163	0.1886
SUPPORT	0.0026	0.0159	0.0185	0.0013	0.0077	0.0089	0.0022	0.0135	0.0157	0.0268	0.1641	0.1909
EDUCA	0.0007	0.0146	0.0153	0.0005	0.0062	0.0067	0.0009	0.0109	0.0118	0.0106	0.1328	0.1434
HEALTH	0.0032	0.0145	0.0177	0.0013	0.0062	0.0075	0.0023	0.0108	0.0131	0.0280	0.1317	0.1597
REACREATION	0.0026	0.0173	0.0199	0.0014	0.0082	0.0096	0.0024	0.0144	0.0168	0.0295	0.1750	0.2045
ACCOMMOD	0.0025	0.0154	0.0179	0.0013	0.0075	0.0088	0.0023	0.0131	0.0154	0.0279	0.1593	0.1872
OTHERS	0.0035	0.0171	0.0207	0.0014	0.0088	0.0102	0.0025	0.0154	0.0180	0.0309	0.1876	0.2185
GOVERNMENT	0.0018	0.0160	0.0178	0.0019	0.0074	0.0093	0.0034	0.0130	0.0164	0.0409	0.1581	0.1990

Notes: I. Productive effect. II. Integration effect III. Total effect.

Source: Own elaboration based in ESAM 2003.

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Resumen. Esta investigación se centra en el estado de Yucatán (México) y proporciona evidencia del desempeño no sostenible de la economía local: la estructura económica local y la distribución de ingresos amplían la brecha entre los hogares ricos y pobres. Una política constructiva que busque el desarrollo sostenible haría mayor hincapié en la reestructuración productiva del sector agrícola, el transporte por carretera y la generación de energía eléctrica, a la hora de diseñar cambios tecnológicos e iniciativas de gestión sostenible de los recursos naturales. Para analizar las interacciones de la economía local con el uso de los recursos, el medio ambiente y la distribución de ingresos se utiliza una matriz exhaustiva híbrida de contabilidad social y ambiental (ESAM, por su siglas en inglés) y modelos de multiplicadores lineales.

抄録:　本稿では、メキシコのユカタン州に注目し、持続不可能な地域経済の実績のエビデンス、すなわち、裕福な世帯と貧しい世帯の格差を拡大させる地域の経済構造と所得分配を提示する。技術変革と自然資源の持続可能な利用管理の実行計画において、持続可能な発展に向けた建設的政策は、農業セクター、道路交通、発電の生産的再構築に重点が置かれるであろう。環境社会会計行列（environmental social accounting matrix: ESAM）と線形乗数モデルの、網羅的なハイブリッドを用いて、地域経済と資源の利用、環境、所得分配との相互作用を分析する。

TABLE A5 Production, integration and total effect on the emission of greenhouse gases in Yucatan Mexico. *Gg* per million pesos

	CO2			CH4			N2O			Nox			CO			NMVOC		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
FARMING	0.0056	0.0510	0.0566	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0000	0.0003	0.0003	0.0001	0.0012	0.0012	0.0000	0.0002	0.0002
MINING	0.0094	0.0506	0.0600	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0000	0.0003	0.0003	0.0002	0.0011	0.0014	0.0000	0.0002	0.0003
WATER&ELEC	0.8860	0.0402	0.9262	0.0009	0.0001	0.0010	0.0023	0.0001	0.0024	0.0034	0.0002	0.0036	0.0010	0.0009	0.0019	0.0002	0.0002	0.0004
CONST	0.0150	0.0474	0.0624	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0002	0.0003	0.0006	0.0011	0.0016	0.0001	0.0002	0.0003
MANUFAC	0.0276	0.0358	0.0635	0.0000	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0002	0.0003	0.0005	0.0008	0.0013	0.0001	0.0002	0.0002
TRADE	0.0159	0.0485	0.0644	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0003	0.0003	0.0002	0.0011	0.0013	0.0000	0.0002	0.0003
TRANSP	0.2168	0.0436	0.2604	0.0009	0.0001	0.0010	0.0006	0.0001	0.0008	0.0020	0.0002	0.0022	0.0168	0.0010	0.0178	0.0032	0.0002	0.0033
INFORM	0.0152	0.0412	0.0564	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0002	0.0003	0.0005	0.0009	0.0014	0.0001	0.0002	0.0003
FINAN	0.0088	0.0640	0.0728	0.0000	0.0001	0.0001	0.0000	0.0002	0.0002	0.0001	0.0003	0.0004	0.0003	0.0014	0.0017	0.0001	0.0003	0.0003
REALESTATE	0.0078	0.0388	0.0466	0.0000	0.0001	0.0001	0.0000	0.0001	0.0001	0.0000	0.0002	0.0002	0.0001	0.0009	0.0010	0.0000	0.0002	0.0002
PROFSERVI	0.0121	0.0472	0.0593	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0002	0.0003	0.0003	0.0011	0.0014	0.0001	0.0002	0.0003
DIRECTION	0.0174	0.0437	0.0610	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0002	0.0003	0.0006	0.0010	0.0016	0.0001	0.0002	0.0003
SUPPORT	0.0085	0.0627	0.0712	0.0000	0.0001	0.0001	0.0000	0.0002	0.0002	0.0000	0.0003	0.0004	0.0002	0.0014	0.0016	0.0000	0.0003	0.0003
EDUCA	0.0073	0.0494	0.0568	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0000	0.0003	0.0003	0.0001	0.0011	0.0012	0.0000	0.0002	0.0002
HEALTH	0.0155	0.0496	0.0651	0.0000	0.0001	0.0001	0.0000	0.0001	0.0002	0.0001	0.0003	0.0003	0.0002	0.0011	0.0014	0.0000	0.0002	0.0003
REACREAT	0.0196	0.0680	0.0875	0.0000	0.0001	0.0002	0.0001	0.0002	0.0002	0.0001	0.0004	0.0004	0.0003	0.0015	0.0017	0.0000	0.0003	0.0003
ACCOMMOD	0.0369	0.0607	0.0976	0.0000	0.0001	0.0002	0.0001	0.0002	0.0003	0.0002	0.0003	0.0005	0.0002	0.0014	0.0016	0.0000	0.0003	0.0003
OTHERS	0.0157	0.0725	0.0882	0.0000	0.0001	0.0002	0.0000	0.0002	0.0002	0.0001	0.0004	0.0005	0.0003	0.0016	0.0019	0.0001	0.0003	0.0004
GOVERNM	0.0222	0.0601	0.0823	0.0000	0.0001	0.0002	0.0001	0.0002	0.0002	0.0001	0.0003	0.0004	0.0004	0.0013	0.0017	0.0001	0.0003	0.0003

Notes: CO_2, CH_4 and N_2O are expressed in *Gg* of CO_2 eq. All other gases are expressed in *Gg*. I. Productive effect. II. Integration effect III. Total effect.

Source: Own elaboration based in ESAM 2003.