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The sustainability of international higher education: Student mobility and global climate change

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Abstract

Much literature discusses higher education as an agent for sustainable development, but the extent to which higher education contributes to unsustainable economic and social systems receives less attention. This paper examines the environmental impacts of international student mobility in higher education. Combining several datasets, the paper presents a model of greenhouse gas emissions associated with international student mobility. Estimates suggest that these emissions are substantial and are rising faster than overall global emissions, but the emissions per student are slowly decreasing, largely due to changes in the patterns of mobility. The paper concludes that although international exchange is increasingly important, a meaningful consideration of higher education for sustainable development should take account of environmental costs of international mobility alongside its benefits.

Highlights

- Estimates emissions from international student mobility in higher education
- Considers emissions from travel and changes in consumption
- Estimates at least 14 megatons of CO_2 per year associated with student mobility
- Emissions per mobile student are decreasing as mobility patterns change

1. Introduction

The crisis of global climate change places higher education institutions and systems in a challenging position. On the one hand, international, national and institutional discourses on higher education center on the production of knowledge and technology with the potential to transform economic activities towards greater efficiency and lower environmental impact (Waas et al., 2009). On the other hand, higher education institutions themselves are embedded in an economy that is heavily reliant on carbon-based energy that produces greenhouse gasses (GHG), the root cause of the global climate change crisis. Therefore, an important question facing higher education institutions and systems is whether the production of knowledge can transform the material economic and social circumstances of its own creation.

This paper contributes to literature on higher education for sustainable development by modeling the global GHG emissions associated with one core aspect of the higher education sector: international student mobility. International study is a core feature of universities' historical tradition, dating to medieval times (Rivza and Teichler 2007, p. 459). In recent years, the number of students who go abroad for higher education has grown rapidly, from 1.4 million in 1999 to 4.8 million in 2016 (UNESCO Institute for Statistics, 2018). While this increase in mobility has many benefits, its environmental consequences have not been studied. The paper's contribution to the literature is to specify an empirical method for estimating GHG emissions associated with international student mobility, to estimate GHG levels under different assumptions, and to identify trends in these emissions levels. This contribution will enable future research to compare these costs with the benefits of student mobility, which include technology transfer, greater efficiency working across borders, and higher levels of social responsibility.

The paper begins with a review of literature on international student mobility and higher education for sustainable development. The focus of the paper is its methodology, which provides a detailed specification for estimating GHG emissions associated with international student mobility. Estimates of emissions under different assumptions are provided in the findings, and several hypotheses about trends in emissions are tested. The paper concludes by discussing the implications of its findings for international higher education and sociological studies of education and knowledge.

2. Literature Review

2.1 The Rise of International Student Mobility

International student mobility refers to students who pursue higher education outside their country of residence; mobility is a global phenomenon, with students from 209 countries studying abroad in at least 143 hosting countries (UNESCO Institute for Statistics, 2018). Literature differentiates between degree and exchange mobility: the former refers to students who purse a full degree abroad while the latter refers to shorter-term exchange or study abroad, usually as part of a degree undertaken in the student's home country (Chien, 2013).

Literature documents a dramatic rise in international student mobility, with numbers of international students now exceeding 4.1 million. It attributes this rise to the convergence of

several factors, including neoliberal funding regimes that require institutions to increase revenues from international student fees (Bessant et al., 2015), global labor markets that place a high premium on skills (Autor, 2014; Gürüz, 2011), and the formation of cosmopolitan identities that shape individuals' identities and aspirations (Tran, 2016; Rizvi, 2011). International student mobility is also closely tied to international labor market migration, with many students migrating to the host country and contributing to the labor force in important areas (Kahanec and Králiková, 2011).

On a global level, the destinations and origins of international students are very polarized: just five English-speaking countries (the United Kingdom, United States, Canada, Australia and New Zealand) host approximately 45% of the global total of international students (UNESCO, 2016). Similarly, newly industrialized countries with growing disposable income account for a large share of students who go abroad for higher education. This trend is exemplified by China and India, which accounted for a combined total of 26.7% of outgoing international students in 2014. Another trend in international student flows is towards regionalization, an increase in students who leave their home country but stay within the larger geographic region (UNESCO Institute for Statistics, 2009, p. 39). The growth of regional mobility flows has been facilitated by regional policy initiatives such as the European Higher Education Area and the ASEAN mutual recognition arrangement (UNESCO Institute for Statistics, 2009; Shields, 2016).

Disaggregation of mobility data by gender or social class is not available at the global level and must be inferred from national-level studies. Research from the US and Europe finds participation in international student mobility is higher for women overall (Pietro and Page, 2008; Salisbury et al, 2010), although studies of the Erasmus mobility program have noted countries where this trend is reversed, including Sweden, Italy, Belgium and France (Böttcher et al., 2009, p.5). In contrast, other evidence shows that mobility can reproduce social disadvantage: ethnic minorities and students with financial difficulties are less likely to study abroad, while those with more educated parents are more likely to undertake mobility (HEFCE, 2009; Stroud, 2010; Souto-Otero et al, 2013).

Literature suggests several important benefits to international study, including intercultural proficiency (Clarke et al. 2009), employability (Crossman and Clarke, 2009; Norris and Gillespie, 2009), and engagement in global issues (Paige et al., 2009), with benefits to both hosting economies and institutions (Luo and Jamieson-Drake, 2013; Perna et al., 2013). Thus, any assessment of the environmental impact of international student mobility should consider social benefits that may outweigh its negative environmental effects, particularly in contemporary contexts of rising xenophobia, nationalism and intolerance. Similarly, from the perspective of their home countries, international students are also agents of knowledge transfer (Gribble, 2008); they return with new skills and understandings of sustainability, and knowledge acquisition has been shown to improve sustainability in business management (Johnson, 2017).

However, a smaller body of more critical studies also points to the important role of international study in social class reproduction and strategies for positional advantage in the labor market (Findlay et al., 2012). Thus, for Shaw and Thomas (2006, p. 211), international students constitute "a new mobile elite" for whom mobility is "considered a rite of passage,

playful experimentation through which the aspiring new middle class may acquire social and cultural capital." This view is supported by research showing that financial concerns are a considerable barrier in participation in study abroad programs, thereby excluding students who are not part of this elite class from acquiring the relevant forms of capital (Souto-Otero et al., 2013).

Although international student mobility has witnessed sustained growth, this trend does not necessarily entail an equivalent rise in GHG emissions because patterns of mobility are changing. For example, increasing regionalization (UNESCO Institute for Statistics, 2009; Shields, 2016) means that a growing share of international students remain relatively close to their home country, which could decrease travel distances and resulting GHG emissions. Additionally, the shifting patterns in countries of origin and destination for international students are important in determining GHG emissions: if students leave their home country to study in a country in which per capita emissions are lower, their personal GHG emissions (i.e from consumption of food, goods and energy) may decrease during their period of study compared to the counterfactual of what they would have been if the student did not go abroad.

2.2 Higher Education and Sustainable Development

The rapid rise in international students has been roughly contemporaneous with increased advocacy for sustainable development and the role of higher education therein. This trend is evident in a growing body of literature on higher education for sustainable development and in numerous declarations and agreements to increase universities' contributions to sustainable development (Karatzoglou, 2013; Leal Filho, 2011; Lozano et al, 2013). Literature on higher education for sustainable development indicates a need for cross-cutting changes to degree programs, interdisciplinary collaboration, leadership, and meta-cognitive skills (Lozano, 2009; Ferrer-Balas et al., 2013). Most literature also emphasizes the agency of universities, which are described as "change agents" (Stephens et al., 2008) or "catalysts" (Pollock et al., 2009; Waas et al., 2010) while it tends to overlook the extent to which universities are constrained by and dependent upon their economic and social contexts. A smaller body of literature highlights how contextual factors such as neoliberal funding regimes, university rankings, and the pressures for international student recruitment constrain universities' agency and thereby their ability to make a meaningful contribution to sustainable development (Bessant et al., 2015; Lukman et al., 2010).

An underpinning assumption in much literature is that "universities bear the responsibility to contribute with their research to sustainable development" (Waas et al., 2010, p.630). This assumption embodies a paradigm in which climate change is best addressed through research – particularly in the physical sciences and engineering – that leads to new technologies (e.g. in energy production, transportation, and manufacturing), resulting in a "win-win" situation that reduces GHG emissions while preserving or advancing quality of life (Bailey and Wilson, 2009; Clark and Dickson, 2003; Komiyama and Takeuchi, 2006). Overall, the higher education sector readily embraces this model of sustainable development and its role therein, with the UK's university advocacy group claiming,

> Universities have a unique and critical role in helping to address the challenge of

> climate change. Our higher education sector is a major player within the global search for solutions to environmental problems and in the development of more sustainable ways of living. Through their research and links with business and industry, universities are positioned to drive forward innovation in all areas of life - construction, energy supply, transport, design and many others. (Universities UK, 2010, p.17)

Thus, it is unsurprising that the United Nations Sustainable Development Goals (SDGs) focus on increasing access to higher education and on utilizing scientific research to produce more sustainable technology, specifically cleaner forms of energy (United Nations, 2015a). However, a more critical strand of literature on higher education and sustainable development identifies conceptual paradoxes involved in "sustainable development" - i.e. a promise of unending growth - as well as a need to redefine the epistemological foundations of the university because they are deeply implicated in unsustainable industrialization (Conceição 2006; Wals and Jickling, 2002). Thus, the transformation of universities is a key theme in both academic literature and policy commitments. For example, the Peoples' Sustainability Treaty on Higher Education (2012) from the Rio+20 conference argues,

> Before higher education can genuinely contribute to sustainable development, it must transform itself. The dominant education paradigm is centered on values and priorities that threaten sustainable development.

By acknowledging the necessity of transformation, the Treaty points to a wider shared ontology between higher education, knowledge, and the social and material circumstances of their production. In other words, to become sustainable universities must not only reform institutions themselves but they must also address their dependence on unsustainable models and practices that are external to the institution.

2.3 Synopsis of Literature

Literature has given substantial attention to international student mobility in higher education with minimal consideration of its environmental impact or sustainability. Additionally, most research on higher education and sustainable development makes little acknowledgment that universities are embedded in and constrained by wider social and economic contexts. Therefore, the link between international student mobility and global climate change constitutes an important gap in the literature, with several resulting issues for empirical investigation.

While it seems likely that rising mobility levels would result in increasing levels of emissions, changes in the patterns of mobility could mean that GHG emissions do not increase with the growth in mobility, therefore:

> *Hypothesis 1: Total GHG emissions from international student mobility are significantly increasing over time.*

If emissions are growing, it is also important to know whether this growth outpaces that of global GHG emissions, as this would indicate that the environmental impact of international student mobility warrants particular attention:

Hypothesis 2: Total GHG emissions from international student are increasing more quickly that total global GHG from all sources.

Finally, even if emissions are increasing, it is also possible that the emissions per student are decreasing. This decrease in emissions per student could occur if the growth in mobility occurs in patterns (i.e. pairs of origins and destinations) that have lower emissions than existing patterns. It would also indicate that the benefits of international student mobility are increasing in relation to its costs, therefore:

Hypothesis 3: GHG emissions per mobile student are significantly increasing over time.

These hypotheses are tested using a model of GHG emissions and accompanying data sources described in the next section.

3. Methods and Data

This section describes a model and dataset for estimating GHG emissions associated with international student mobility. At the most basic level, these emissions can be considered as the sum of two sources:

- Travel-related emissions – mainly from aviation – that students undertake as part of their mobility
- Changes in emissions that result from students' personal consumption (e.g. energy use, food) while studying abroad

This section begins by discussing these how these two sources are modeled, and the data sources used to estimate output. It then identifies assumptions and error in the model and concludes with its formal mathematical specification. In addition to the information provided in this section, the full model source code and data are available online, so that the results can be reproduced in full.[1]

3.1 Travel-Related Emissions

Travel is a defining characteristic of international student mobility; the concept of mobility entails physical movement by definition and this criterion is applied in relevant data on international student mobility (UNESCO Institute for Statistics, OECD and Eurostat, 2016). The vast majority of international students are likely to travel through international aviation, as the sector accounts for the overwhelming majority of international transportation. While only contributing only 2% of total global GHG emissions (ICAO, 2016, p.141), per passenger emissions of aviation are very high. Emissions from a single long-haul flight (e.g. 972 kg for London to Shanghai) can easily exceed the entire annual emissions of an average individual in many countries (e.g. 628 kg per capita in Rwanda). Drastically reducing emissions from long distance travel is therefore an essential component of a successful response to climate change (Rockström et al., 2017).

The process of estimating travel-related emissions can be summarized as follows:

1. For each combination of origin and host country, a set of likely airport pairs is

identified, and the distance between them is calculated. This distance takes into account routing between the airports (i.e. direct versus connecting flights).

2. For distances greater than a specified threshold (see assumptions below), air travel is assumed and the carbon emissions for the distance traveled are estimated using GHG loading factors published by the UK Department for Environment, Food and Rural Affairs (DEFRA, 2013).
3. For distances less than this threshold, rail travel is assumed and GHG emissions are estimated using rail loading factors (DEFRA, 2013).
4. Students are assigned probabilistically to the airport pairs identified in Step 1 based on the airports' share of passengers in the country. The distances involved between the airport pairs are multiplied by the number of international students and appropriate carbon loading factors.

3.2 Consumption Emissions

To accurately model the GHG emissions associated with international student mobility, the model must consider emissions caused by changes in personal consumption (e.g. energy use, food, local transportation) associated with mobility. Consumption emissions are estimated by the differences in GHG emissions per capita between the source and destination country. Unlike travel-related emissions, consumption emissions can also be negative, as it is possible that students would produce less GHG in the host country than they would have at home.

However, estimates of consumption emissions are treated with caution in the model for two reasons. First, it is likely that many international students do not represent a random sample of their country of origin, and therefore their personal GHG emissions at home are likely different from national averages. Thus, changes in their consumption emissions may be poorly represented by differences in national averages. As a hypothetical example, a student from India may have a high-consumption lifestyle (e.g. a personal car, frequent use of air conditioning, etc.) relative to the national average (2,320 kg per capita). Studying in the UK may entail use of public transportation and reduced consumption that would likely mean that their emissions are lower than the national average (9,066 kg per capita) and possibly lower than their emissions in India would have been. Thus, personal consumption emissions could remain constant despite national differences in per capita emissions. Second, per capita GHG emissions include industries that are unrelated to international student mobility and do not scale with population size. For example, per capita emissions from Australia (32,466 kg per capita) include significant emissions from mining industries, even though the activities of mining companies would likely have no marginal increase due to student migration.

3.3 Data Sources

The model combines three sources of data to estimate the GHG emissions associated with international student mobility.

*Bilateral flows of degree-mobile international student*s are taken from the UNESCO Institute for Statistics (UIS). The data are collected as part of a joint initiative between UNESCO Institute for Statistics, the OECD and Eurostat, with national governments and/or reporting agencies providing the number of incoming students broken down by country of origin. Mobility data are reported by the destination country and not the

origin; this approach is most reliable because exit immigration records at the country of origin may not be available or properly identify outgoing students. The reporting guidelines identify mobile students as those who study outside their country of previous residence or education, and therefore explicitly focus on those students who crossed an international border for study and exclude online education or delivery through a satellite or offshore campus (UIS, OECD and Eurostat, 2016). Data collection includes only students in tertiary education, as defined by levels 5 to 8 of the International Standard Classification of Education (European Commission, 2015). Thus, the data are a good representation of actual movements of students and are therefore an appropriate basis to estimate GHG emissions. The data contain 98,262 bilateral flows between 209 countries from 1999 to 2014 (16 years).

The locations of all international airports (N=1,248) and *scheduled flight*s (N=67,663) are taken from the OpenFlights dataset. These data are used to estimate travel distances and GHG emissions from travel.

Per capita GHG emissions are taken from the World Bank's World Development Indicators. The model uses country-year observations (N=3,440) from 1999 to 2014 (the latest reported year).

3.4 Assumptions and Error

There are three important aspects of international student mobility GHG emissions that are not represented in the data.

Number of trips per year: There are no data on the number of trips mobile students make to their home country. The number of trips could range from less than one (e.g. one trip to the home country every other year) to several trips per year.

Exchange Mobility: UIS data are limited to students pursuing a full degree, but a significant number of students participate in non-degree mobility (e.g. study abroad, exchange programs, Erasmus, short courses, etc.). The number of international students who are undertaking non-degree mobility is unknown but is estimated based on degree-mobility data. Specifically, data from the Institute of International Education (2015), which includes study abroad students, indicate 4.5 million mobile students in 2012, while UIS data indicate only 3.2 million. The difference (40%) represents a plausible increase in degree-mobile student numbers to include study abroad. It is notable that the European Union's Erasmus program sponsored 272,497 students on short-term mobility in 2013; thus, this program alone is approximately 7% of degree mobility total (European Union, 2015).

Modes of transportation: The share of air, rail and other transport for international study is unknown but is estimated based on the distance of travel.

Because there are no empirical data for these parameters, the model is used to estimate GHG emissions under two sets of assumptions as identified in Table 1. These sets of assumptions also entail varying parameters for flight routing and radiative forcing, which refers to the net warming effect attributable to aviation (DEFRA, 2013; Dessens et al, 2014; Sausen et al., 2005). The models range from no consideration of radiative forcing (low estimate), to a

multiplier of 1.89 recommended by DEFRA (2013) using results from Sausen et al. (2005) (high estimate). In addition to these unknown parameters, the model treats consumption related emissions with caution due to the uncertainty of actual emissions sources. For this reason, only 25% of these emissions are included in the low estimate, and 50% in the high estimate.

TABLE 1

	Low	High
Round-trips per year	1	2
Short-term Mobility Factor	20%	40%
Consumption GHG Factor (W_L)	25%	50%
Sub-Optimal Routing (W_S)	8%	8%
Radiative Forcing (W_R)	44%	89%
Consumption Emission (W_c)	25%	50%

TABLE 1: Two sets of assumptions used to calculate low and high estimates of GHG associated with international student mobility.

In addition to unknown parameters, the model assumes error in measurement at several levels: for example, actual flight distances, fuel consumption and emissions will differ from model predictions, and changes in actual consumption emissions will not match differences in national per capita emissions. The assumption is not that error does occur in these measurements, but that error is not biased; in other words, the model will underestimate GHG emissions as much as it will overestimate them.

In other aspects, the model specifically underestimates rather than inflates GHG emissions. For example, it includes emissions for students themselves but not travel for university faculty members, staff and administration in supporting mobility (e.g. to study abroad conferences or to visit partner institutions), nor does it include travel to and from international airports (including domestic flights). The model also does not include more systemic and indirect forms of emissions; for example, universities' construction and refurbishment activities represents a major source of emissions to which international student enrolments partly contribute (Jones et al., 2016; Lou et al., 2017), but these emissions are not considered in the model. Thus, the overall estimate is quite conservative.

3.5 Formal Model Specification

The model is implemented in the R statistical programming language, all analysis and scripts are available online with an open source license to allow replication of results or modification of the model. Readers interested in the technical details are advised to consult model source code, but the formal specification can be summarized through the following set of equations:

$$(1)\ GHG_t = \sum_i^N \sum_j^N (T_{ijt} + C_{ijt})$$

$$(2)\ C_{ijt} = W_C\, S_{ij} (C_{jt} - C_{it})$$

$$(3)\ T_{ijt} = \sum_k^{R_{ij}} S_{ij}\, P_k\, E_k$$

$$(4)\ E_k = W_R\, W_S\, L_k D_k$$

Equation 1 specifies the total GHG emissions in year t (GHG_t) as the combination of travel related emissions (T) and consumption emissions (C) for all combinations of origin and destinations countries (i *and* j). Equations 2 and 3 break down the travel-related and consumption emissions independently. Equation 2 presents the calculation of consumption-related emissions for a given country-pair in a given year (C_{ijt}), where S_{ij} denotes the number of mobile students between countries i and j and C_{jt} and C_{it} are the per capita GHG emissions in destination j and origin i. W_C is a constant weighting factor provided for the high and low sets of assumptions specified in Table 1. Equation 3 specifies the travel-related emissions. Each country pair ij is associated with up to 25 travel routes (R_{ij}). The travel-related emissions for each route are calculated as the product S_{ij}, the number of mobile students between countries i and j, P_k, the proportion of student who would travel this route given airport traffic, and E_k, the emissions for the given route. The calculation of E_k (Equation 4) – the total GHG emissions for a given route – is given by the appropriate carbon loading L_k (in kg per kilometer) specified by DEFRA (2013) and the distance travelled in kilometers D_k. The emissions are also multiplied by constant weightings for radiative forcing (W_R) and suboptimal routing (W_s) using the assumptions specified in Table 1.

4. Results

Figure 1 provides context for interpreting the model estimates by showing trends in global GHG emissions and total numbers of international students over period of analysis (1999 - 2014). The figure indicates a consistent growth in both indicators, but it also shows that the growth rate of international students is considerably higher: on an annualized basis international student numbers grew at 5.26% per year versus 1.65% growth for GHG emissions. These results suggest that unless the emissions per student are decreasing significantly, emissions associated with international student mobility are likely to grow at a greater rate than global GHG emissions.

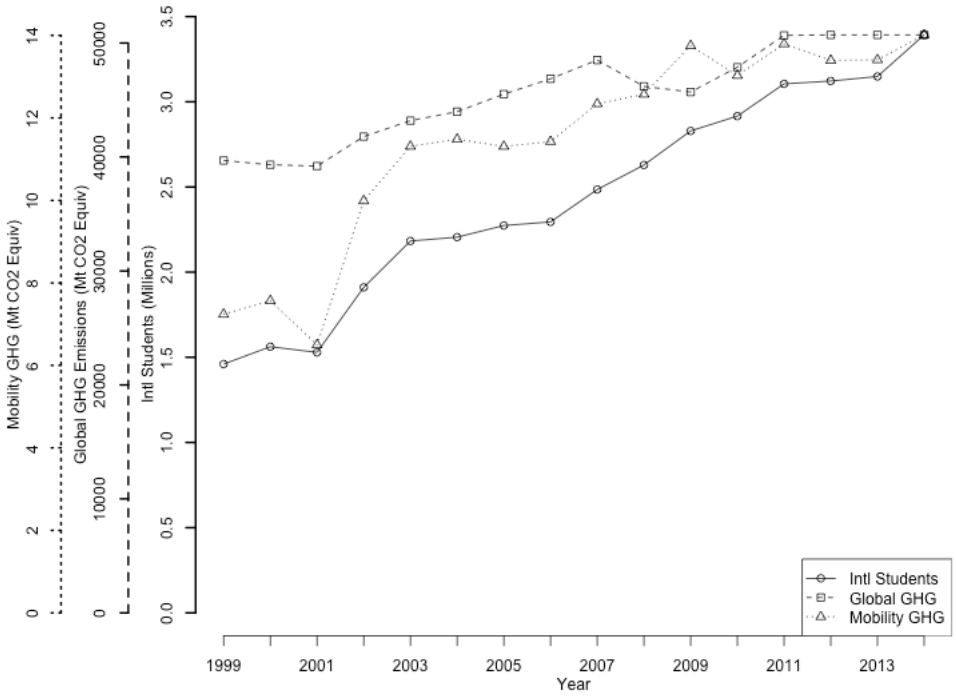

Figure 1: A comparison of global GHG emissions, international student numbers, and estimated GHG emissions from international student mobility: 1999 - 2014.

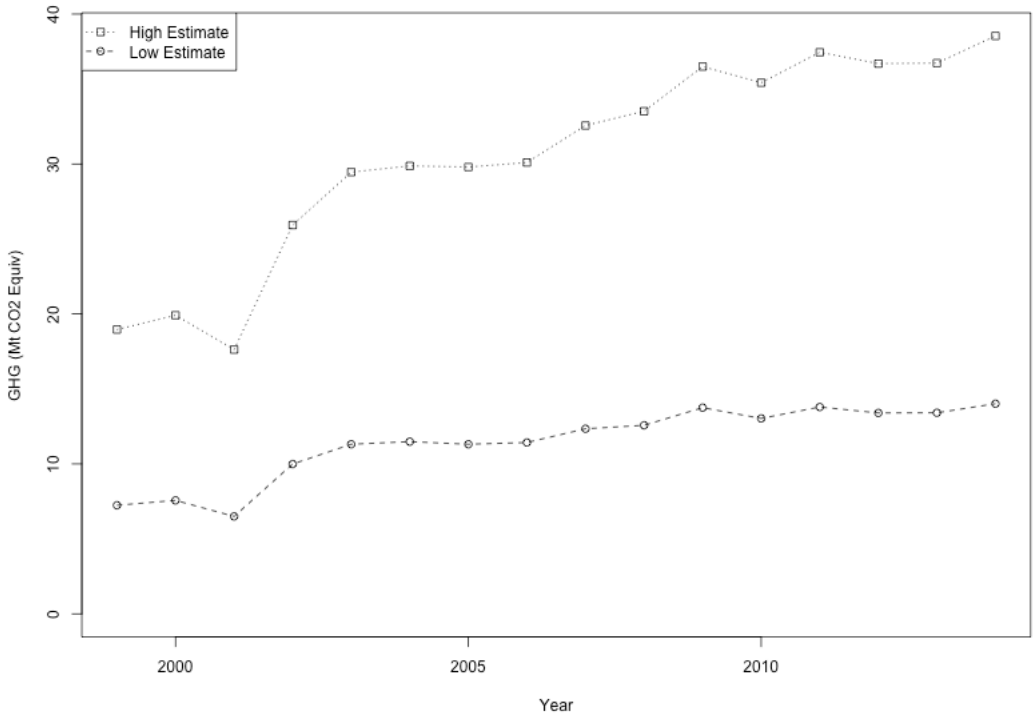

Figure 2: Modeled GHG emissions associated with international student mobility between 1999 and 2014 using the low and high sets of assumptions identified in Table 1.

Figure 2 shows estimates from the model using the high and low sets of assumptions

identified in Table 1 between the years 1999 and 2014 (16 years). Results show that the magnitude and trajectory of estimates differ, but in both cases emissions increase consistently across 16 years. The only exception is a marked decrease in 2002 that can largely be explained by decreased mobility to the United States following the 2001 World Trade Center attacks: the decrease is more pronounced for the high estimate because it places greater weight on consumption-related emissions, which are relatively high in the United States (23,937 kg per capita versus a global average of 8,566 kg per capita in 2001).

The results indicate that GHG emissions associated with international student mobility were between 14.01 and 38.54 megatons of CO_2 equivalent per year in 2014, having increased from between 7.24 and 18.96 megatons in 1999. To contextualize these figures, the low estimate is comparable to the national annual emissions of Latvia (13.94 megatons) or Jamaica (15.47 megatons), while the upper estimate is comparable to those of Croatia (30.42 megatons) or Tunisia (39.72 megatons).

Another important consideration is role of mobility in the economic development of low-income countries. The Paris Agreement specifically recognizes that reducing GHG emissions will take longer for developing countries under the principle of "common but differentiated responsibilities" (United Nations, 2015b, p.1), and emissions from international mobility can be partly explained in the context of developing countries' growth strategies, particularly the development of skilled labor and the transfer of knowledge and technology. To demonstrate this breakdown, Table 2 shows emissions according to the World Bank's income country classification for origin and destination countries. Emissions from developing countries are a substantial share of the global total: students from low-income countries comprise 31.05% of mobile students and 37.73% of GHG emissions associated with mobility. Thus, some environmental impacts of mobility could be considered in the context of developing countries' economic growth and longer timelines for emissions reduction, although there are also benefits for high-income countries (e.g. income for universities). However, the majority of mobility and GHG emissions occur between high-income countries.

	Low-Income Destination	High-Income Destination
Low-Income Origin	3.45% Students 1.55% GHG	27.60% Students 36.18% GHG
High-Income Origin	1.82% Students 0.60% GHG	67.13% Students 61.66% GHG

TABLE 2: Breakdown of mobility and GHG emissions by income classification. High-income countries comprise those classified as "High" and "Upper Middle" income; low income countries include those classified as "lower middle" and "low income." GHG figures are calculated from the low estimate of the model output.

4.2 Hypothesis Testing

To test the hypotheses specified above, the growth of both low/high GHG emissions and global emissions were tested using a simple linear model of the form

$$GHG_t = \beta t + \varepsilon_t$$

Where GHG_t represents estimated emissions as a percentage change from the 1999 baseline, and t is numbered in years from 1999. β is therefore a growth slope that is estimated from observed data and represents the average percentage increase per year, and ε is a residual error term.

Results in Table 3 show the estimated values of β and a 95% confidence interval range. The first column shows that Hypothesis 1 is supported. As expected, emissions have increased significantly over time. However, Hypothesis 2 is not supported: emissions per student did not increase over the period. On the contrary, they significantly decreased over time, albeit at a slow rate (approximately -0.72% to -1.01% per year). This reduction is explained by changes in the patterns of mobility, particularly mobility that involves less travel such as the growth of intra-regional mobility (UNESCO Institute for Statistics, 2009; Shields, 2016).

	GHG Emissions (Total)	GHG Emissions (per Student)
Mobility GHG (Low Estimate)	6.41** (4.71 - 8.12)	-1.01* (-1.71 - -0.31)
Mobility GHG (High Estimate)	7.09** (5.60 - 8.59)	-0.72* (-1.28 - -0.15)
Global GHG	2.18** (1.76 - 2.59)	

* $p < 0.05$, ** $p < 0.005$

Table 3: Estimates of growth slope (β) for both high and low model estimates and total GHG emissions. The dependent variables are GHG emissions (total) and GHG emissions per student. Total Global GHG emissions per student is not of interest and is therefore not analyzed. The 95% confidence interval of each estimate of β is presented in parentheses.

Finally, using the 95% confidence intervals for the slope parameter (β), it is possible to compare the trajectory of GHG emissions from mobility to the global total in order to test Hypothesis 3. For both the low and high estimates, the slope of mobility-related GHG is significantly higher than that of global GHG emissions, as the 95% confidence intervals do not overlap. This result shows that emissions from mobility are a growing share of global GHG emissions, although the share is still small in absolute terms.

5. Discussion

Results present a mixed picture. On the one hand, it is clear that GHG emissions associated with international student mobility are substantial and growing. This finding indicates some restraint and caution are needed in the support for international mobility found in policy discourses and the extensive literature on the benefits of mobility. On the other hand, the results also show that a substantial share of mobility involves developing countries, and the resulting GHG emissions could be linked to the longer times for emissions reduction in developing countries in the Paris Agreement (United Nations, 2015b). Furthermore, changing

patterns of mobility show that emissions per student are decreasing, over the period of analysis each new mobile student tended to contribute less GHG than the preceding one, meaning that benefits of mobility are increasing relative to its environmental costs.

As a contribution to the literature on higher education and sustainable development, this analysis presents a critical rejoinder to studies that construct higher education institutions agents of change for sustainable development without considering the extent to which they are embedded in and dependent upon unsustainable economic and social contexts. Drawing upon literature that views mobility as part of students' social positioning and class reproduction strategies (Shaw and Thomas, 2006), the findings represent a measurement of the extent to which students are able externalize the environmental costs of these strategies.

Additionally, the findings of this paper present a measure against which to compare and assess the many benefits of mobility. As outlined above, these benefits include increased intercultural awareness, international cooperation, and knowledge transfer (Clarke et al. 2009; Johnson, 2017; Paige et al., 2009; Perna et al., 2013; Roy et al, Forthcoming). It is highly likely that some of these benefits would result in reductions in GHG emissions, for example more efficient approaches to production through skills acquired or exposure to and application of sustainable approaches to management. By providing an estimate of the environmental costs of international mobility, this study could provide a foundation and starting point for a larger research agenda that considers both the costs and benefits of international higher education. To date, the literature has focused almost entirely on the benefits of education for sustainable development; this study seeks to move the discussion forward by highlighting the environmental costs that exist alongside these benefits.

5.1 Limitations

While the study provides an estimate of GHG emissions associated with international student mobility and an analysis of trends in these emissions, its findings are nevertheless subject to certain limitations. The first limitation is that data on international student flows are incomplete: not all countries report data on incoming students and thus the data underestimate the number of mobile students. However, the 143 countries that do report data account for a large majority of global higher education enrolment, and one can plausibly assume that those countries that don't report data have comparatively low numbers of incoming students. Nevertheless, it is inevitable that there is some unreported mobility, which results in an underestimation of GHG emissions. Second, the estimations of carbon loadings used to estimate travel-related emissions were developed by DEFRA for carbon accounting in the UK. Therefore, they may have greater error when applied globally, where there is greater variation in factors such as aircraft fleet age and rail infrastructure. Finally, as discussed above the differences in emissions related to lifestyle and consumption are difficult to measure, and for this reason they are only partially included in the model.

However, these empirical limitations don't undermine the validity of the analysis. The presence of missing data contributes to a conservative estimate of GHGs, when combined with the other conservative assumptions around domestic travel, rail travel, and faculty mobility described above (section 3.4) this approach prevents an unrealistically high estimate of mobility-related GHG emissions. Other sources of error such as travel-related loading

factors will bias estimates upwards for some locations and down in others, meaning that they are likely to approximate a mean error of zero across the full range of countries. Thus, the estimates presented here remain a useful starting point in considering the environmental costs of international student mobility and in considering whether the benefits identified above might outweigh these costs.

5.2 Implications and Future Research

The findings hold important implications for contemporary higher education policy and management. Evidence of the substantial GHG emissions associated with international student mobility raises concerns over the lack of serious attention to the issue in higher education policy and management. Higher education organizations (e.g. the British Council, Institute of International Education) advocate increased levels of mobility without consideration of the environmental consequences or sustainability of this goal. These organizations could begin to address the sustainability of international higher education by undertaking serious advocacy for sustainability in other areas (e.g. energy efficiency on campus and climate policy at the national/international levels). While it is unlikely that these efforts would entirely compensate for emissions from international student travel, they would help to address the contradicted position of universities in relation to sustainable development and provide a greater legitimacy for their efforts. Alternatives to student mobility, for example mobility of teaching staff or distance education, could also decrease some of the demand for international student mobility.

Accounting for GHG emissions from international student mobility is also difficult within current frameworks. Since they are not easily attributed to a single nation-state, aviation emissions are currently excluded under most reporting methods specified by the United Nations Framework Convention on Climate Change (UNFCC) and hence the Paris Agreement (Afionis et al., 2017; Barret et al., 2013). More recently, emissions reporting and accounting initiatives specifically for the aviation sector have been launched: the European Union's Emissions Trading Scheme (ETS) now covers flights within the European Economic Area, and the International Civil Aviation Organization (ICAO) has also related initiatives to measure and offset aviation emissions (ICAO, 2013; Scheelhaase et al., 2018). Accounting for emissions at the university level is improving, with initiatives such as the American College and University Presidents Climate Commitment including emissions from air travel as part of voluntary campus-wide emissions reporting (Klein-Banai and Theis, 2013). However, these travel-related emissions are related to commuting and air travel purchased by the institution, and so would not include the impact of student mobility (Second Nature, 2018).

In a more general sense, the emissions modeled here are better understood as evidence of the dependency of higher education on unsustainable economic and social systems than a form of carbon accounting. In their criteria for carbon accounting, Kander et al (2015) describe how the criterion of additivity requires that the sum of all emissions sources is not greater than the global total. If international student mobility were counted as an independent sector, then the "double counting" of travel and lifestyle emissions in other relevant sectors (e.g. travel, energy, food) would mean that the sum of all sectors would be greater than the global total. Therefore, this model is a measure of associated emissions, but not a carbon accounting.

However, Kander et al (2015, p. 431) also point out that "countries should not be able to reduce their national carbon footprints in ways that contribute to increased global carbon emissions," for example by shifting carbon intensive production to other countries. While international student mobility does not shift production, as a new form of educational delivery it does involve externalize environmental costs, regardless of how emissions are attributed from an accounting perspective. As agents for sustainable development, dependency on these environmental costs could negatively impact universities' cognitive and normative legitimacy (Suchman, 1995), even in the context of their other contributions to sustainable development.

Furthermore, these results should not be taken as evidence that international student mobility should be reduced, but rather that the higher education sector needs to more seriously engage in discussions regarding its role in global climate change. Indeed, the literature highlights many benefits of international student mobility that could have benefits beyond immediate educational outcomes (Roy et al, Forthcoming), including contributions to greater global cooperation and reduced international conflict. Instead, the results question the extent to which literature can plausibly argue for higher education as a change agent in sustainable development due to its high level of dependence upon unsustainable economic and social systems. If higher education is to be an agent of change, literature must develop a plausible account of how this agency can be exercised given the economic constraints facing most institutions and systems. Furthermore, advocates of increased international student mobility and accompanying policy targets for international student enrollment need to also consider environmental costs.

The larger issue of maintaining long-distance travel and global connections is one of the most difficult challenges in a successful response to climate change (Rockström et al., 2017). Future technological developments could reduce the environmental impacts of mobility. These developments could include improvements to aircraft fuel efficiency and the availability of aviation biofuels (Hileman and Stratton, 2014; Lu, 2018). It is very hard to predict long-term trends in fuel efficiency. While NASA and the European Union have set targets to reduce aviation fuel efficiency by 60% to 75% by mid-century, academic studies predict more modest gains, with possible reductions of 20-40% though incremental improvements (Graham et al., 2014). However, modeling of aviation emissions predicts that growth in passenger numbers means that emissions increases by a factor of 2.0 to 3.6 are likely by 2050 (Owen et al., 2010). While predictions in this area are very speculative, it presents a key opportunity for universities to reduce global GHG emissions through research and knowledge transfer.

The findings also lead to several areas for future research. An important continuation of this enquiry would be to estimate the potential benefits of mobility and compare these benefits to the environmental costs estimated here. Such a study would need to take account of how the skills, knowledge and attitudes developed through mobility reduce emissions, improve sustainability, relate to greater levels of social responsibility, or, in the case of low-income countries, contribute to economic development. In conjunction with this paper, an estimate of the environmental benefits of international student mobility would provide the basis for a well-informed cost-benefit analysis. Such an analysis would also be able to identify

geographic areas and academic disciplines in which mobility is most sustainable, and to inform policy on international student mobility for sustainability.

Another area for future research is to provide empirical estimates of the assumptions specified in Table 1. This research would require empirical data from different destination countries, but it would also reduce the range of the estimates provided above. Finally, future research could examine how the contradictions between aspirations for higher education as an agent of change for sustainable development and its dependency on unsustainable economic and social models is manifested and negotiated at the individual and organizational levels. An understanding how students, academics and university administrators reconcile and negotiate this contradiction would help to better understand the possibilities for more meaningfully engaging the global higher education sector in sustainable development.

As a contribution to the literature on higher education and sustainable development, this study takes a novel approach by viewing higher education as a production of economic and social contexts. This approach contrasts with much other literature on the topic, which tends to assume or emphasize the ability of higher education institutions to transform these contexts. However, we cannot seriously consider how higher education can contribute to a transition to more sustainable societies without first understanding the scope and implications of higher education's embeddedness in unsustainable social and economic models. Only with this understanding can we begin to understand the role of higher education, knowledge and technology in a transformation to a more sustainable society.

Notes

[1] The full model source code in the R statistical programming language is available at http://bit.ly/HigherEdGHG

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