Spatiotemporal distribution of inclusive wealth data: An illustrated guide

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Spatiotemporal distribution of inclusive wealth data: An illustrated guide

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Abstract. In this paper we develop an illustrated guide for IWR2017 data. Graphical representations aim to reveal the multi-layer nature of IWR data with self-explanatory schemes. There are four parts of the analysis. In the first part, we present the spatial distribution of the three types of capitals - natural, human and produced - associated to social well-being. In the second part, we illustrate capitals' temporal variation over 1990-2014, on different geographical and economic backgrounds. We investigate the dynamic evolution of capital assets and capture the key trend among different geographical regions and among regions with different economic growth. The third part makes an additional focus on natural capital and its spatial distribution over different income levels and regions. The forth part examines the causal relation between pollution and wealth. All four research questions are confronted with ease, clarity, and accuracy, with digital methods for mapping. A variety of graphical styles and/or forms is employed to indicate the resource use, capital exploitation trends of countries of different economic integration, uncover policies per income level.

Keywords: Wealth creation, natural capital, visual analytics, visual interfaces.

JEL Codes: C63; C88; P28; Q51; Q53; Q58.

1. Introduction

The policy and business community increasingly rely on comprehensive datasets and indicators which assist in monitoring progress towards green growth (Giljum et al., 2015). The first level of situation awareness is about perceiving the status, attributes and dynamics of relevant elements in the research context (Kohlhammer et al., 2009).

Visual modelling is a straight and unbiased way to explore data which provide clear economic interpretation. Policies that promote green growth and resource efficiency need to be based on a deep understanding of the multidimensional parts of data. To seek for possibilities influencing resource use and resource efficiency, the data requires a sound knowledge of the information hidden in the data.

For policy monitoring and design, datasets need to be complemented with causal relations, dynamic evolution of variables and spatial analysis of influential parameters (Halkos, 1992, 1993, 1994, 1996). The ordering of plots, the selection of variables used in graphical analysis, the way the axes are arranged in a graph, can impact the way the reader understands the data. The assessment of variation of capital assets and air pollution for regions and income levels across the years of study can uncover correlations and patterns (Halkos and Tsilika, 20161a,b; 2018). It can help to quickly identify relevant variables, trends and relationships. This way there is less need to rely on guesses or intuition.

Visual analytics results support policy interpretation and conclusions for decision making (Savikhin et al., 2008), (Kohlhammer et al., 2009) (Giljum et al., 2015). There are several important messages that can be conveyed with decision centered visualization (Kohlhammer et al., 2009). Recent economic policy issues to achieve sustainable development goals are presented in (Aurangzeb and Stengos, 2012), (Halkos and

Zisiadou, 2017), (Halkos and Managi, 2017), (Halkos et al., 2017), (Managi and Halkos, 2015). Inclusive wealth plays key role in understanding status of sustainable development goals for society (Dasgupta et al., 2015).

Our global multi-country multi-region dataset comprises four clusters of economic development and 19 geographical regions. To represent and integrate data for countries, regions and income levels, we employ solely open source technologies. Our visual analytics approach is organized in three sections. In section 2 we conduct a geographical and chronological analysis for capital assets, comparing different geographical regions and regions of different degree of economic integration. The graphic evaluation reveals a positive trend between inclusive wealth and time passing. In section 3, visualization and reporting the natural assets' spatial distribution makes obvious that high and upper-middle income countries absorb the lion's share of natural assets. The question in what proportions the global natural capital is partitioned in regions and income levels, is also answered. In section 4 some results concerning pollution and wealth inequalities could guide environmental policy.

2. Dataset and Variation of Wealth

The global dataset covers 4 income categories and 19 geographical regions for all countries worldwide (see figure 2.1) and reports annual time series from 1990 to 2014. Countries of inclusive wealth database used in this study are clustered in four income categories (i.e. high, upper middle, lower middle, low) and in 19 geographical regions (i.e. South-Central Asia, South-Eastern Asia, Western Asia, Eastern Asia, South America, Northern America, Central America, Australia-New Zealand, Western Europe, Eastern Europe, Southern Europe, Northern Europe, Eastern Africa, Western Africa, Southern Africa, Northern Africa, Middle Africa, Caribbean, Melanesia).

Figure 2.1. The division of the 140-country sample into four income categories, nineteen regions. Circular dendrogram was obtained using RAWGraphs[1]

For each country the three capitals - inputs in the production system are calculated (Managi and Kumar, 2018). These three capitals are produced capital (hereafter PC),

[1] (Mauri et al., 2017)

human capital (hereafter HC) and natural capital (hereafter NC). Produced capital is the easiest to imagine: roads, ports, cables, buildings, machines, equipment, and other physical infrastructures. Human capital consists of population (size and composition), knowledge and skills acquired by education, and health (enhancing the quality of life, extending life, and boosting productivity). For natural capital, the current accounting addresses sub-soil non-renewable resources, forests, agricultural land, but it should ideally include ecosystems in general (Chapter1 in Managi and Kumar, 2018). In our 140-country sample, the total inclusive wealth (hereafter IW) is a combination of the three capitals, as shown in figures 2.2 and 2.3.

Figure 2.4 provides a comparative effect among types of capitals and income levels. The three rings in the graph – each one representing a certain type of capital - stand for the productive base of economies. Each ring is divided into a number of arcs, each representing a different income category. The length of the arcs indicate that upper middle and high-income countries make up the largest fraction share of global natural capital (82.3% of the global natural capital). The rest 17.7% belongs to lower middle and low-income countries. The second reading of this graph reflects the resource use, capital exploitation trends of countries of different incomes, uncovers policies per income level. Figure 9 also permits a comparison between the rich and the poor on the basis of their possession of capital assets.

Figures 2.5 and 2.6 illustrate the geographical distribution of capital assets over regions and countries accordingly.

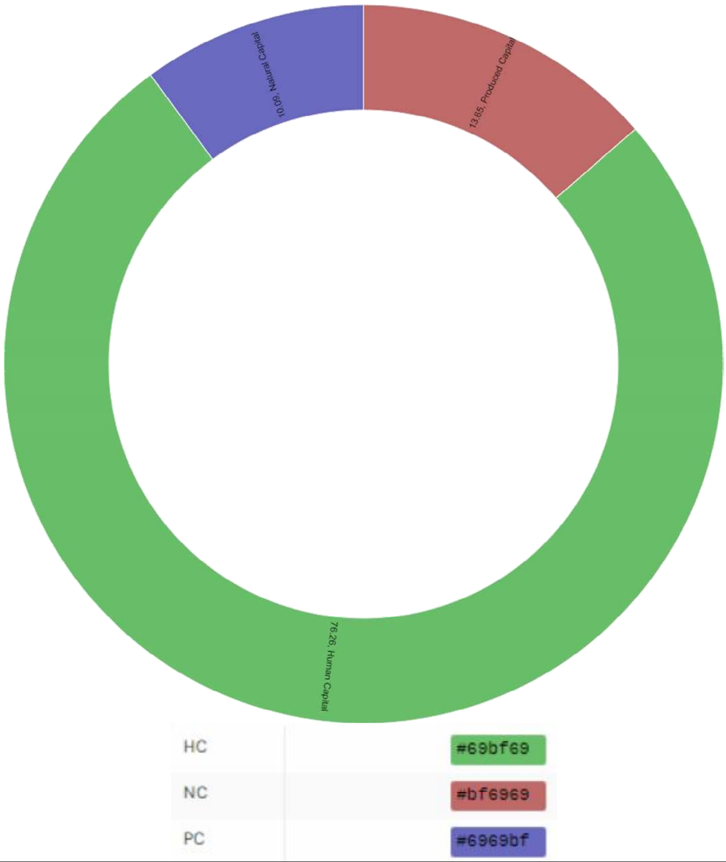


Figure 2.2: Global IW and its partition in NC, HC, PC.
Donut chart was obtained using RAWGraphs

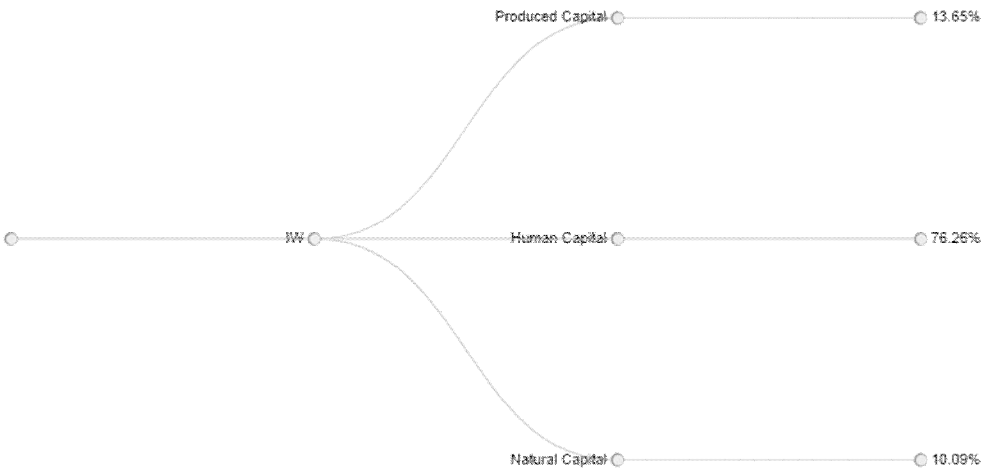


Figure 2.3: Global IW and its partition in NC, HC, PC.
Cluster dendrogram was obtained using RAWGraphs

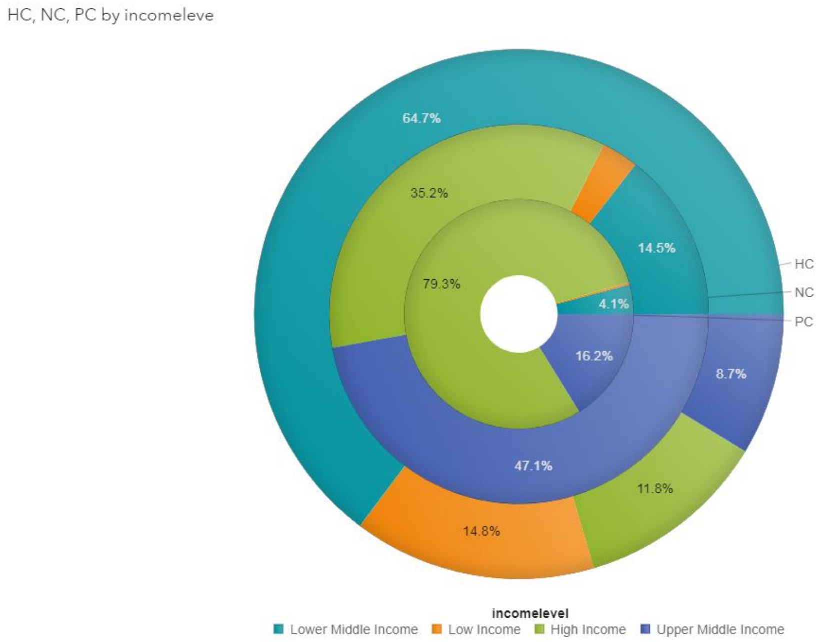


Figure 2.4: Capitals' shares for countries of different income levels.
Donut chart was obtained using SAS Visual Analytics 8.2 (on SAS Viya).

Figure 2.5: Capitals' shares per region.
Regions are shown in descending order of IW assets.

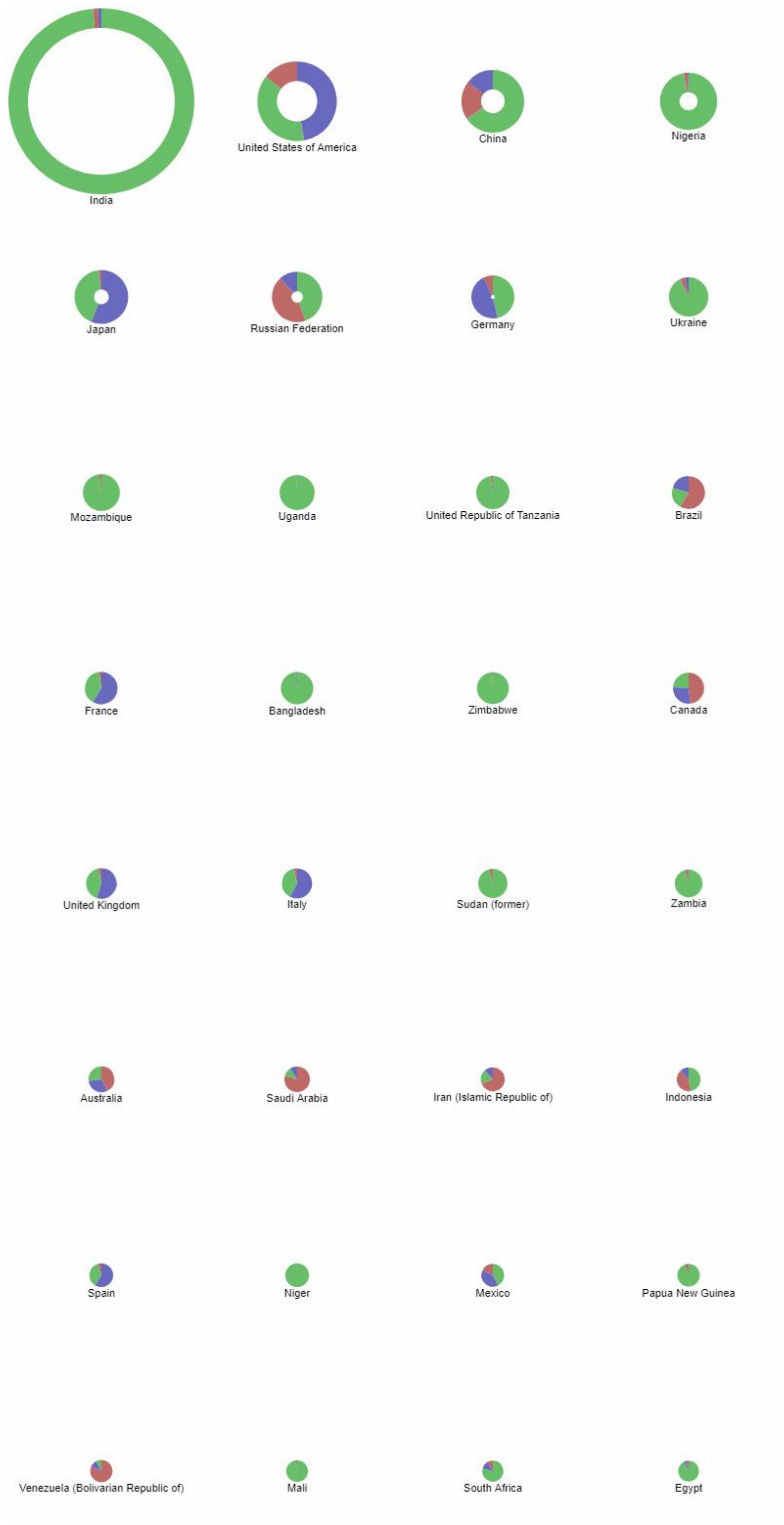


Figure 2.6: Capitals' shares per country. Countries are shown in descending order of IW assets. Only the 32 top-ranked countries in IW assets have been included.

2.1 Temporal variation of wealth: The evolution between clusters.

In this section we present time-dependent data of the IW report of 140 countries and identify assets associated with three types of capitals. Data are filtered by income level.

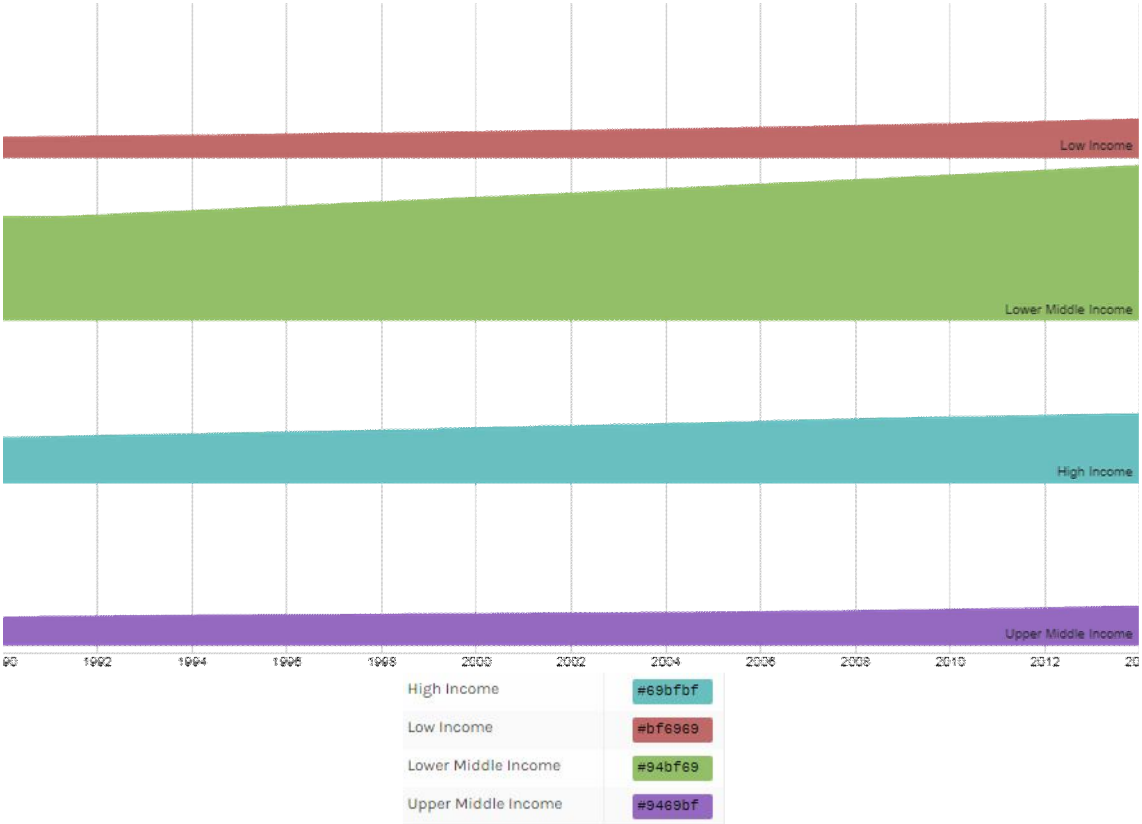


Figure 2.7: A visual comparison of the inclusive wealth for different income levels Note: IW assets per income level classification (same scale used) over 1990-2014. The thickness of each area represents the level of inclusive wealth. Area graph was obtained using RAWGraphs

Inclusive wealth (hereafter IW) year-by-year evolution depicted in figure 2.7 reveals an ascending trend through time. Figure 2.7 also demonstrates that low middle-income regions' IW assets are, on average, about threefold to fourfold larger than the IW assets of the countries in the rest income categories. As time passes, wealth grows for all income categories, in different rates of course.

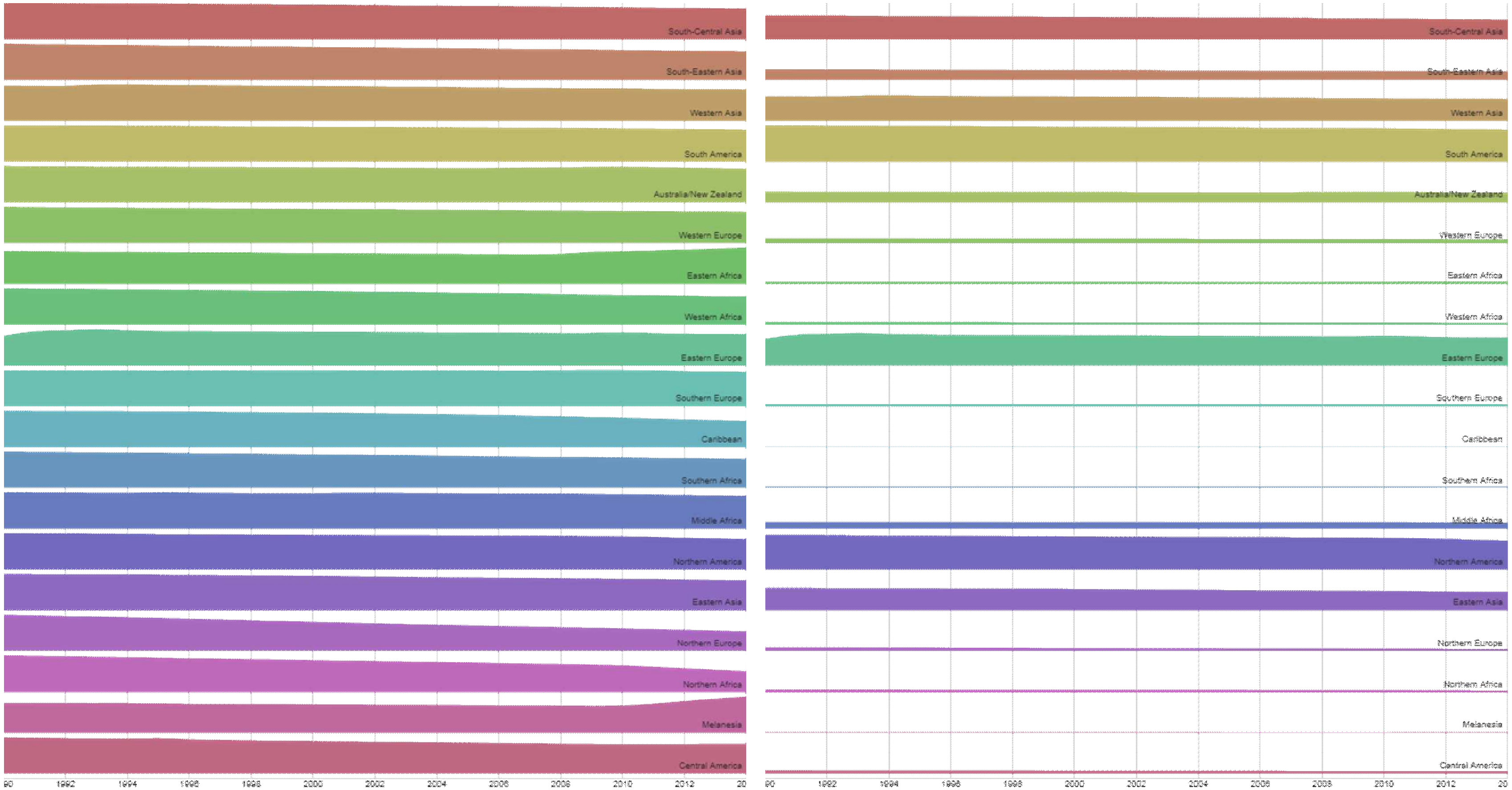
Figure 2.8: A comparative assessment/ visual comparison of the inclusive wealth (IW) annual relative changes per income level classification over 1990-2014.
Note: Areas represent the annual relative changes of IW assets and are sorted according their ranking. Bump chart shows the variation in rankings and values of IW annual relative changes between 1990 and 2014. Bump chart was obtained using RAWGraphs

Our findings in figure 2.8 call into question the sole rate of change[2] of IW for each one of the four income categories. Figure 2.8 reveals the hierarchy of IW rates of change among different income regions. Also indicates at which time of the 25-year period IW assets are highly stressed. Two periods of variability are indicated: 1992-1996 (related to globalization) and 2007-2011 (related to global financial crisis). During the financial crisis (specifically during the period from 2009 till 2012) high income countries demonstrate a significant reduction in their IW assets. From 2010 till 2012, low income

[2] Calculated by the formula (IW of year n - IW of year n-1)/ IW of year n-1

countries increase their IW assets. Figure 2.8 reflects each regions' reaction (or policies) to crucial periods of economic history (namely globalization period, global financial crisis period and the recovery period). Throughout the 25-year period of study, upper middle-income countries are of the most benefit. High income countries feature a dramatic decrease their IW values. Local and regional differences in precipitation amount cause a high temporal variability of the IW assets.

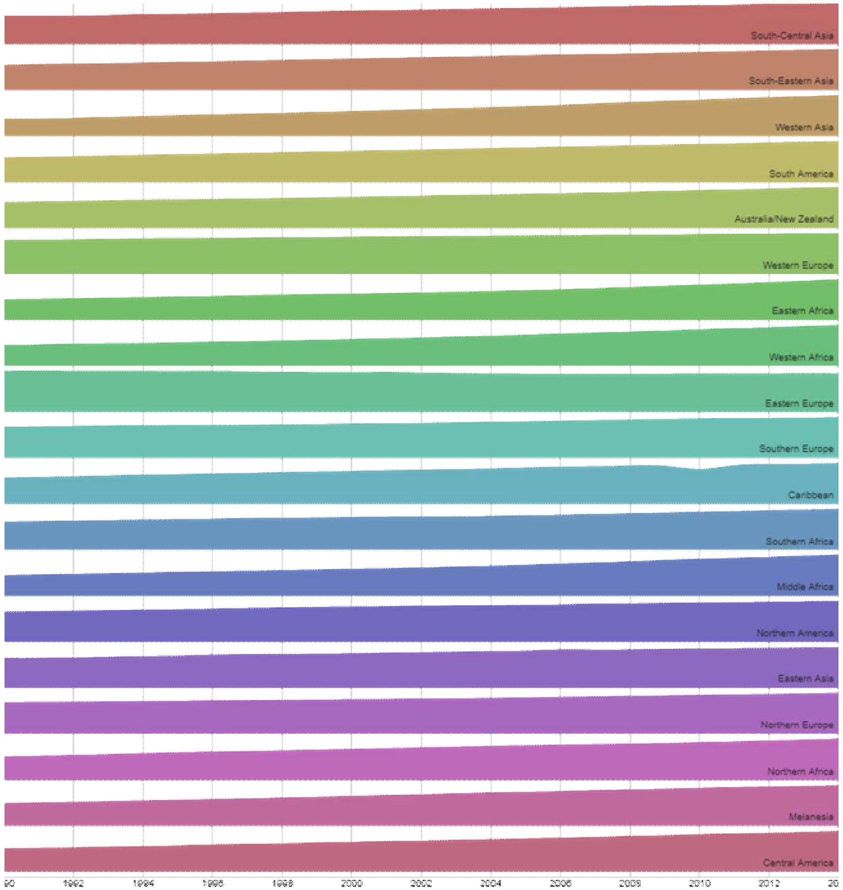
While figure 2.7 compares IW evolution over 1990-2014 for different income levels, figures 2.9-2.11 are dedicated in each type of capital and its evolution over 1990-2014, for different geographical regions.



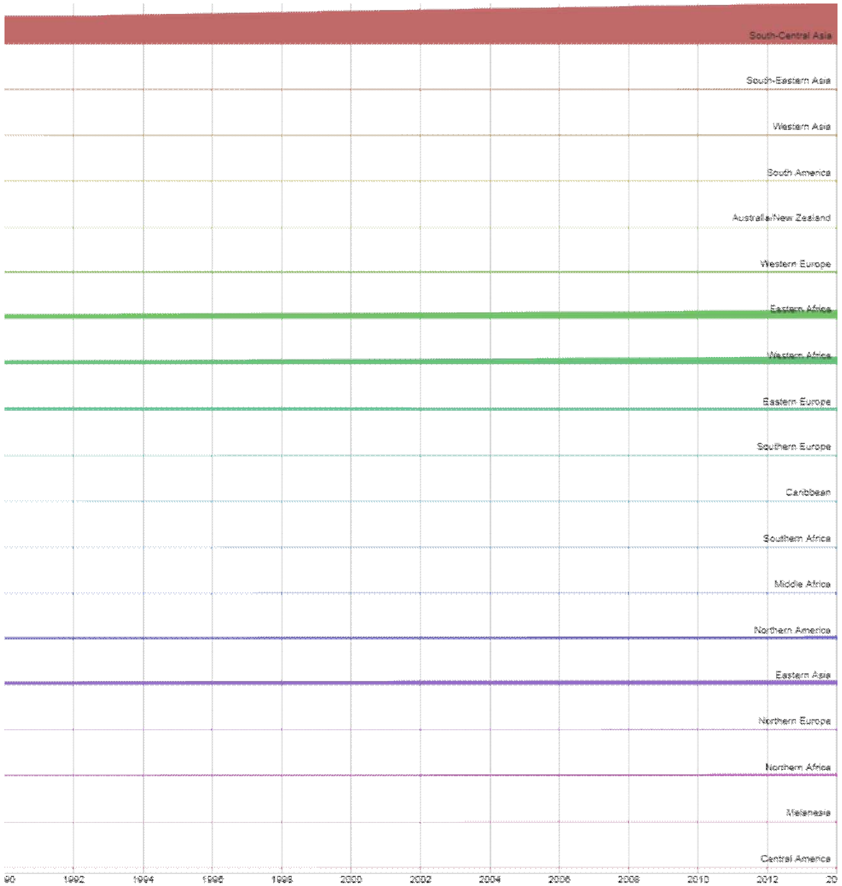
The general trend of natural capital evolution per region (shows the behavior) over 1990-2014. Natural capital levels are illustrated with lack of parallelism. Relative changes over time per region are visible.

A visual comparison of the natural capital assets among regions (same scale used) over 1990-2014. The thickness of each area represents the level of natural capital.

Figure 2.9: Natural capital trends over time

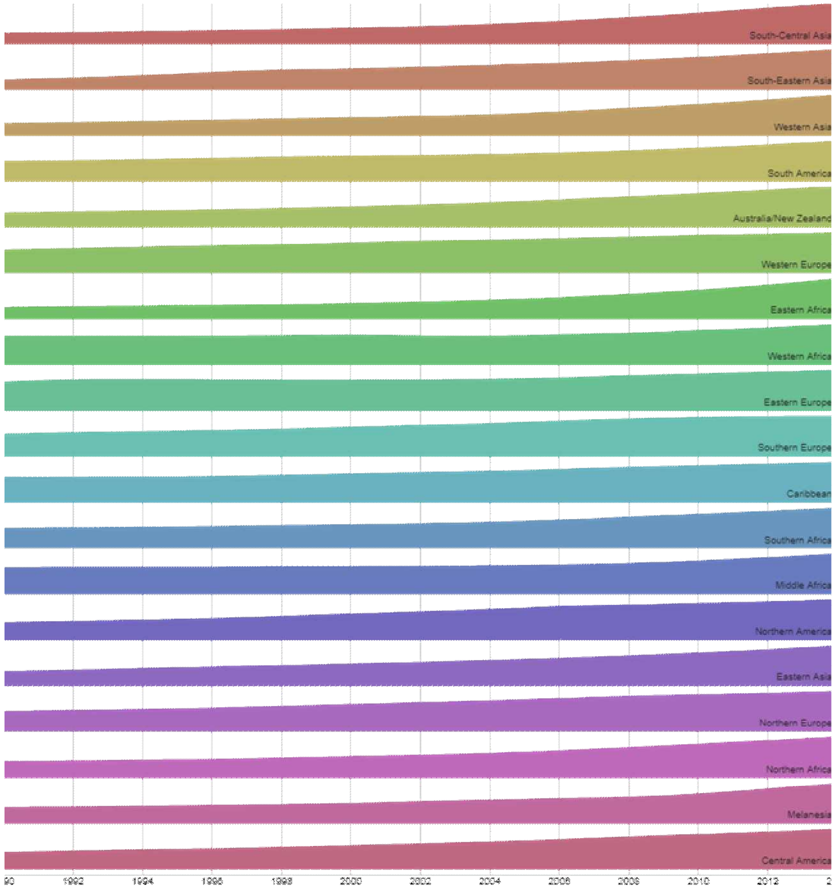


The general trend of human capital evolution per region (shows the behavior) over 1990-2014. Humal capital levels are illustrated with lack of parallelism. Relative changes over time per region are visible.

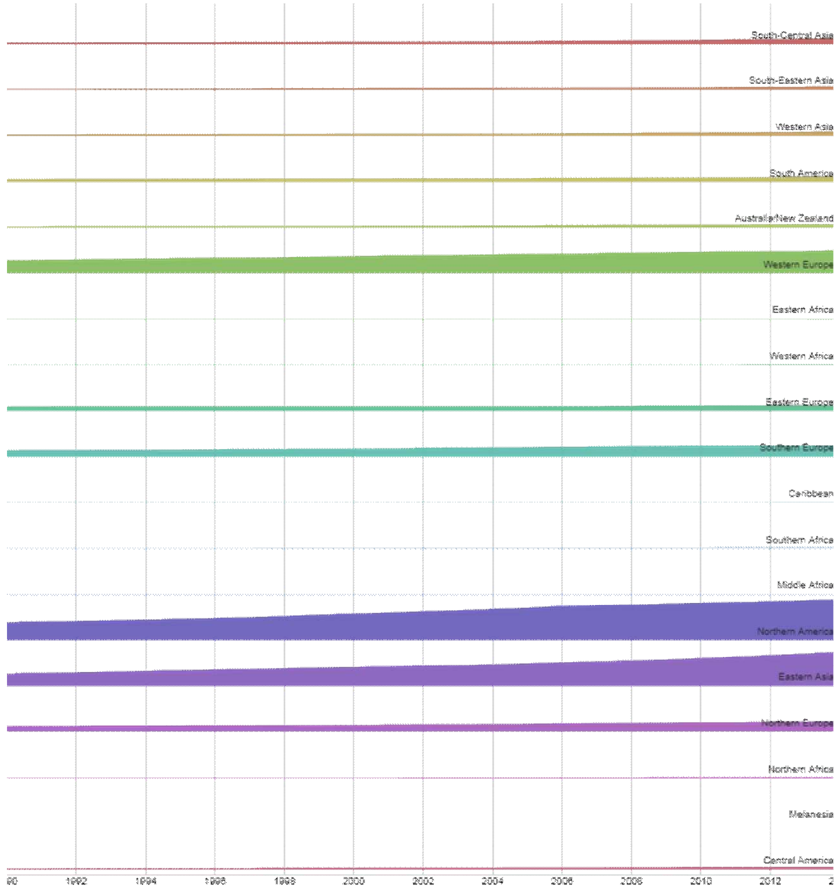


A visual comparison of the human capital assets among regions (same scale used) over 1990-2014. The thickness of each area represents the level of human capital.

Figure 2.10: Human capital trends over time

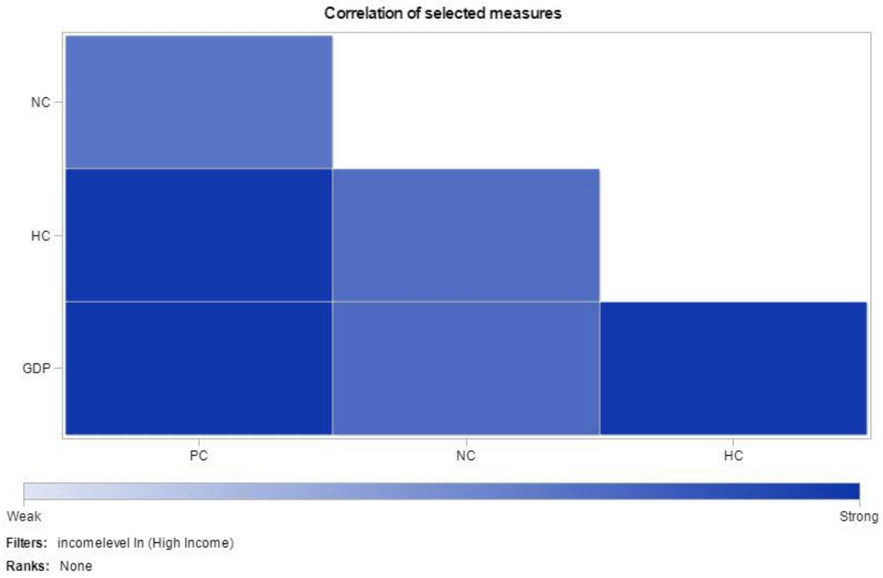


The general trend of produced capital evolution for each region (shows the behavior) over 1990-2014. Produced capital levels are illustrated with lack of parallelism. Relative changes over time per region are visible.

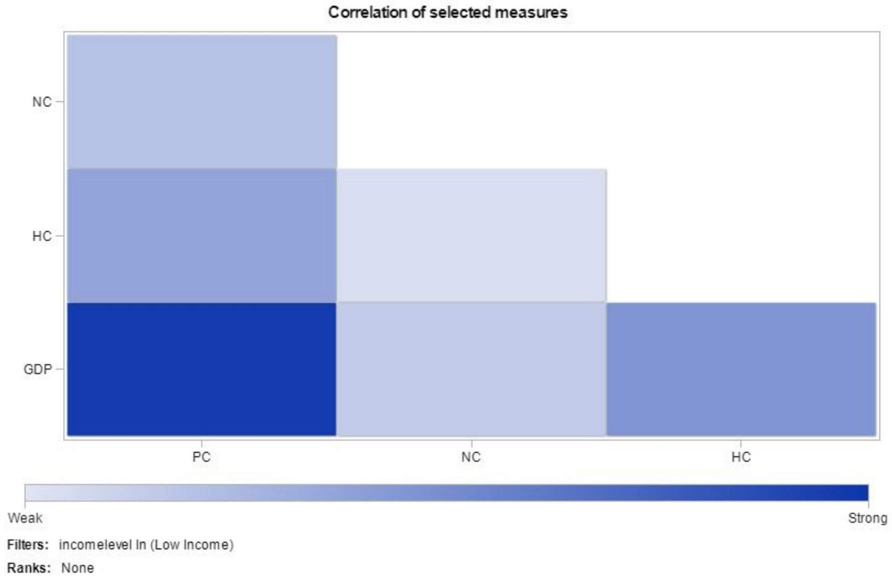


A visual comparison of the produced capital assets among regions (same scale used) over 1990-2014. The thickness of each area represents the level of produced capital.

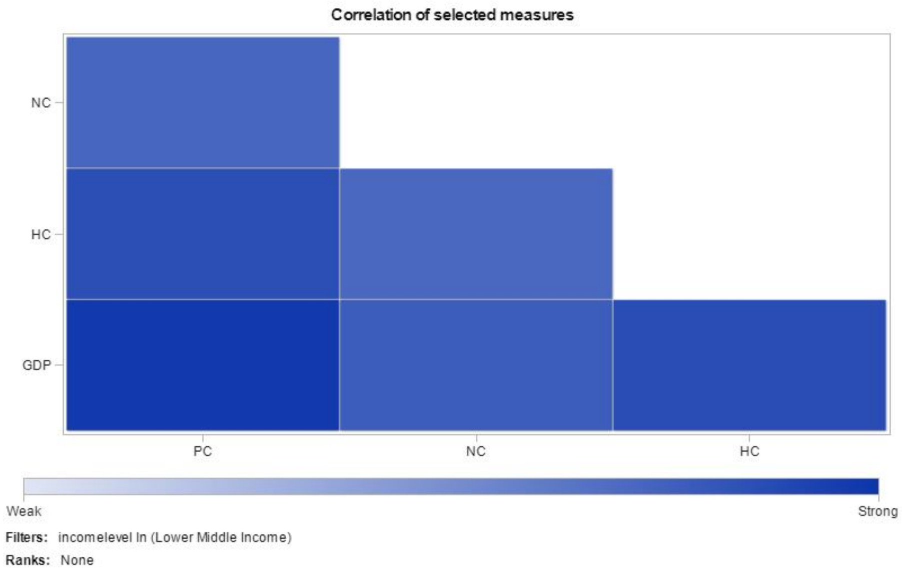
Figure 2.11: Produced capital trends over time. Area graphs were obtained using RAWGraphs



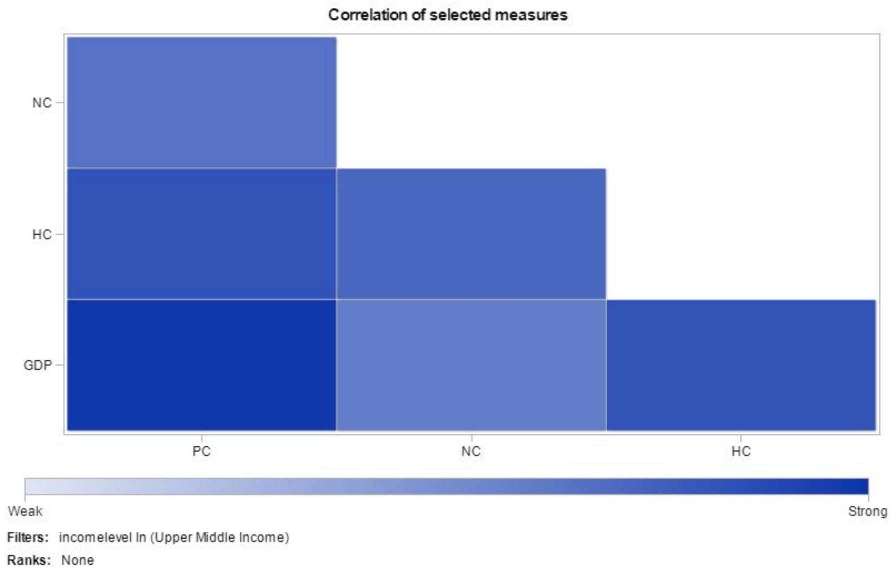
(a) High income countries



(b) Low income countries

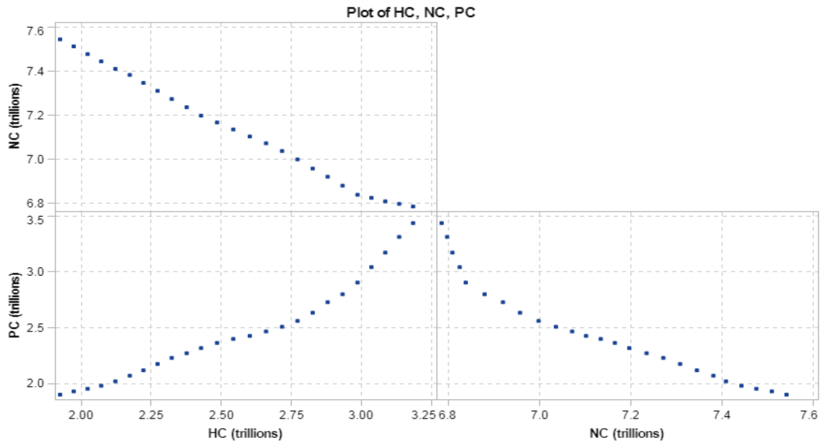


(c) Lower middle income countries



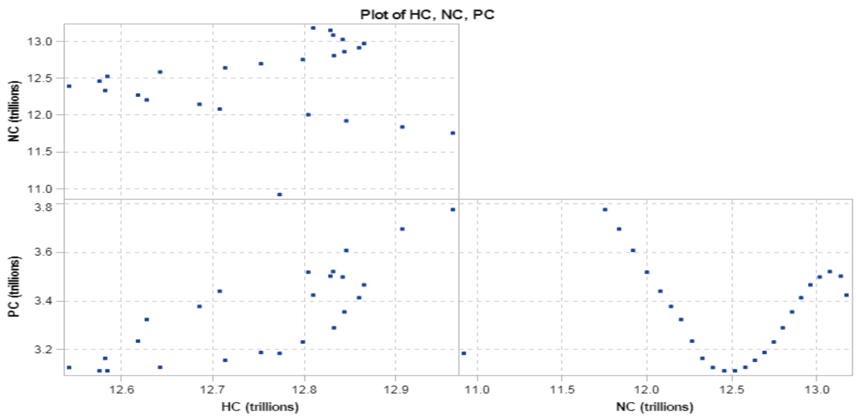
(d) Upper middle income countries

Figure 2.12: The correlations among capitals and GDP per income level classification through 1990-2014. Note: Correlation matrices were obtained using SAS Visual Analytics7.3



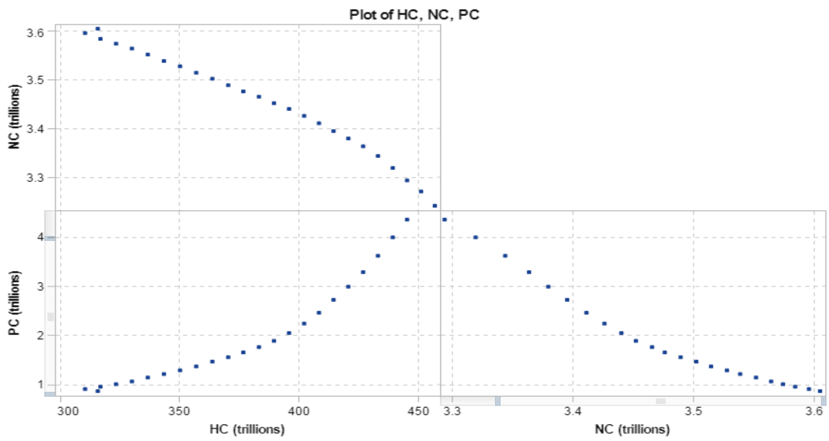
Filters: country In (Brazil)
Ranks: None

Brasil



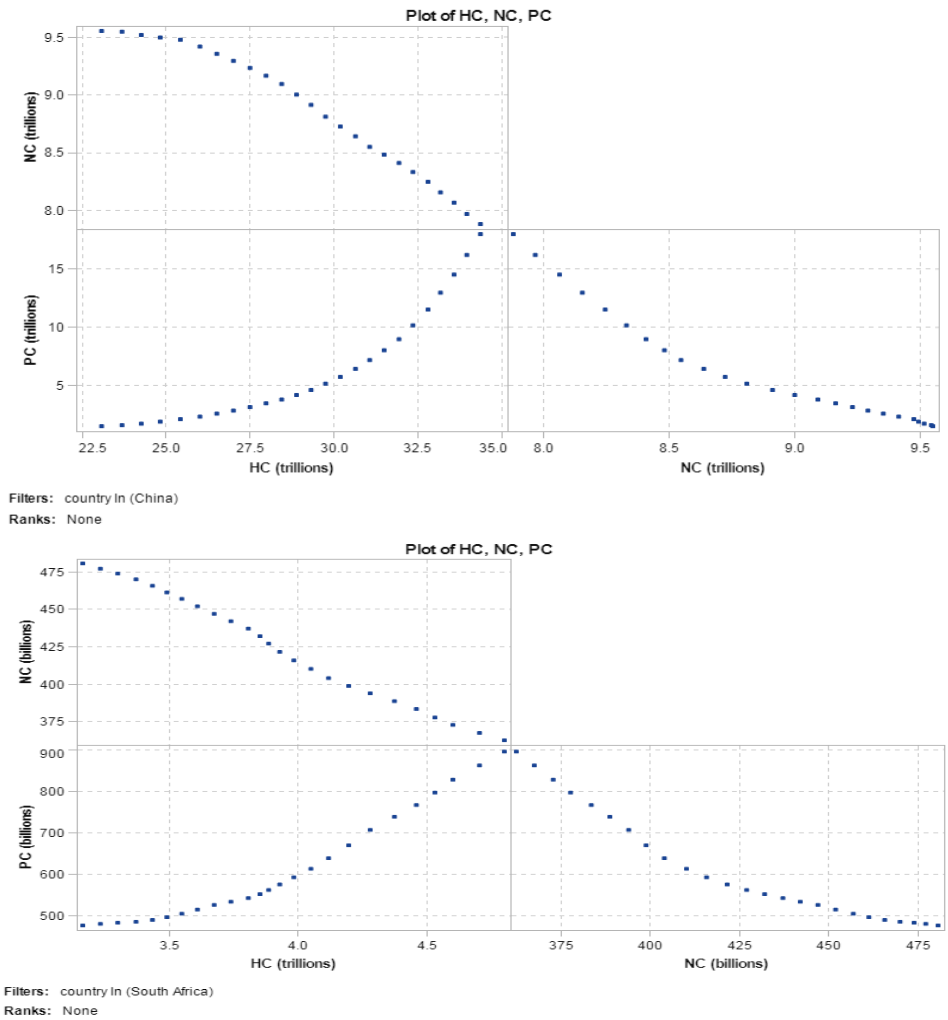
Filters: country In (Russian Federation)
Ranks: None

Russia



Filters: country In (India)
Ranks: None

India



China

South Africa

Figure 2.13: Correlations among capitals in BRICS countries over 1990-2014. Human capital vs Produced capital vs Natural capital scatterplots

Figure 2.12 reflects the growth model of each income category. Figure 2.12 actually reveals to what extend an economy depends on a certain type of capital. The bottom row of each correlation matrix uncovers policies for growth and development. Natural capital seems to have limited contribution to the creation of GDP compared to the other types of capital, in all income categories. In low income countries, natural capital has the minimum contribution to the GDP creation. In figure 2.13 we make an additional focus on the relationship between capitals in BRICS countries. Russia is the country that differentiates severely the trends compared to the other BRICS countries.

3. Spatial distribution of natural capital

In this section, we see in what proportions the global natural capital is partitioned in regions and income levels. The sum of 25-year natural capital per country and per income level is illustrated using a number of graphics. With four visual versions of the same quantities, in figures 3.1-3.4, we support different views of natural resource management. In all figures, we succeed to view and compare numerous numbers of values; far too many for a bar chart.

Figure 3.1: Distribution of natural capital by income level and by region.
Note: Natural capital assets are summed up over 1990-2014 time period. Sunburst was obtained using RAWGraphs

In the sunburst diagram of figure 3.1, the basic idea is to divide a circle into a number of arcs (segments), each representing one region. An inner circle is also divided into arcs covering income categories, while color shows region names for the aggregated natural capital values.

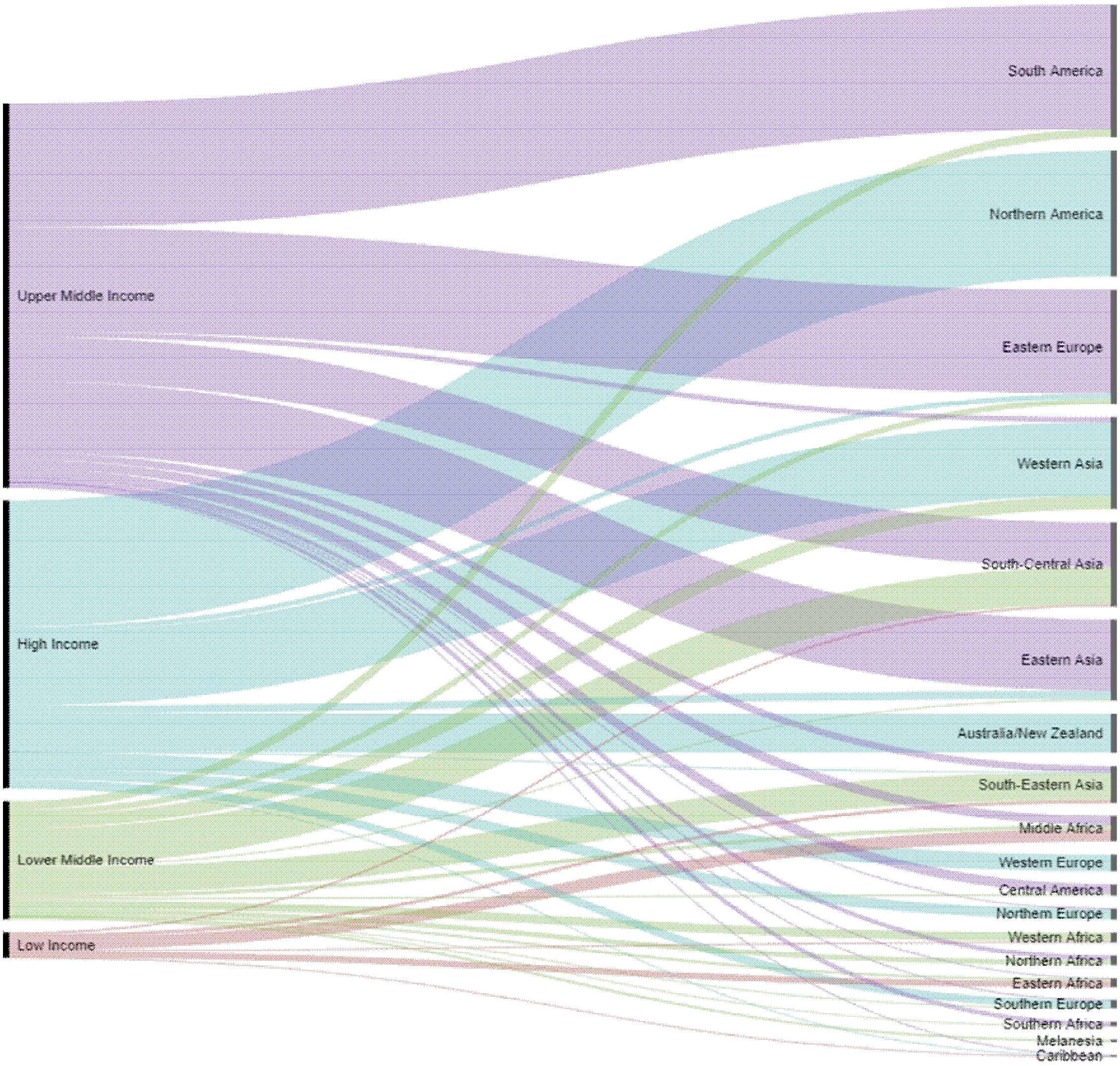


Figure 3.2: Natural capital distribution by income level and by region.
Note: NC assets are summed up over 1990-2014 time period. Alluvial diagram was obtained using RAWGraphs

The visualization in figure 3.2 displays the relationship between income levels and regions where the natural capital came from. It allows readers to highlight an income level or region to see the individual relationships between these categories. The ranking of the regions from highest to lowest based on their natural capital, is made in the right column of figure 3.2.

Figure 3.2 clearly shows that South and Northern America, Eastern Europe, Western South-Central and Eastern Asia are ranked high in their natural capital assets. It is worth noticing that the geographical area of Eastern Europe is significantly smaller than the rest of the top ranked regions. Nevertheless, Eastern Europe is impressively rich in natural resources compared to the economically integrated Western and Northern European countries in total.

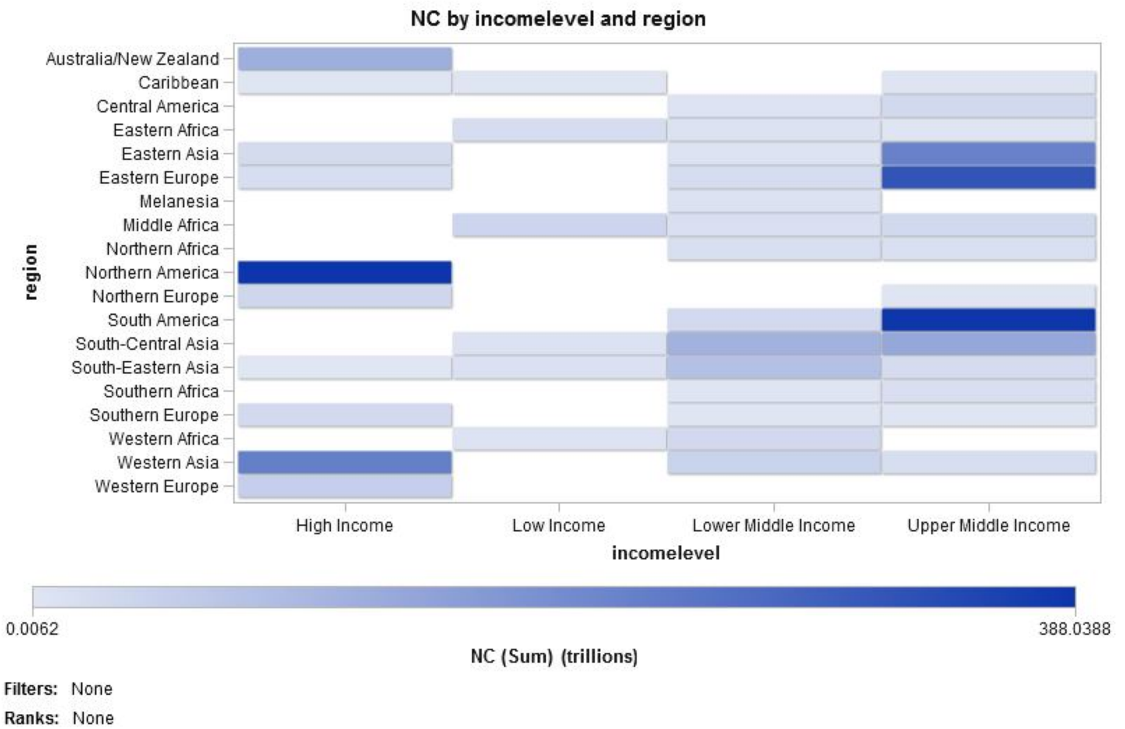


Figure 3.3: Distribution of natural capital by income level and by region.
Note: NC assets are summed up over 1990-2014 time period. The darkest colors stand for the highest levels of natural capital. Heat map was obtained using SAS Visual Analytics 7.3

The leading regions in natural capital shares are clearly noticeable in the heat map of figure 3.3. The dark blue rectangles (signing high values of NC variable) that are observed in high income and upper middle-income countries, show immediately and clearly that, more integrated – more developed countries preserve and/or manage sustainably their natural assets.

The tree map of figure 3.4 is a rectangular container, which is divided into smaller rectangles. The tree map resides in the category of visualizations that feature part-to-whole relationships (Few, 2014). As figure 3.4 reveals, the highest share of natural capital stems from the Americas (27.111% of the global natural capital). China plays an important role contributing 8.81% to the global natural capital. 12.39% of the world natural capital belongs to Russian Federation. Saudi Arabia is the second Asian contributor (5.88% of the global natural capital). Smaller amounts of natural capital are embodied in Iran, Australia, India, Indonesia. Furthermore, it is obvious that high income and upper middle-income countries dominate, taking the largest rectangles of the global tree map.

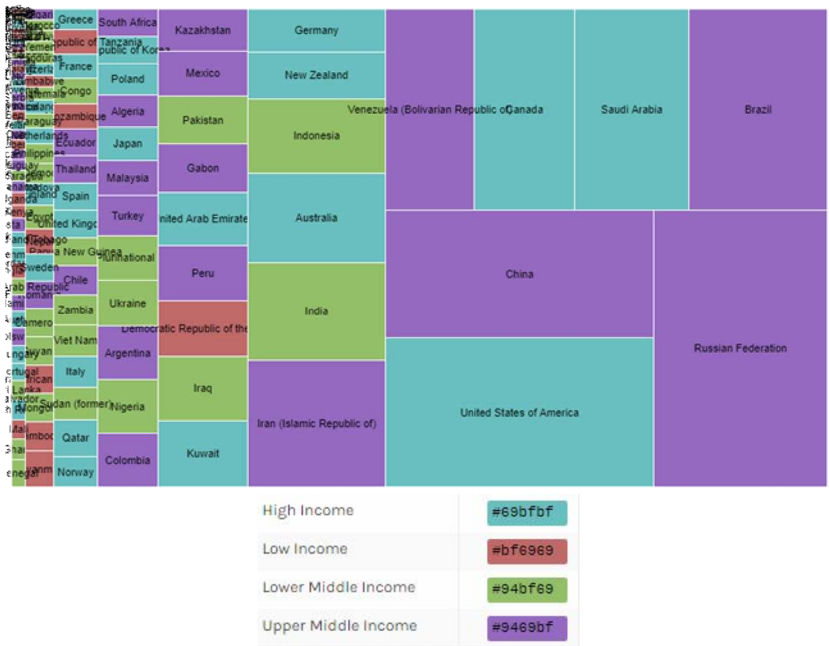


Figure 3.4: Shares of natural capital over income categories and countries.
Note: Treemap of natural capital by country and income level (obtained by RAWGraphs)

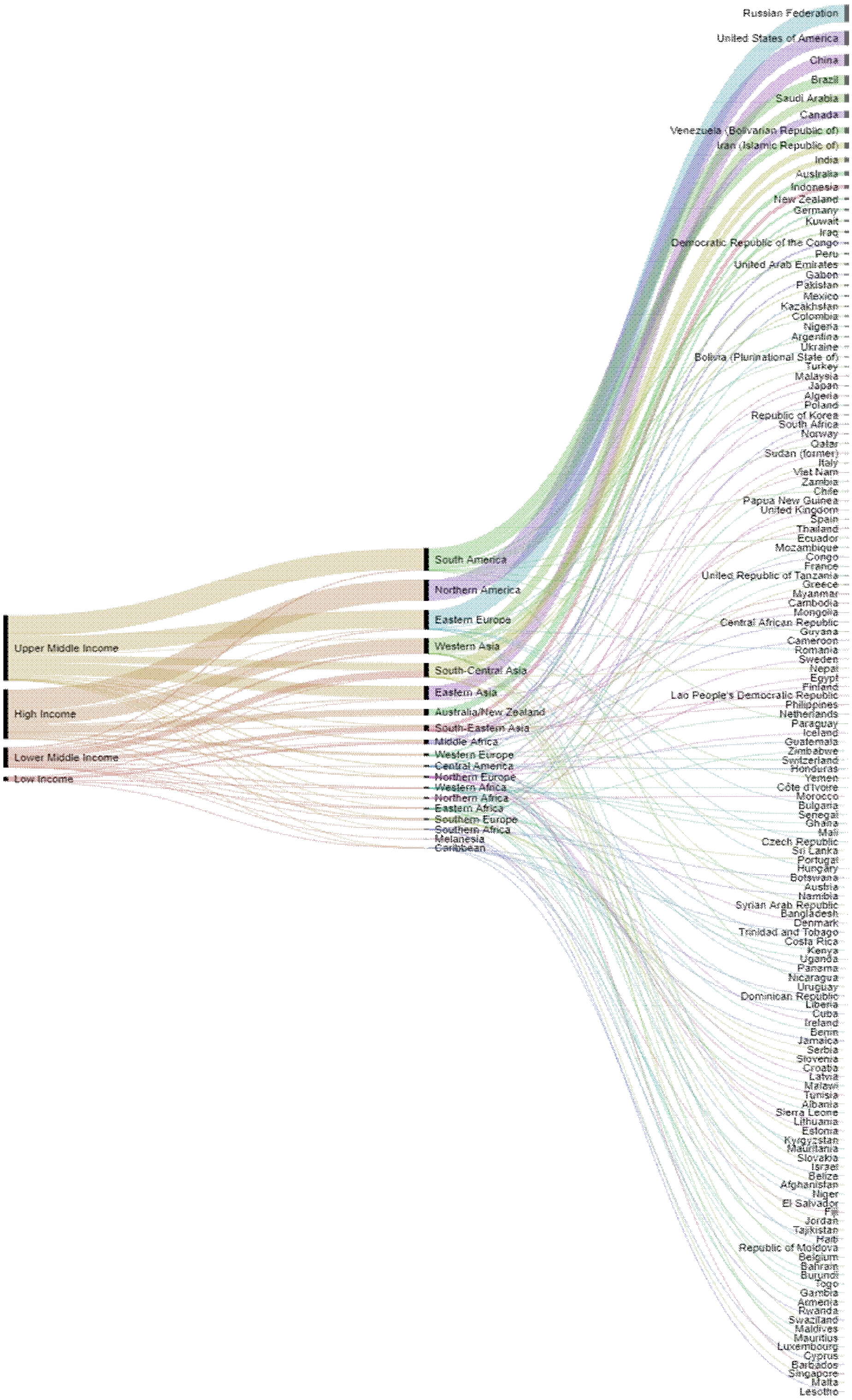


Figure 3.5: Distribution of natural capital by region and country. The figure makes the ranking of the countries from highest to lowest based on their natural capital, in the third column of the figure. Alluvial diagram was obtained by RAWGraphs

Figure 3.6: Distribution of natural capital by country over 1990-2014. Word size is proportional to country's natural capital. The bigger the name, the richer in natural capital the country is. Word cloud was obtained by SAS Visual Analytics 7.3

Figures 3.5-3.6 perform a ranking of countries, according to their natural capital assets.

4. Pollution and economic growth: an empirical investigation

In this section we investigate the degree of responsibility for the global production of air pollution (as measured and estimated by carbon damage variable) in geographical regions and regions of different income level (Halkos and Tsilika, 2017). We also seek for correlations between income level and carbon damage.

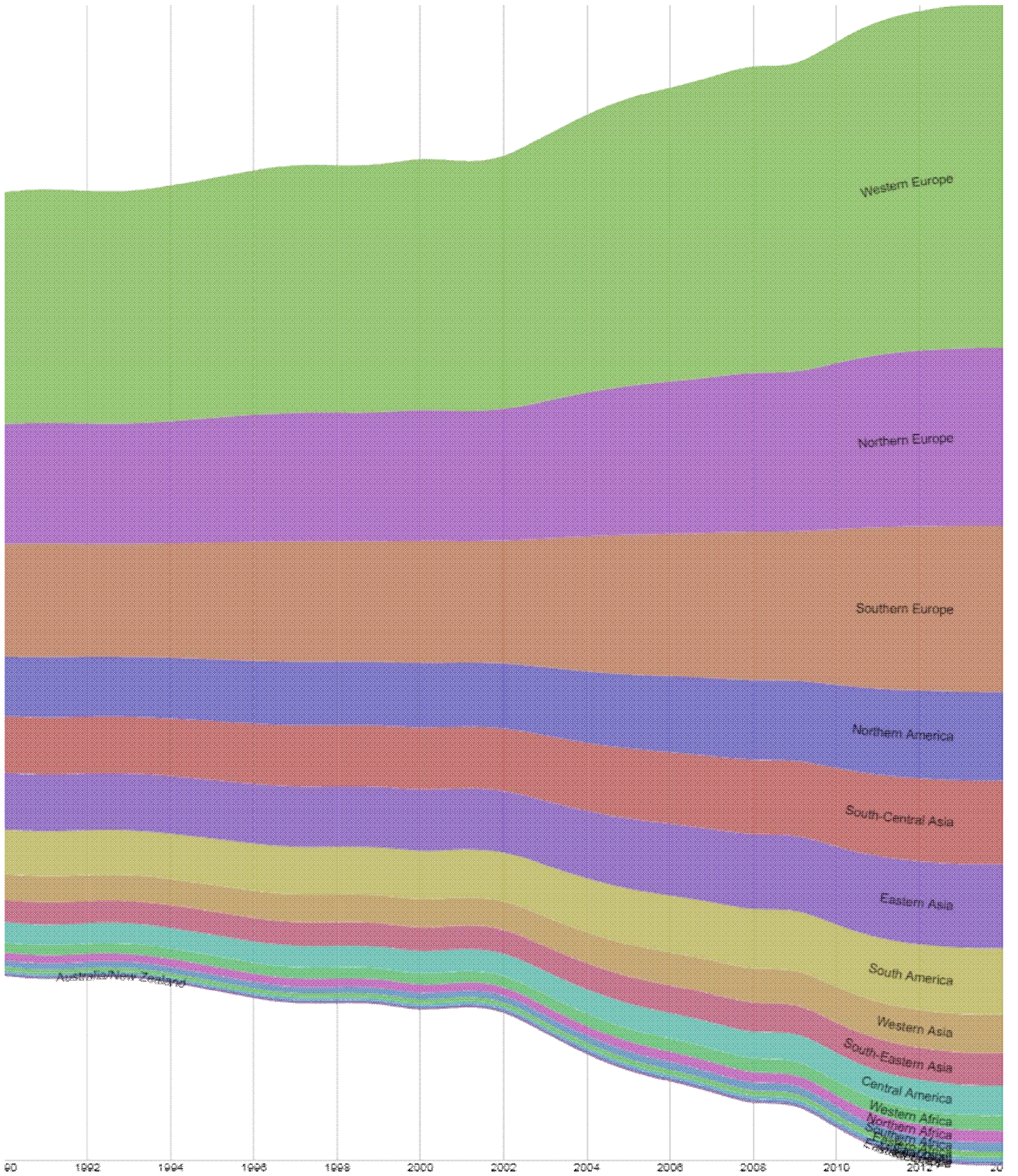


Figure 4.1: Carbon damage shares by region through 1990-2014.
Note: Area graph was obtained using RAWGraphs

In figure 4.1, areas represent the carbon damage and are sorted according their ranking. It is obvious that European regions take the first places. Let's confront some more questions. Is there a causal relation of pollution and economic growth? To what extend are carbon damages the result of economic growth?

Figure 4.2 depicts the trends and the size of carbon damage (figure 4.2(a)) and capital assets (figures 4.2 (b-d)) of the nations of the four income categories over the 25-year period under study. We observe the same trend over time for carbon damage and PC assets in the global framework. So figure 4.2 gives evidence to connect pollution with economic growth.

Figures 4.3(a-b) present the relationship between air pollution and economic growth (Wiedmann et al., 2015). Information for Parallel Coordinates plot can be found in (Heinrich and Broeksema, 2015). It is evident that more integrated (i.e. high income and upper middle income) countries are mainly responsible for carbon emissions.

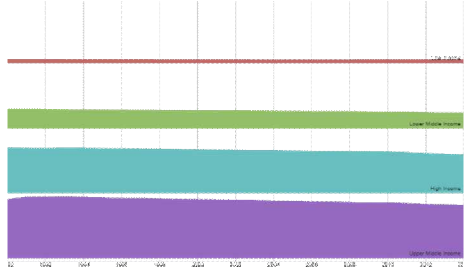


Figure 4.2(b): A visual comparison of the NC assets among income level (same scale used) over 1990-2014

Figure 4.2(c): A visual comparison of the HC assets among income level (same scale used) over 1990-2014

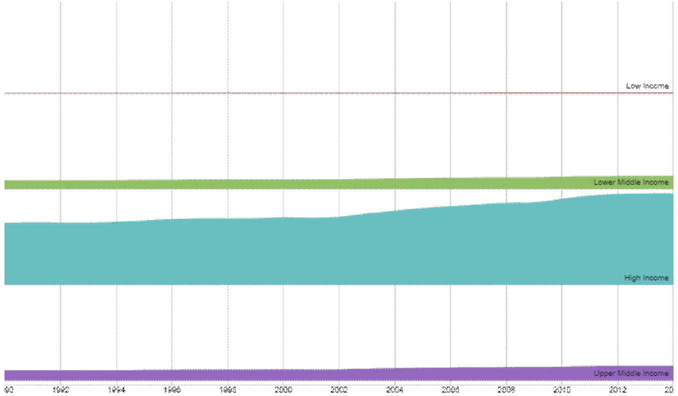


Figure 4.2(a): A visual comparison of the carbon damage among income level (same scale used) over 1990-2014

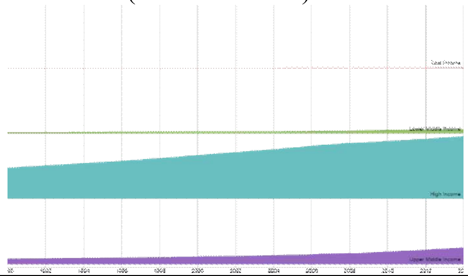


Figure 4.2(d): A visual comparison of the PC assets among income level (same scale used) over 1990-2014

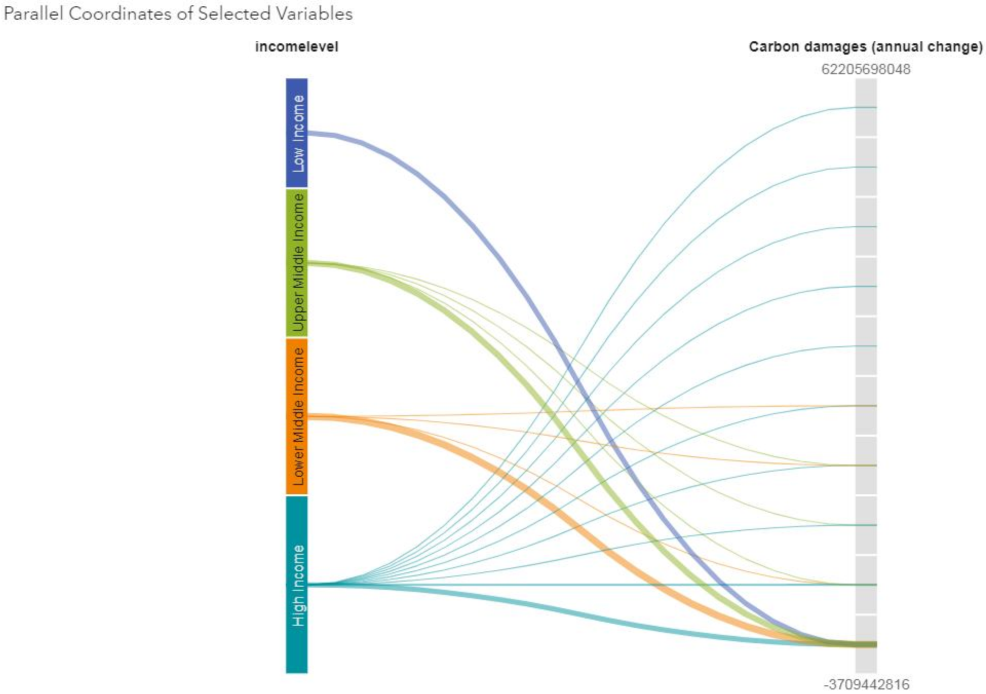


Figure 4.3(a): Carbon damage distribution by income level

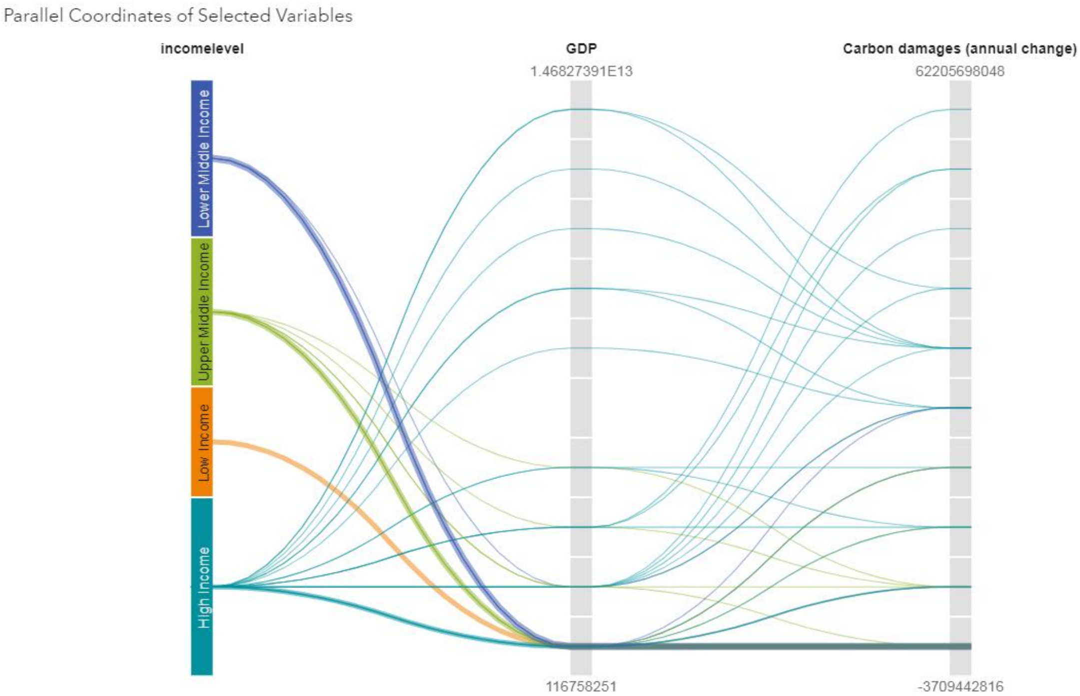


Figure 4.3(b): Carbon damage distribution by income level and GDP.
Note: Parallel coordinates plots were obtained using SAS Visual Analytics 8.2 (on SAS Viya)

5. Conclusions

Economists tend to provide rather simple interpretation from conventional graphs and tables from empirical analysis. With the advances in mathematics visualization techniques, we show it is importation to take further action for conveying more interpretations with more clustering on different groups of the world. Performance measurement in inclusive wealth can provide a guide for each country where status and its change over time matters (Kurniawan and Managi. 2017). Identification of any social and economic changes might have an impact to inclusive wealth and its decomposed wealth such as natural capital (Rajapaksa, et al., 2017).

This paper provided new insights of Inclusive Wealth data with better interpretation. We created perceptual and cognitive mappings of a world-wide situation for resource use and air pollution. Our methodological approach employed graphics to explore and analyze data. We have analyzed natural capital data, filtered by a number of variables and we have applied several visual analytics software. Natural capitals' world-wide distribution was visually modelled in a number of ways. Visual modelling sets the baselines for sustainable development goals.

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