Relationships and Spillovers: Higher Education Institutions and Metro Area Sustainability Performance

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Keywords

Sustainable Development Goal (SDG); spillover effects; transformative university; fourth mission; urban sustainability

Abstract

Recent scholarship has sought to further articulate the specific ways that higher education institutions (HEI) can contribute to transitions to a more sustainable society. Characterized as so-called fourth mission imperatives, transformative university models, or quadruple helix arrangements, the literature has increasingly sought to frame these contributions in the context of community interactions and co-created practices. Empirically, however, questions remain as to the connection between the presence of sustainability minded HEIs and the sustainability performance in the surrounding areas. Per the fourth mission, transformative university, and quadruple helix model literatures, we might expect HEIs to encourage performance of local sustainability practices through partnerships, direct knowledge transfer, and practice transformation. There is also the potential that individual spillovers might occur from HEIs to the surrounding communities, through neighbor effects triggered by sustainability-minded university employees or through self-sorting, Tiebout effects. Here, we assess the performance of local sustainability as defined by established sustainable development goal (SDG) indicators

in U.S. metropolitan statistical areas (MSA) hosting HEIs nationally ranked for their sustainability efforts. Our findings provide insight into the relationship between individual university sustainability practices and those of the surrounding community and contribute much-needed empirical evidence to both the HEI and sustainable transitions literature.

Introduction

The evolution of university missions has set to become an important paradigm shift in higher education institutions (HEIs) throughout history. Scholars have increasingly examined what the transformative university model means as a model of choice among HEIs to address the challenges of sustainable development (Evans et al., 2015; Paletta & Bonoli, 2019; Sáez de Cámara et al., 2021; Trencher et al., 2014a). Earlier research has determined the fundamental difference between the third and fourth missions is the economic scope, giving way to the development of co-creation for sustainability (Trencher et al., 2014a). These include the adoption of a development role in society of HEIs (Cuesta-Claros et al., 2022); the roles that HEIs can play in and around multi-stakeholder initiatives, emphasizing collective action to resolve complex problems (Dentoni & Bitzer 2015), and the idea of transforming the university as a living lab to apply to teaching and researching on sustainability (Evans et al., 2015).

However, since the fourth mission of HEIs has just appeared in recent decades, the research on HEIs' fourth mission has had a shortage of exploration of what HEIs as transformative institutions can do to play an increasingly leading role in developing sustainability at the local, regional and national scale (Trencher et al. 2014a). The shortage has become more intense with the theoretical debate on whether the fourth mission is a brand-new role of HEIs or should be considered as a part of the third mission (Rinaldi et al., 2018). The debate has become even more obscure when Beynaghi et al. (2016) proposed three trends in the university's future sustainability scenarios, namely socially oriented, environmentally oriented, and economically oriented universities, which is the mixture of the third and fourth mission. Although earlier research has sought to build a comprehensive model of the transformative university, there have been relatively few scholarly efforts to investigate the detailed effects of the HEIs' fourth mission on local sustainability.

In the analysis that follows, we explore whether an association exists between sustainability performance in universities and the communities they reside within. Drawing from the transformative university literature and the potential influence of both neighbor and Tiebout effects at the community level, the paper explores how the sustainability transformation in HEIs might lead to the environmental, social and governance change in MSAs. Although we do not find a statistically significant association between sustainability performance in an area's HEIs and overall community sustainability performance, we do find significant associations between HEI sustainability performance and particular aspects of sustainability in an MSA.

The remaining portion of the paper is organized as follows. First, we provide a theoretical framework for our analysis, introducing transformative university literature from the triple to quadruple helix model, and the relevance of potential neighbor and Tiebout effects at the individual and community levels, which in turn give rise to our research question and central hypotheses. Next, we provide an overview of our methods and data, describing in depth our variables and selected model. We present our results in the section that follows and conclude with a discussion of our findings and their implications for both practice and future research.

Theory and Hypothesis

From Triple Helix to Quadruple Helix Model

The HEIs' mission roots back to the end of the twelfth century and the early beginning of the thirteenth century (Arbo & Benneworth, 2007; Christensen Hughes, 2022; Ford, 2002; Haskins, 1971; Trencher et al., 2014a). The University of Paris, "the only one which in this period fully became a university" (Haskins, 1971, p.372), centered solely on its teaching and training as the first and traditional role, conducted in the context of the Catholic Church (Arbo & Benneworth, 2007; Christensen Hughes, 2022; Ford, 2002). Evolved from the first mission as a storehouse of knowledge (Youtie & Shapira, 2008), the second mission did not happen until the nineteenth century with the trigger of the Humboldtian Reform to create German research universities (i.e., the University of Berlin), which requires universities to self-govern, create academic freedom, and integrate research into education (Bongaerts, 2022; Brockliss, 2000; Trencher et al., 2014a). More recently, with the development of the knowledge economy and the introduction of The Bayh–Dole Act in the US in the 1980s, the third mission of HEIs, namely technology transfer, emerged from Massachusetts Institute of Technology and Stanford University, in which the universities played as entrepreneurial universities in a Triple Helix model, where it intertwined with government and industry to fulfill the mission (Amaral et al., 2011; Etkzowitz et al., 2000; Trencher et al., 2014b).

Ten years after the third mission, the sustainability crisis brought the notion of co-creation for sustainability in HEIs (Clarke, 2012; Talwar et al. 2011; Trencher et al., 2014a; Whitmer et al. 2010). The fourth or emerging mission transforms universities into a Quadruple Helix model where HEIs interact with government, industry, civil society, and beyond (Rinaldi et al., 2018) towards a more societal focus (van Winden & de Carvalho, 2015). The research of Trencher et al. (2014a, 2014b) has advanced the Triple to a Quadruple

Helix model (see Figure 1). The study looks to add arguments on the Triple Helix model from a sustainable view, where the author promotes the incorporation of sustainable development and place-based co-creation for sustainability into the Triple Helix model. According to Trencher et al. (2014a, 2014b), five channels of partnership may exploit to transform into the Quadruple Helix model, namely (1) knowledge management, (2) technical demonstration projects and experiments, (3) technology transfer and economic development, (4) reform of built or natural environment, and (5) socio-technical experiments. One of the best ways to integrate the university into the fourth model is to promote the university as a living lab to co-produce the knowledge for sustainable development. The 2012 University Living Lab initiative transformed the University of Manchester's campus into a hub to solve the applied problems related to building design and infrastructure, low-carbon technologies, and many others through collaborative labs that include many stakeholders (Evans et al., 2015).

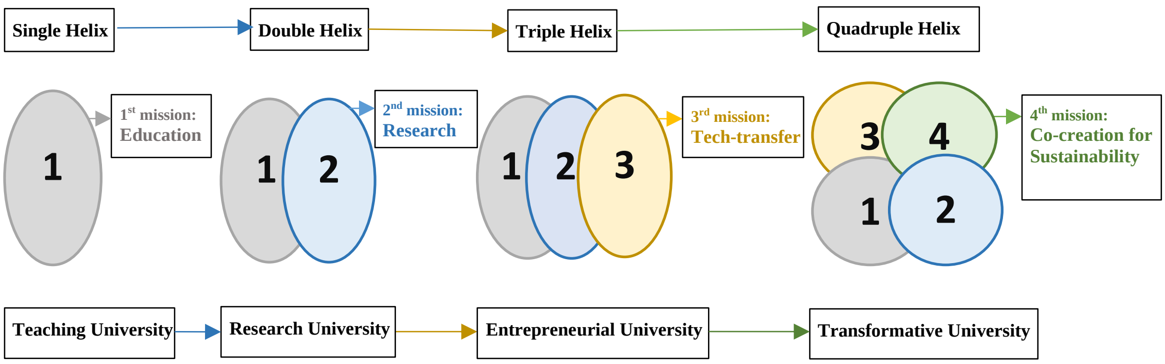

Figure 1. Mission evolution in HEIs. Source: Cuesta-Claros (2022), Trencher et al. (2014a)

A recent study shows that the triple and quadruple helix models are remarkably complementary, especially when the social system is becoming more polycentric and synergic (Cai & Lattu, 2022). At the time when the Quadruple Helix model was developed, the authors of the Triple Helix model had advanced an updated version of the model, which developed different layers of government interactions, i.e., central and local government (Cai

& Etzkowitz, 2020). Cai and Lattu (2019) proposed a civically engaged Triple Helix model combining the literature on Triple Helix and Quadruple Helix (see Figure 2). The purpose of this change is to integrate sustainable development into each sector as long-term societal benefits. The goals and interests of each sector in the model are different, thus, ensuring their shared commitments to society and the environment can align their differentiation. The model emphasizes the role of civil society in all three sectors, namely sustainable entrepreneurial university, sustainable corporation, and sustainable government. Based on the rationale of the Triple Helix model, each institutional sector can take the role of the others as the key mechanism of interactions. It means that the HEIs' model of sustainability can be applied by a sustainable local government or a sustainable corporation regardless of their differences in organizations. Therefore, a high frequency of using the term of a transformative university or a sustainable entrepreneurial university converges into integrating the content of sustainable development or sustainability into HEIs' agenda. This paper tends to use the term "sustainability university" to replace both terms.

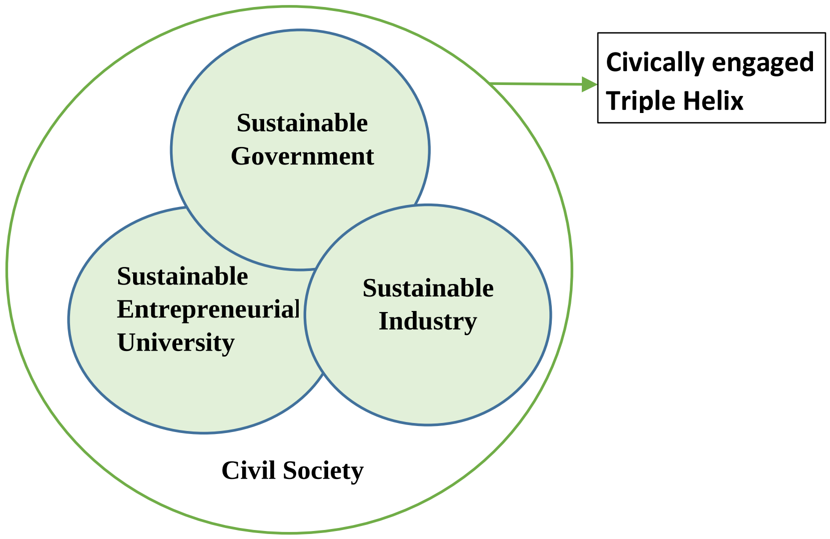

Figure 2. An updated Triple Helix Model. Source: Cai & Lattu (2019); Cuesta-Claros et al. (2022)

Many scholars have focused on the concept of university social responsibility (USR) over the past ten years (Chen & Vanclay, 2021; Larran Jorge & Andrades Peña, 2017; Meseguer-Sanchez et al., 2020; Vasilescu et al., 2010). Larran Jorge and Andrades Peña (2017) define the USR concept as the integration of social, ethical, and environmental principles into HEIs' main function, namely training, research, management, and community engagement activities. Vasilescu et al., (2010) emphasized the role of USR in terms of enhancing civil citizenship when HEIs are encouraged to promote ecological and environmental commitment to reach sustainable development for the local and global population. Not only the definition but scholars also investigated the discourses of the concept to know how it roots. According to Chen and Vanclay (2021), the concept of USR comprises four roots: (1) the university's main goals; (2) the application of Corporate Social Responsibility (CSR), human rights and Environmental, Social and Governance (ESG) into all organizations including universities as institutions; (3) the concept of green university, campus sustainability, and eco campuses; and (4) the importance of community and university engagement where HEIs should play roles in the communities. Consequently, the role of HEIs in sustainable development has increased under the analysis of scholars around the world, where HEIs show interest and investment in policies and strategies to spread their social responsibility.

The concept of university social responsibility has become more popular when the requirement for a social role of HEIs has been increasing to drive SDG-led transformation in their cities and communities. HEIs are now both as a traditional institution with education, training and research, and as an anchor link in a broader network of institutions to convene stakeholders across public and private organizations to tackle the shared adaptive challenges of SDGs. Such a social role of an institutional HEI requires a wide range of efforts including not only living labs, but also new models, new ways of working, new structures of roles and governance. The scale of sustainability efforts has been indexed in 17 interlinked SDGs as part of the Post-2015 Development Agenda under the United Nations General Assembly.

Impact of HEIs' Sustainability Efforts on Local Communities

The transformation to sustainable development requires all levels of involvement, from state to non-state actors working together to achieve 17 SDGs outlined in the UN Agenda 2030 (Banerjee et al., 2020). A whole-of-society approach underlines the engagement of multistakeholder problem-solving processes of national, federal, state, and local governments to individuals (Hemmati, 2012). Implementing such an approach means greater involvement from local communities and their residents to mainstream sustainability into all aspects of their life, leading to improving efficiency, cost reduction, innovation, co-learning, and new relationships (Banerjee et al., 2020).

As shown in Figure 3, the impact of HEIs' sustainability efforts on local communities can be investigated through three intertwined spillover processes. (1) Institutions to institutions: The actions of HEIs as anchor institutions impact the decisions of the local governments or entities to deploy environmental practices, leading to the emergence of environmentally friendly utility services such as solar energy and water recycling in the surrounding area; (2) Institutions to individuals in such institutions and/or residents. At the same time, the residents show their willingness to pay to use such public services from the local governments and/or self – implement their environmental behaviors such as registering a new electric vehicle. (3) Individuals to individuals. The officers, faculty or students from HEIs could play as role-models to the residents in the surrounding area in terms of practicing sustainability programs, education or training. Such three processes could happen separately or causally. The explanation for the processes can be based on (1) institutional theory, (2) spillover effects and (3) both neighbor and Tiebout effects.

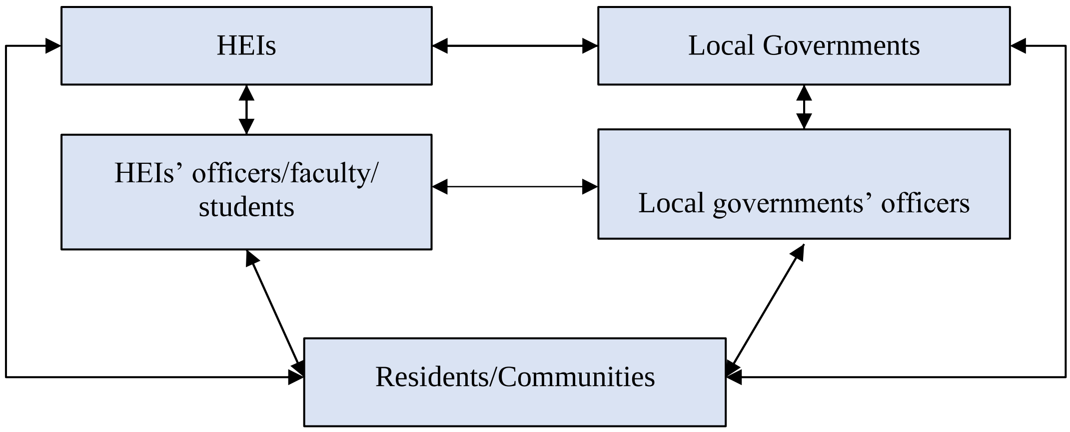

Figure 3. Spillover effects of HEIs' actions on local communities.

Local governments or local entities can legitimately adopt their actions under pressure from other institutions (DiMaggio & Powell, 1983). The process leads to the development of isomorphism, in which the organizations tend to be more homogenous under the same environmental conditions (DiMaggio & Powell, 1983). Three pressures are leading to isomorphic changes, namely coercive, normative and mimetic pressures. The coercive mechanism is rooted in the demand for political influence or the pressures from upper-level institutions; the normative mechanism follows the norms of social networks and professionalism, and the mimetic mechanism is an imitation of peer institutions. This paper investigates the relationship between HEIs sustainability efforts and local communities (i.e., local governments and/or its residents) means to look into the mimetic mechanism between two peer institutions. An institution imitates other peer institutions since the policymakers in such institutions perceive that the policy at their peer institution is worth looking at (Simmons et al., 2006; Karch, 2007).

The adoption of a new policy, program, or infrastructure might be not only rooted in the mimetic mechanism but also in what is called the spillover effect. The behavioral spillover effect happens when a transformation or intervention that aims at one behavior leads to a secondary effect, positively or negatively, on another non-targeted behavior (Carrico, 2021; Galizzi & Whitmarsh, 2019; Poortinga et al., 2013). The spillover effect theory can help us have more insights into why residents adopt a new environmental practice where the local governments also adopt a new policy or supply new public services under the effects of HEIs' actions. The sustainability efforts from HEIs that target to improve the images of the universities themselves to follow the transformative trend (e.g., Triple Helix or Quadruple Helix), lead to the fact that it could affect the behaviors/actions of the local governments to activate or approve their environmentally friendly public service programs such as solar deployment or water recycling at large. The programs from such institutions can also impact individuals such as its own employees, employees of local governments or the residents in the way that it changes their individual choice of pro-environmental behaviors such as using electric cars, willingness to pay for using solar energy, or water recycling provided by local governments. Galizzi and Whitmars (2019) emphasize the attractiveness of behavioral spillover notions from the policy perspective since it promises behavior changes cost-effectively. Especially, in climate change issues, the spillover method can be an explanation for a lifestyle change (Capstick et al., 2014; Truelove et al, 2014).

At the individual - individual interactions, neighbor effect and Tiebout effect could be the explanations of why local peer networks make impacts on individuals. Neighbor effects emphasizes the role of peer groups as an influence on individual preferences (Bauder, 2002; Mau et al., 2008). Alternatively, Tiebout effects describe the ability of people to freely choose where to live to enjoy public services of their choosing (Tiebout, 1956). In the case of the communities in which universities are located, residents have the ability to choose where they live in response to the services a particular community may offer. For example, research has found that local public goods are among important determinants on the people's decision on where to live or migrate (Howe & Huskey, 2022). People in urban areas are willing to trade off to maintain their quality of life (Allen, 2015) or willing to pay for an additional fee for safety in an apartment area (Canales et al., 2022).

An MSA includes a wide range of HEIs inside its boundaries from private to public colleges and universities. The sustainability practices from HEIs can spill over to their peer institutions (i.e., other HEIs, local governments, profit and non-profit organizations…) through sustainability program/initiative mimetics, to its own employees, their peer institutions' employees and the residents through spillover mechanisms. Consequently, based on the above background on institution theory, neighbor effects, and Tiebout effects regarding the effect of HEIs sustainability efforts on local communities' sustainability performance and behaviors, we hypothesize that:

Hypothesis 1: A higher level of sustainability performance of HEIs in a given metropolitan statistical area (MSA) is positively associated with a higher level of overall sustainability performance on SDG Index of that MSA.

Although there is value in assessing aggregate sustainability performance, capturing a wide array of social, environmental, and economic considerations, it is possible that HEIs may be more influential in affecting particular elements of sustainability, particularly for those economic and social aspects of university missions that have historically been the emphasis of the HEIs. If we use individual SDGs as proxies of these different elements of sustainability, we can likewise hypothesize that there is a positive association between the performance of an MSA and sustainability performance of HEIs in that MSA.

Hypothesis 2: A higher level of sustainability performance of HEIs in a given MSA is positively associated with the higher performance of individual SDGs in that MSA.

Methods and Data

This empirical analysis examines the performance on SDG Index in 105 US metropolitan areas for which comparable data on the sustainability performance of HEIs in the area are available (Table 1). The model examines different dependent variables to gauge metro area performance on SDGs: namely (1) Overall SDG performance and (2) Individual SDG performance, including performance score from SDG 1 to SDG 13, SDG 15, and SDG 16. The data are extracted from the 2019 US Cities Sustainable Development Goals Index compiled by the Sustainable Development Solutions Network (SDSN) Secretariat. The 2019 Cities SDG Index covers the 105 most populous cities (measured as MSAs) in the U.S, accounting for 66 percent of the US domestic population. It synthesizes data across 57 indicators spanning 15 of the 17 SDGs that apply to urban areas (Lynch et al., 2019). Given how much progress MSAs have made towards achieving the SDGs, the overall score is ranged from 0 to 100, with 0 as the lowest and 100 as the highest score (Espey et al., 2018). Each individual SDG from goal 1 to goal 16 (not including goal 14 and 17) is also translated to a 0 to 100 scale which can be interpreted in the same way. Such individual SDG scores are based to calculate the average of the overall ranking for 105 MSAs in the study.

Table 1. Variable Names, Definitions, Descriptive Statistics, and Data Sources

Variable Name	Operational Definition	Obs	Mean	S.D.	Min	Max	Source
Dependent Variables							
Overall SDG performance	Overall SDG Index performance score of an MSA	105	48.85	7.70	30.29	69.65	a
Individual SDG Performance	Individual SDG Index performance score of an MSA (SDG1->13, 15,16)						
SDG1	No Poverty index score	105	46.75	20.80	0	87.36	a
SDG2	Zero Hunger index score	105	36.38	14.16	7.06	74.27	a
SDG3	Health & Well-being index score	105	49.44	16.37	17.63	90.02	a
SDG4	Quality Education index score	105	42.59	12.76	16.03	76.39	a

SDG5	Gender Equality index score	105	37.34	14.99	.75	66.70	a
SDG6	Clean Water & Sanitation index score	105	77.33	12.74	26.14	92.64	a
SDG7	Affordable & Clean Energy index score	105	28.59	13.31	10.45	78.20	a
SDG8	Economic Growth index score	105	53.08	16.97	6.59	93.89	a
SDG9	Industry & Innovation index score	105	36.59	17.21	0	87.19	a
SDG10	Reduced Inequality index score	105	54.61	11.51	24.82	79.96	a
SDG11	Sustainable Communities index score	105	46.03	7.89	22.18	59.96	a
SDG12	Responsible Consumption index score	105	62.79	11.54	28.58	85.78	a
SDG13	Climate Action index score	105	41.68	23.68	0	88.03	a
SDG15	Life on Land index score	104	74.45	24.25	0	100	a
SDG16	Strong Institutions index score	105	45.36	16.34	4.18	94.62	a
Independent Variables							
Weighted HEIs Sustainability Performance	The weighted sustainability performance score of total HEIs in an MSA	105	28.71	36.23	0	136.4	b, c, d, e
Control Variables							
Student Pop Size	Student population in an MSA (log)	105	10.37	.92	6.73	12.45	b
Population Size	Total population in an MSA (log)	105	14.12	.83	12.81	16.81	f
Education	% of bachelor's degree or higher	105	32.70	7.05	16.12	50.56	f
Minority	% of non-white	105	26.50	12.05	8.10	78.99	f
Election	% of Democrat over the total votes	105	52.28	9.87	26.43	78.79	e, g
Household income	Household median income (log)	105	11.03	.18	10.56	11.65	f

Note: a = US Cities SDG Index from SDSN (2019); b = College Score Card from the US Department of Education (2018-2019); c = QS Sustainability Universities Ranking (2022-2023); d= HEIs' official websites; e = compiled by the authors; f= U.S. Census Bureau, American Community Survey 5-Year Estimates (2015-2019); g = County Presidential Election Returns 2000-2020 from MIT Election Data and Science Lab, Harvard Dataverse.

The main variables of interest are the measure of overall HEI sustainability performance in each MSAs. The data for the variables of interest is extracted from the 2018-2019 College Scorecard from the US Department of Education. The dataset contains aggregate data for each HEI in the US, including zip code, city, its institutional characteristics, enrollment, student aid, costs, and student outcomes. Another supporting data source to calculate this independent variable is the QS Sustainability Universities Ranking 2023 published in October 2022, which features 700 HEIs in the world. The rankings are evaluated based on two dimensions: environmental sustainability including sustainable institutions, sustainable education and sustainable research, and social impact which includes equality, knowledge exchange, educational impact, employability and opportunities, and quality of life.

As defined here, overall HEI sustainability performance in each MSAs (variable of interest) is measured through a weighted HEI sustainability performance score. The steps and equations used to approximate the magnitude of these weighted scores are described as follows.

- Step 1: Collecting the public and private universities in each MSA, not including community colleges and online education institutions, with the data on its student population and its score in Environmental Impact and Social Impact in the QS Sustainability University Rankings 2023. The total number of HEIs in this step is 427 universities, including 153 public universities, and 274 private universities and liberal arts colleges in the US.
- Step 2: Calculate the *Aggregate QS Sustainability Score* for each HEI in each MSA:

$$Aggre\ QS\ Sus\ Score_a = Environmental\ Impact\ Score_a + Social\ Impact\ Score_a$$

where the *Aggregate QS Sustainability Score* of a university *a* is equal to the sum of environmental impact score and its social impact score, based on the QS Sustainability University Rankings 2023.

- Step 3: Calculate the *Weighted HEI Sustainability Performance* for each MSA:

$$Weighted\ HEI\ Sus\ Performance_i = \frac{\sum(Aggre\ QS\ Sus\ Score_a * HEI\ Student\ Population_a)}{Total\ Student\ Population_i}$$

where the *Weighted HEI Sustainability Performance* in an MSA *i* is equal to the sum of each aggregate QS sustainability score of an HEI *a* times its student population, divided by total student population in all listed HEIs in an MSA *i*. The way to figure this out is to multiply each QS aggregate sustainability score of an HEI by its weight (number of students) and add the products together, then divide by the sum of the weights. Resulting scores equal the weighted total sustainability score across all universities in a given MSA.

Some control variables are potentially relevant for variation explanation in the sustainability efforts of HEIs and local government/residents. First, the factors in HEIs' characteristics as the total number of students might relate to the participation of HEIs in promoting sustainability. Second, not only HEIs', but the characteristics of local governments such as MSA population size, household median income might also affect the local governments' and residents' willingness and capacity to implement the sustainability plan. Also, education attainment is the factor motivating local governments to reach sustainability agreements responding to the public concerns (Ba and Galik, 2022; Meyer, 2015). Likewise, scholars have found that political ideology is among the roots screwing the direction of environmentally friendly policy and initiatives (Konisky et al., 2008), therefore, we also control for this variable. Last, minority populations are more likely to be affected by exogenous factors such as negative environmental impacts, energy insecurity problems or climate change (Agyeman & Evans, 2003; Carley, 2022; Pearson et al., 2018). The large population of such communities might affect how and to what extent the local governments implement pro-environment initiatives and investments. Therefore, the variable of percent of non-white population is controlled at MSA level in the model.

Results

To answer the question of whether there is an association between HEIs' sustainability performance and the local community 's SDG Index Performance, the paper uses linear regression models to produce the results presented in Table 2.

Table 2. Regression model output, association of HEI sustainability performance with MSA sustainability using aggregate and individual SDG indices as proxies for performance.

Model	(1) Overall SDG	(2) SDG1	(3) SDG2	(4) SDG3	(5) SDG4	(6) SDG5	(7) SDG6	(8) SDG7
Independent Variables								
Weighted HEIs	0.016	0.132***	0.033	-0.011	0 .0335	0.017	-0.056	-0.007
Sustainability	(0.014)	(.046)	(.034)	(.035)	(.031)	(.048)	(.0462)	(.048)
Performance		*t=2.84*						
Control Variables								
Student Pop Size (log)	-6.412	-31.367	-39.713**	-26.398	8.427	51.243*	25.306	3.662
	(7.524)	(25.32)	(18.444)	(19.258)	(16.943)	(26.383)	(25.230)	(25.923)
Population Size (log)	-4.424	-19.411	-30.031*	-23.241	4.455	51.619**	20.350	7.142
	(6.218)	(20.923)	(15.242)	(15.914)	(14.001)	(21.802)	(20.849)	(21.421)
Student Pop Size (log)*	0.419	2.100	2.861**	2.018	-.583	-4.103**	-1.778	-.495
	(.547)	(1.840)	(1.340)	(1.400)	(1.231)	(1.917)	(1.834)	(1.884)
Education	8.958	-94.517***	-78.156***	-17.074	99.872***	64.652*	11.988	-26.106
	(10.303)	(34.669)	(25.254)	(26.369)	(23.198)	(36.125)	(34.546)	(35.494)
Minority	-16.357***	-38.445***	-18.760**	-30.459***	-16.166**	21.102*	4.294	-7.635
	(3.375)	(11.357)	(8.273)	(8.638)	(7.600)	(11.834)	(11.317)	(11.628)
Election	25.699***	55.584***	8.273***	58.164***	-5.215	51.739***	-22.009	32.873*

	(5.194)	(17.478)	(12.732)	(13.294)	(11.695)	(18.212)	(17.416)	(17.895)
Household income (log)	25.055***	87.172***	55.318***	56.944***	16.109*	-38.569***	11.351	19.705
	(3.671)	(12.354)	(8.999)	(9.397)	(8.267)	(12.873)	(12.310)	(12.648)
Constant	-172.678*	-615.900*	-157.657	-289.827	-226.329	-248.890	-328.247	-261.322
	(94.148)	(316.812)	(230.782)	(240.966)	(211.995)	(330.116)	(315.69)	(324.356)
N	105	105	105	105	105	105	105	105
R^2	0.773	0.6472	0.5964	0.6706	0.5802	0.2626	0.0660	0.0968

Note: Standard errors in parentheses.

Dependent Variable 1: Overall SDG Index performance score of an MSA

Dependent Variable 2 ->16: Individual SDG Index performance score of an MSA

Indicate statistical significance at ∗p < 0.10, ∗∗p < 0.05, ∗∗∗p < 0.01.

Model	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
	SDG8	SDG9	SDG10	SDG11	SDG12	SDG13	SDG15	SDG16
Independent Variables								
Weighted HEIs	-0.025	0.061*	0.071**	0.0192	-0.0627*	0.080	-0.050	0.359
Sustainability	(.046)	(.032)	(.035)	(.023)	(.035)	(.058)	(.085)	(.049)
Performance		*t=1.9*	*t=2.04*		*t=-1.79*			
Control Variables								
Student Pop Size (log)	-3.605	17.391	12.557	-2.271	47.873**	-32.541	-90.458**	-35.372
	(24.922)	(17.522)	(18.996)	(12.703)	(19.151)	(31.532)	(45.626)	(26.819)
Population Size (log)	.295	11.718	11.215	-2.353	29.312*	-17.223	-79.474**	-30.156
	(20.595)	(14.479)	(15.698)	(10.497)	(15.825)	(26.057)	(37.700)	(22.162)

Student Pop Size (log)*	.207	-1.222	-.942	.225	-3.333**	2.231	6.449*	2.577
	(1.811)	(1.273)	(1.381)	(.923)	(1.392)	(2.291)	(3.316)	(1.949)
Education	125.944***	121.701***	-90.870***	38.527**	42.816	-30.668	-45.304	6.748
	(34.124)	(23.991)	(26.010)	(17.393)	(26.222)	(43.175)	(62.642)	(36.722)
Minority	-38.447***	-28.431***	-20.625**	-13.057**	10.325	-18.226	-12.309	-38.612***
	(11.179)	(7.859)	(8.521)	(5.698)	(8.590)	(14.144)	(20.462)	(12.030)
Election	-61.767***	10.312	-7.530	.185	23.055*	148.382***	-14.659	62.026***
	(17.204)	(12.095)	(13.113)	(8.769)	(13.220)	(21.767)	(31.497)	(18.513)
Household income (log)	25.065**	29.773***	57.127***	7.279	-19.983**	7.376	38.863*	24.028*
	(12.160)	(8.549)	(9.269)	(6.198)	(9.344)	(15.385)	(22.324)	(13.086)
Constant	-218.669	-497.398**	-688.705***	-20.326	-164.206	148.018	785.440	169.343
	(311.836)	(219.238)	(237.689)	(158.942)	(239.623)	(394.544)	(571.293)	(335.578)
N	105	105	105	105	105	105	104	105
R^2	0.4864	0.7534	0.3522	0.3830	0.3439	0.5778	0.1585	0.3589

Note: Standard errors in parentheses.
Dependent Variable 1: Overall SDG Index performance score of an MSA
Dependent Variable 2 ->16: Individual SDG Index performance score of an MSA
Indicate statistical significance at ∗p < 0.10, ∗∗p < 0.05, ∗∗∗p < 0.01.

In total, we ran 16 linear regressions with the same controls but using different independent variables. Model (1) presents the overall version of the model. In the model, we regress the overall SDG Index performance score of an MSA on the weighted sustainability performance score of total HEIs in an MSA and all demographic covariates, including student population in an MSA (log), total population of an MSA (log), percent of population having bachelor's degree or higher, percent of minority communities, percent of Democrat votes over the total votes, household median income (log) (Figure 4). From Model (2) to Model (16) (total 15 models), we run linear regressions on individual SDG scores, namely Individual SDG Index performance score of an MSA from SDG1 to SDG 13, SDG 15 and SDG 16. We lack the data on SDG 14 and SDG 17; thus, we cannot run regressions on such goals to test the correlation between SDG 14, SDG 17 and the MSA sustainability performance score. In such models, we run to capture the impact of HEI sustainability actions on the performance of each SDG goal within an MSA.

The results from this analysis are mixed to our expectations in H1 and H2. While overall SDG Index Performance in an MSA is not significant, some individual SDG Index Performance are statistically significant such as SDG1 "No Poverty", SDG 9 "Innovation and Infrastructure", SDG 10 "Reduced Inequality" and SDG 12 "Responsible Consumption and Production". In Table 2, we report the results from the regression analysis, a p-value greater than 0.1 indicates a correlation between SDG Index Performance in an MSA and HEI sustainability efforts, holding all other variables constant.

Our regression estimates indicate that HEI sustaibility performance does not correlate with the aggregate SDG Index Performance of an MSA (Model 1) (Figure 4). Therefore, we do not find support for our first hypothesis about the relationship between overall local sustainability performance on SDG Index and the higher sustainability efforts from HEIs in the area using the data and methods reported here. Yet when we seperated SDG Index individually, the SDG Index Performance of an MSA has statistically significant correlation, both negatively and postively, with the individual sustainability efforts of HEI in the area (Model 2, model 10, model 11, model 13).

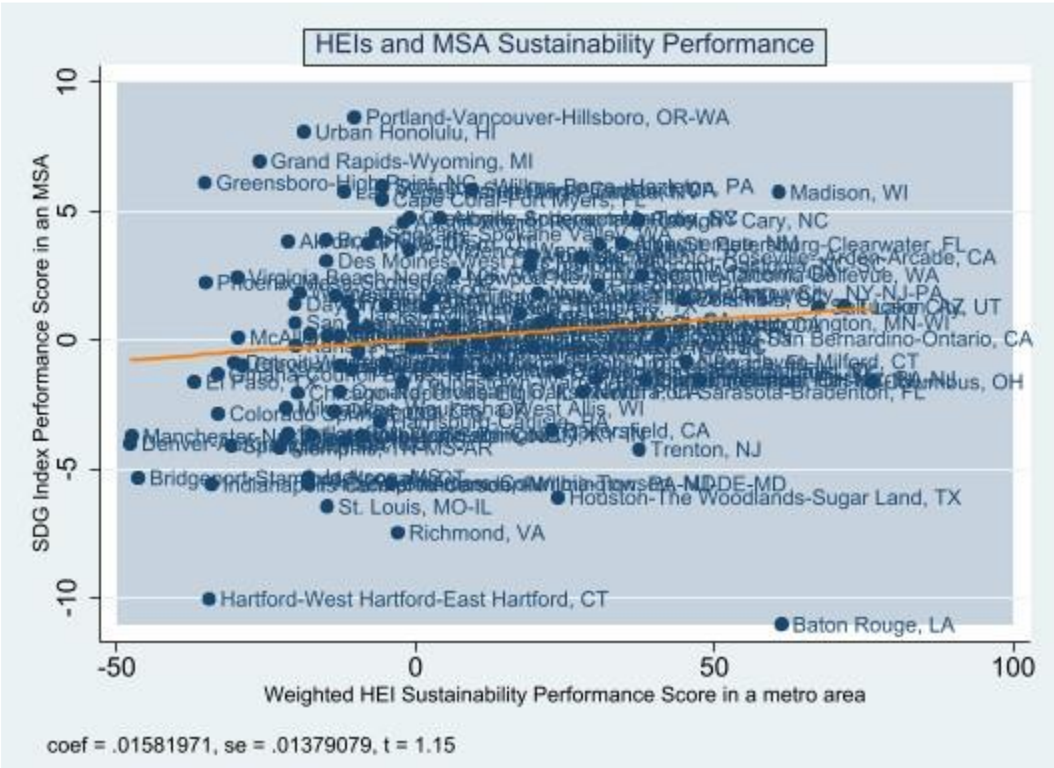

Figure 4. HEIs Sustainability Performance and MSA Overall SDG Index Score

In the case of model 2, holding all else equal, one point increase in Weighted HEI sustainability score in a metro area is associated with a 0.1317 point increase in the SDG 1 Index Performance on combating poverty ("No Poverty") (Figure 5). For Model 10, it also show the positive correlation between the sustaianbility efforts from HEIs in the area and the SDG 9 Index Performance, which leads to a 0.061 point increase in the efforts for "Innovation and Infrastructure" at 0.1 level significance (Figure 6). Specifically, the efforts from HEIs in the metro area is positively related to the activities to "Reduce inequality" as stated in the SDG 10 Index, which bring a 0.07 point increase in the local sustainability score (Figure 7). However, we noticebly find that there is a slightly negatively correlation between HEIs sustainability action and the SDG 12 "Responsible Consumption and Production" performance in MSA when it lead to a -0.063 decrease in the sustainability score. Given the results, our second hypothesis is partly supported (Figure 8).

Figure 5. Correlation between HEIs Sustainability Performance and MSA SDG1 No Poverty Index Score

Figure 6. Correlation between HEIs Sustainability Performance and MSA SDG 9 Industry and Innovation Index Score

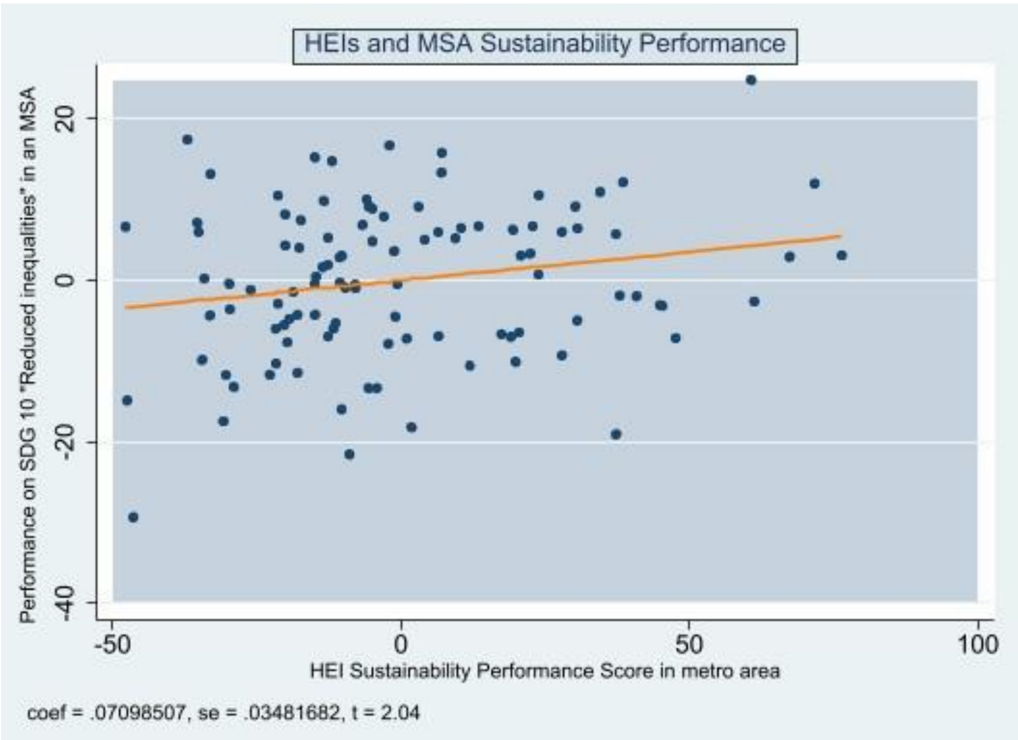

Figure 7. Correlation between HEIs Sustainability Performance and MSA SDG 10 Reduced Inequality Index Score

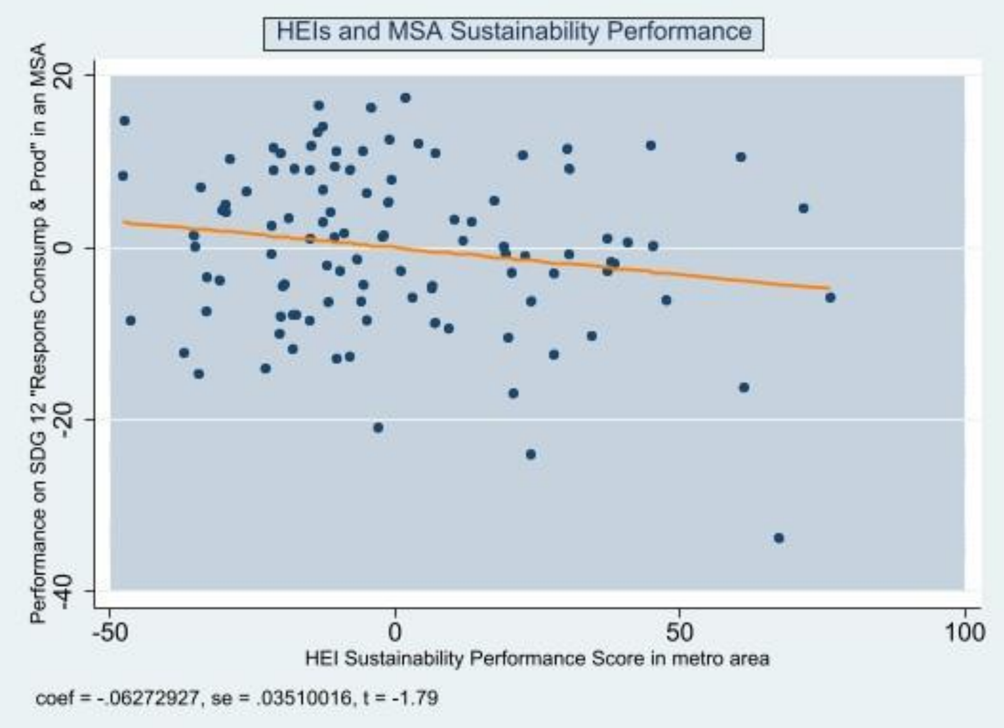

Figure 8. Correlation between HEIs Sustainability Performance and MSA SDG 12 Responsible Consumption Index Score

Discussion and Conclusion

Our exploratory analysis to assess the association between the sustainability performance of HEIs and the sustainability performance of the communities in which they reside fails to identify a statistically significant correlation between aggregate community sustainability as measured by an index of combined SDG indicators. In examining the association between the sustainability performance of HEIs and individual measures of sustainability performance these same communities, however, we do find possible support for specific aspects of sustainability. In particular, we find statistically significant association between the sustainability performance of HEIs and a reduction in poverty, a reduction in inequality, and an increase in innovation, but also a decrease in the performance of responsible consumption and production.

Our mixed findings suggest that the higher-preforming HEIs are perhaps still influencing their communities through the traditional model of the university, in which emphasis was placed on economic growth and innovation missions. While our research offers an important contribution to our understanding of HEI contribution to a so-called fourth mission as transformative universities, further research is of course necessary. A first step would be repeating our analysis with a more fine-grained analysis of HEIs and the communities in which they reside. Although the MSA scale is useful for capturing a wide array of parameters, it may be perhaps too large of an assessment area to capture many of the discrete phenomena we hypothesize could be at work (e.g., neighbor and Tiebout effects). Building on efforts to incorporate more fine-grained data into our analysis, we also see value in exploring the causal mechanism behind the observed association between individual SDGs and HEI performance, be it through the institution, the individual, or some combination of the two.

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