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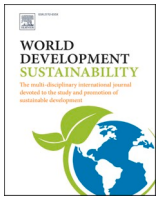
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A multiscale integrated analysis of six developing countries with established tourism economies: the case of Cuba, Dominican Republic, Jamaica, Malaysia, Jordan, and Tunisia

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ABSTRACT

This paper investigates the socio-economic and the energy changes that have taken place in six developing countries characterized by established tourism economies. By considering the years 2000 and 2021, the MuSIASEM approach is used to analyse the energy allocation and use that have taken place in Cuba, Dominic Republic, Jamaica, Jordan, Malaysia, and Tunisia. Results show that for all the countries the percentage variation of GDP has been higher than the energy consumption increase, denoting efficiency improvements across all the sectors, with exception of the service compartment of Tunisia and Jamaica. Tunisia has also been the only country to increase the exosomatic metabolic rate of the household and the paid sectors, denoting an energy consumption rise per unit of human time. All the areas have increased the percentage contribution of the service sector to employment and GDP generation. Given the extensive role that tourism activities are playing in these countries, further analysis should be devoted to investigating alterative development approaches and the related sustainability goals.

1. Introduction

During the last few decades, developing countries have followed a socio-economic path of reforms underscored by structural, legislative and policy changes that have contributed to rising standards of living and economic growth. At the same time, the definition of sustainability strategies and the reduction of fossil fuel dependency has become a development priority [1,2]. In line with the expectations of the Sustainable Development Goals (SDGs) economic profitability cannot be achieved through exploitation and inequality increase. For this reason, integrated analyses oriented to investigate the socio-economic and the environmental impacts are a fundamental factor for the definition of sustainability strategies [3]. Within this context, an increasing number of studies have been recently oriented to investigate the spill-over effects of the development approaches. The inclusion of the Goal 17 into the Agenda 2030 is an example of the importance that the partnership for the goals is playing in the achievement of the sustainability aims [4,5]. When considering the development trends of countries particular attention need then to be devoted to investigating how specific economic practices can impact on the socio-environmental structures. These types of analysis are particularly important for a large set of countries that have historically invested in development structures based on mass tourism intake. Despite the rapid generation of revenue, this economic approach is strictly connected with a large set of impacts, such as extensive landscape transformation, exponential waste generation, water scarcity and augmented energy demand. In addition, the inequal distribution of income, the rising costs of living and the over-reliance on the seasonal activities can also contribute to increase the vulnerability of local communities and institutions. In various cases, multinational corporations and external investors are also capturing most of the revenues, limiting the benefits for local businesses and communities [6,7].

Given the exponential growth of the tourism compartment, specific analysis should then be devoted to investigating these interrelated sustainability effects. According to data provided by the United Nation World Tourism Organization, in the 2020 alone, the international tourist arrivals rose by 760 million accruing US$1.91 trillion in tourist receipts and contributing 10.5 % to global employment. However, with the beginning of the COVID-19 pandemic, the total number of tourists across the globe fell by 72 % recording a loss in tourist revenue of US$559

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billion. The impact of the Covid-19 pandemic continued through 2021 when arrivals rose marginally with total tourism receipts at US$638. The impact on tourism employment worldwide was equally devastating with losses of >70 million tourism jobs in 2020 and a steep decline in the tourism contributions to the GDP generation, that reduced from 10.4 % in 2019 to 5.5 % in the following year [8,9]. These data clearly highlight the extensive role that the tourism compartment is providing to GDP and employment generation. For this reason, tourism activities have been largely advocated as a possible driver for the achievement of various sustainability goals, such as 8, 9 and 10 (decent work and economic growth; industry innovation and infrastructure; reduced inequalities). The extensive energy demand driven by transport, refrigeration units and air conditioning has however been extensively recognized as a major sustainability concern, as well as the related environmental impacts included in goals 13, 14 and 15 (climate action; life below water; life on land). The rising energy use has also been advocated as a potential driver for vulnerability increase, particularly when energy needs to be imported from abroad [6,7]. All these elements are clearly contradicting the intentions of various sustainability goals, and tourism-based development approaches need then to be analysed in relation to the socio-economic and environmental effects. To this aim, the present paper uses a Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) to analyse the socio-economic and energy changes that have taken place in six developing countries with established tourism economy. Due to data availability and consistency, six countries have been included in this study, namely: Cuba, Dominican Republic, Jamaica, Malaysia, Jordan and Tunisia. These countries are particularly interesting as during the considered period (2000–2021) have been able to progress in the achievement of various development goals, such as:

- Moving from low to middle-income country status (GNI per capita of between USD 4466 and USD 13,845 (2021 income levels)) [10]
- Improving the Human Development Index (HDI) by moving from low to medium or from medium to high [11]
- Reducing absolute or relative poverty [12]
- Implementing energy efficiency and renewable energy policies.

For these geographical areas, a better understanding of the main socio-economic and energy constraints is a key element for the design of effective sustainability strategies. That is because these countries are more influenced than others by international and climate vulnerability elements, such as:

- Large import dependency of agricultural and industrial products, and related trade deficit [10]
- Large import dependency of energy input and related impacts of price volatility [13]
- Higher exposure to effects of global crises on the food, energy and economic security.
- High risk from sea level rise, flooding, and extreme weather events [14]
- High water scarcity coupled with water management inefficiencies in 70 % of SIDS (UNCTAD) and the MENA region [15].

The considered period includes the years 2000 and 2021, that are particularly interesting as the global tourism industry has been growing exponentially until the year 2020 when the global pandemic halted all travel, with countries closing borders for at least one year.

This paper contributes to the existing knowledge by extending, for the first time, the use of the Multi-Scale Integrated Analysis (MuSIASEM) to a group developing countries with a dominant tourism economy. Traditionally focused on European areas [16,17], major global economic players [18–23], and large developing regions [24], the MuSIASEM technique has not been extensively applied to small and medium-sized developing states [25,26]. The paper also contributes to the enrich the limited research that has been so far conducted to analyse the energy patterns of the Small Island Developing States (SIDS). Most of the existing studies have mainly been focused on non-SIDS regions, where various econometric models have been applied to investigate economic and energy trends. The contribution of these studies is however mainly 'theory-testing, forecasting and policy formulation' [27]. In contrast, the metabolic approach used in this paper, provides integrated descriptions across socio-economic and energy variables and allows to investigate the sustainability impacts of development policies and trends. The approach of this paper is also suitable to be replicated for other developing areas and when available, the dataset can be extended with more updated years.

The paper is structured as follow: Section 2 reviews how existing literature has investigated the relationship between tourism activities and related environmental impacts. In Section 3 the MuSIASEM approach and the data are presented. Section 4 summarizes the results and discusses the main differences existing across the considered countries. In Section 5 conclusion and policy recommendation are provided.

2. Literature review

Research exploring the relationships between tourism activities and related energy and environmental impacts have increased considerably since the 1990s when nature-based tourism has emerged as an alternative market and policy options for developing countries [28]. More recent research explores the nature of tourism as a contributor to environmental quality or environmental degradation and utilises the growing availability of macro- and micro-data to investigate the relationships existing between socio-economic and environmental variables. Examples are provided by [29–33] that use econometric tools to analyse the EKC hypothesis for different countries. Results shows that growing tourism intake increased emission trends in ASEAN but decreases emissions in MENA. Other econometric studies offer alternative outcomes, for example [6], revealed long term tourism activity on environmental quality and energy use in Morocco, Tunisia and Egypt that resulted in neutral, positive and negative outcomes respectively. Fewer studies have focused on SIDS [13]. for example reveals that fossil energy imports remain essential and although renewable energy can diversify and securitise the energy mix, it does not lead to reduced emissions, while [27] highlights the energy-global openness nexus as critical for SIDS economic growth and therefore support renewable energy progress for securitisation purposes. As previously stated, the volume of research employing econometrics and EKC hypothesis to understand the nexus between tourism, energy and environmental variables has increased considerably. Contradictory results, however, have been so far produced, as revealed by [34] that compiled a systematic review of 81 articles covering 151 countries. Given these existing differences [35], further analysis should then be devoted to investigating the socio-economic, energy and environmental relationships of the tourism focused economies. Withing this context an integrated approach, able to analyse the interconnected feedback existing between these variables, should be used. To this aim, the present paper applies, for the first time, the MuSIASEM technique to analyse the socio-economic metabolism of Cuba (CUB), Dominican Republic (DOM), Jamaica (JAM), Jordan (JOR), Malaysia (MYS) and Tunisia (TUN). The objective is to investigate the energy allocation and use of six developing countries characterized by large tourism intake. In doing so, the present paper analyses the role of socio-economic and energy trends and discusses the related impacts through human time, structural changes and development stages. Although previous analyses have investigated the energy metabolism of a wide a range of regions [16,17,36,37] specific studies have not been focused on middle-income countries characterized by a well-established tourism economy. During the last few decades, the MuSIASEM approach has for example been applied to analyse a wide range of sustainability issues, such as land and water use [26,38,39],

urban development [21,37], energy production [36,40] and energy use [25]. Recent studies have also extended the MuSIASEM application to the end-use matrix, that investigate how energy is used to perform different end-uses human activities, to the analysis of the energy embedded into traded products [41] and to the quantification of the working time included into production, consumption, and trade [22]. Limited studies, however, have been so far devoted to investigating tourism activities, and the existing analysis has been mainly focused on developed areas [42,43] for example produced metabolic analysis of Menorca and the Balearic Island and [44] recently discussed social metabolism and sustainable practices for Ikaria Island. As reported above, this study will provide the first application of the MuSIASM approach to the tourism activities of six developing areas. Results can contribute to extending the socio-economic and energy approaches that are presently used to investigate the sustainability of this fast-growing economic compartment. In addition, by investigating the socio-economic and the energy effects of the development path of countries, this paper questions the extensive focus that the considered areas are devoting to the model of the mass tourism intake.

3. Method and data

To investigate the socio-economic and the energy metabolism of the six countries considered in this paper, the Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism (MuSIASEM) has been used. Developed with the intention to complement the existing sustainability frameworks with the findings of the complex hierarchical systems theory, the MuSIASEM approach has been largely used to integrate information across different level of analysis [40,45,46]. Starting from the idea that socio-economic and energy variables are interrelated elements contributing to shape the structure of the human systems, the MuSIASEM technique allows to investigate how societies evolve and self-organize by considering the impact of changes across dimensions (e.g., economic, social, energetic, biophysical) and scales (e.g., national, regional, sectoral) [47,48]. Compared to similar existing methodologies, such as the Material and Energy Flow Analysis (MEFA), the Input-Output (IO) technique and the Energy Returned on Energy Invested (EROI), the MuSIASEM approach specifically focuses on the interlinkages across the system and subsector compartments and allow to investigate the cascading effects across dimensions and scales [26,49].

By using a wide range of extensive and intensive variable, derived from socio-economic, demographic, and energy data, the MuSIASEM approach provide integrated narratives explaining how changes in dimensions and scales can impact the transformations taking place in a considered socio-economic structure. Within this framework, the MuSIASEM technique is particularly useful to investigate the development of countries characterized by extensive structural change, as the case of the six developing countries considered in this paper.

In line with the methodological approach used by studies that have previously analyzed the metabolism of areas characterized by large tourism intake [42,43] the three levels of analysis reported in Table 1 are considered together with the extensive and intensive variables reported in Tables 2 and 3.

Population and GDP data have been collected from the World Bank database, while information on energy use have been sourced from the International Energy Agency that provide the total final energy consumption disaggregated for economic activities and residential sector. The International Labour Organization (ILO) database has been used for employment rate, labour force and ratio of total worked hours to working age population. Due to data availability and consistency, the period of time considered in this paper includes the years 2000 and 2021, and the countries selected are Cuba (CUB), Dominican Republic (DOM), Jamaica (JAM), Jordan (JOR), Malaysia (MAY), Tunisia (TUN). The lack of consistent data on tourism activities does not allow to specifically disaggregate the tourism compartments from the service sector. However, given that all the countries considered have a well-established international tourism activity, largely contributing to GDP and employment growth, indirect analysis can be derived from the data considered. Disaggregated data are also not provided for the working time allocation, that has been here estimated as number of employed * 5 days * 8 h *56 weeks. This is probably an overestimation as it considers only full-time equivalent hours. The selected period of analysis includes the years 2000 and 2021 that is particularly relevant as it covers significant global agreements and action towards the achievement of the sustainable development approach, namely: the UN Millennium Development Goals, the UN Sustainable Development Goals and Conference of the Parties summits related to the Paris Agreement of 2015.

Table 1
Levels of analysis.

Level	Description
N	National level, consider the entire socio-economic structure and uses data related to GDP, population, and total energy throughput
N-1	Disaggregate the national level information between the paid and the household sectors and analyze how energy and time are distributed between the paid and non-paid activities
N-2	Disaggregate the paid sectors into economic activities, such as agriculture, industry and services

4. Results

Three of the countries considered in this paper are Small Island Developing States (SIDS) characterized by a tourism dependent economy. The remining three areas are non-island nations where tourism is part of a more diverse economic structure. In Table A1 of the Appendix, the number of international tourist arrivals largely increased between 2000 and 2019 and tourist receipts mirrored that rise for the considered countries. However, global crises in the years 2020 and 2021 highlighted the precarity for countries depending wholly or partly on tourism for economic development and employment generation. The Covid-19 pandemic led to devasting consequences for global tourism with −72.2 % change in global arrivals from 2019 −2020 and −68.9 % change between 2019 and 2021. Similarly, tourism receipts were affected by −62.8 % and 59.5 % across the same period. Emerging economies were impacted more than advanced economies with NE Asia and SE Asia impacted the most out of all regions with % changes in tourist arrivals between −81 % (2019 / 2020) and −97 % (2019/2021) [8]. Further to this, global trade was significantly impacted by the closure of the Suez Canal following the Ever Given crash in 2021, which led to price increases and delayed shipments as maritime trade returned to pre-Suez trade routes around the African continent [50]. The speed, spread and severity of the global health crisis on the low- and middle-income countries, particularly dependent on international trade and tourism, was extraordinary compared with other structural breaks such as global financial crisis of 2008 [50,51].

As highlighted in Fig. 1, GDP largely increased across all considered areas, with percentage variations that have been higher than the Total Energy Throughput (TET) and Total Human Activity (THA) changes. This trend highlights an increased efficiency both in terms of energy and human activity use. According to data reported in Table A2 of the appendix, Cuba and Dominican Republic experienced the largest energy intensity drops (EI) (−71.4 % and −38.8 % respectively), with Cuba and Jamaica also accounting for a reduction in the Total Energy Throughput (TET) (−48.7 % and 20.7 % respectively). All the other countries, on the contrary increase the quantity of energy used. However, the extensive GDP rise contributed to reduce the energy intensity of production that dropped for all the countries considered in this paper. Tunisia and Jamaica have been the only areas to increase the energy intensity of the service compartment. Both are characterized by an extensive growth of the tourism activities, that in Tunisia accounted for 75 % of service exports [52]. Following the revolution, tourism increased steadily until

Table 2
Extensive variables.

THA - Total human activity: Total time available in a country during an entire calendar year (365×24h*population). It is measured in hours (h)
HA_{HH} - Human time allocated to the household activities
HA_{PW} - Human time allocated to the paid working activities
HA_{PWa} - Human time allocated to the agricultural activities
HA_{PWi} - Human time allocated to the industrial activities
HA_{PWs} - Human time allocated to the service activities
TET - Total energy throughput: Total primary energy used during an entire calendar year to support the activities taking place in a country. It is measured in megajoule (MJ)
ET_{HH} - Energy throughput used by the household activities
ET_{PW} - Energy throughput used by the paid activities
ET_{PWa} - Energy throughput used by the agricultural activities
ET_{PWi} - Energy throughput used by the industrial activities
ET_{PWs} - Energy throughput used by the service activities
GDP - Gross domestic product: Value added generated in a country during an entire calendar year. It is measured in dollar ($)
GDP_a - Value added generated by the agricultural activities
GDP_i - Value added generated by the industrial activities
GDP_s – Value added generated by the service activities

Table 3
Intensive variables.

HA_{PW}/THA – Human time allocated to the paid activities
HA_{HH}/THA – Human time allocated to the household activities
GDP_a/GDP – Contribution of agricultural activities to GDP generation
GDP_i/GDP – Contribution of industrial activities to GDP generation
GDP_s/GDP – Contribution of services activities to GDP generation
EI – Energy intensity (TET/GDP) (MJ/$): Energy used per unit of GDP generated
EMR – Exosomatic metabolic rate (TET/THA): Energy used per hour of human activity
EMR_{HH} –Energy used per hour allocated to the household activities
EMR_{PW} – Energy used per hour allocated to the paid activities
EMR_{PWa} – Energy used per hour of agricultural activities
EMR_{PWi} – Energy used per hour of industrial activities
EMR_{PWs} – Energy used per hour of service activities

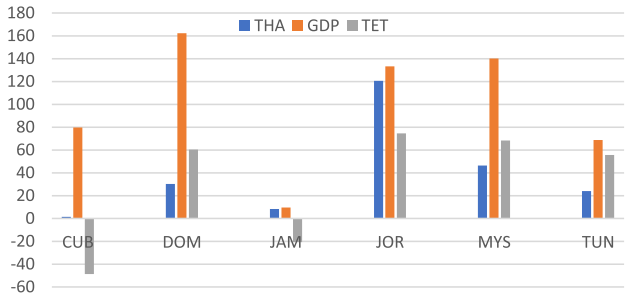


Fig. 1. Total human activity, GDP and total energy throughout: percentage variation between the years 2000 and 2021.

the global pandemic of 2020, with international arrivals rising from 4782,000 in 2011 to 9429,000 in 2019 [53]. During the last few years, Jamaica experienced a diversification of the service sector, aiming to dilute the extensive dominance of the tourism compartment. This strategy has contributed to generate significant economic benefits mainly related to the financial services increase [54] reports the service sector contributed to approximately 78 % of GDP in 2020 and employed 69 % of the labour force before the pandemic.

Given the extensive fossil fuel dependency and the risks associated with the vulnerability of international energy prices and volatile geopolitical relations more recently, all the countries considered in this paper have progressively introduced policies aiming to increase efficiency and renewable energy sources [13]. In Jordan the Master Strategy of the Energy Sector (2007–2020) together with the National Energy Strategy (2015–2025) have for example committed to increase the domestic energy supply from 2 % to 40 %, and the production of renewable energy sources to 11 % by 2025 [50]. As recently highlighted by [55] Jordan was declared, in 2018, as one of the three main emerging markets for clean energy investments. The transition was mainly motivated by security energy concerns. However, technical restraints and historical fossil fuel dependencies have partially undermined the efforts toward the sustainable energy changes. In Tunisia a Solar Plan was introduced in 2009 with the aim to produce, by 2030, 30 % of the total energy needs from renewable sources. The outdated electricity infrastructure together with the lack of private investments are however slowing down the transition process and the country is still heavily dependent on the import of fossil fuel [56]. In late 2023, the Tunisian government announced an economic reform programme, spearheading tourism as a major economic contributor and committing to increase the renewable energy production to 35 %. Incentives for private renewable energy investment together with reduced fossil fuel subsidies were announced in the 2024 budget [57].

Most SIDS are dependent on fossil fuel imports [13]. However, during the last few years, governments have introduced a wide range of policies aiming to promote the domestic energy supply. In Jamaica, the National Renewable Energy Policy 2009–2030 specifically aims to reduce the energy imports by driving up the renewable energy production, and by promoting the modernization of the energy infrastructure. Tourism is foregrounded as a sector suitable for carbon-neutral status if appropriate energy conservation measures are embedded in tourism policy [58]. Cuba decentralised the energy grid in the year 2000 making it more suitable for localised, renewable energy than fossil energy. Although Cuba's continued dependence on fossil fuels is high with 82 % of energy generated from this source, the infrastructure is already in place for the country to transition to renewable energy [59]. In 2006, the 'Energy Revolution' policy was also implemented with the aim to reduce the use of oil and the dependency on energy imports [60]. However, high fossil fuel imports sustain vulnerability to disruptions in global supply and subsequent price shocks.

A similar approach has also been adopted in the Dominican Republic's Renewable Energy Incentives Law (2007) [61,62] aiming to increase domestic production of renewable energy sources with the support of market-based instruments, such as incentives and tax breaks

for businesses. Given the size of the tourism industry in the Dominican Republic it is logical for this sector to be a front runner in the energy transition as reported by the Minister for Energy and Mines: "Tourism is a pillar of our growth, and clean energy drives this. We must align the energy transition to the growth of tourism" [61].

National level data considers the entire socio-economic structure and is represented as total human activity, GDP and total energy throughput. In Fig. 1, the percentage variation between 2000 and 2021 shows increases in GDP and to a lesser extent total human activity in all considered countries. Total energy throughput is less consistent with increases taking place in four of the six countries.

When considering disaggregated data for the energy efficiency of sectors extensive differences exists across countries. According to data reported in Fig. 2, Cuba and Jordan accounted for significant energy intensity declines that have mainly taken place for the extensive modernization of the industrial sector. However, when considering the percentage contribution to GDP generation (Fig. 3), the industrial sector of Cuba progressively reduced the overall contribution. On the contrary, the service sector largely expanded accounting in 2021 for 77 % of the total GDP generation. The economic liberalization measures introduced by Raoul Castro from 2009 progressively contributed to increase the international tourism arrivals. Between 2010 and 2019 annual international tourist arrivals rose from 2.5 million to 4.26 million. International tourism receipts rose moderately, from US$2.187 million to US $2596 million [63]. However, given the impact of the global pandemic of 2020, significant declines have affected the generation of tourism related income, that declined from 2019 data to US$404 million with just 356,000 tourist arrivals. The trend for all-inclusive tourism resorts may explain the moderate gains in tourism receipts before the pandemic, however travel restrictions throughout 2020 and much of 2021 led to significant losses.

Malaysia was the only country to increase the energy intensity of the agricultural sector and to perform some of the smallest energy efficiency increase [64]. Ioannidis and Chalvatzis [13] found that oil producing and exporting island states are slower to transition to renewable energy sources, and the use of biofuels did not reduce emissions or energy intensity. This is supported by [30] findings for the ASEAN region where renewable energy increases led to short term emission reductions, and this may be relevant for Malaysia's case. Malaysia's 12th Plan (2021–2025) recognises tourism as one of eight key economic sectors to drive economic growth, and the National Energy Transition Roadmap (NETR) released in July 2023, details flagship projects for catalysing renewable energy transition in Sabah and Sarawak [65]. Both areas are important tourism destinations. In contrast, neighbouring countries

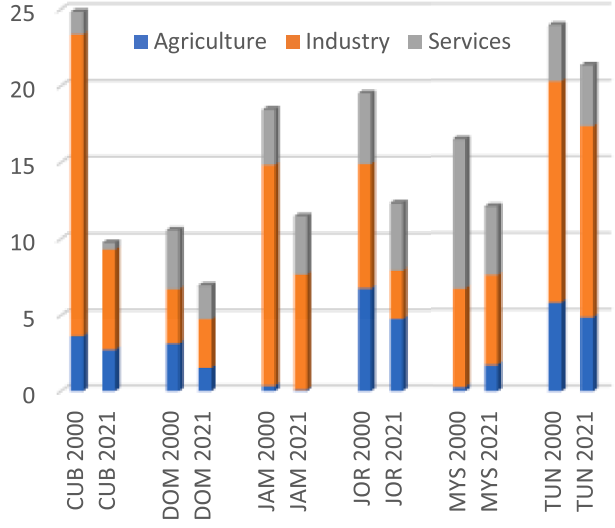


Fig. 2. Energy intensity economic sectors ($ETpw_i/GDP_i$).

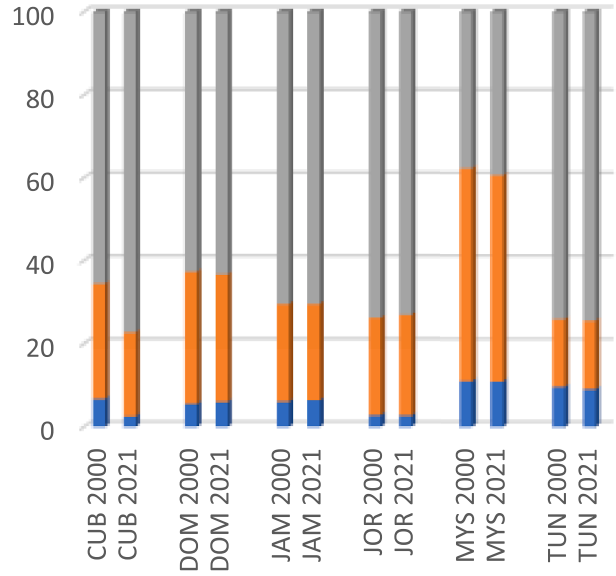


Fig. 3. Percentage contribution of economic sectors to GDP generation.

competing for the same tourist markets as Malaysia appear to be ahead. For example, Indonesia's Tourism and Creative Economy Ministry launched a roadmap for decarbonising tourism in October 2023 [65] while Thailand is one of few to incentivise renewable energy transition as a policy directive already [66]. The broad market trend for fairer and 'greener' production and consumption practises suggests neighbouring countries have the competitive advantage over Malaysia.

When considering the population trends, the total human activity has increased for all the considered countries, with the largest percentage variation taking place in Jordan (+120 %) and the lowest in Cuba (+1.36 %) (Table A2 of the Appendix). The population changes have been affected by various internal and external shocks that have impacted on livelihoods and economic opportunities. Cuba's population growth rate has for example fallen by 99 % since the 1950s. The progressive net emigration rises, together with one of the lowest birth rates of the Caribbean region is leading to a large aging population with economic consequences in terms of dependency rate and workforce reduction [67,68].

Jordan, by comparison, has witnessed an increasing population growth due to the rising birth rate, declining infant mortality and steady inward migration of refugees from neighbouring Middle East countries [69]. In 2015, the Jordanian population was 9.53 million (includes Jordanians and Jordanian citizens of Palestinian origin), but an additional 2.92 million registered non-Jordanians (refugees) raised the population to above 10 million. The remaining four countries experienced declining birth rates, but with significantly different infant mortality rates (Dominican Republic: 24; Tunisia: 13.5; Jamaica: 12.2; Malaysia: 6.2, per 1000 births in 2014) [70].

Across the considered areas, the declining population growth rate can be mainly related to declining birth rates, with consequent rising of populations aged 65 years and above. Four of the six countries also experienced high levels of emigration mainly driven by long-standing socio-economic problems such as for Cuba, [71] and Jamaica; and high unemployment rates, particularly for Tunisia, where during the years that preceded the Jasmine Revolution (2010/2011) an extensive 'brain drain' affected the tertiary educated people [72]. Dominican Republic also experiences a similar trend, with increasing rate of secondary and tertiary educated migrants moving to USA [73].

In Fig. 4 the percentage variation of human time allocated to the paid and to the household sector is reported. In Cuba, the significantly low percentage variation (−0.1 %) of human activity spent in the household sector (Table A3 of the Appendix) has been largely influenced by a series

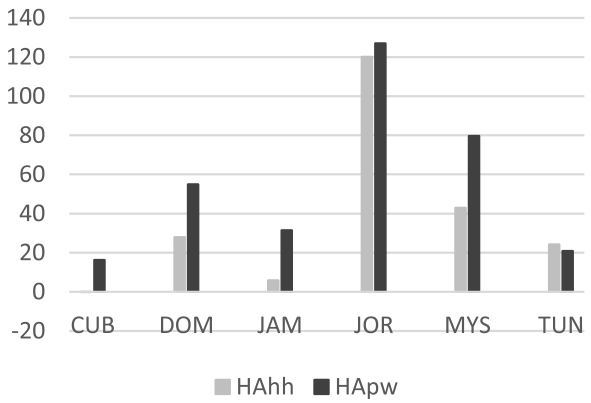


Fig. 4. Human Activity allocated to the household and to the paid sectors: % variation between the year 2000 and 2021.

of economic and structural reforms aiming to expand the private sector and the opportunities for self-employment. As reported in Fig. 5, the service sectors largely increased mainly driven by activities related to tourism commerce, retail and professional services [71]. In Jordan, on the contrary, the significantly higher variation of human activity that have taken place both in the household and in the paid sector, highlighting large shifts in the population structure and size. As previously reported by [74], unemployment rates have also increased with significant intake of lower skilled jobs from migrant workforce and increasing numbers of highly educated citizens. Females on the contrary are more likely to enter informal employment opportunities as unemployment and low wages in the formal sector typically impact women, rather than men.

In Cuba the reduced human time in agriculture (Fig. 5) is an outcome of underinvestment and lack of technical support and innovation which resulted in low productivity and continued high dependency on imported food (80 %) [75]. In the Dominican Republic, the noted decline reflects the challenges for farmers to access capital to adapt to the new technological development [76]. On the contrary, in Tunisia the increased mechanisation is likely to have contributed to reduced human activity employed in agriculture.

For all the considered countries, the percentage contribution of agriculture to GDP generation has progressively declined (Fig. 3). This downward trend is contributing to food security challenges that are exacerbated by: 1) the effects of climate change (drought, floods, storm surges, sea temperature increases) 2) the dependence on food imports and subsequent underinvestment in food production, storage and supply chain logistics (most acute in SIDS), 3) underinvestment in technology and innovation, 4) limited access to capital for farmers, and depleting

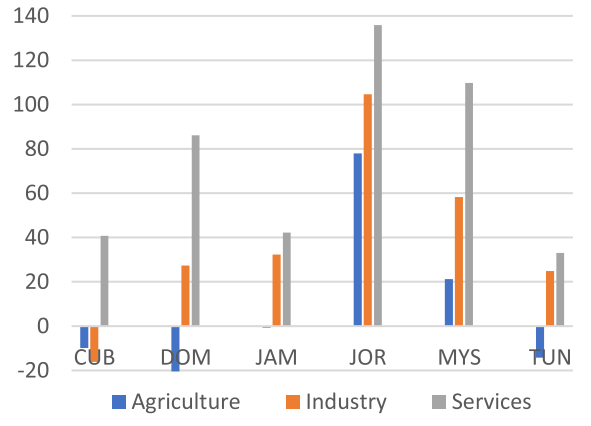


Fig. 5. Human Activity allocated to the economic sectors: % variation between the year 2000 and 2021.

fish stocks from climate change impacts, overfishing and illegal fishing [77] Tunisia and Jordan, are particularly impacted by climate change. The region is 'the most water-scarce in the world' and contends with high food imports to ensure food security. The reliance on non-renewable water sources and rising demand to accommodate population increases, especially in urban areas, is outstripping the supply. For example, Jordan experiences water poverty brought on by a raft of obstacles including low rainfall, sudden rises in refugee population, high rates of unaccounted water, mismanagement and pollution. This contributes to economic poverty through lack of potable water and water for irrigation [78]. The small increases in GDP generation noted in Jordan and Jamaica is likely outcomes from diversification of small farming businesses. In Jordan, a number of strategies introduced in the 2010s including the Agricultural Development Strategy (2016–2020) and Jordan Poverty Reduction Strategy (2013–2020) are targeted programmes to enhance food security and productivity, and to provide a livelihood for Syrian refugees [79]. Similarly, the Eat Jamaican campaign was launched in 2003 to improve food security, integrate rural development [80], and increase domestic production [81]. Although the campaign was supported by a leading all-inclusive resort chain in the early years, the dependence on international tourism may delay opportunities to innovate the sector and improve supply chain logistics and infrastructure. The tourism sector is reported to consume 60 % of all imported food in Jamaica [82].

The dominance of the service sector shows a rise in GDP generation in all countries except Jordan and Jamaica. For Malaysia, the liberalisation of much of the service sector in 2009 paved the way for developing the largest financial centre for Islamic banking as well as developing medical tourism as a sub-sector of tourism [83]. The Dominican Republic's emphasis on free-trade zones and tourism, and protective measures against "domestic inefficiencies and impediments to progress" [84], has resulted in securing more human time in paid work in the service sector. However, the country's historic reliance on foreign labour for economic development that continues today, is crucial for the country [73] note that 'nearly 4 % of the country's population is foreign-born, and 86.5 % of this migrant population is from Haiti', and identify the tourism and construction sectors as particularly attractive to foreign workers (and shunned by domestic workers). As with Cuba, Tunisia and Jamaica's percentage variations in human activity in the service sectors between 2000 and 2021 is below 50 % (Fig. 5). The loss of tertiary educated workforce through emigration in the early 2000s (95.8 % in Jamaica and 33.5 % in Tunisia [85] is a contributory factor.

According to data reported in Fig. 6, the energy used per hour of domestic activities (EMRhh) has increased both in Malaysia and Tunisia (46.9 % and 17.7 %%, respectively) The increase suggests improvements in the material standard of living in line with the rising middle class. As size of households has not significantly changed over the considered period, the increase in energy used per hours correlates with more material gains.

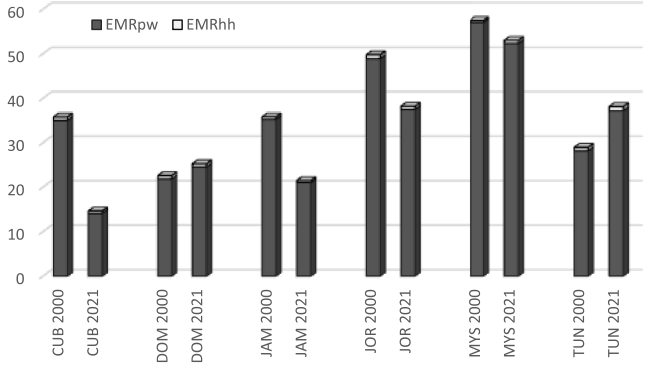


Fig. 6. Energy used per hour spent in the paid and household sector.

The countries reporting a decline in the energy used per hour in the household have similar characteristics and vulnerabilities associated with limited land and / or population size, elevated vulnerability to climate change impacts, outward migration of skilled workforce, and increased risk of price volatility from global economic shocks because of dependencies on 1) energy imports, 2) food imports, and 3) international tourism. Loss of household income is particularly relevant in Cuba where the decline in energy used in the household was >28.8 % (Table A3 of the Appendix). The geo-political relationship with the USA has been particularly detrimental to the tourism economy which brings in much needed foreign currency. In turn, Cuba's dual currency system, which was set up to capture foreign revenue from tourism and remittances cannot operate effectively when the key tourist market (USA) is cut off. For the remaining countries, the decline in energy used per hour is marginal suggesting there is no real change to material standard of living. In Jamaica and Jordan, for example, the outward migration of skilled labour and the associated higher incomes coupled with higher costs of living, suppress material gain and subsequent energy use (−19.5 % and −20.2 % respectively) (Table A3 of the Appendix).

The total energy used per hour in the paid sector (EMRpw) decreased in Cuba (−59.7 %), Jamaica (−40.4 %), Jordan (−23.3 %) and Malaysia (−8.3 %) (Fig. 6 and Table A3 of the Appendix) and a likely outcome from energy efficiency measures. The impact of the Covid-19 pandemic should be considered here, and the very gradual easing of national lockdowns and international travel restrictions which affected the countries differently [86] reports in April 2020 of 91 % of the global population under some form of travel restriction. Malaysia for example closed national borders for two years (March 2020 until April 2022) and Movement Control Orders (MOC) restricting inter-state travel until September 2021 [87]. The impact on international tourist arrivals is very clear with 26.1 million international arrivals in 2019 in contrast to 135,000 arrivals in 2021 [8]. Meanwhile losses in the paid sector were most acutely felt in manufacturing, wholesale, retail and tourism sectors as businesses folded due to loss of business and income or downsized to maintain a small work force [88]. This trend in industry and service sector job losses was also noted in Tunisia [89] who reports that agricultural sector benefited from this period. According to data reported in Table 4, Tunisia is the only country that increased the EMR across all the sectors and this may be explained partly by early strict intervention and low infection rates leading to it being 'one of the world's least restrictive countries by mid-June 2020′ [90]. Cuba and Jamaica, on the contrary reduced the Exosomatic Metabolic Rate of agriculture, industry and services.

Labour productivity gains are made in all countries apart from Jamaica where the industry and service sector show negative percentage variation. Jordan also reduced the labour productivity of the service sector (Fig. 7).

Labour productivity in the agriculture sector increased in all the countries considered in the paper and in four of them the percentage variation was higher than that performed in the industrial and the service sectors. The mechanization trend that took place in all these countries largely contributed to reduce the quantity of human time employed in the agricultural sector. In Jordan and Malaysia, the GDP increase (281 % and 54 %, respectively) was the main driver of the labour productivity rise as for these two countries the value added

Table 4
Percentage variation exosomatic metabolic rate of economic sectors (2000–2021) recheck values.

	%Δ EMR_{PWa}	%Δ EMR_{PWi}	%Δ EMR_{PWs}
CUB	−43.10	−47.90	−54.94
DOM	58.56	68.46	−14.87
JAM	−62.61	−63.35	−16.49
JOR	50.38	−52.46	−10.10
MYS	728.98	0.63	−22.18
TUN	62.36	7.62	39.16

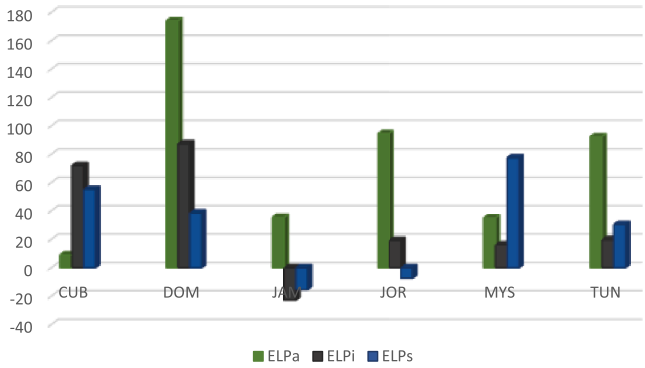


Fig. 7. Labour productivity: % Variation between 2000 and 2021.

generated was higher than the percentage agricultural employment increased (78 % and 21 %, respectively). Jamaica's labour productivity for industry and services shows negative percentage variation (Fig. 7) and is the only country to show a decline in both sectors. The small population of Jamaica and therefore workforce, high outward migration of the skilled workforce and a declining number of 0–14-year-olds (Table A3 in the Appendix) has contributed to negative labour productivity gains. A similar trend in Jordan's service sector is also likely to be a result of outward migration.

5. Conclusion

In this paper, we analyze the metabolic profile of six developing countries for the years 2000 and 2021, with the aim of investigating the interrelated changes across socio-economic activities, human time, and energy use. These countries were selected due to their status as established tourist destinations that experienced exponential growth in international tourist intake during this period. The study aligns with the objectives of the Sustainable Development Goals (SDGs) and provides an integrated overview of socio-economic and energy changes, using a multidimensional approach to analyze the development paths of the countries. This study also contributes to the existing MuSIASEM debate by expanding the analysis to relatively small developing areas that are heavily affected by international instability and climate vulnerability. Key findings can be summarized as follows:

- Economic and Employment Growth: All six countries experienced significant increases in Gross Domestic Product (GDP), Total Human Activity (THA), and tourist intake. High migration rates of skilled workers, as well as the inward migration of refugees and economic migrants, have played a crucial role in shaping the employment characteristics of these countries, thereby contributing to increases in THA.
- Tourism Sector Dynamics: The tourism sector saw a substantial increase in tourist intake up until 2019. However, its contribution to GDP and employment has not kept pace, indicating a relative decline in the economic efficiency of tourism. This trend suggests that diversification into other sectors has been a significant driver of GDP and employment growth.
- Energy Use and Efficiency: The Exosomatic Metabolic Rate of the paid workforce (EMRPW) declined in all countries, except for the Dominican Republic and Tunisia, where agricultural and industrial mechanization led to higher energy consumption. Tunisia also saw an increase in the energy used per hour in the household sector (EMRHH). In contrast, most countries (except Malaysia) showed reductions in EMRHH, signaling that energy efficiency gains were able to offset the increase in domestic energy use.
- Impact of COVID-19 and Global Shocks: The COVID-19 pandemic caused a severe setback to economic, social, and energy progress made between 2000 and 2019. Additionally, a short yet impactful

global IT outage in 2024 harmed service sectors, particularly banks and air travel, highlighting vulnerabilities to global disruptions.

While data on the tourism sector remain limited, trends indicate that tourism has become less efficient in generating GDP and employment growth, while energy consumption has significantly increased. This is especially problematic for countries with limited energy supply and heavy dependence on energy imports, exposing them to international and climate-related vulnerabilities. Small Island Developing States (SIDS) face unique challenges, such as higher import costs, limited resources, and climate change impacts, making them more susceptible to these risks. Despite efforts to implement energy policies and improve energy efficiency, the increasing demand for energy, driven by sectoral mechanization and the growth of mass tourism, has outpaced these efforts. Malaysia, for example, has seen a rise in energy consumption due to a growing economy and higher household incomes. In light of the SDGs, it is necessary to reconsider the current development model by integrating economic profitability, long-term sustainability, and risk exposure. The findings from this paper, along with the adopted approach, can inform policy decisions aimed at reducing external dependencies and promoting more sustainable development. Key policy recommendations with related implementation paths can be summarize as follows:

- Integration of Tourism and Renewable Energy Policies: Governments should integrate policies related to key economic sectors such as tourism and transport with renewable energy frameworks. This would foster a coordinated approach that supports national decarbonization goals while aligning with sectors like tourism that have a significant economic footprint. Establish multi-sectoral committees that bring together stakeholders from tourism, energy, and transport sectors to develop coordinated policies. Set clear deadlines for renewable energy adoption in tourism infrastructure, similar to the approach adopted by the Dominican Republic, which has incorporated renewable energy goals into its tourism strategy.
- Incentivize Renewable Energy Transition and Phase Out Fossil Energy Subsidies: Accelerate the transition to renewable energy while gradually reducing fossil fuel subsidies. The transition should be designed to minimize negative impacts on vulnerable communities and SMEs. Introduce phased subsidy cuts to fossil fuels, with concurrent support mechanisms for vulnerable sectors. Create financial incentives such as tax breaks and low-interest loans for businesses and households that adopt renewable energy solutions. Indonesia's commitment to renewable energy transition can serve as a model for structuring this approach.
- Promote Equitable Employment Practices in Tourism: Implement and enforce equitable and fair employment practices within the tourism sector, applicable to both domestic and international companies. This will enhance tourism productivity, increase GDP contributions, and improve socio-economic conditions, particularly in tourism-dependent economies like SIDS. Establish a regulatory framework to enforce labor standards in tourism, including fair wages, workers' rights, and employment security. Create training programs to raise the skill level of workers and increase tourism productivity. Regular audits and enforcement mechanisms should be set up to ensure compliance with labor standards, with incentives for businesses that comply. The case of SIDS could be supported through international cooperation and partnerships to ensure these policies are effectively implemented.

By incorporating these policy recommendations, developing countries can not only enhance their economic efficiency but also build resilience against global and climate-related shocks, fostering long-term sustainable development that aligns with the SDGs.

CRediT authorship contribution statement

Valeria Andreoni: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Julia Jeyacheya:** Writing – original draft, Conceptualization.

Declaration of competing interest

None.

Appendix

Table A1
Country level data: population for the year 2000 and 2019, total international tourist arrivals, international tourist receipts, for the years 2000, 2019 and 2021.

		CUB	DOM	JAM	JOR	MYS	TUN
Population 0–14 years old (thousands)	**2000**	2.356	2.992	873	2.039	7.694	2.982
	2021	1.778	3.042	574	3.635	7.709	3.056
Population 15 +years old (thousands)	**2000**	8.749	5.548	1.7739	3.016	15.252	6.911
	2021	9.477	8.076	2.254	7.512	25.865	9.207
International Tourist Arrivals (thousands)	**2000**	1774	3161	2230	2700	10,222	5058
	2019	4263	6446	2681	4488	26,101	9429
	2021	356	4994	1464	2012	135	2474
International Tourist Receipts (USD millions)	**2000**	1948	2860	1577	935	5873	1977
	2019	2596	7472	3598	5786	19,829	2116
	2021	404	5697	2097	2758	77	1025

NB: tourism data for 2019 is included to differentiate pre-Covid tourism data with post-Covid data in 2021, one year after global lockdowns.

Table A2
Level N – Extensive and intensive variables.

		CUB	DOM	JAM	JOR	MYS	TUN
GDP (Million $)	**2000**	45,684	35,659	12,852	18,379	148,271	27,937
	2021	82,070	93,508	14,072	42,875	356,073	46,178
	%Δ	79.65	162.23	9.49	133.26	140.15	68.66
THA (Million h)	**2000**	97,287	74,817	22,883	44,292	200,999	86,665

(*continued on next page*)

Table A2 (*continued*)

		CUB	DOM	JAM	JOR	MYS	TUN
	2021	98,605	97,393	24,771	97,659	294,107	107,423
	%Δ	1.36	30.17	8.25	120.49	46.32	23.95
TET (TJ)	**2000**	374,316	185,962	87,877	138,007	1,124,533	223,031
	2021	192,086	298,168	69,660	240,856	1,891,767	346,939
	%Δ	−48.68	60.34	−20.73	74.52	68.23	55.56
EI (TET/GDP) (MJ/$)	**2000**	8.19	5.21	6.84	7.50	7.58	7.97
	2021	2.34	3.19	4.95	5.61	5.31	7.35
	%Δ	−71.43	−38.85	−27.60	−25.18	−29.95	−7.77
EMR (TET/THA) (MJ/h)	**2000**	3.84	2.48	3.84	3.11	5.59	2.57
	2021	1.95	3.06	2.81	2.47	6.43	3.23
	%Δ	−49.37	23.17	−26.77	−20.85	14.97	25.49

Table A3
Level N-1 – Extensive and intensive variables.

		CUB	DOM	JAM	JOR	MYS	TUN
HA_{PW} (Million h)	**2000**	8,734	6,124	2,180	2,068	18,285	5,623
	2021	10,151	9,493	2,868	4,695	32,864	6,794
	%Δ	16.23	55.01	31.54	127.03	79.74	20.81
HA_{HH} (Million h)	**2000**	88,553	68,693	20,702	42,224	184,714	81,042
	2021	88,455	87,899	21,902	92,963	261,242	100,629
	%Δ	0.11	27.96	5.79	120.17	42.97	24.17
ET_{PW} (TJ)	**2000**	305,192	133,522	76,763	100,993	1,041,466	158,303
	2021	142,879	232,644	60,193	175,856	1,717,234	252,318
	%Δ	−53.18	74.24	−21.59	74.13	64.89	59.39
ET_{HH} (TJ)	**2000**	69,124	52,440	11,114	37,014	83,066	64,728
	2021	49,207	65,524	9,476	65,000	174,533	94,621
	%Δ	−28.81	24.95	−14.82	75.61	110.11	46.18
EMR_{PW} (MJ/h)	**2000**	34.94	21.80	35.20	48.83	54.95	28.15
	2021	14.07	24.51	20.98	37.45	62.25	37.14
	%Δ	−59.72	12.40	−40.39	−23.30	8.26	31.93
EMR_{HH} (MJ/h)	**2000**	0.78	0.76	0.53	0.87	0.45	0.79
	2021	0.55	0.4	0.43	0.69	0.67	0.94
	%Δ	−28.73	−2.35	−19.48	−20.23	46.95	17.73

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