sustainability

MDPI

Article

An Empirical Analysis of Synergies and Tradeoffs between Sustainable Development Goals

Judith M. Ament [1,2,*], Robin Freeman [1], Chris Carbone [1], Anna Vassall [3] and Charlotte Watts [3,4]

1 Institute of Zoology, Zoological Society of London, Regent's Park, London NW1 4RY, UK; robin.freeman@ioz.ac.uk (R.F.); chris.carbone@ioz.ac.uk (C.C.)
2 Centre for Biodiversity and Environment Research, University College London, Gower St, London WC1E 6BT, UK
3 Department of Global Health and Development, Faculty of Public Health and Policy, London School of Hygiene and Tropical Medicine, Keppel Street, London WC1E 7HT, UK; Anna.Vassall@lshtm.ac.uk (A.V.); C-Watts@dfid.gov.uk (C.W.)
4 Foreign, Commonwealth and Development Office, 22 Whitehall, London SW1A 2EG, UK
* Correspondence: judith.ament.15@ucl.ac.uk

Received: 9 August 2020; Accepted: 15 September 2020; Published: 13 October 2020

check for updates

Abstract: The UN Sustainable Development Goals (SDGs) represent a universal agenda that nations have committed to achieving by 2030. The challenge is substantial, with no country excelling across all SDGs. Using global UN data, we assess patterns of positive and negative correlations between indicators of SDG status and progress. For nearly 70% of SDG indicators, status is positively associated with GDP/capita. Progress on SDG indicators, however, occurs in both poorer and wealthier countries. When GDP/capita is controlled for, positive associations remain between health, environment and energy usage indicators. Economic growth is negatively associated with changes in some health and environment indicators. For SDGs targets to be achieved, major opportunities and conflicts will need to be identified, prioritized and acted upon.

Keywords: sustainable development goals; synergies and tradeoffs; interlinkages; sustainable development; international policy; time-series; connectivity

1. Introduction

In September 2015, the UN General Assembly adopted the 2030 Agenda for Sustainable Development as a universal plan of action to shift the world towards a more sustainable and resilient future [1]. The Agenda comprises 17 Sustainable Development Goals (SDGs), further clarified in 169 SDG Targets. The Agenda is designed as an integrated and indivisible whole, covering areas of critical importance both to humanity and the planet, with interconnectedness embedded in the overall vision and policy wording [2]. However, no country excels in all areas covered by the Agenda [3], and historically, progress on some aspects of the SDG agenda has not always aligned with other policy areas, such as biodiversity conservation [4,5] and climate change [6,7]. UN estimates suggest that the achievement of SDG targets by 2030 will require an additional spending of US$2.6 trillion across low-income and emerging market economies [8]. Even with substantial domestic resource mobilisation, this is an ambitious funding target. Understanding how progress on one SDG may be correlated with, amplify or hinder progress on other SDGs is essential to identify opportunities both to achieve synergies and co-benefits, as well as anticipate areas of policy incoherence [9–11]. Although the literature on prioritization, implementation and national progress is growing [12,13], analyses of the interactions between SDG goals and targets primarily rely on expert opinion [9,14–18]. Complementary empirical analyses are still scarce.

The study presented here advances current analyses on SDG interlinkages in two main ways. First, we use empirical data in our analyses, as opposed to prior studies relying on expert opinion. Evidence-based insights on global patterns in SDG attainment require large amounts of data that are comparable across countries [19]. The global SDG indicator framework adopted by the UN General Assembly in July 2017 [20] facilitates the process of collating such information. Here, we use available SDG indicator data [21] to conduct cross-national analyses of patterns of association between different indicators.

Second, in addition to using empirical data, the analyses presented here also consider two novel metrics: (1) *SDG status* (i.e., the current state of development, defined as the most-recent SDG indicator values for each country), and (2) *SDG progress* (i.e., the change in development levels over time, calculated as the mean annual rate of change in SDG indicator levels between 2000–2015). We consider two metrics because, over time, levels of SDG *status* may become correlated as progress is achieved. The use of a metric of change provides important additional insights into the degree to which rates of progress are similar across indicators. Presenting these two complementary metrics side-by-side, while using otherwise similar model structures, allows us to contrast and compare the insights that could be gained when using only a singular metric.

For the purpose of this study, we define the level of SDG *connectivity* as the proportion of significant correlations across all SDGs. Correlations between SDG *status* indicators have recently been shown to be strongly associated with country income per capita [22]. In the following sections of this paper, we therefore first assess the degree to which SDG *status* and *progress* are associated with per capita country income (GDP/capita). We then calculate the degree of SDG *connectivity*, i.e., the proportion of significant correlations across all potential connections between SDG *status* and *progress* indicators, respectively, while controlling for GDP/capita. By doing this we are able to identify where there are non-income-dependent associations between SDG indicators.

2. Materials and Methods

2.1. Materials

Indicator data for the UN Sustainable Development Goals were obtained from the dissemination platform of the Global SDG Indicators Database [21]. From this platform, all SDG indicator series were downloaded that are conceptually clear, for which internationally established methodology and standards are available, and for which data are regularly produced by countries (Tier 1 indicators, Table S1) [23]. We used only numerical, national-level data series, disregarding potential disaggregation by income, sex, age, race, ethnicity, migratory status, disability and geographic location, or other characteristics, which may not be available for all countries. SDG indicator time series had varying lengths, ranging from 1983–2017 but predominantly spanning 2000–2015 (Figure S1), which was therefore assumed as the focal temporal scope of the present study.

2.2. Methods

For the purpose of this study, we define *SDG status* as the current SDG indicator levels, measured as the most-recent-available SDG indicator values for each country, and *SDG trends* as the change in SDG indicator levels over time, measured as the mean annual rate of change in indicator values between 2000–2015.

SDG trends were calculated using two distinct methods. For data-sparse times series ($n_{obs} < 6$), linear models were used to describe SDG indicator trends over time, derived with the R 'stats' package [24]. Trends of longer time series ($n_{obs} > 5$), were described using Generalized Additive Models (GAM) derived in the R 'mgcv' package [25], to better capture potential nonlinearity in these time series. GAM smoothing parameters were set to half the length of the time series. Missing years were imputed with linear interpolation using the R 'zoo' package [26] for linear models, and predicted from model parameters for the GAM procedure. From each complete time series, annual trend values were calculated as the change in (predicted) values between subsequent years, after which the mean over the study period (2000–2015) was taken as the final *SDG trend*.

Despite using only national-level Tier 1 SDG indicators, not all resulting indicators had the same number of countries (Figure S2), and indicator data gaps were strongly mismatched between countries (Figures S3 and S4). To prevent missing country data from influencing cross-national assessments of patterns in SDG attainment, we filtered *SDG status* and *trend* values to generate a complete set of countries and SDG indicators, balancing the exclusion of data-poor indicators with the exclusion of data-poor countries to maximize the number of SDG indicators observed across the largest number of countries. Countries were thus homogenized across SDG indicators by first removing any countries missing data on more than 50% of indicators (i.e., very data-poor countries). Second, excluding any SDG indicators missing more than 10% of remaining countries (i.e., very data-poor indicators), and finally, retaining only countries with complete indicator coverage after these first two steps. For *SDG status,* this complete set contains 42 indicators in 123 countries, while the complete set of *SDG trends* contains 29 indicators in 127 countries (Table S1, Figures S2 and S3), 83% and 85% of the total of 149 UN Member States.

SDG status and *trend* values were normalized across countries before subsequent analyses using the R 'bestNormalize' package [27], to overcome the influence of high-leverage points in skewed distributions of original values. Series for which greater indicator values indicate a less desirable outcome (e.g., mortality rates) were inverted (i.e., multiplied by −1), so that for all SDG indicators, greater indicator values signify more desirable outcomes (see Table S1 for a complete list).

Economic capacity is likely to affect implementation and effectiveness of SDG policies. To account for this confounding effect, we first derive a set of regression models that evaluate relationships between SDG indicators and economic capacity, using Ordinary Least Squares (OLS) for parameter estimation:

$$SDG_i \sim \alpha_{i,GDP} + \beta_{i,GDP} \times GDP + \varepsilon_{i,GDP} \tag{1}$$

where SDG_i represents *SDG status* or *trend* values, $\alpha_{i,GDP}$ represents the model intercept, $\beta_{i,GDP}$ denotes the coefficient for the effect of economic capacity, measured as per capita gross domestic product (*GDP*), on SDG indicator i and $\varepsilon_{i,j}$ represents a model error term. For *SDG status*, we use recent (2015) GDP per capita data (PPP 2011 international $), while for *SDG trends*, we use GDP data from the beginning of the study period (2000).

Residuals from models above (Equation (1)) were then used to assess interlinkages between *SDG status* and *trend* values:

$$SDG_i \sim \alpha_{i,j} + \beta_{i,j} \times SDG_j + \varepsilon_{i,j} \tag{2}$$

where SDG_i and SDG_j are the residuals from *SDG status* or *trend* models following Equation (1). In Equation (2), $\alpha_{i,j}$ represents the model intercept, $\beta_{i,j}$ represents the relationship between SDG indicator j and SDG indicator i, and $\varepsilon_{i,j}$ represents a model error term. Linear model theory shows that exchanging dependent and independent variables in regression model derivation affects the effect size of relationships (i.e., the magnitude of $\beta_{i,j}$), but not the T- and F-statistic, nor the significance level for the relationship. We use this symmetry here by reporting significant interlinkages between SDG pairs without assigning directionality to these relationships. We do not attempt to discover any underlying mechanisms behind the observed patterns, which will be almost impossible to determine, as they are the results of complex feedbacks in societies. Instead, we report on the manifested relationships, as evidenced in the currently available data. Significance of relationships between SDG indicators calculated from Equation (2) are evaluated at a false discovery rate of $\alpha = 0.05$, corrected for multiple comparisons [28].

Network- and indicator-level metrics were calculated using the R 'igraph' package [29]. Network connectivity C is calculated as the ratio of significant links L_{sig}, over the total number of possible links:

$$C = L_{sig} / (N \times (N - 1)) \tag{3}$$

where N denotes the number of nodes (SDG indicators) in the network. At the indicator level, degree centrality D is defined as the proportion of significant links $L_{i,sig}$ that connect an SDG indicator i to all other SDG indicators, normalized over the number of possible links:

$$D = L_{i,sig}/(N-1) \tag{4}$$

Significant relationships were visualized using the R 'chorddiag' [30] and 'circlize' packages [31]. All analyses were performed in R version 3.5.1 [24].

3. Results

SDG data availability varies greatly across countries and indicators (Figures S2–S5), hindering comprehensive analyses of connectivity between indicators. We limit our analyses to a subset of countries and indicators with complete data coverage, to avoid potential biases associated with differing country samples across indicator pairs (Figure S6, Table S1, see Methods for details). In this way, we ensure that differences in linkages between SDG indicator pairs are not due to the inclusion or exclusion of specific countries on different indicator pairs, as would be the risk if we included all possible data. Numbers of available indicator time series also vary strongly across SDGs (Figure S5), leading to unbalanced comparisons when aggregating to the goal-level. We, therefore, describe patterns in interlinkages at the indicator-level. We only use national time series, not disaggregated by age, gender, region, or other descriptors. In total, we assessed a consistent set of 42 SDG indicators across 123 countries for SDG *status*, and 29 SDG indicators across 127 countries for SDG *progress*, representing 83% and 85% of all 149 UN Member States, respectively. In the analyses, a few indicators were inverted so that for all indicators, greater *status* and *progress* signify outcomes closer to SDG targets. With these methods, we thus: (1) Highlight the dependence of SDG *status* on country income, and (2) after controlling for income dependence, identify both positive SDG associations (i.e., synergistic, high-high, low-low *status* or *progress* on SDG indicators), and negative SDG interlinkages (i.e., antagonistic, high-low *status* or *progress* on SDG indicators).

GDP/capita is strongly and consistently associated with SDG *status* (predicting levels of 83% of SDG indicators, Figure 1A). In general, SDG *status* is higher in countries with higher GDP/capita (69% of indicators, including all health indicators except alcohol consumption and suicide mortality). Some indicators, however, appear to show higher status in lower-income counties (14%—lower-income countries tend to have lower alcohol consumption, lower suicide mortality, lower freshwater stress, lower domestic material consumption, more renewable energy use, and more remittances, e.g., through money transfers from migrant workers to their home countries). In low-income countries, initial increases on some indicators such as domestic material consumption (i.e., declining SDG *progress*) may be necessary precursors to other types of development.

GDP/capita is also correlated with SDG *progress* across 69% of SDG indicators (Figure 1B), but progress occurs in both poorer and wealthier countries. In 38% of indicators, SDG *progress* is significantly faster in lower-income countries. Conversely, in 31% of SDG indicators, higher-income countries are improving faster. Change on health indicators is split between high- and low-income countries, with some health issues (e.g., neo-natal mortality, under-five mortality), not surprisingly improving more rapidly in lower-income countries, while other health issues (e.g., reductions in cardiovascular disease, cancer and diabetes mortality, road-traffic mortality) progressing more rapidly in countries with higher GDP/capita. Internet usage and broadband subscriptions are also progressing much more rapidly in richer nations, leading to very high levels of *status* (Figure 1A), compared to 2G mobile coverage, which, while higher in richer countries (Figure 1A), is increasing faster in lower-income countries (Figure 1B).

Given the strong correlation between GDP/capita and SDG *status* and *progress* (Figure 1), we control for this in our analysis of SDG connectivity (see Figure S6 for SDG connectivity before accounting for GDP/capita). Eighteen percent of connections between SDG *status* indicators assessed in this way are significantly positive (Figure 2B). This percentage is largely made up of connections among health indicators (11 health indicators are positively correlated with more than 25% of other indicators, Table S2), and indicators for information access (internet broadband subscriptions and internet usage), remittances, electricity access, and clean fuels and technology. Only 4% of connections between SDG *status* indicators are negatively correlated (Figure 2A), largely driven by connections with alcohol consumption and renewable energy consumption, which tend to be inversely aligned with many other aspects of the SDG Agenda (see Table S2).

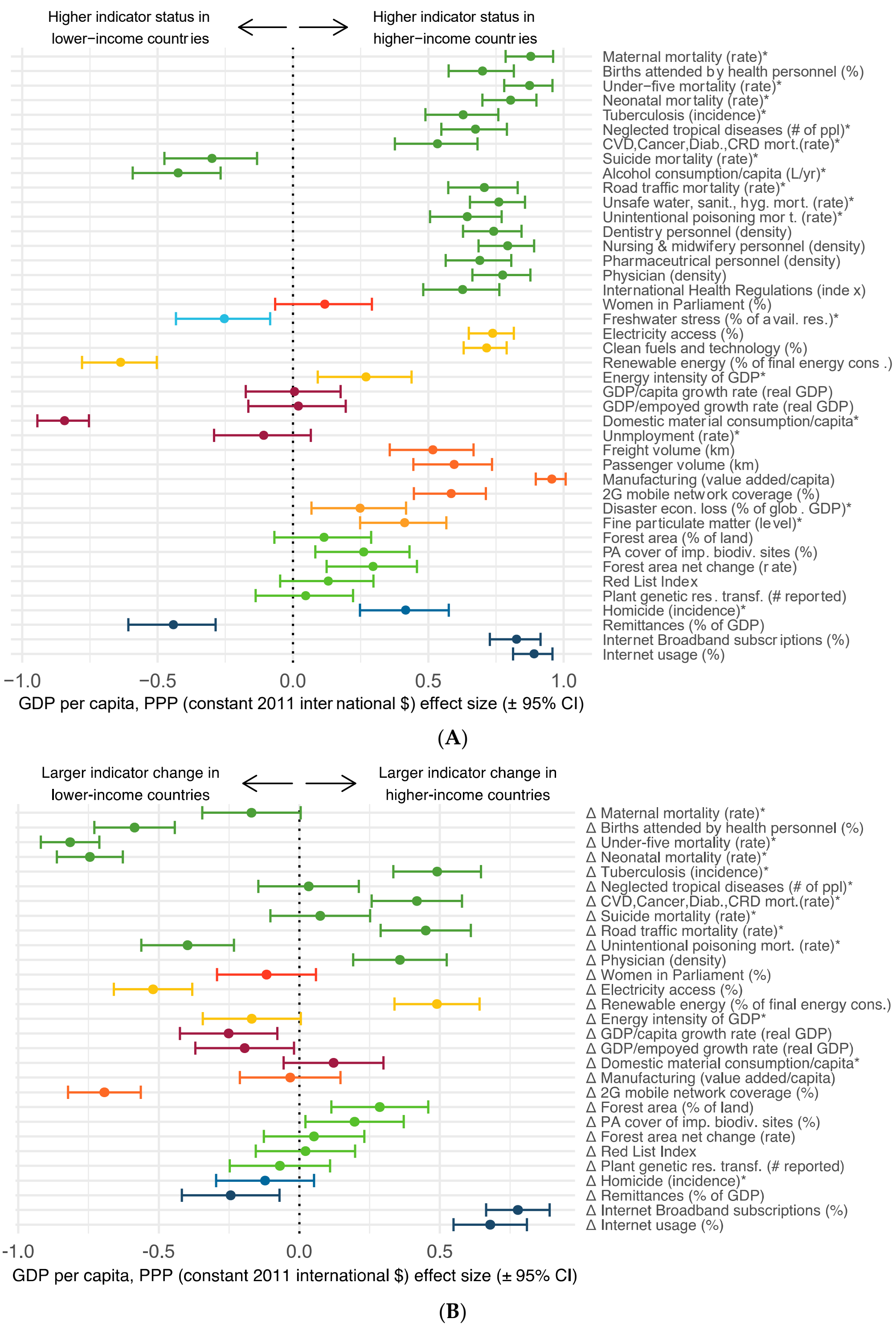

Figure 1. Dependence of SDG attainment on GDP per capita. Showing regression coefficients for GDP

per capita (PPP 2011 international $) derived from regression models of normalized values for SDG *status* in 123 countries (**A**) and SDG *progress* in 129 countries (**B**). Positive GDP regression coefficients signal SDG indicators on which *status* (**A**) or *progress* (**B**) are significantly higher in higher-income countries. Negative GDP regression coefficients signify SDG indicators on which *status* (**A**) or *progress* (**B**) are significantly higher in lower-income countries. Indicator names appended with an asterisk were inverted (i.e., multiplied with −1), so that greater SDG indicator values signify more desirable outcomes for all indicators.

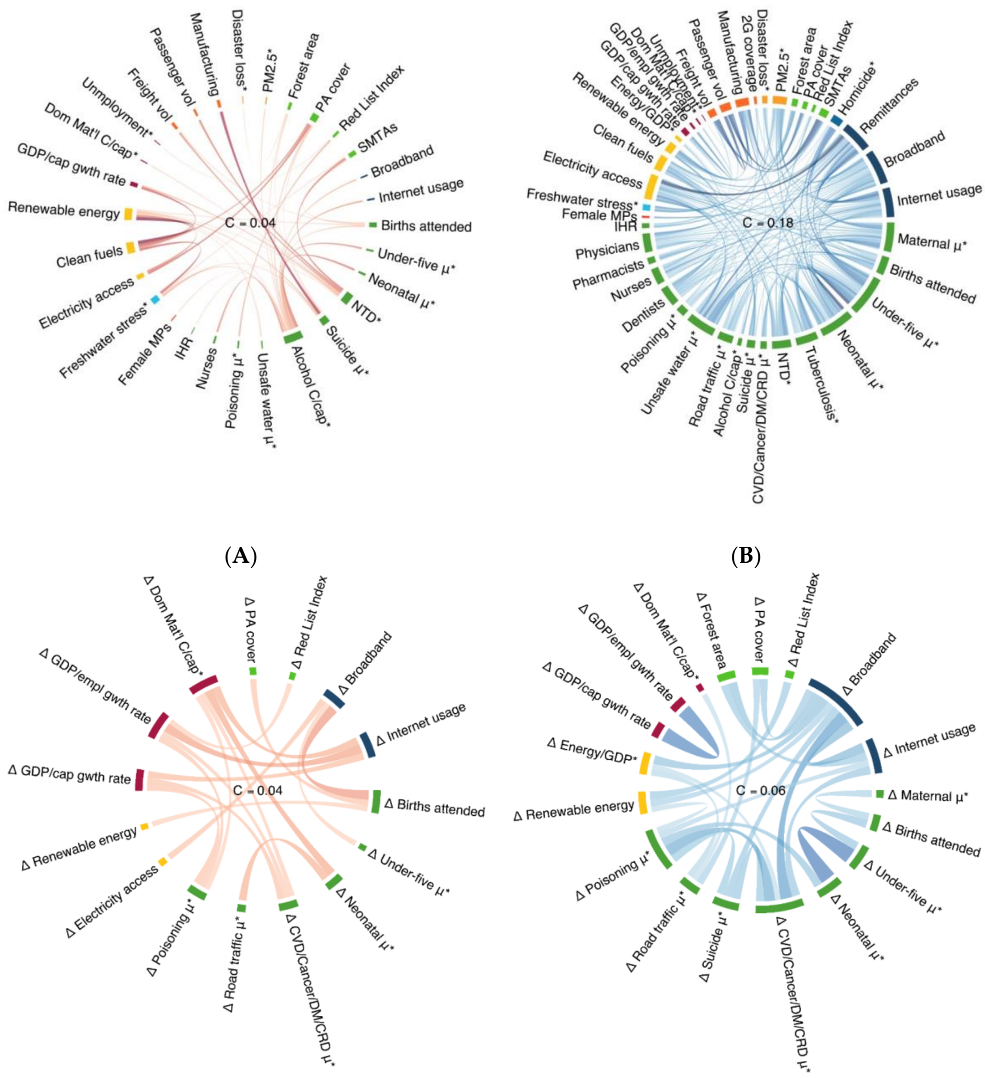

Figure 2. Connectivity of SDG *status* (top, (**A**,**B**)) and *progress* (bottom, (**C**,**D**)) derived from regression models after controlling for GDP/capita. Connections show significant negative (**A**,**C**) and positive (**B**,**D**) relationships. Significance cutoff's are corrected for multiple comparisons following Benjamini and Hochberg [28], resulting in q^* = 0.011 for *status* models (**A**,**B**), and q^* = 0.005 for *progress* models (**C**,**D**), equivalent to a false discovery rate α = 0.05. *Status* models use most-recent reported SDG indicator levels on 42 SDG indicators across 123 countries, *progress* models use mean annual change values on 29 SDG indicators between 2000–2015 across 127 countries. Inside the diagrams, quantity C specifies network connectivity: The proportion of relationships significant at q^*. Link color and width are proportional to relationship strength. Indicator sector colors reflect overarching SDG, indicator sector width is proportional to total relationship strength for each indicator. Indicator names appended with an asterisk were inverted (i.e., multiplied with −1), so that greater SDG indicator values signify more desirable outcomes for all indicators.

Compared to SDG *status* indicators, the connections between *SDG progress* indicators are weaker and more directionally balanced (overall connectivity 10%, 6% positive, 4% negative, Figure 2C,D). Health indicators represent roughly half of the significant positive *and negative* connections in these models. Negative connections (tradeoffs, Figure 2C) exist between *progress* in GDP growth rates, an SDG indicator in itself, and *increases* in domestic material consumption (economic indicators, both negatively associated with a range of health indicators and some environment indicators). While changes in economic indicators also have positive connections (Figure 2D, correlations between SDG *progress*), these are mostly connections with other economic indicators: The results indicate no synergies for the rate of economic growth across SDGs. Cross-SDG positive synergies are apparent between health, environment and energy usage indicators. Taken together, these results provide no evidence for positive associations between increasing economic activity (GDP/capita acceleration) and improvement in a range of health, environment and sustainable energy indicators, once country income levels have been accounted for. Therefore, while the level of income (GDP/capita) is strongly associated with SDG *status* and *progress*, the pace at which income is improved may potentially mitigate improvements on other SDGs (Figure 1).

4. Discussion

Negative connections between SDG *status* levels signal indicators that are at odds with general levels of development. Renewable energy consumption and alcohol consumption, for instance, have many negative connections (Table S2), suggesting that alcohol consumption is relatively higher in more developed countries, while renewable energy consumption is relatively lower in more developed countries. Lower-income countries often lack centralized energy infrastructure resulting in a faster adoption of off-grid renewable energy solutions. Alcohol consumption may increase with income levels, and more generally with development, as these results are robust against controlling for economic capacity (Table S2).

Negative connections between measures of SDG *progress* highlight areas of the SDG agenda where relative change on SDG indicators is divergent. Figure 2C shows that, for instance, change in under-five mortality and the incidence of tuberculosis are strongly negatively connected. This suggests that countries that are making progress (achieving reductions) in these areas do not make progress in both at the same time. Similarly, countries were shown to either increase the number of internet subscriptions or reduce under-five mortality. The results also suggest that countries showing accelerating economic growth (measured as increasing GDP per employed person growth rate), also tend to experience increases in internet usage and mortality from suicide, accidental poisoning, cancer, cardiovascular disease, diabetes and/or chronic respiratory diseases (Figure 2C).

Positive connectivity of SDG progress stems from several intrinsically-linked indicator pairs, such as internet usage and broadband subscriptions, neonatal and under-five mortality, and GDP per capita and per employed person growth rates. Other positive links may be more interesting, such as those between change in electricity access and births attended by health personnel, or renewable energy consumption and the Red List Index of Threatened Species. Additional patterns are revealed through the combination of SDG *status* and SDG *progress* metrics. For instance, suicide mortality is high in developed countries (Table S2), but as countries combat suicide mortality, they also progress on many other SDG indicators (Table S3).

Domestic material consumption is often highlighted as a threat for global sustainability [32–34], and is known to create performance gaps, even in top-performing countries [3]. Here, we show that *status* on this indicator is negatively associated with *status* on 63% of the tested indicators, before accounting for GDP (Table S2). These associations are diminished when accounting for economic capacity, but for SDG *progress*, connections with domestic material consumption become more pronounced after accounting for country GDP, suggesting that irrespective of wealth, change on many SDG indicators is associated with increases in material consumption.

Before controlling for GDP, SDG *status* shows moderate total connectedness (connectivity 0.58, Figure S7A,B), largely resulting from positive connections (positive connectivity 0.43), suggesting that national status across SDG indicators is well-linked. Fewer SDG indicators are connected through negative relationships (negative connectivity before-GDP 0.15), suggesting tradeoffs between certain SDG indicators. In a similar analysis based on expert opinion [16], connectivity was reported to be much higher (0.8) than the total evidence-based (before-GDP *status*) connectivity found here (0.58). We find that positive connectivity is largely driven by health indicators: 15 health indicators are each significantly correlated with 59–68% of all indicators (Table S2). Other positively connected indicators are manufacturing value added, internet broadband subscriptions and internet usage (all significantly positively correlated with 68% of indicators). These indicators correlate with more than half the total number of tested indicators and might thus make reasonable candidates for proxies of overall SDG *status*.

Negative connectivity of SDG *status*, before controlling for GDP, is driven by per capita alcohol consumption, domestic material consumption, renewable energy consumption, and suicide mortality. These indicators are negatively correlated with large proportions (49–66%) of all other indicators, suggesting that developed countries perform relatively poorer on these indicators than less-developed countries, and vice-versa.

Economic growth has long been linked with many other aspects of human development, such as health and education indicators [35,36]. There is a growing field of literature, however, calling for a move away from consumption-based macroeconomic indicators such as GDP, for measuring economic progress and human development more broadly [37–39]. Recently, economic growth in the EU was shown to be unrelated, for instance, to other economic performance indicators and inversely related to environmental and well-being indicators [40]. Here, we show that although GDP/capita levels are a determining factor in the types of development that we observe across countries (Figure 1), there are many positive correlations between other types of development that cannot be explained by differences in income levels (Figure 2). Our results thus both provide support for correlations between income levels and other development indicators, as well as suggest there are many other intrinsic interlinkages between human development metrics after income levels have been accounted for, and thus suggest a nuance between these schools of thought.

Positive relationships between some SDG indicators have also been noted in other studies, for instance, between indicators related to reducing (gender) inequalities, eradicating poverty, education and some health indicators [41]. Spaiser et al. [42] also identify factors which can promote socioeconomic development and ecological sustainability simultaneously, without spurring negative interactions between these realms. Our research echoes the conclusions from prior research on the importance of policy coherence [43,44] within the realm of the SDGs [40,45], by demonstrating the interdependence of individual SDG indicators and thus underwriting the indivisibility of the SDGs as a system of policy objectives that necessitates careful consideration of the downstream interactions between individual policy measures.

The study presented here describes statistical correlations between national-level indicators of human development. There are a number of limitations associated with the chosen methodological approaches which may indicate new directions for future research. Firstly, the uncovered statistical correlations indicate that there are human development indicators which tend to align (inversely) across countries. The common mechanisms (if any) linking such indicators *causally* cannot be inferred from the current macro-level, cross-country analysis. It would be interesting to further understand the within-country processes leading the relationships observed across countries. Simultaneously, by using national-level indicators, no attention can be paid to subnational differences in status or progress on these indicators. While it is an explicit goal of SDG Agenda to achieve the Agenda's Goals and Targets for all nations and for all segments of society [46], the current analysis does not shed light on nations nor sections within societies potentially lagging behind in reaching the Goals as set out in the Agenda. Global country rankings are published by the UN directly (e.g., dashboards.sdgindex.org), and so the study presented here is merely intended to be complementary in its cross-national and cross-SDG approach. Finally, in our attempt to generate such overarching insights unbiased by differing country samples between SDG indicators, we have had to exclude certain data-poor countries and indicators, to ensure an identical sample of countries across indicators. This has resulted in certain obvious data gaps, such as missing indicators for SDGs 1 and 2, but we feel this is preferable than drawing conclusions for different SDGs on differing sets of countries. Overall, this paper highlights the connectivity of the SDG Agenda, and thereby serves as a reminder to carefully explore both intended as well as unexpected outcomes of policy interventions.

5. Conclusions

Assessing national-level SDG data, we find three broad patterns in SDG attainment and network connectivity. First, GDP/capita predicts 69–83% of SDG indicators (Figure 1) and accounts for up to half the connections between indicator pairs, irrespective of measuring *status* or *progress* (Figure S7). These findings illustrate, fundamentally, the central correlations between economic development (here represented as GDP/capita) and progress on many SDGs. Given this, it is important to control for GDP/capita when exploring other potential synergies and tradeoffs between SDG indicators.

Second, the interconnected nature of the SDG agenda is reflected in a high percentage of significant correlations between indicators of *SDG status* (Figure 2A,B). Indeed, there are over four times more positive than negative correlations, even when controlling for GDP/capita.

Third, SDG *progress* shows far fewer significant associations (10% overall) which are roughly equally distributed between positive and negative correlations (Figure 2C,D). Notably, after controlling for differences in GDP/capita, there are positive associations between SDG *progress* on health, environment and sustainable energy indicators, while there are negative associations between the acceleration of economic growth and some of these indicators (e.g., reductions in cardiovascular disease, cancer and diabetes mortality, and the Red List Index of species threatened with extinction). While higher income levels are associated with higher SDG achievement (Figure 1A), the results suggest that higher or accelerating economic growth may mitigate some of these benefits (Figure 2C,D). Rapid economic growth may change economic structures (patterns of consumption, labor markets) in a way that counters the effect of GDP per capita.

Together, these findings illustrate the complexity of monitoring progress on the SDGs—given differences in income levels, it may be more appropriate for different countries to prioritize different sets of targets within goals. They also show that considerations of opportunities to achieve SDG *progress* are complementary to analyses of SDG *status*. The findings suggest both that SDG *status* and *progress* are often associated with GDP/capita, and also that there are many other areas of synergy. However, for global ambitions for sustainable development to be achieved, major opportunities and conflicts need to be articulated, prioritised and acted upon.

Supplementary Materials: The following are available online at http://www.mdpi.com/2071-1050/12/20/8424/s1, Figure S1: Temporal coverage of SDG indicator data, Figure S2: Number of countries available by SDG indicator, Figure S3: SDG indicator availability for high- and low-income countries, Figure S4: SDG indicator availability for middle-income countries, Figure S5: Number of SDG indicators available by tier, Figure S6: Countries included in analyses, Figure S7: Connectivity of SDG status and trends without controlling for GDP per capita, Table S1: Descriptions of SDG indicators at tier 1, Table S2: Proportion of significant links for SDG status indicators, Table S3: Proportion of significant links for SDG progress indicators.

Author Contributions: J.M.A.: Conceptualization, funding acquisition, methodology, data curation, formal analysis, visualization, writing—original draft, writing—review & editing; R.F.: Conceptualization, funding acquisition, methodology, formal analysis, visualization, writing—review & editing; C.C.: Conceptualization, funding acquisition, methodology, writing—review & editing; A.V.: writing—review & editing; C.W.: Conceptualization, funding acquisition, methodology, writing—review & editing. All authors have read and agreed to the published version of the manuscript.

Funding: J.M.A. is supported by a Natural Environment Research Council (NERC) Doctoral Training Partnership (DTP) studentship (grant number: NE/L002485/1).

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability: All data are available through the dissemination platform of the Global SDG Indicators Database (https://unstats.un.org/sdgs/indicators/database/).

References

1. UN General Assembly. *Transforming Our World: The 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2015.
2. Le Blanc, D. Towards Integration at Last? The Sustainable Development Goals as a Network of Targets. *Sustain. Dev.* **2015**, *23*, 176–187. [CrossRef]
3. Sachs, J.; Schmidt-Traub, G.; Kroll, C.; Lafortune, G.; Fuller, G. *Sustainable Development Report 2019*; Bertelsmann Stiftung and Sustainable Development Solutions Network (SDSN): New York, NY, USA, 2019.
4. Ament, J.M.; Collen, B.; Carbone, C.; Mace, G.M.; Freeman, R. Compatibility between agendas for improving human development and wildlife conservation outside protected areas: Insights from 20 years of data. *People Nat.* **2019**, *1*, 305–316. [CrossRef]
5. *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*; IPBES 2019; IPBES Secretariat: Bonn, Germany, 2019.
6. *Summary for Policymakers*; IPCC 2018; World Meteorological Organization: Geneva, Switzerland, 2018.
7. Nerini, F.F.; Sovacool, B.; Hughes, N.; Cozzi, L.; Cosgrave, E.; Howells, M.; Tavoni, M.; Tomei, J.; Zerriffi, H.; Milligan, B. Connecting climate action with other Sustainable Development Goals. *Nat. Sustain.* **2019**, *2*, 674–680. [CrossRef]
8. Gaspar, V.; Amaglobeli, D.; Garcia-Escribano, M.; Prady, D.; Soto, M. *Fiscal Policy and Development: Human, Social, and Physical Investment for the SDGs*; IMF Staff Discussion Notes: Washington, DC, USA, 2019.
9. *A Guide to SDG Interactions: From Science to Implementation*; ICSU 2017; International Science Council (ICSU): Paris, France, 2017. [CrossRef]
10. Nilsson, M.; Chisholm, E.; Griggs, D.; Chapman, R.; Mccollum, D.; Messerli, P.; Neumann, B.; Stevance, A.-S.; Visbeck, M.; Smith, M.S. Mapping interactions between the sustainable development goals: Lessons learned and ways forward. *Sustain. Sci.* **2018**, *13*, 1489–1503. [CrossRef]
11. United Nations Department of Economic and Social Affairs. *The Sustainable Development Goals Report 2019*; United Nations Department of Economic and Social Affairs: New York, NY, USA, 2019.
12. Allen, C.; Metternicht, G.; Wiedmann, T. Initial progress in implementing the Sustainable Development Goals (SDGs): A review of evidence from countries. *Sustain. Sci.* **2018**, *13*, 1453–1467. [CrossRef]
13. El-Maghrabi, M.H.; Gable, S.; Rodarte, I.O.; Verbeek, J. *Sustainable Development Goals Diagnostics: An Application of Network Theory and Complexity Measures to Set Country Priorities*; World Bank: Washington, DC, USA, 2018.
14. Nilsson, M.; Griggs, D.; Visbeck, M.; Ringler, C. *A Draft Framework for Understanding SDG Interactions*; International Council for Science: Paris, France, 2016.
15. Machingura, F.; Lally, S. *The Sustainable Development Goals and Their Trade-Offs*; Overseas Development Institute: London, UK, 2017.
16. McGowan, P.J.K.; Stewart, G.B.; Long, G.; Grainger, M.J. An imperfect vision of indivisibility in the Sustainable Development Goals. *Nat. Sustain.* **2018**, *2*, 43–45. [CrossRef]
17. Nilsson, M.; Griggs, D.; Visbeck, M. Policy: Map the interactions between Sustainable Development Goals. *Nature* **2016**, *534*, 320–322. [CrossRef]
18. Tremblay, D.; Fortier, F.; Boucher, J.; Riffon, O.; Villeneuve, C. Sustainable development goal interactions: An analysis based on the five pillars of the 2030 agenda. *Sustain. Dev.* **2020**, *11*, 1–13. [CrossRef]
19. Reyers, B.; Stafford-Smith, M.; Erb, K.-H.; Scholes, R.J.; Selomane, O. Essential Variables help to focus Sustainable Development Goals monitoring. *Curr. Opin. Environ. Sustain.* **2017**, *26*, 97–105. [CrossRef]
20. UN General Assembly. *Work of the Statistical Commission Pertaining to the 2030 Agenda for Sustainable Development*; United Nations: New York, NY, USA, 2017.
21. UN Statistics Division. *SDG Indicators Global Database*; United Nations: New York, NY, USA, 2017.
22. Lusseau, D.; Mancini, F. Income-based variation in Sustainable Development Goal interaction networks. *Nat. Sustain.* **2019**, *2*, 242–247. [CrossRef]
23. UN Economic and Social Council. *Report of the Inter-Agency and Expert Group on Sustainable Development Goal Indicators*; United Nations: New York, NY, USA, 2017.

24. R Development Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2018.
25. Wood, S. *Generalized Additive Models*; CRC Press: Boca Raton, FL, USA, 2006.
26. Zeileis, A.; Grothendieck, G. zoo: S3 Infrastructure for Regular and Irregular Time Series. *J. Stat. Softw.* **2005**, *14*. [CrossRef]
27. Peterson, R.A. Ordered quantile normalization: A semiparametric transformation built for the cross-validation era. *J. Appl. Stat.* **2019**, 1–16. [CrossRef]
28. Benjamini, Y.; Hochberg, Y. Controlling the False Discovery Rate: A Practical and Powerful Approach to Multiple Testing. *J. R. Stat. Soc. Ser. B Stat. Methodol.* **1995**, *57*, 289–300. [CrossRef]
29. Csardi, G.; Nepusz, T. The igraph software package for complex network research. *InterJournal* **2006**, *1695*, 1–9.
30. Flor, M.; Tang, E. Chorddiag: Interactive Chord Diagrams. 2014. R Package Version 0.1.2. Available online: http://github.com/mattflor/chorddiag/ (accessed on 4 December 2019).
31. Gu, Z.; Gu, L.; Eils, R.; Schlesner, M.; Brors, B. circlize implements and enhances circular visualization in R. *Bioinformatics* **2014**, *30*, 2811–2812. [CrossRef] [PubMed]
32. Pradhan, P.; Costa, L.; Rybski, D.; Lucht, W.; Kropp, J. A Systematic Study of Sustainable Development Goal (SDG) Interactions. *Earths Futur.* **2017**, *5*, 1169–1179. [CrossRef]
33. UN Environment. *Global Environment Outlook—GEO-6: Healthy Planet, Healthy People*; UNEP 2019; Cambridge University Press: Cambridge, UK, 2019.
34. Wackernagel, M.; Hanscom, L.; Lin, D. Making the Sustainable Development Goals Consistent with Sustainability. *Front. Energy Res.* **2017**, *5*, 518. [CrossRef]
35. Ranis, G.; Stewart, F.; Samman, E. Human Development: Beyond the Human Development Index. *J. Hum. Dev.* **2006**, *7*, 323–358. [CrossRef]
36. Bloom, D.E.; Canning, D.; Sevilla, J. The Effect of Health on Economic Growth: A Production Function Approach. *World Dev.* **2004**, *32*, 1–13. [CrossRef]
37. Costanza, R.; Kubiszewski, I.; Giovannini, E.; Lovins, H.; McGlade, J.; E Pickett, K.; Ragnarsdóttir, K.V.; Roberts, D.; De Vogli, R.; Wilkinson, R. Development: Time to leave GDP behind. *Nature* **2014**, *505*, 283–285. [CrossRef]
38. Kubiszewski, I.; Costanza, R.; Franco, C.; Lawn, P.; Talberth, J.; Jackson, T.; Aylmer, C. Beyond GDP: Measuring and achieving global genuine progress. *Ecol. Econ.* **2013**, *93*, 57–68. [CrossRef]
39. Fioramonti, L.; Coscieme, L.; Mortensen, L.F. From gross domestic product to wellbeing: How alternative indicators can help connect the new economy with the Sustainable Development Goals. *Anthr. Rev.* **2019**, *6*, 207–222. [CrossRef]
40. Coscieme, L.; Mortensen, L.F.; Anderson, S.; Ward, J.; Donohue, I.; Sutton, P.C. Going beyond Gross Domestic Product as an indicator to bring coherence to the Sustainable Development Goals. *J. Clean. Prod.* **2020**, *248*, 119232. [CrossRef]
41. Niessen, L.W.; Mohan, D.; Akuoku, J.K.; Mirelman, A.J.; Ahmed, S.; Koehlmoos, T.P.; Trujillo, A.; Khan, J.A.M.; Peters, D.H. Tackling socioeconomic inequalities and non-communicable diseases in low-income and middle-income countries under the Sustainable Development agenda. *Lancet* **2018**, *391*, 2036–2046. [CrossRef]
42. Spaiser, V.; Ranganathan, S.; Swain, R.B.; Sumpter, D.J.T. The sustainable development oxymoron: Quantifying and modelling the incompatibility of sustainable development goals. *Int. J. Sustain. Dev. World Ecol.* **2016**, *24*, 457–470. [CrossRef]
43. Nilsson, M.; Zamparutti, T.; Petersen, J.E.; Nykvist, B.; Rudberg, P.; McGuinn, J. Understanding Policy Coherence: Analytical Framework and Examples of Sector-Environment Policy Interactions in the EU. *Environ. Policy Gov.* **2012**, *22*, 395–423. [CrossRef]
44. Cejudo, G.M.; Michel, C.L. Addressing fragmented government action: Coordination, coherence, and integration. *Policy Sci.* **2017**, *50*, 745–767. [CrossRef]

45. Collste, D.; Pedercini, M.; Cornell, S.E. Policy coherence to achieve the SDGs: Using integrated simulation models to assess effective policies. *Sustain. Sci.* **2017**, *12*, 921–931. [CrossRef]
46. United Nations Department of Economic and Social Affairs. *The Sustainable Development Goals Report 2016*; United Nations Publications: New York, NY, USA, 2016.