Applicability of the Inclusive Wealth Index as a Measure of Sustainable Development for the Kingdom of Saudi Arabia

by

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Submitted to the Institute for Data, Systems, and Society
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Abstract

Following UNEP's global assessment of nations' sustainable development in 2012 and 2014, the Kingdom of Saudi Arabia's Inclusive Wealth Index (IWI) growth per capita has been negative. This study evaluates the extent to which the Inclusive Wealth Index is applicable to the nation. The study evaluates the method and makes new contributions for Saudi Arabia by adding components that had been omitted in the initial assessment, such as fisheries and minerals. The stocks for the fossil fuels had been changed to represent technically recoverable reserves, addressing the current paradox of increasing reserves. The global database sources are replaced with the local Saudi for 1999 until 2013. As a result, the new IWI is found to be closer to the 2014 report in absolute numbers and in comparable in the relative figures to the 2012 report, representing a still negative, unsustainable growth. The second part of the study looks at adapting the Inclusive Wealth Index to a subnational level, revealing large regional discrepancies between the Eastern Province and the Central regions, such as Mecca, Riyadh and Medina.

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Contents

List of Figures

List of Tables

Chapter 1

Introduction: Sustainable Development in the Kingdom of Saudi Arabia

1.1 Problem Introduction

Historically, the Kingdom of Saudi Arabia (KSA) has always been centrally governed. Since 1970, the government has been issuing National Plans, which are 'blueprints of reforms', sets of forward-looking policies.[1] Particularly, the last two Plans, the Ninth (2010-2014)[2] and the Tenth - *Vision 2030*[3] - have been calling for diversification of the economy. *Vision 2030*, in particular, supports the continued shift of the economy away from its dependence on the vast oil reserves. For instance, the Kingdom plans for non-oil exports' share of GDP to increase from 15% to 50% by 2030.[4]

The metric that the Kingdom is notably using for its development is Gross Domestic Product (GDP). The Kingdom's GDP growth rate has been on average around 4% over the past ten years, oscillating between 0.2% (2013) and 10% (2011)1-1[5], which follows the trend of oil prices quite closely. However, the GDP growth rate as a measure tells us little about the sustainable development of a country. Figure 1-1 shows an increase of the Human Development Index, however, that too shows only a facet of development and alone it does not answer the question of the substitutability of the progress.

Saudi Arabia is in the active transitioning phase with ambitious plans; however, *the fea-*

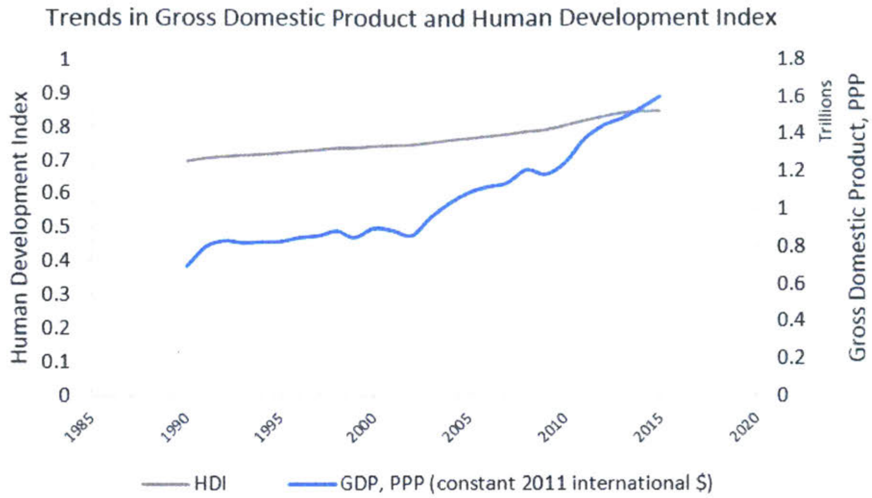

Figure 1-1: Gross Domestic Product (PPP in 2001 USD) and Humand Development Index across the years. Source: World Bank[7] and UN Human Development Index [19]

sibility of high economic growth is threatened by the underdevelopment of social and physical infrastructure, according to A. San.[6] The problem could be exacerbated in the light of Saudi Arabia's rapidly growing population. The annual population growth rate has been between of 2 and 3%, which will result in a 50% increase in the population from its current levels by 2040, (see fig.1-2). This demographic transition will naturally lead to an associated increase in demand for resources such as potable water, energy, transportation services, as well as employment and social support systems, such as hospitals and universities.

The National Plans have always been sets of forward-looking policies for the development of the country. However, there are a number of concerns about using GDP as a metric for capturing economic development. In order to support the population and the country's stability, it is in the government's interest to ensure the development is sustainable: with a strong economic base but also with an equal support for its social and environmental resources. In the recent governmental calls for accountability and stricter auditing in all sectors, introducing a measure of the sustainable development could be an important tool.

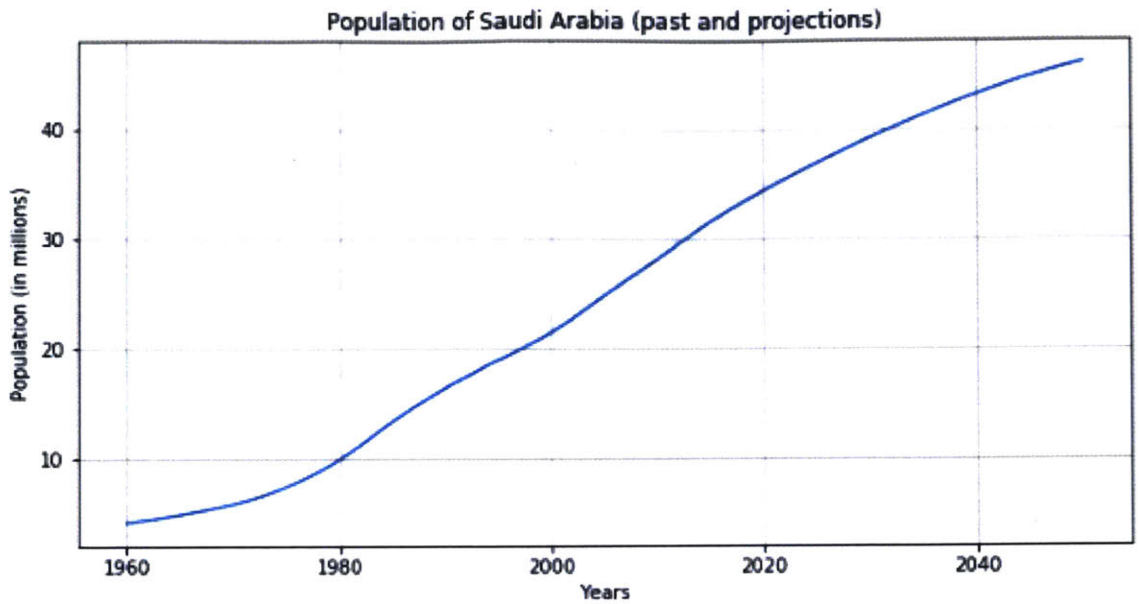

Figure 1-2: Saudi Population: past and future projections. Source: World Bank[7]

1.2 Research Questions and Goals

The focus of this thesis is the application of the Inclusive Wealth Index (IWI) as a metric for sustainable development. There have been two global IWI assessments done in the past, in 2012 and 2014.[8],[9] However, for its application in policy-making on either national or subnational level by the Saudi government, there is a question of whether a global-scale metric is relevant and suitable as a basis for decision-making. This thesis explores this issue by attempting to answer the following research questions:

1. Is IWI an appropriate metric for Sustainable Development analysis?

2. If so, to what extent is the globally estimated IWI an appropriate metric for the Kingdom of Saudi Arabia?

3. If it appropriate, how can the IWI be used for policy making when it is a backward-looking metric, capturing the past?

Finally, the Kingdom of Saudi Arabia is a large country with different regions holding various resources. Therefore, the objective of this research is to introduce a subnational spatial dimension to the metric to allocate the resources. The final question is therefore:

4. For a large country such as KSA, to what extent could the IWI metric be applied regionally?

1.3 Structure and Approach

This thesis is divided into three major parts, spanning seven chapters. Part I presents an overview of the various sustainability metrics (Chapter 2), the underlying theory and methodology for the IWI (Chapter 3) and the relevance of the results of the existing global assessments done in 2012 and 2014 for KSA, before concluding with the results of the updated assessment on the national level (Chapter 4).

Part II is an investigation of the fourth research question, providing an overview of literature on regionalizing the global development indices (Chapter 5), and revision of the methodology to overcome any data sparsity issues on the Saudi subnational scale (Chapter 6).

Part III discusses the application of IWI for the policy-making specifically in the Kingdom (Chapter 7) and addresses the third and fourth research questions.

Finally, Chapter 8 draws conclusions from the study, makes recommendations for policy-making, and proposes new questions for future work.

Chapter 2

Measuring Sustainability

In September 2015, all 193 member states of the United Nations adopted the 17 *Sustainable Development Goals* (SDGs) as a successor to the *Millennium Development Goals* agreed on in 2005. The SDGs include 169 specific targets, cutting across the three dimensions of development: economic, social and environmental. The agreement is non-binding. However, despite this diplomatic effort, the high number of SDGs and specific objectives reflect the complexity of such an agreement. Sustainability as such, is a concept hard to define, let alone to measure due to its multifaceted nature. This chapter provides an overview of the concepts involved in the definition, and a list of the most popular metrics currently in use for the governments to capture sustainable development progress.

2.1 Definitions of Sustainability

Historically, the concept of sustainability has been a challenge to capture and define. The most frequently quoted definition is from the *Brundtland Commission*'s report: *Sustainable development is the kind of development that meets the needs of the present without compromising the ability of future generations to meet their own needs.*[11] The definition suggests that the *Commission* mostly expects that the future generations will have no less of the means to meet their needs than we as the current generation do, leaving the debate open on the issues of intergenerational justice. For instance, it implies that the current generation should leave as much of the 'productive' base as it had itself inherited. However, there is no mention as to how this productivity base could be measured. The Nobel Prize winner, Robert Solow in his 1991 speech entitled *"Sustainability: An Economist's Perspective"* puts forward that sustainability needs to be defined as the societal outcomes that allow future generations to be at least as well off as people are today, which agrees with the *Brundtland* definition. It is not that sustainability requires saving specific resources; in fact, it is that there is *sufficient capital*, a combination of human, physical and natural, to maintain the living standards of today. [12]

This definition has been extended further: Ashford and Hall [13] differentiate it to four dimensions through the Global System for Sustainable Development (GSSD):

- *Economic production & consumption*, whereby economic production and consumptions do not threaten ecological systems,
- *Ecological configuration*, whereby ecological systems exhibit balance and resilience,
- *Governance & Politics*, whereby governance models reflect participation and responsiveness,
- *Institutions & Performance*, whereby institutions demonstrate adaptation and feedback

Within the scientific and policy-making communities, there is a fundamental debate on whether to follow *strong* or *weak* notions of sustainability. For *strong* sustainability there cannot be any depreciation in the stock of Natural Capital, because the Human Capital cannot substitute the life-support systems of the planet of the Natural Capital.[14] *Strong* sustainability implies that non-renewable resources cannot be depleted. By contrast, *weak* sustainability allows for one capital depletion to replace another capital of equal value, i.e. Human Capital can substitute for Natural Capital.

2.2 Metrics of Sustainability

Table 2.1 provides a summary of most popular metrics in chronological order in the domain of sustainability, such as *Gross Domestic Product*, *Human Development Index*, *Ecological Footprint*, *Happy Planet Index*, *Adjusted Net Savings* and *Inclusive Wealth Index.* Below is a brief introduction to each of them.

Table 2.1: Overview of Sustainability metrics

Metric	Economic domains	Environmental domains	Social domains	Inter-generational aspects
Gross Domestic Product	Consumption, Investment, Governmental Spending, Exports and Imports	-	-	-
Human Development Index	Gross National Index	-	Life expectancy at birth, schooling	-
Ecological Footprint	Production, Import-exports, consumption	Materials and Energy flows	-	-
Happy Planet Index	-	Ecological Footprint	Experience Well-being, Life Expectancy	-
Adjusted Net Savings	National Accounting aggregates: savings, depletion, and degradation	Agriculture, Forests, Oceans, Energy and emissions, Water and sanitation, Environment and health	Population	-
Inclusive Wealth Index	Gross Capital Formation	Fossil Fuels, Agriculture, Forests, Fisheries, Minerals	Life expectancy, Schooling, Mortality rates, Population	Captured

Gross Domestic Product

Initially introduced in the 1930s, the *Gross Domestic Product* (GDP) stays as one of the most popular - although as we argue below - controversial measures of the sustainable development. Global Overview of the GDP growth is presented in fig. 2-1. The GDP is captured by the following equation:

$GDP = C + I + G + (X - M)$,

where C is consumption, I is investments, G is government expenditure, X is exports, and M is imports. This equation captures the flow of goods and services through the markets' transactions. However, even the chief architect of the measure, Simon Kuznets, is said to have warned "against equating its growth with well-being."[15] GDP takes account of the economic activities, many of which do not advance "real" economic development. Much of the literature on development argues that using the GDP as the sole metric prioritizes the gross revenue of a country at the expense of profitability, efficiency, sustainability, or flexibility.[16]

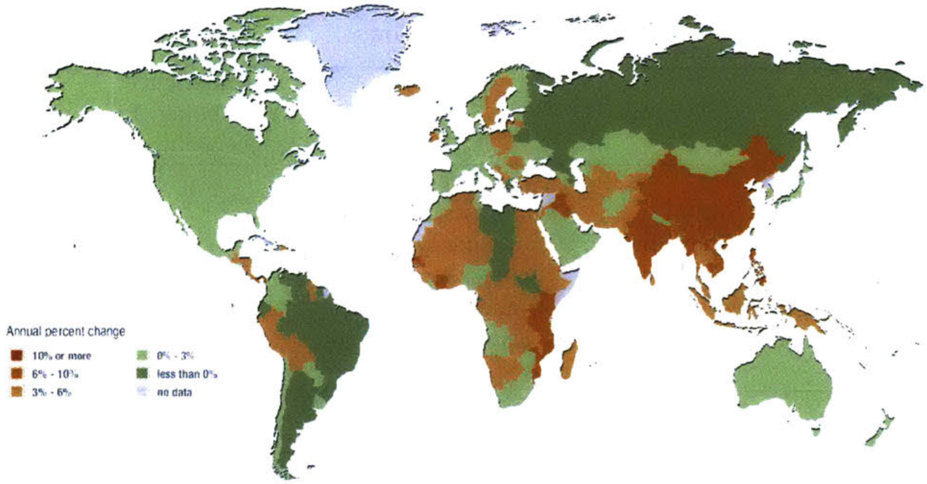

Figure 2-1: Global Overview of the GDP growth in 2016. Source: International Monetary Fund, World Economic Outlook (April 2016). Available at : IMF Data Mapper, http://www.imf.org/external/datamapper [18]

In fact, as Constanza et al. further point out, "increased crime, sickness, war, pollution, fires, storms, and pestilence are all positive for GDP because they increase the economic activity".[16] One of the most remarkable examples is the aftermath of the *Deepwater Horizon* oil spill in 2010. Despite the destruction of jobs and the environment, the event's contribution to the local GDP was, in fact, positive, showcasing the danger of using this metric for sustainability. The GDP also does not capture the nature of the economy. Saudi Arabian GDP's average growth of 5-6% over the last ten years is comparable to that of South Korea, for instance. However, the primary driver for the growth has been the vast oil reserves, whereas South Korea's was its manufacturing industry. In the first case the natural resources (oil) are being depleted; in the second they are sustained. The GDP does not capture any of these aspects.

Human Development Index

The emphasis of the *Human Development Index* (HDI), a metric devised in 1990, is people, as the name suggests. The human capital is identified as a critical determinant of growth and poverty alleviation, highlighted by the United Nations Millennium Development Goals and the Sustainable Development Goals.[17] It is assessed annually and in the 2016, among the the highest-scoring countries were Canada, the USA, Australia, and Saudi Arabia. Among the lowest human development indices was most of the Sub-Saharan Africa, Syria and Papua-New Guinea (see fig. 2-2)

HDI comprises three components (Table 2.1): life expectancy at birth, expected and mean years of schooling, and Gross National Income based on purchasing power parity. These three are thought to contribute to a long and healthy life, knowledge and a decent standard of living.[19]

The index then allows us to rank the countries annually. However, whereas this indicator is designed to complement GDP, it fails to take into account the population size, or the state of natural resources in a country. Therefore, it may not be a sufficient metric for measuring sustainable development.

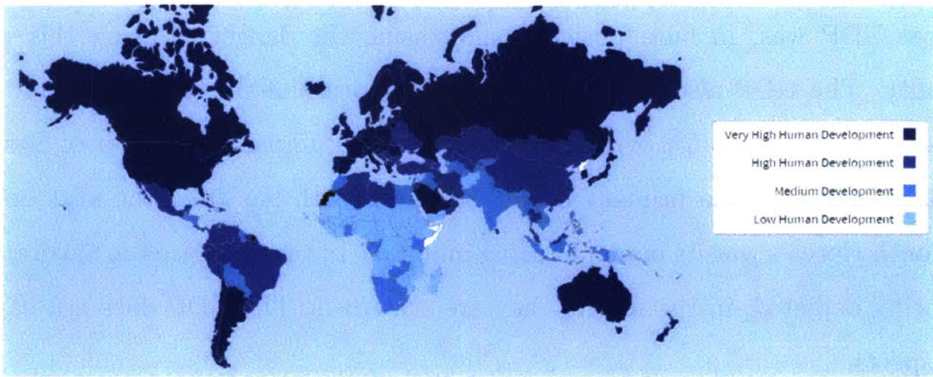

Figure 2-2: Global Overview of the HDI in 2016. Source: Human Development Report 2016. Available at: http://hdr.undp.org/en/content/human-development-index-hdi [19]

Ecological Footprint

Unlike the HDI, the *Ecological Footprint*, created in 1992, captures the elements of environment and economic activities.[20] Fundamentally, it has been designed to measure demand on and supply of nature at a particular moment on a national, regional or municipal level (see fig.2-3).

The supply and demand refer to the dynamics of a regional biocapacity, which is measured by the rates of resources consumption, waste generation, waste absorption, and resource generation (see Equation 2.1). The former two are measured as energy, settlement, timber and paper, food and fiber, and seafood. The latter two are measured in the carbon demand of various land coverages: built-up, forests, croplands, pastures, and fisheries. The units for the measures are global hectares, whereby one global hectare is the average productivity of all biologically productive areas on earth in a given year.

$$EF_C = EF_P + (EF_I - EF_E) \tag{2.1}$$

where EF_c is the ecological footprint of consumption, which indicates the consumption of biocapacity by a country' (or region') inhabitants.

EF_P is the ecological footprint of production, which looks at the consumption of biocapacity resulting from production processes, within a given geographic area, such as country or region. This measure mirrors the GDP

(EF_I-EF_E) is the net ecological footprint of trade that indicates the use of biocapacity within international trade.

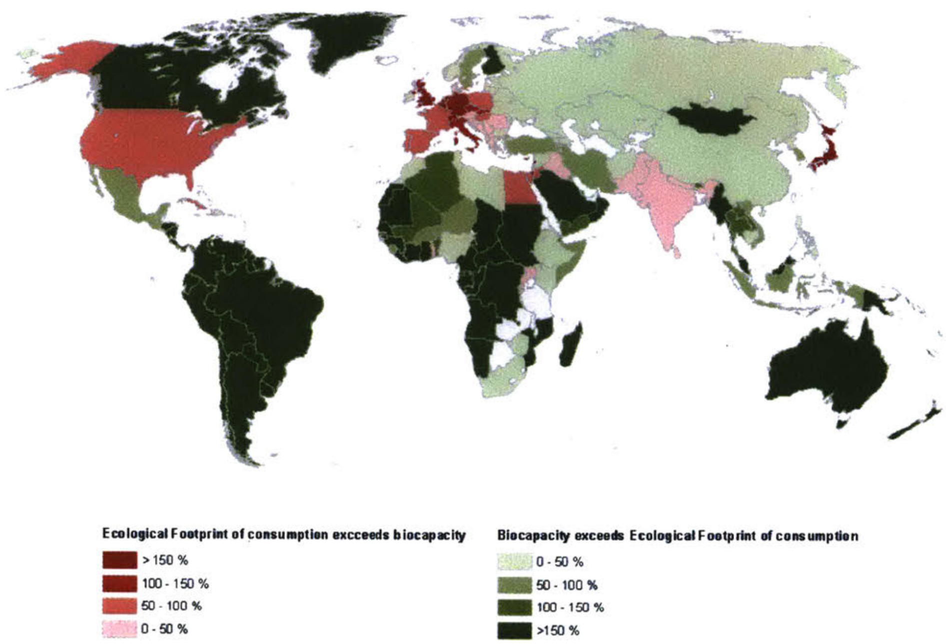

Figure 2-3: Global Overview of the Ecological Footprint for the world in 2016. Source: Global Footprint Network. Available from: http://www.footprintnetwork.org/countries/ [20]

Happy Planet Index

Created in 2006, the New Economics Foundation's *Happy Planet Index* looks at the human well-being and the environmental impact.[21] The *Happy Planet Index* is measured in global hectares *per capita*. Its equation is as follows:

$$HPI = \frac{Wellbeing * Life\ expectancy * Inequality\ of\ outcomes}{Ecological\ Footprint} \tag{2.2}$$

where *Wellbeing* is captured by surveys collected by the Gallup World Poll on *"How satisfied the residents of each country say they feel with life overall, on a scale from zero to ten.*[22]

Life Expectancy is an average number of years a person is expected to live in each country based on data from the UN.

Inequality of outcomes measures the inequalities between people within a country based on life expectancies and happiness perceptions. Inequality of outcomes is expressed as a percentage

Ecological footprint is the average impact that each resident of a country places on the environment, discussed in detail in the previous subsection. This index, however, does not

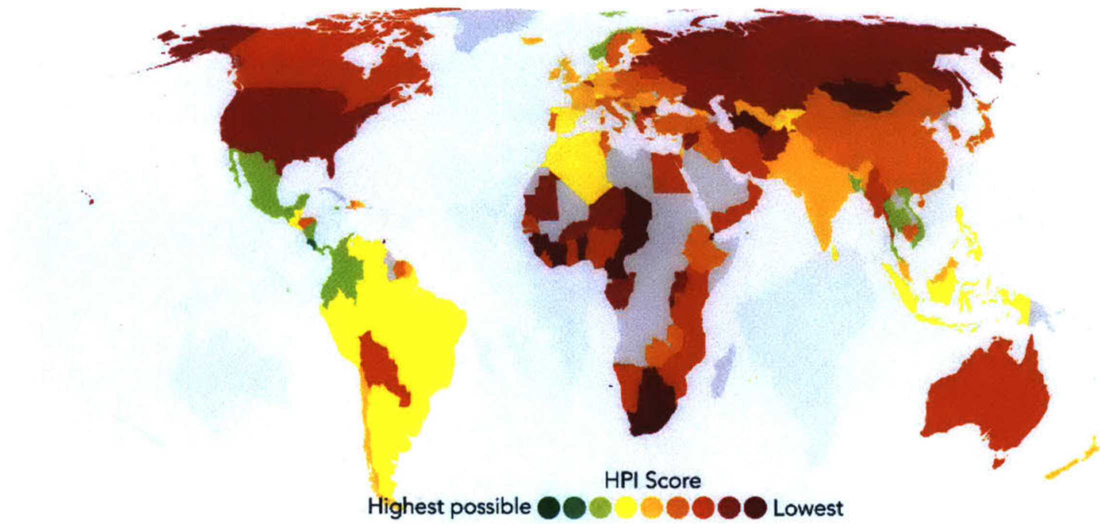

Figure 2-4: Global Overview of the Happy Planet Index in 2016. Source: Happy Planet Index: 2012 Report. Available from: http://neweconomics.org/2012/06/happy-planet-index-2012-report [21]

look at any economical impact and population size. Furthermore, the index is only available for the year 2012, due to limitation in the data availability. The overview of the global results is given in fig. 2-4.

Adjusted Net Savings

Also known as *G enuine Savings*, *Adjusted Net Savings* (2014)[23] - introduced in 2014 - looks at the changes in annual wealth, and the total amount of natural, human-made, and human capitals. It monitors whether the depletion of natural capital, such as minerals or forests, is compensated for by investment in other assets, such as human capital or infrastructure.[24] By definition, the *Adjust Net Savings* is net investment in produced capital minus net depreciation of natural capital plus the investment in human capital (education).[25] This metric follows the sustainable development goals, as well as the UN Millennium goals.

However, this metric assumes a constant population, and as the population has grown in all countries, it is unclear how the findings could be interpreted. Furthermore, by capturing a global set, the size of the sample is so large for these particular calculations, that the limitations in data compelled the authors to ignore changes in a number of potentially important capital assets, such as fossil fuels.[26]

Inclusive Wealth

The United National Environmental Program (UNEP) provided a new methodology, based on Nobel Prize Economist Kenneth Arrow's work on the Inclusive Wealth (IW) theory. In 2010 Kenneth Arrow et al. developed a theoretical framework for assessing whether economic growth is compatible with sustaining *well-being* over time.[26] This framework integrates natural, human, and reproducible capitals, as well as population growth, technological and health aspects. The largest deviation from the *Adjusted Net Savings* is the emphasis on the IW on the intergenerational aspect of sustainable development. The wealth creation for the current generation should not be occurring at the cost of the future generation. In other words, *by sustainable development we mean a pattern of societal development along which (intergenerational) well-being does not decline.*[26],[27]

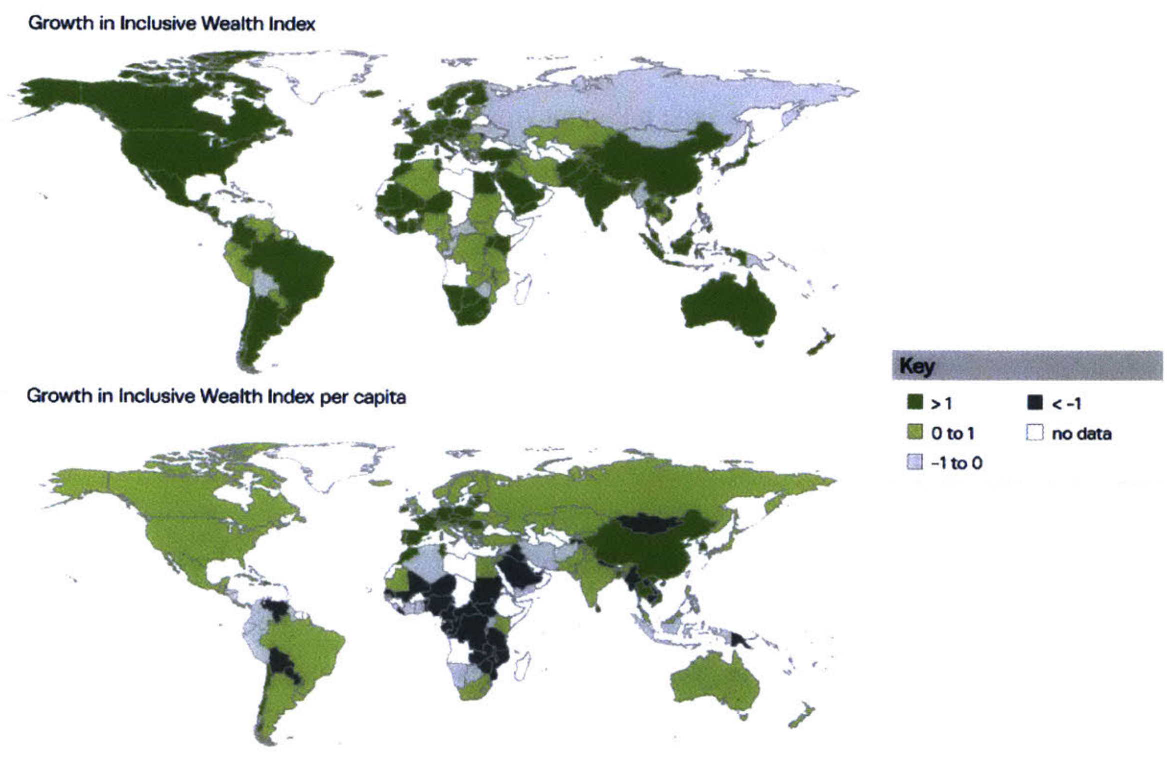

Figure 2-5: Global Overview of the Growth in the Inclusive Wealth Index and the Inclusive Wealth Index per capita by 2014. Adapted from UNEP Inclusive Wealth Report 2014.[9]

The IW focuses on the three main categories of capital for which relatively good global data is available. A nation's capital asset include natural capital (e.g. oil resources, land), produced capital (e.g. infrastructure, equipment, factories) and human capital (e.g. education, population). The Produced Capital essentially represents the entirety of the list of capital assets: accumulation of reproducible, or otherwise known as "manufactured" capital. Human capital is not transferable without cost from one person to another, because education is a means as well as an ends carrying an intrinsic worth, as the authors of the report point out. Finally, the Natural Capital refers to stocks of nature which produces a range of ecosystem services

A note needs to be made about the research on social capital (from governance to performance), mentioned above in the four categories by Ashford and Hall[13]. In this IW Framework, the social capital, such as institutions, culture, and religion, are treated as enabling assets: they enable the allocation of goods and services. The present discounted value of social well-being as a function of the current stocks of capital assets acts as the social capital in the allocation of resources.[28] The creators acknowledge that the IWI may also be suffering from the lack of data for practical policy-making, but they also allude to the case of GDP. Often when the government is missing data necessary for GDP, it nonetheless continues to use the GDP for economic policymaking.

Currently, the *Inclusive Wealth* looks only at the historical data. The *Inclusive Wealth Report 2012* focused on the 20 countries from 1990 until 1998 whereas *the Inclusive Wealth Report 2014*looked at 140 countries between 1990 and 2014, by studying the Index at a specific time and its growth (see fig. 2-5).

2.3 Conclusion

The above section provides insight into factors of sustainability, followed by an overview of the most commonly used metrics. Sustainable development needs to include environmental, social, and economical aspects, as well as the intergenerational aspect. This review finds that GDP may not be sufficient because it does not capture the elements necessary for sustainable development, and in fact can show false positives, i.e. for the *Deep Horizon* incident in 2010. The trio of the *Human Development Index, Ecological Footprint* and the *Happy Planet Index* tend to cover only two of the three domains of the environment, social and economy at a time. The *Human Development Index* fails to capture the environmental aspects; the *Ecological Footprint* falls short of capturing the social domains, and the *Happy Planet Index* does not cover any of the economic domains.

There are only two measures from the list that incorporate elements from all three of these aspects: the *Adjusted Net Savings* and the *Inclusive Wealth Index.* However, unlike the *Adjusted Net Savings*, the *Inclusive Wealth Index* captures the intergenerational aspect needed for sustainable development. The next chapter studies the *Inclusive Wealth Index* in greater detail before investigating how to apply it to the Kingdom of Saudi Arabia.

Chapter 3

Inclusive Wealth Index: Theory and Methodology

The methodology used for the *Inclusive Wealth Reports 2012 and 2014* (IWR 2012 and IWR 2014 respectively[8],[9]) is adapted by UNEP's Pablo Muñoz from the work on "Sustainability and the Measurement of Wealth" by Kenneth Arrow, Partha Dasgupta and others (2010)[26]. The methodology below describes the underlying theory and the methodology used in those reports.

3.1 Theoretical Foundations

Let us begin with defining sustainable development as **a pattern of societal development along which intergenerational well-being does not decline.**

Therefore, the intergenerational well-being $V(t)$ is

$$V(t) = \int_t^{\infty} [U(\mathbf{C}(t))e^{-\delta(\tau-t)}]d\tau, \delta \geq 0 \qquad (3.1)$$

where $C(t)$ denotes a vector of consumption flows at time t and δ is the discount rate, $U(C(t))$ is utility (the satisfaction that one enjoys from consuming goods and services) flow at time τ. The flow of goods and the services can vary from material goods to services nature provides (including. among others, aesthetic gratification or spiritual values).

In order to get the criterion for sustainability, we first do a substitution in Equation 3.1 using the Equation 3.2 to specify intergenerational well-being at t, $V(t)$, and a set of vector stocks of capital assets at time t and M, representing evolution of the political economy.

$$V(t) = V(K(t), M, t) \tag{3.2}$$

Using the chain rule, the Equation 3.1 could be differentiated with respect to time, giving us the criterion for sustainability discussed in the previous chapter, here below in 3.3.

$$dV(t) = \frac{\Delta V}{\Delta t} + \sum_i [\Delta V(t)/\Delta \mathbf{K}_i(t))(d\mathbf{K}_i(t)/dt] \geq 0 \tag{3.3}$$

In order to capture intergenerational well-being for a unit change in the respective capital asset, we define the shadow prices to represent the marginal value contribution,. This is a small change in *V(t)*, denoted by $\Delta V(t)$; and a small change in the capital asset i at time t denoted by $\Delta K_i(t)$ in Equation 3.4 below.

$$P_i(t) \equiv \frac{\Delta \mathbf{V}(t)}{\Delta \mathbf{K}_i(t)} \textit{for all } i \tag{3.4}$$

To measure the Inclusive Wealth, we take the shadow price of time as *Q(t)*:

$$Q(t) = \Delta V(t)/\Delta t \tag{3.5}$$

Therefore, *Q(t)* measures the shadow price of time as a result of change in social well-being caused by exogenous changes (e.g. changes in international trade prices, over which there is no control). Inclusive Wealth treats time as a surrogate for such exogenous events.

The aggregate index of a country's stock of capital assets can be constructed using the shadow prices as weights. Therefore, the IWI is calculated using Equation below 3.6 :

$$\mathbf{W} = \mathbf{Q}(t)t + \sum_i P_i(t)\mathbf{K}_i(t) \tag{3.6}$$

Where $P_i(t)$ is the shadow prices of capital assets $K_i(t)$.

In order to formalize the relationship between changes in the Inclusive Wealth at constant prices and intergenerational well-being, let Δ represent the changes in Equation 3.7:

$$\Delta V(t) = \left[\frac{\Delta \mathbf{V}(t)}{\Delta t}\right]\Delta t + \sum \left[\frac{\Delta \mathbf{V}(t)}{\mathbf{K}_i(t)}\right]\Delta \mathbf{K}_i(t) \tag{3.7}$$

With Equations 3.4 and 3.5, we can rearrange equation 3.7 as follows:

$$\mathbf{V}(t) = \mathbf{Q}(t)\Delta t + \sum_i P_i(t)\Delta\mathbf{K}_i(t) \quad (3.8)$$

Equation 3.8, therefore, shows that changes in well-being are equivalent to changes in wealth (Equation3.7), and this change is equal to the change in the capital asset base, otherwise known as the productive base of a nation. The authors of the Inclusive Wealth Report make a point that the Inclusive Wealth's productive base does not rely solely on the natural systems, but also on a critical level of human and produced capital for the human well-being, as well as for maintaining the levels of these for the present and future generations.

The practical applications of the Equation 3.8 are described below in Section 3.2.

3.2 Three Capitals: Natural, Human, and Produced

The three capitals are Natural, Human and Produced Capitals, which are described in detail below. The general methodology that the IWI follows consists of multiplying a stock by its average price and its rental rate[1], as per the equation below (3.9).

$$Wealth\ of\ Resource_t i = Stock_{ti} \cdot \overline{Price_{ti}} \cdot Rental\ Rate_i \quad (3.9)$$

and where the resources are being used in a particular year, t, the stocks are then to be defined by the following expression:

$$Stock_{t-1} = Stock_t + Production_t \quad (3.10)$$

3.2.1 Natural Capital

Within the IWI model, the natural capital (local ecosystems, biomes, subsoil resources) refers to stocks of nature that are inputs to production, e.g. oil, minerals. These are assumed to be benefits for the human well-being. Natural Capital comprises the following sub-capitals: Agriculture, Fossil Fuels, Minerals, Fisheries, and Forests. Below we discuss how the IWR2012 and IWR2014 treated these sub-capitals.

[1]Rental Rates are defined as "Economic rent is an excess payment made to or for a factor of production over the amount required by the property owner to proceed with the deal"[57]

Agricultural land: Crops and Pastures

Following the general form,given by Equation 3.9, the stocks for agricultural capital are measured in land quantity (separated for crops and pastures), The average global prices using the FAO data (see Table 3.1), and the rental prices found using a proxy from the Global Trade Assessment Project.[29]

Table 3.1: Key variables and data sources used in the measurement of Agricultural Capital stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Quantity of crops produced	FAO [30]
Price of crops produced	FAO [30]
Rental Rate	GTAP [29]
Harvested area in crops	FAO[30]
Discount rate	assumed at 5%
Permanent crops land area	FAO[30]
Permanent pasture land area	FAO [30]

The average rental price per hectare is defined as follows:

$$RPA_j = \frac{1}{A}\sum_{k=1}^{159} R_{jk}P_{jk}Q_{jk} \tag{3.11}$$

where *R, P, Q* are the rental rate of crop k for the j year, price per amount of crops and quantity of production of crop k respectively. A is the area of the harvested crops. "159" refers to the number of crops provided by the FAO.

In order to calculate wealth of the hectare *(Wha)*, the following Equation was used:

$$Wha_j = \sum_{t=1}^{\infty} \frac{RPA_j}{(1+r)^t} \tag{3.12}$$

where r is the discount rate. Therefore, the average wealth values per hectare ($\overline{Wha}$) over the years of study, y are the following :

$$\overline{Wha} = \frac{1}{y}\sum_{j=1}^{y} Wha_j \tag{3.13}$$

From Equation 3.13, the total wealth in cropland (WCL) can therefore be derived as:

$$WCL_{ij} = \overline{Wha_i} \cdot CLA_{ij} \tag{3.14}$$

where CLA is the physical amount of total cropland area in year j. As such, the WCL is the total wealth of cropland in the corresponding year for the country. Similarly, the pasture lands' capital, WPL_{ij} is then found by:

$$WPL_{ij} = \overline{Wha_i} \cdot PLA_{ij} \tag{3.15}$$

where PLA is the physical amount of total pastures land area in year j.

Fossil Fuels: Oil, Natural Gas, Coal

The methodology for the fossil fuels followed both the general Equations 3.9 and 3.10. One should also note that as a resource is depleted, the rental rate is expected to rise and the capital gains are expected to increase. However, with the increasing scarcity of the resource, the real wealth of the residents would depend on whether the resources are consumed or sold.

In order to calculate the wealth of the fossil fuels, as per the Equations 3.9 and 3.10, the estimates of oil and natural gas consumption, extraction, and proven reserves are taken from the *Statistical Review of World Energy* and *US Energy Information Agency*, listed in table 4.2. Proven reserves are the known quantity that is economically recoverable given current technology. Arrow et al. make a note that the estimates for the reserves are the best to the knowledge at a given time and with the improvements in technology, these could be changed.[26] This, however, is not reflected in the IWR2012 and IWR2014.[8],[9]

Minerals

The IWR 2012 and 2015 use the minerals reserves from the US Geological Survey (USGS) (see Table 3.3). The choice of the minerals is limited to ten: bauxite, copper, gold, iron, lead, nickel, phosphate, silver, tin, and zinc. Stocks were calculated using Equation 3.10.

Fisheries

Fisheries are an asset described in detail in IWR2012. The wealth of fisheries was estimated for only four countries: Australia, Canada, South Africa and the United States due to data scarcity (see Table 3.4). For these countries, 12 species of fish were identified for Australia, 9 for Canada, 10 for South Africa and 80 for the USA. The prices were then found using the *Sea Around Us Project*[36], which helped to estimate representative prices per ton. These prices were then averaged over time and multiplied by the fisheries' rental rate. Finally, using Equation 3.10, the total value of the stocks was estimated by multiplying the prices by the total stock of biomass.

Forests

Forests can be thought of a resource in a dual way: forests for timber and forests for other uses have a value for their ecological services over time. The timber assets are estimated using the density of timber per area. The price was estimated for a weighted average price of industrial round-wood and fuel-wood.

The average rental price over the whole time was estimated using the following steps. First, a conversion for the annually estimated values from current to constant prices using country-specific GDP deflater, then the regional rental rates for time using Bolt et al. [31] (here assumed to be constant). As such, the methodology from Equation 3.9 applied to the proxies above would give the information for the timber wealth of a country.

This contribution was estimated with the following formulation:

$$ESW_t = \int_t^T P_t(Q_t r_t) e^{-\delta t} dt \tag{3.16}$$

where ESW is ecosystem service wealth, δ is the discount rate, assumed to be 5%, T is the planning horizon, assumed to be infinite, t is the year studied, P_t is the marginal contribution of the ESW flow to inter-temporal economic welfare, Q is the total forest area excluding

Table 3.2: Key variables and data sources used in the measurement of Fossil Fuels Capital stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Reserves	EIA [32]
Production	EIA [32]
Prices	BP [33]
Rental Rate	GTAP [29]

Table 3.3: Key variables and data sources used in the measurement of Minerals Stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Reserves	USGS [34]
Production	US GS [34]
Prices	USGS [34]
Rental Rate	GTAP [29]

Table 3.4: Key variables and data sources used in the measurement of Fisheries stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Fishery stocks	Richard et al. [35]
Value of capture fishery	SAUP[36]
Quantity of capture fishery	SAUP [36], Sumalia et al. [37]
Rental Rate	GTAP [29]

cultivated forest, and r is the fraction of the total forest area to obtain benefits. The product between Q and r therefore gives the area of the forest in question. The IWR study, using the overview of literature, takes the portion of the whole asset area to be 10%.

3.2.2 Produced Capital

The original method for the Inclusive Wealth proposed by Arrow et al.[26], makes a careful distinction between the stocks of reproducible capital owned by investors outside of a specific country and stocks owned by the residents. The IWI considers the second type of the stocks. The proposed method is to take estimates of net holdings of international assets from the balance of payment and other IMF data. Arrow et al.[26] note that in developing countries there is little data on accumulated stocks of foreign assets and liabilities.

Reproducible Capital, otherwise known as the Manufactured Capital, is calculated using an approach originally developed by Harberger (1978), the *Perpetual Inventory Method*(PIM). The initial state of the economy was assumed to be in a steady-state, maintaining the capital-output ratio constant.

$$k = \frac{I/y}{\delta + \gamma} \tag{3.17}$$

Where,k is the capital-output ration, I is investment, y is the output of the economy, and γ is depreciate rate of the capital, assumed to be 4%. The ratio was then multiplied by the output of the economy of the studied country to get a first estimate of the produced capital stock in the initial period, K_0. The first estimates were in the 1970s, with the reasoning to minimize errors within the period of studies, as by the 1990s the stocks would have depreciated and be less than 20% of its original value. The PIM allows capturing of the dynamics of the produced capital accumulation by studying the yearly changes in investment. The corresponding formula developed by the authors of the report then becomes the equation below:

$$K_t = (1-\delta)^t K_0 + \sum_{j=1}^{t} I_j (1-\delta)^{t-j} \tag{3.18}$$

The produced capital is based on the data references in Table 3.5.

Table 3.5: Key variables and data sources used in the measurement of Produced Capital stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Investment	UN Statistics Division [38]
Depreciation rate	assumed 4% [39]
Assets lifetime	assumed indefinite

3.2.3 Human Capital

Basing the work on the theory of Arrow et al.[26] and Klenow and Rodriguez-Clare[40], the report sets the human capital to be made up of the following components: the life attainment, population, and the shadow price of working, as per Equation 3.19 below. The methodology used for the IWI first calculates human capital per individual, composed of *Edu*, which is the educational attainment function which is an equivalent of the average years of schooling per person, and ρ, which is the additional compensation over time, fixed at 8.5%. The 2014 report uses a population old enough to be engaged in education, starting from the age of 5, whereas IWR2012 looks at the population that had obtained a basic level of education at the age of 15. The data sources for these calculations are listed in Table 3.6.

$$Human\ Capital = e^{Edu \cdot \rho} \cdot Population_{(15+Edu)} \cdot \int_{t=0}^{T} \overline{r} \cdot e^{-\delta \cdot t} dt \qquad (3.19)$$

The integral in equation above is the shadow price per unit of human capital with $\overline{r}$, the average labor compensation, the T, discounted sum of the wages a person would receive over the expected number of working years. The total number of years working is calculated using age-gender participation rates and mortality rates.

Table 3.6: Key variables and data sources used in the measurement of Human Capital stocks in IWR2014 [9]

Variables	Data Sources used in IWR
Educational attainment	Barro and Lee [41]
Population by age, gender, time	UN Population Division [43]
Mortality rates by age, gender, time	WHO [44]
Labor Force rates by age, gender, time	ILO [45]
Market rate of interest	Klenow and Rodriguez-Clare [40]
Discount rate	assumed 8.5%
Employment	ILO [45], Conference Board [46]
Compensation of Employees	Feenstra et al. [39], UN Statistics Division [43], Conference Board [46], OECD [47], Lenzen et al.[48],

3.3 Applying theory to practice

Let us study the example of a few regions: Europe in fig.3-1 and Asia in fig.3-2.

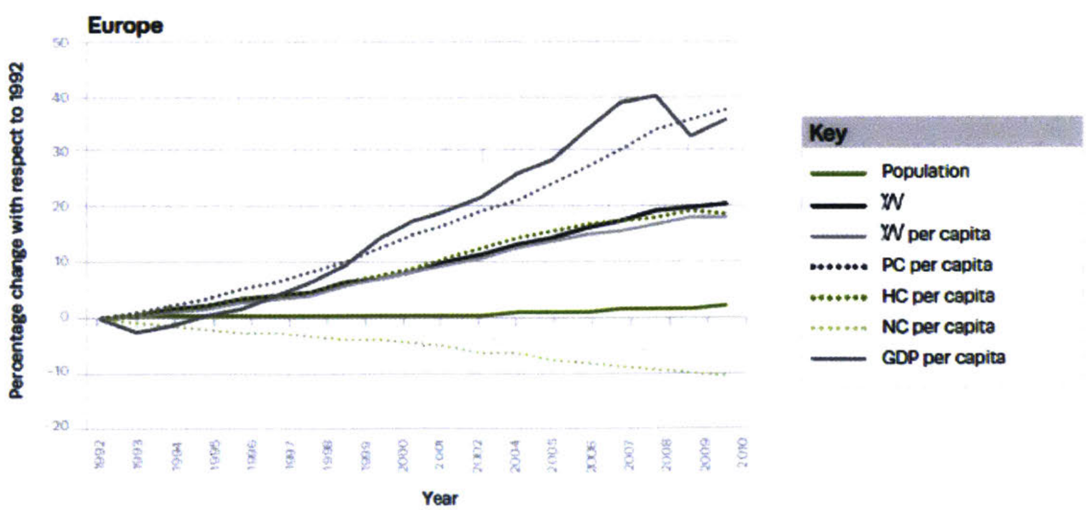

Figure 3-1: Percentage change of IWI for Europe. Source: *Inclusive Wealth Report 2014*, p.56[9]

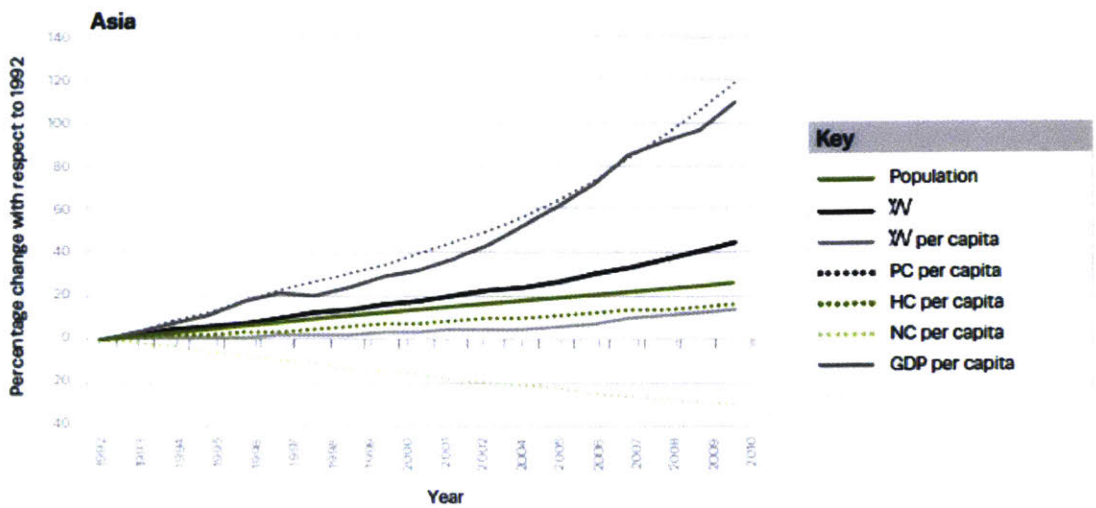

Figure 3-2: Percentage change of IWI for Asia. Source: *Inclusive Wealth Report 2014*, p. 56. [9]

Examining figure3-1 the population is growing steadily, but as the Natural Capital *per capita* is declining, the increase in the Human and Produced Capitals *per capita* compensates for the decline. Therefore, the overall IWI *per capita* is positive. The IWI *per capita* in Asia is positive, as similarly the decline in the Natural Capital *per capita* is secured by the sufficient increases in the Produced and Human Capitals *per capita*. In both cases, the IWI *per capita* follows the GDP and shows that the development of both regions can be considered sustainable.

3.4 Conclusion

The Inclusive Wealth Index is a comprehensive, appropriate metric for sustainable development that takes into account social, economic and environmental aspects, as well as the inter-generational concept, based on the soft sustainability principles. However, the authors do warn of the limitations and have made a number of assumptions to capture rental rates. These tend to hamper the calculations and may prove to be even harder for developing and transitioning countries. Furthermore, as the authors acknowledge, there may be caveats in the state of knowledge over some resources, such as oil. These resources are environmentally intrinsic, because given the evolving state of art of technologies, we may not know the true value of the quantities available at a particular time.

Chapter 4

Inclusive Wealth Index for the Kingdom of Saudi Arabia

Having presented the methodology and underlying theory for the IWI in detail in the chapter 3, this section looks at applying this methodology specifically to Saudi Arabia. The prime research question is to what extent is the global IWI metric applicable to the Kingdom. To answer it, we revisit the results from the reports of 2012 and 2014 and adapt, where possible, the data sources and methods discussed in the previous chapter to the country. The final section then draws comparisons between the two approaches, the global database and the national KSA data.

4.1 What does IWI 2012 and 2014 say about KSA?

To date, there has been two global assessments of the IWI performed by the UN, in the *Inclusive Wealth Report 2012* (IWR2012) and the *Inclusive Wealth Report* 2014 (IWR2014).[8],[9]. Saudi Arabia's total IWI measured in million USD (2005) in 2008 was 7 946 619 according to IWR 2012; 7 469 646 according to IWR 2014 (figs.4-1 and 4-2). The natural capital in both cases is slowly decreasing, produced capital staying at almost constant levels and the human capital increasing steadily (figs. 4-1 and 4-2). However, if the IWI is studied *per capita* (figs. 4-3 and 4-4), the growth of the IWI is negative, due to the population growth outpacing the Capitals' growth. Therefore, according to the IW theory, Saudi Arabian's development is not currently sustainable. This is a concern for the policy-makers. As the IWR calculations had been done using the data and methods adapted for the global use, this section looks if the results will be similar using Saudi data. Therefore, we are revisiting the method and data to be made more relevant to the Saudi context.

Figure 4-1: The Inclusive Wealth Index results for Saudi Arabia from *Inclusive Wealth Report 2012*[8]

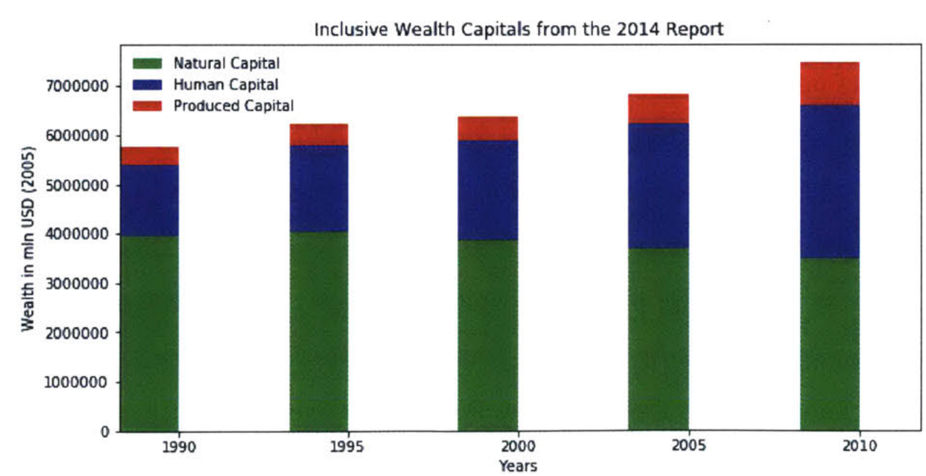

Figure 4-2: The Inclusive Wealth Index results for Saudi Arabia from *Inclusive Wealth Report 2014*[9]

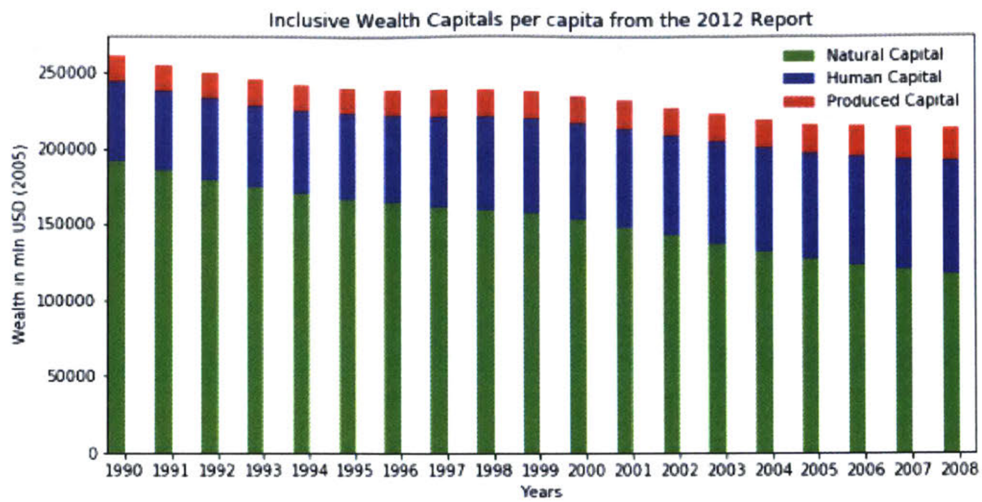

Figure 4-3: The Inclusive Wealth Index *per capita* results for Saudi Arabia from *Inclusive Wealth Report 2012*[8]

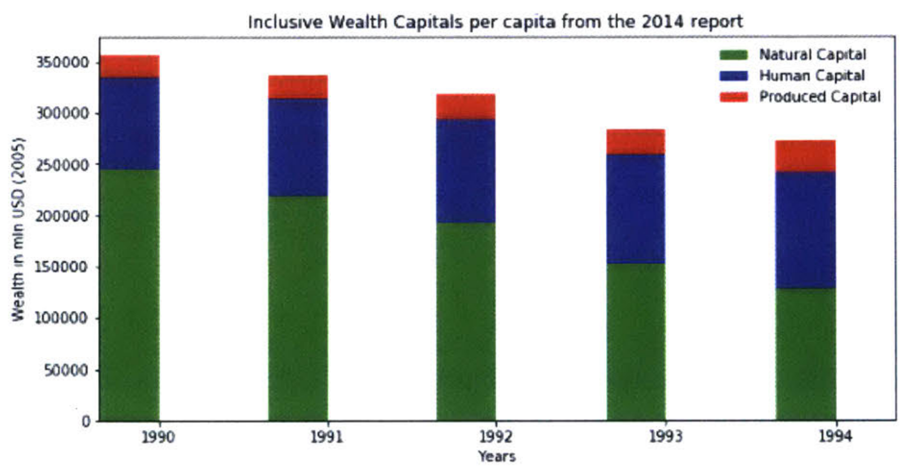

Figure 4-4: The Inclusive Wealth Index *per capita* results for Saudi Arabia from *Inclusive Wealth Report 2014*[9]

4.2 Adapting methodology and data for Saudi Arabia

In this section, we make an evaluation of the methodology and data for capitals of the Inclusive Wealth: Natural, Human and Produced. Initially, we used the same data to verify the methods. Where methods and data sources have been modified, these modifications are described below.

4.2.1 Natural Capital

The Natural Capital is made up from the Agriculture, Fossil fuels, Minerals, Forests, and Fisheries. This section revisits the data sources and methodology for any possible changes to make the calculations more relevant for the Saudi national context.

Agriculture: Croplands and Pasture lands

Following the methodology described in the previous chapter we estimated the Agricultural Capital. The first modification was to Equation 3.13, where the study period was shortened to 16 years. The equation was then simplified for the Saudi case to the following:

$$Wha_j = \frac{\sum_{j=1}^{j=16} RPA_j}{r} \tag{4.1}$$

As for the data, (Table 4.1), one can see that we could replace the data for quantity of crops, the harvested area and the permanent cropland and pastures with the local data.

The data available for individual types of crops is rather sparse. In contrast, datasets grouped for cereals, vegetables, fodder, and fruits are available from 1996 until 2012. Therefore, following analysis of what are the most common crops from the Food and Agriculture Organization's (FAO) data for Saudi Arabia, we created a weighted average price for each of the four categories. For any individual data points missing, similar to the IWR, the missing data numbers were estimated as by linear regression.

Currently, there is no Saudi data equivalent for pastures, therefore we used the FAO approximations.

Fossil Fuels: Oil and Natural Gas

The data for fossil fuels, such as oil and natural gas, is available from Saudi Aramco. Since it manages 99% of the resources, this source represents the total Fossil Fuel stocks.

Table 4.1: Key variables and data sourced used in the measurement of Agricultural Capital stocks

Variables	Data Sources used in IWR	Data Sources for KSA
Quantity of crops produced	FAO [30]	SAMA [71], most consistent by families of crops
Price of crops produced	FAO[30]	FAO [30]
Rental Rate	GTAP [29]	GTAP [29], *vfm* parameter
Harvested area in crops	FAO [30]	SAMA [71], most consistent by families of crops
Discount rate	assumed at 5%	assumed at 5%
Permanent crops land area	FAO [30]	SAMA [71]
Permanent pasture land area	FAO [30]	FAO [30]
Livestock density	—	FAO [30]

The data, however, showed an interesting phenomenon, seemingly contradictory to the expectations. Fossil fuels are non-renewable in nature: the oil in Saudi peninsula was formed mostly during the Paleozoic and Jurassic periods[49], therefore with more extraction, the reserves are supposed to decrease. However, in 1991 there were 260.93 billion barrels in reserves, whereas in 2016 it was reported that the reserves were then 266.58 billion barrels. The increase could be attributed to technological improvement in the discovery and extraction processes. The IWR theory refers to the fossil fuels resources as the finite and recoverable, rather than what is technologically recoverable at the moment. We modified the methodology to take for the initial reserves all of the oil that had been discovered up to the latest data available as the initial reserve, R_O, and if the reserve information, r_i becomes available by year i.

$$R_i = R_0 + \sum_{j=0}^{i} R_{dj} - \sum_{j=0}^{i} R_{ej} \tag{4.2}$$

Where R_i is the reserves in a particular year i; R_{dj} is the discovered reserves; R_{ej} is the exploited reserve in year j; R_0 is initial reserves as known in year $i = 0$.

We then subtract stocks in production from the initial reserves. As such, $Stock_1 =$

Table 4.2: Key variables and data sourced used in the measurement of Fossil Fuels Capital stocks

Variables	Data Sources used in IWR	Data Sources for KSA
Reserves	US Energy Information Administration [32]	ARAMCO Corporate Reports [50]
Production	US Energy Information Administration[32]	ARAMCO Corporate Reports [50]
Prices	BP [33]	BP [33]
Rental Rate	GTAP [29]	GTAP [29] *vfm* parameter

$R_i - stock_i$ to replace the general expression for stocks in Equation 3.10.

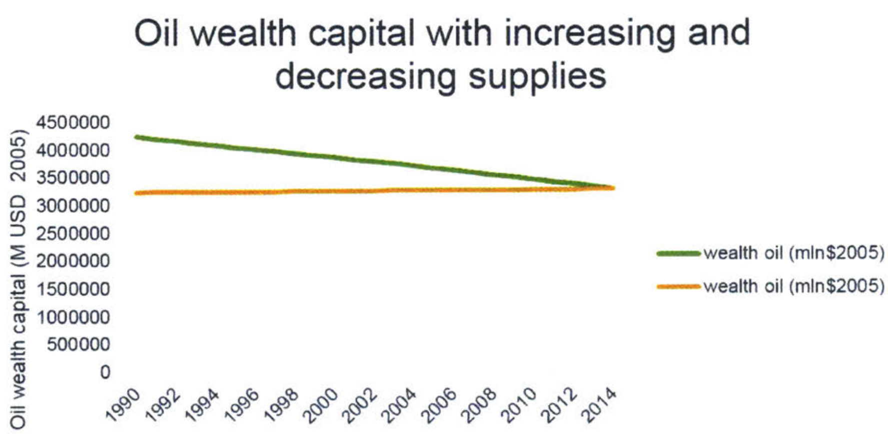

Figure 4-5: Recalculating the reserves' depletion. Example for oil.

The rental rates were taken from the GTAP database, using the *vfm* variable for oil and natural gas for Saudi Arabia over total production of the resources at each year. For the fossil fuel prices, the prices were taken for the period of 21 years from 1990 until 2010 and were deflated to the level of USD of 2005.

Minerals

The minerals are an industry that is in an early development stage in Saudi Arabia. The choice of the minerals was changed from the IWR2014's methodology to include most prominent materials in the country (Table 4.3). Similarly to the fossil fuel prices, the prices were taken for the period of 21 years from 1990 until 2010 and were deflated to the level of USD of 2005. The rental rates were taken from a GTAP database, using the *vfm* variable for minerals for Saudi Arabia.

Table 4.3: Key variables and data sourced used in the measurement of Minerals Stocks

Materials Selection	Source
Feldspar, Limestone, Gypsum, Granite, Bauxite, Copper, Gold, Iron, Lead, Nickel, Phosphate, Silver, Tin, Zinc, Marble	Prices, reserves: USGS [34]
Uranium	Reserves: IEAI. [51] Prices: NYMEX - CME Group [52]
Rental Prices	GTAP [29] (*vfm* parameter)

The approach for prices remained the same: to deflate the prices for minerals to the USD 2005 level, average them across the years, and multiply by the stocks and appropriate rental rate.

The approach used for estimating the stocks of the minerals was changed to be the same as for the fossil fuels, according to Equation 4.2. One must note, however, that the information is very limited on the initial reserves, therefore the factor R_e is the main drivers in the reserves to date.

The wealth of the minerals capital is less than 1% of fossil fuel wealth in the KSA.

Fisheries

Currently not included into the Saudi Arabian IWI, fisheries were added to the IWI recalculations in this study. The data, such as prices and quantities were gathered through a visit to the Saudi Ministry of Agriculture. The methodology followed the same form of Equations 3.9 and 3.10.

Forests

The data and method were unchanged from the IWR one. We used the estimated parameter of 150 USD/ha/yr.[8] Discount rate was kept at 5%.

Table 4.5: Key variables and data sourced used in the measurement of Forests Stocks

Variables	Data Sources used in IWR	Data Sources for KSA
Forest area	FAO [30]	FAO [30] (*forested areas* variable)
Value of non-timber forest benefits(NTFB)	Lampietti and Dixon [96]	Lampietti and Dixon [96]
Percentage of forest area used for the extraction of NTFB	WB [7]	WB [7]
Discount rate	assumed 5%	assumed 5%

4.2.2 Human Capital

For Human capital, the quality of local data is rather high. The Saudi data is available for the population, mortality rate, and labor force participation for 2000, 2007 and 2013. The years in between are interpolated linearly, as seen in figs. 4-6, 4-7, and 4-8.

For our calculations, the total wage was taken from the GTAP database (parameter *SkLab* and *UnskLab*) over Saudi population.

Table 4.4: Key variables and data sourced used in the measurement of Fisheries Stocks

Variables	Data Sources used in IWR	Data Sources for KSA
Fishery Stock	Richard et al.[35]	Ministry of Agriculture [53]
Value of Capture fishery	SAUP [36]	Ministry of Agriculture [53]
Quantity of capture fishery	SAUP [36] and Sumaila et al. [37]	SAUP [54]
Rental rate	GTAP [29]	GTAP [29] *(vfm parameter)*

Table 4.6: Key variables and data sourced used in the measurement of Human Capital Stocks

Variables	Data Sources used in IWR	Data Sources for KSA
Educational attainment	Barro and Lee [41]	Barro and Lee [42]
Population by age, gender, time	United Nations Population Division [43]	SAMA [71]
Mortality rates by age, gender, time	WHO [44]	SAMA [71]
Labor Force rates by age, gender, time	ILO [45]	SAMA [71]
Market rate of interest	Klenow and Rodriguez-Clare [40]	Klenow and Rodriguez-Clare [40]
Discount rate	assumed 8.5%	assumed 8.5%
Employment	ILO [45], Conference Board [46]	ILO [45], Conference Board [46]
Compensation of Employees	UN Statistics Division [38], OECD [47], Feenstra et al. [39], Lenzen et al. [39], Conference Board [46]	GTAP [29] *(parameters SkLab, UnskLab)*

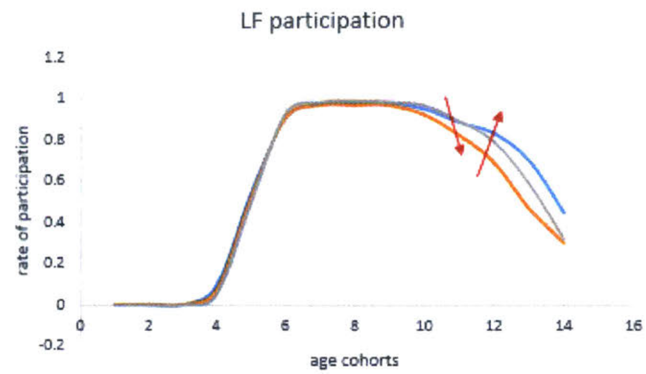

Figure 4-6: Saudi Labour Force Participation variation with time

Figure 4-7: Mortality in Saudi Arabia variation with time

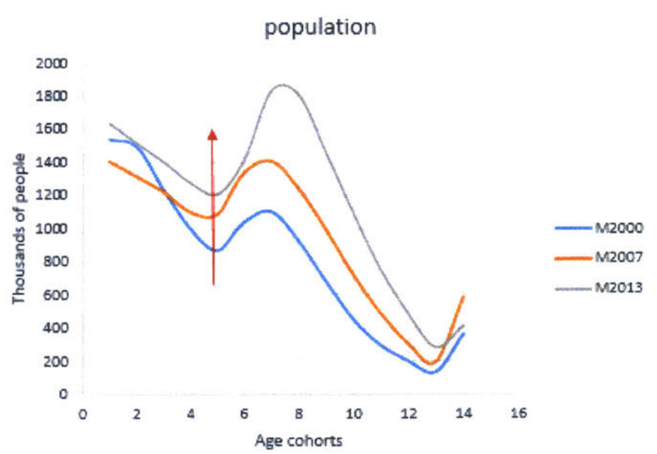

Figure 4-8: Saudi Population variation across the age cohorts

One modification was made to the Human Capital calculations in order to adjust it to the Saudi context. The Human Capital was calculated separately for the Saudi and Expats populations. The Expats carry a strong contribution to the Human knowledge. Using a range of data, we can assume the non-Saudis to be from India, Pakistan, Egypt and other countries listed in a UN review on the population of foreign workers in the Gulf States by the UN[55].

4.2.3 Produced Capital

The produced capital was taken as an accumulation of the Gross Capital Formation over the years for Saudi Arabia, and has been depreciated at 4% since 1971, similarly to the IWR methodology and data, using the World Bank's Gross Capital Formation.[59] No modifications have been made.

4.3 Sensitivity

As the IWI calculation takes into account a large number of parameters, the question of its sensitivity to the parameters is critical. The sensitivity is analyzed in two ways: elasticity of parameters on the capital value and MinMax analysis of the data.

4.3.1 Elasticity of the parameters

The results of this analysis show how much the wealth value of each Capital change if we alter its constituent parameters by 1%. With this method we identified that the largest drives for the Human Capital are the population and the shadow price (total wage bill), closely followed by discount rates, education level of attainment, and educational discount rates (fig.4-9). For the Natural Capital, the largest changes are driven by oil prices, reserves and rental rates. Finally, for the Produced Capital, it is the amount of investment.

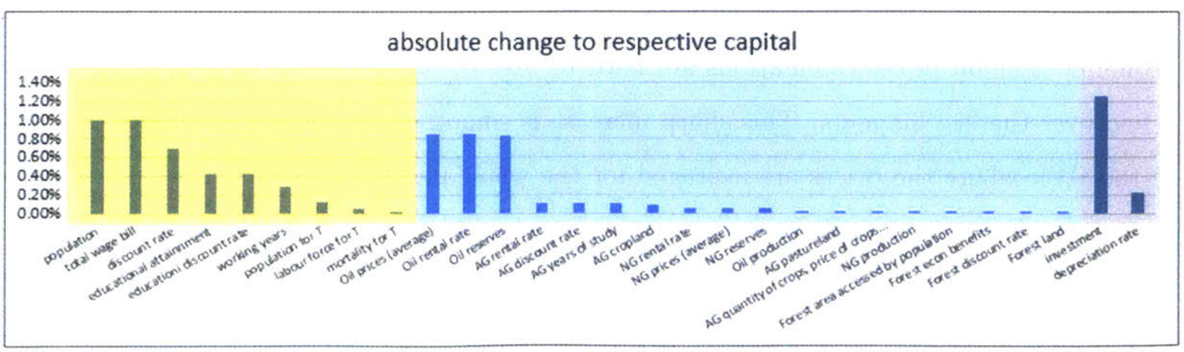

Figure 4-9: Elasticity of the parameters of IWI

4.3.2 MinMax analysis of IWI

Due to the variety of the sources for some parameters and in the light of data scarcity, a sensitivity analysis would have to include a notion of ranges rather than purely deterministic value. We have then selected best estimates of the minimum and maximum values for each data input for each year, giving us a range of the possible capital values (fig.4-10).

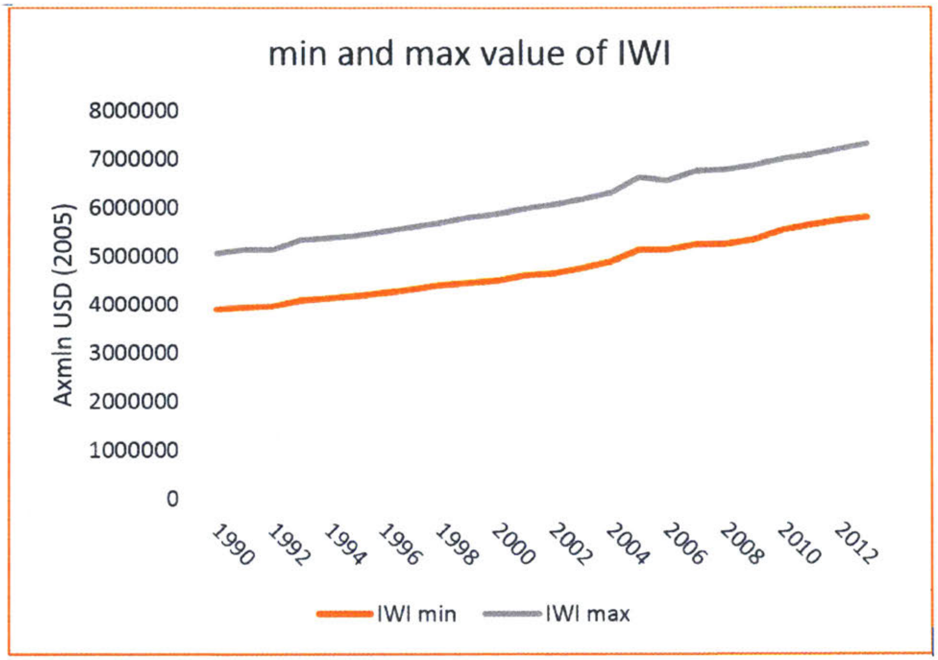

Figure 4-10: Min and max range of values for the total IWI

The min max analysis therefore shows a range of studies to be around 1 trillion USD uncertainty associated with the IWI value.

4.3.3 Volatility

A key issue facing the Saudi government is the extent of the contribution of oil to the economy. The oil prices calculations are hard to predict (fig.4-11), yet they have increased 5-fold over the last 20 years. This sharp increase is smoothed out by the methodology used in the IWI, where the prices are averaged for the whole period of study (21 years). This is done to neglect any volatility.

However, if the averages were taken for every three years instead, the value of the fossil fuels would indeed be approximately five times higher (fig.4-12). The policymakers may feel that this is a truer representation of the value of the fossil fuel stocks. However, the theory behind IWI argues otherwise: by adding this volatility, we are 'borrowing' the wealth from the future generations, should the price drop again. Sustainable development needs to address the intergenerational aspects.

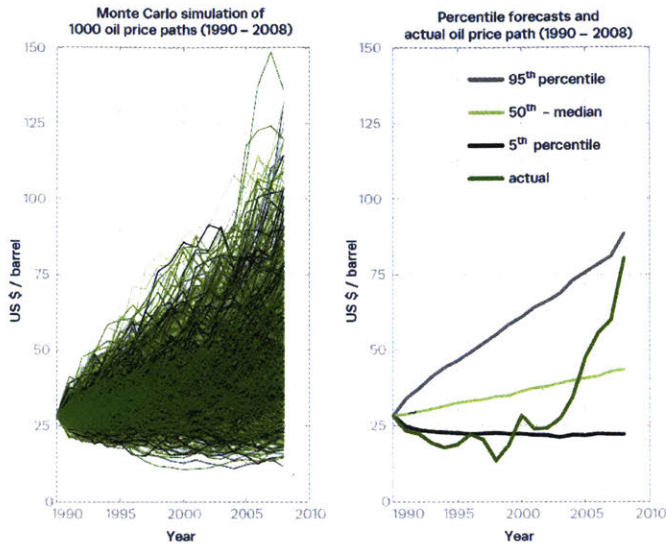

Figure 4-11: Trajectories of the 1000 oil prices simulations for 1990 until 2008, modeled using GBM. Source: *Inclusive Wealth Report 2014*, p.213 [9]

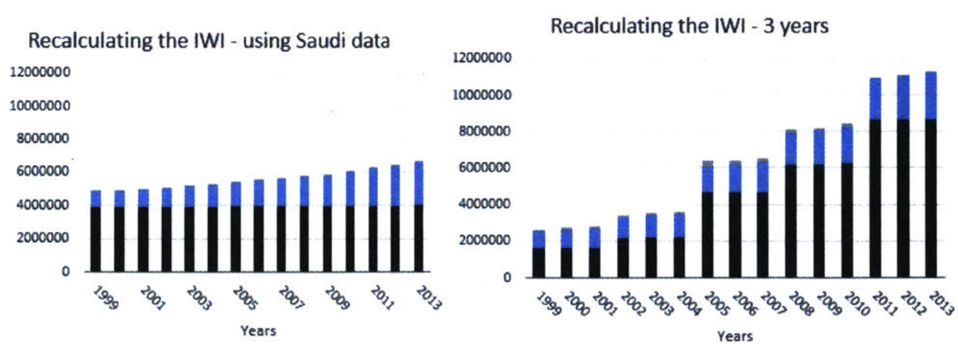

Figure 4-12: Recalculating the IWI using 3 year average over 20 years average

4.4 Results

The results of the methodology described in Chapter 3 with modifications presented in this chapter are shown below in the same order as the methodology had been described. The results are accompanied by similar calculations performed in IWR2012 and IWR2014 when appropriate.

4.4.1 Natural Capital

The results for the Agriculture, Fossil Fuels: Oil and Natural Gas, Minerals, Fisheries and Forests are shown below.

Agriculture: Croplands and Pasture lands

The calculations (fig. 4-13) show a large disparity between the 2012 and 2014 reports and the Saudi data. For instance, in 2008, the latest datapoint available in all the studies, the agricultural capital (measured in million USD (2005), was valued at 551 004 by the 2012 report, 845 801 by the 2014 report, and 159 351 using the Saudi data. The data here, following the elasticity analysis (fig. 4-9) is driven mostly by the agricultural sector production quantity and land used. These results already showed disparity at the data input stage: the Saudi Ministry of Agriculture reporting less than a million times of the agricultural land available, which may be the factor leading to the gap in the results.

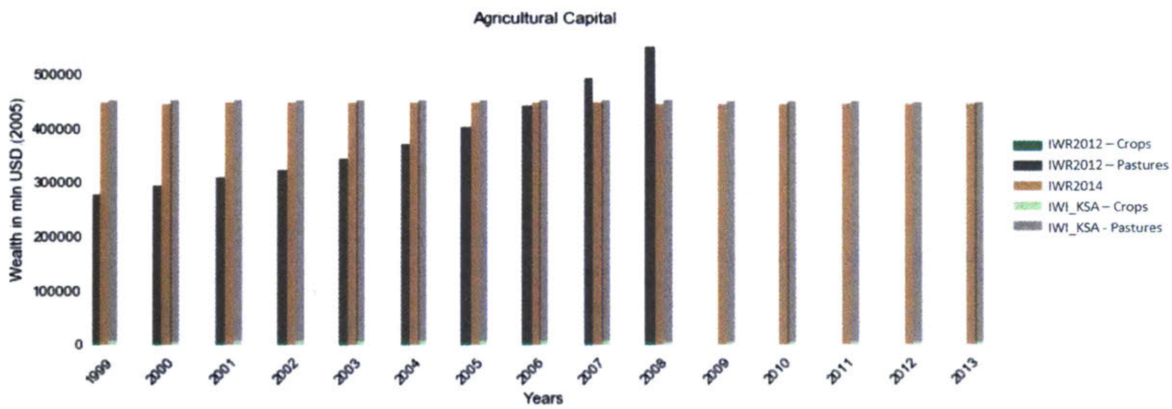

Figure 4-13: Recalculations of the Agricultural Wealth using Saudi data and adapted methodology, compared with the results from the *Inclusive Wealth Reports 2012 and 2014*.[8],[9] All are normalized to USD (2005)

Fossil Fuels: Oil and Natural Gas

Fossil fuels after recalculations match the higher values of the IWR2012, but the slope of the second report in 2014. For 2008, the value allocated to the total fossil fuels capital were 5 261 018 mln USD (2005) from the 2012 Report, 2 717 892 from the 2014 report and 5 266 163 from the current calculations. The change between 1999 until 2008 was positive, at 23% for the IWR2012 data, but negative 11% for the IWR2014 data, and -6% with Aramco data and adjusted methodology.

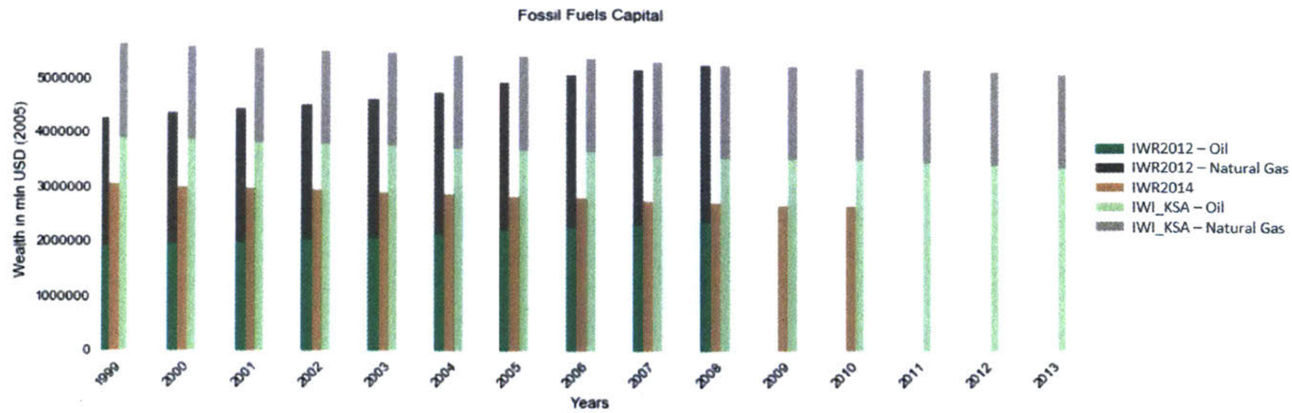

Figure 4-14: Recalculating the Fossil Fuels Wealth using Saudi data and adapted methodology, compared with the results from the *Inclusive Wealth Reports 2012 and 2014*.[8],[9] All are normalized to USD (2005)

These results also agree with the IWR2012 and IWR2014 results. However, with the reserves adjusted to account for technically recoverable reserves, the depletion is more rapid.

Minerals

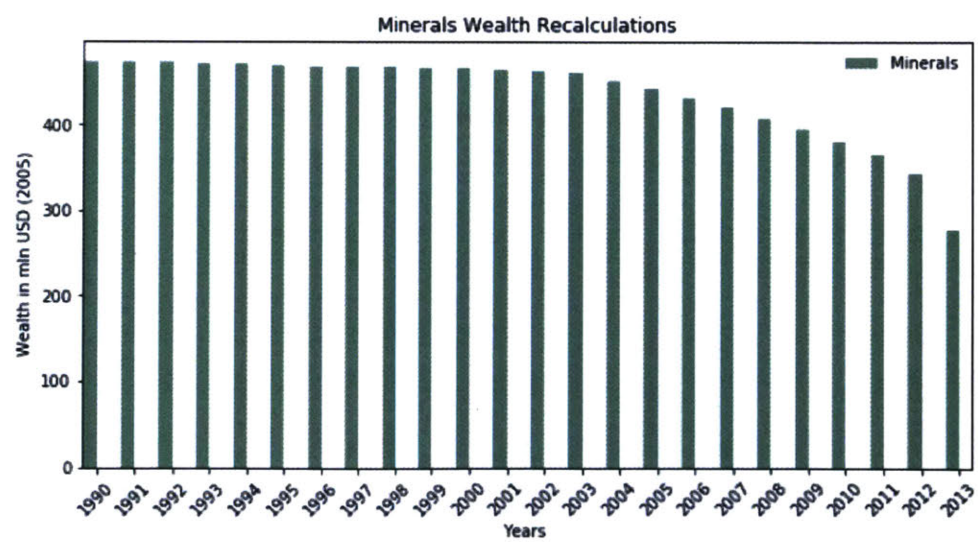

Figure 4-15: Calculations of the Minerals Stocks Capital

These results are a first estimation for the minerals as wealth for Saudi Arabia. However, with the more information becoming available with time, the initial reserves could be corrected. In 2008 it was 1 720 947 million USD (2006).

Fisheries

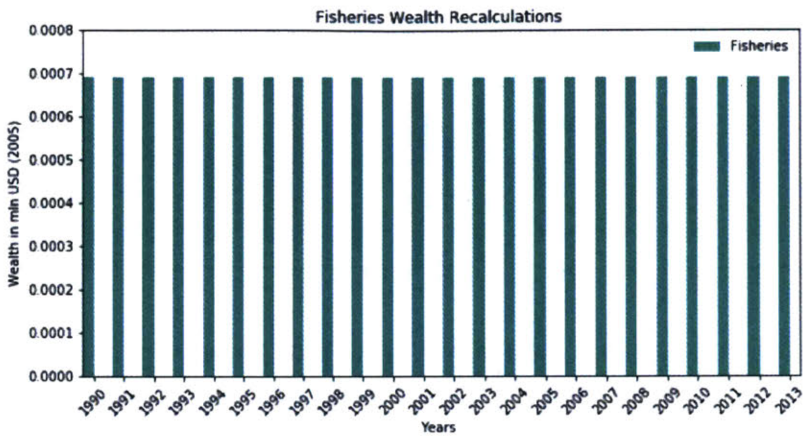

Figure 4-16: The Fisheries stocks Capital

Figure 4-16 shows a first approximation of the fisheries stocks for Saudi Arabia. However, one must note the scale of the fisheries contribution to be 0.7 thousands USD (2005). This is around 1.3 of 10^{-8} *per cent* of the Natural Capital.

Forests

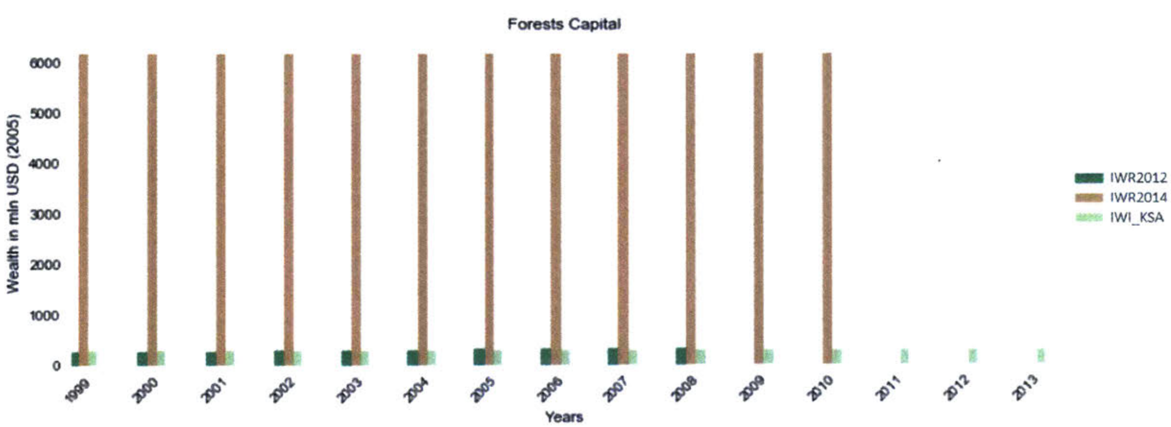

Figure 4-17: Recalculations of the forests stocks using Saudi data and adapted methodology, compared with the results from the *Inclusive Wealth Reports 2012 and 2014*.[8],[9] All are normalized to USD (2005)

Having followed the IWR2014 methodology, we find that the results of our study to be comparable to the results from the 2012 report.

4.4.2 Human Capital

The Human Capital was the highest for the 2014 report, whereas the recalculations match more closely the 2012 data (fig.4-18). For 2008, measured in million USD (2005) for instance, 1 861 853 according to the 2012 report, 2 885 584 according to the IWR2014 report and 1 672 621 according to new recalculations. In2013, 45% of the Human Capital was a contribution from the non-Saudi Human Capital.

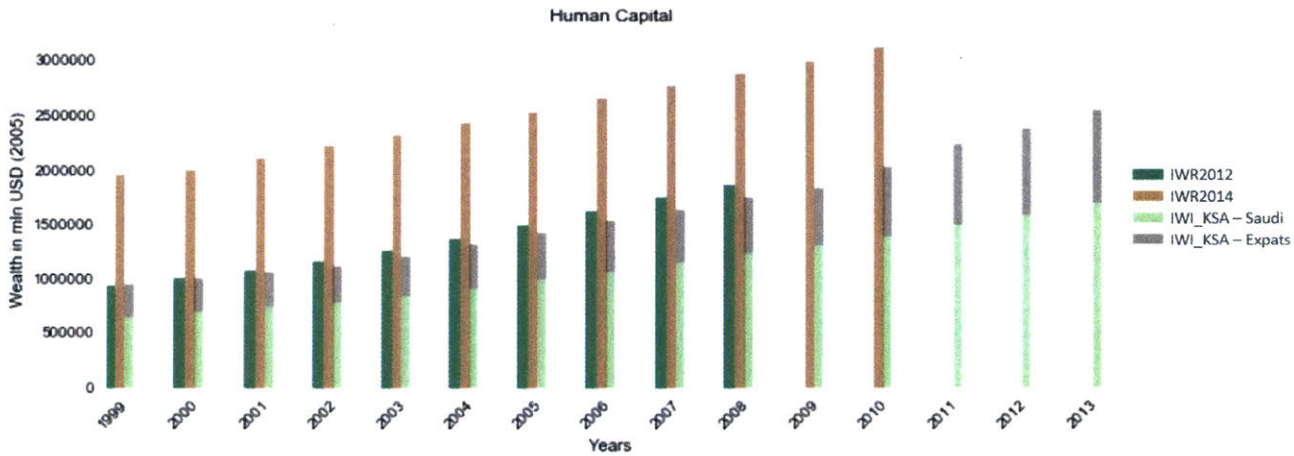

Figure 4-18: Human Capital calculations in comparison with *Inclusive Wealth Reports 2012 and 2014*.[8],[9] All are normalized to USD (2005)

The results we have computed are in the same range as the results from the IWR2012. The Saudi to the Expats ratio is approximately one to two.

4.4.3 Produced Capital

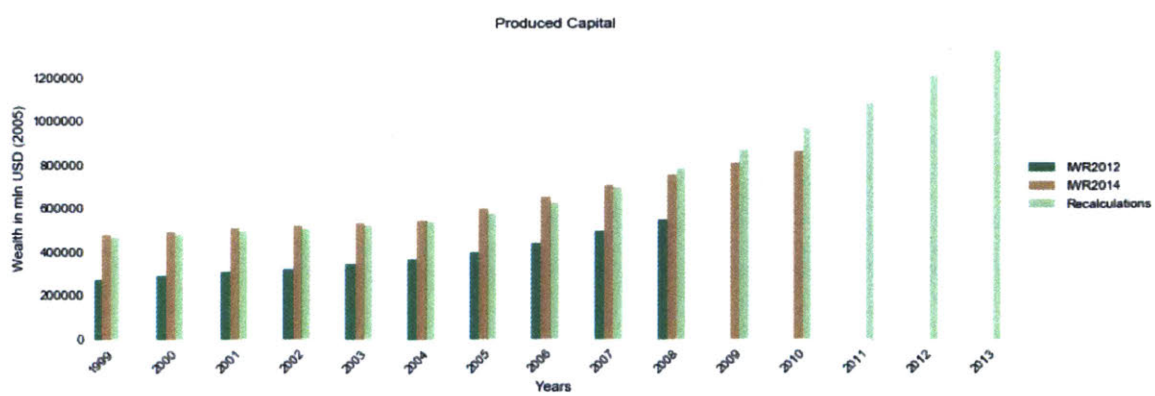

Figure 4-19: Produced Capital results in comparison with *Inclusive Wealth Reports 2012 and 2014*.[8],[9] All are normalized to USD (2005)

As there is no data available to date from the Saudi sources, we utilized the same data sources and the same method provided us with the same results as the Inclusive Wealth Reports. Following the methods described in the Inclusive Wealth Reports[8], [9], we took the Gross Capital Formation Data, available from 1972 from the World Bank.[59] One should then note that the Produced Capital at a given year is equal to the sum of the stock of this year and all the stocks of previous years depreciated at 4%. In order to have a comparable analysis between the Saudi and IWR data, the Saudi stocks data should cover at least 30 years, which is not the case until 2020. Hence, the global data was used.

4.4.4 National Inclusive Wealth Index

The combined results of the recalculations are presented in figs.4-20 and 4-21.

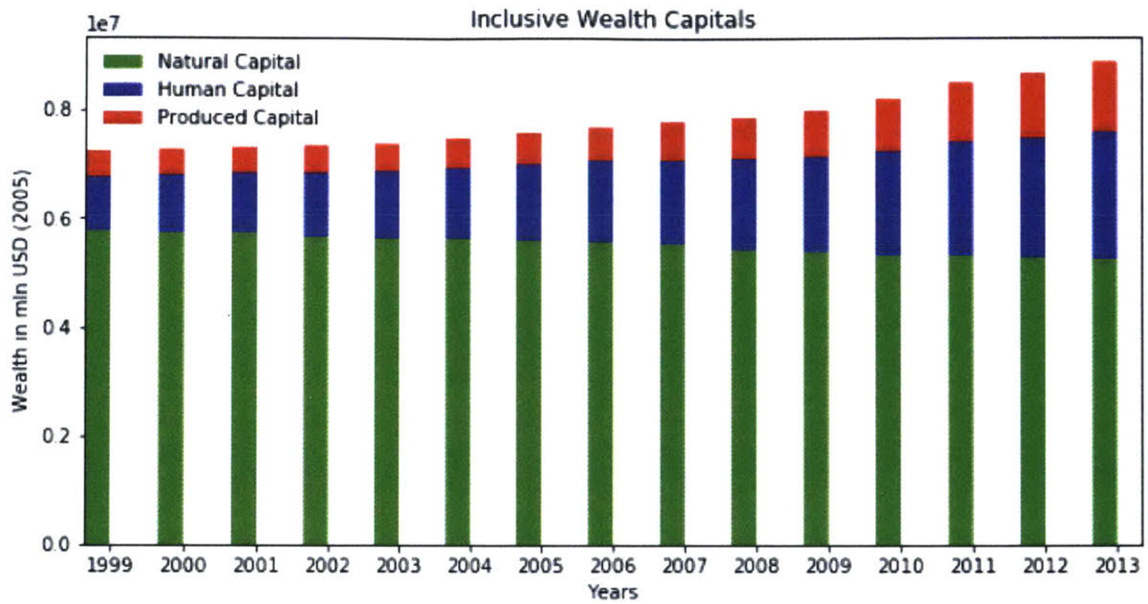

Figure 4-20: Recalculating the IWI and its rates

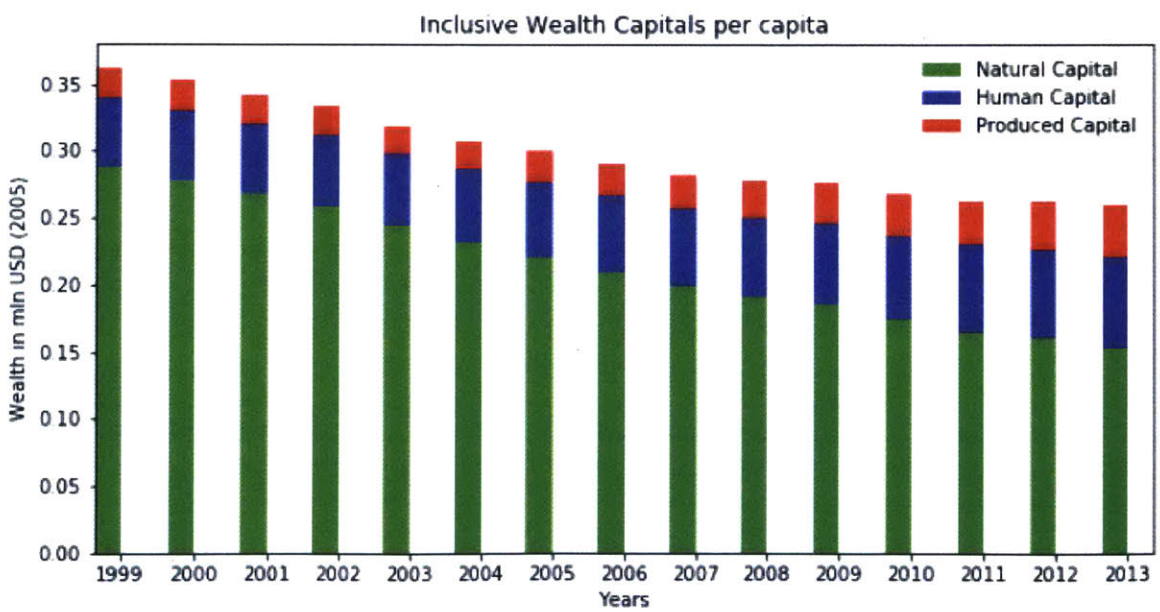

Figure 4-21: Recalculating the IWI *per capita* and its rates

In order to look at the sustainability condition, we made comparison charts between the changes in Capitals and their rates for our recalculations and the results from the IWR2012 and the IWR2014 (figs. 4-22 and 4-23). For the years that are in common between all three studies (1999-2008), our recalculations follow the same trend and are in the same range as the IWR2014 (fig.4-22 a). The major difference from the IWR2012 lies in the Human Capital. If we are to study the longest periods available, the changes for our recalculations are more pronounced. The rates of changes (fig.4-22, c) are closest to IWR2014. The IWI changes *per capita* (fig. 4-23) confirm the trend of comparable results between our recalculations and the IWR2014. The difference with the results from the IWR2012 are even larger.

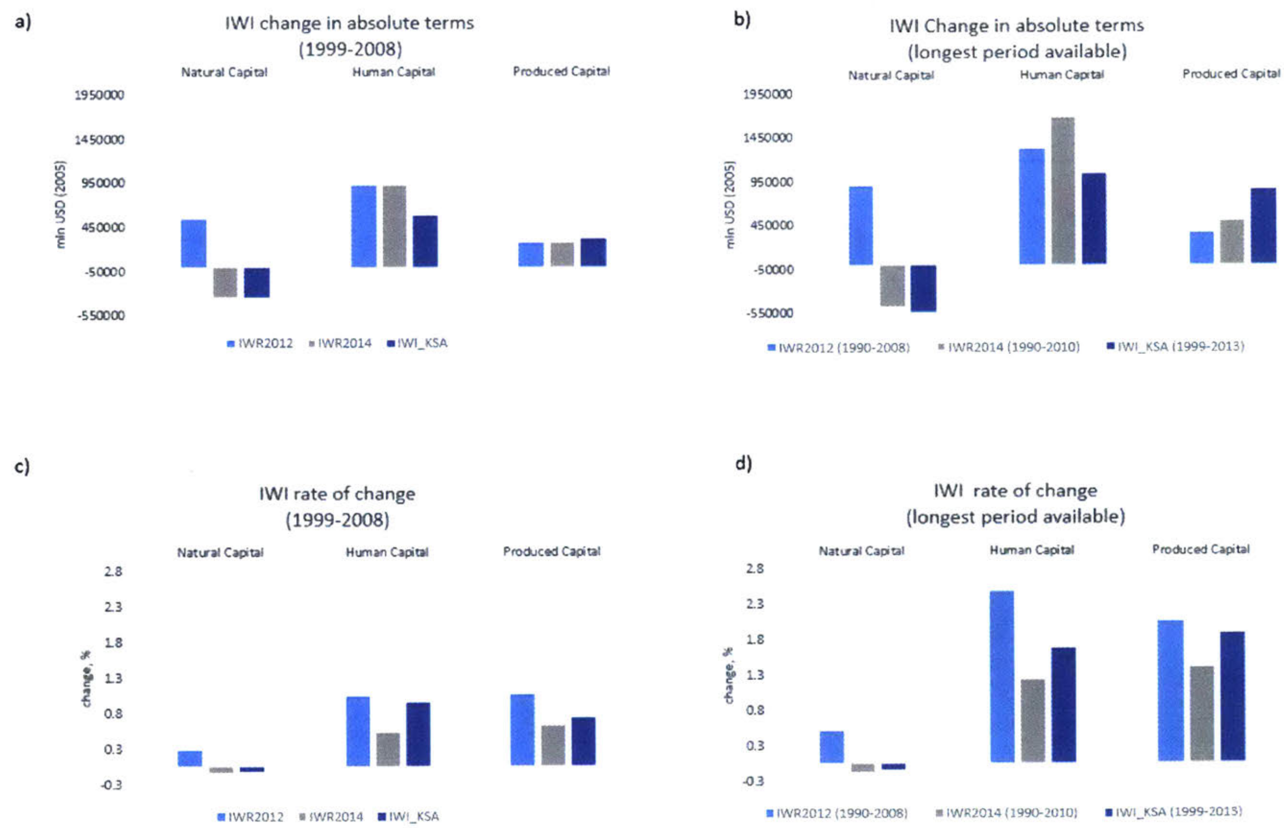

Figure 4-22: Comparison between the IWI calculations for Saudi Arabia from the Reports of 2012 [8], and 2014 [9] and this study

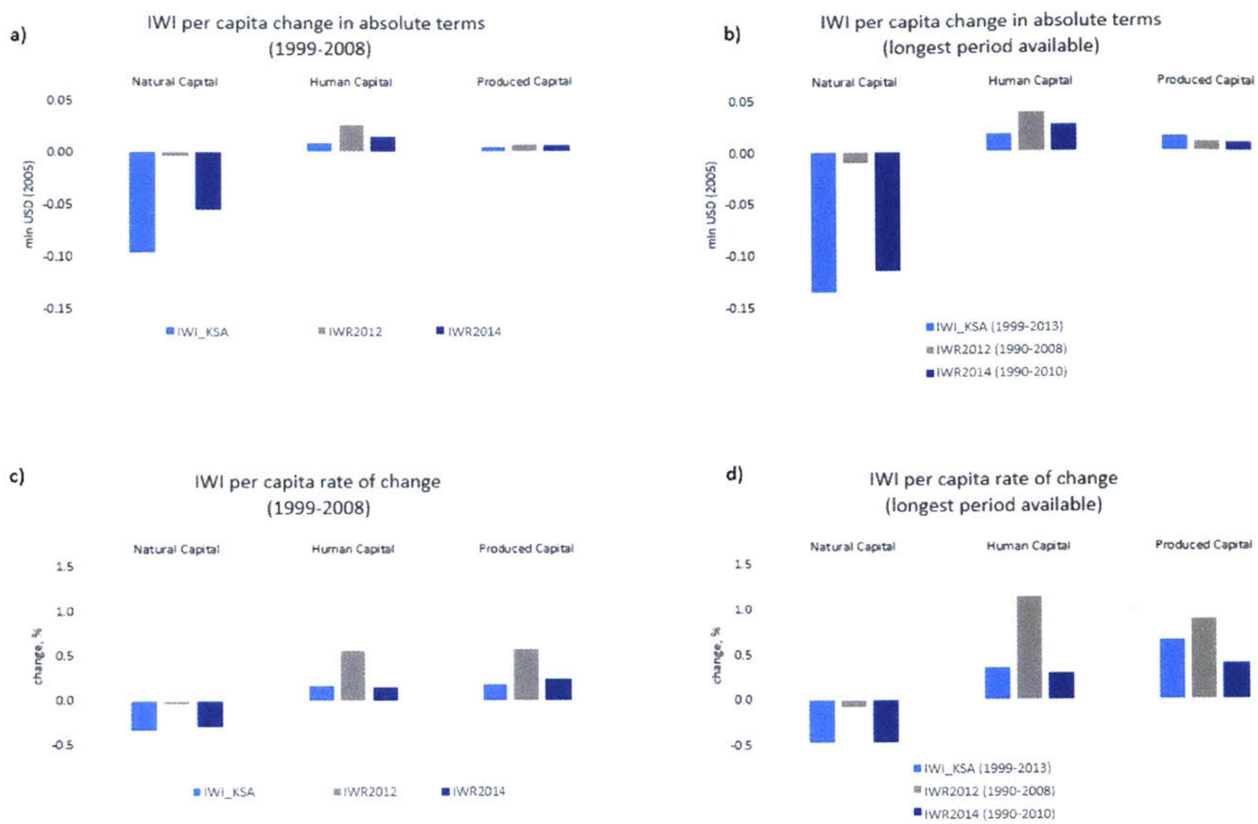

Figure 4-23: Comparison between the IWI *per capita* calculations for Saudi Arabia from the Reports of 2012 [8], and 2014 [9] and this study

4.5 Conclusion

The analysis of the IWI recalculations using local data matches closely the UNEP reports. The results between the two UNEP reports vary substantially themselves and all of our results fall within the same order of magnitude. Additionally, when using the nationally available information, the overall pattern remains the same: the Inclusive Wealth of the country is growing, however the IWI growth *per capita* remains negative.

The IWI has been adjusted to make it as nationally accurate and valid as possible. The results *per capita* show even deeper changes and clearly indicate a problematic dynamic with Natural Capital. Its rapid depletion seems not to be compensated by the Human and Produced Capitals to ensure the nation' sustainability.

Chapter 5

Subnational Sustainable Development: Rationalization of National Development Indices

Development and environmental policy-making for larger regions is a multidimensional problem, especially when taking into account regional variability, be it in oil wells or cities with more universities. However, with information available sub-nationally, the policies could be more targeted and effective, which explains the academic and governmental drive to make such data and analysis available. Below is an overview of examples of the European, North American, East Asian, and Middle Eastern approaches to the question of regionalization of national indices.

5.1 Europe

There has been some attempts to bring large scale indices into smaller, more regional ones. Europe is leading the way. With the 2016 report –"Beyond GDP: Global and regional development indicators"[60], the European Commission confirms that the view that GDP alone is an insufficient measure and has been looking at indicators that would be relevant for regional policy design, monitoring, and evaluation. The report reviews sustainability metrics, such as the *Ecological Footprint*, and *Adjusted Net Savings.* These, however, would only be available on the national, rather than regional, level. By contrast, the *Human*

Development Index (HDI), *Innovation Scoreboard*, *Competitiveness Scoreboard* (fig. 5-1), as well as *Regional Index of Sustainable Economic Well-Being* had been regionalized. These studies allowed a deeper understanding of priorities across various areas for future EU-level decision making.

The authors of the report highlighted two particular challenges with the regionalization. The first issue was with the data availability and reliability. For the data publications that were not up to date, a set of required proxies were to be adopted. As such, the maintenance of the regional databases has been proven to be harder than on the national level. Secondly, the nomenclature of territorial units was not harmonized across the indices, which has caused some disputes over the boundaries of the regions. These debates raised questions on how to define the territorial units to consider in this study, and a need to include these in the future work.

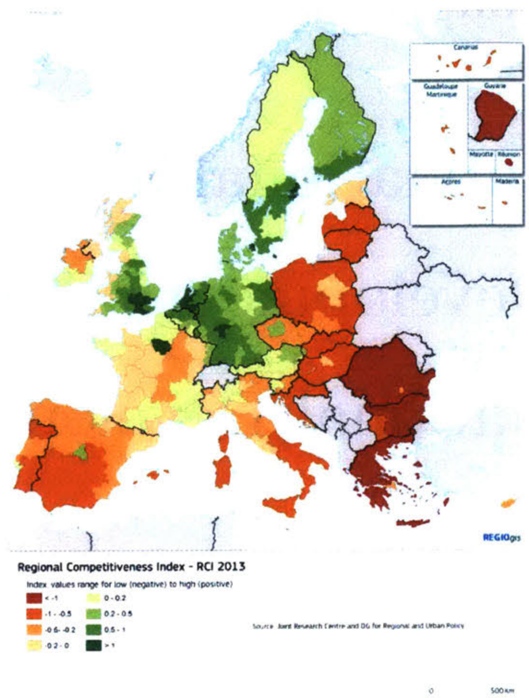

Figure 5-1: *Regional Competitiveness Index* results across Europe. Source: Regional Competitiveness Index 2013 [60]

5.2 East Asia

A notable attempt to regionalize development indicators was a study in China on the Human Development Index (HDI) that helped to investigate the regional inequality[61], [62]. The authors used 31 provincial-level administrative units with data from the annual yearbooks of China on GDP and *hukou* (household registration system), compiled from 1952 until 2013. This study explored the differences between the coastal and inland regions. The increasing rates of wealth were greater on the coast. The authors attributed export-oriented manufacturing to be at the heart of creating intensive disparities. Many programs to further the *harmonious society* [63] in the national *Eleventh Five-Year Plan* (from 2006 until 2010) have been implemented to target the inequality, which was informed by this type of regional analysis.

5.3 North America

Until today, the only attempt to measure regional and sub-regional Inclusive Wealth has taken place in the USA, for the state of West Virginia. The authors mapped the information available to the regions. This information came from databases ranging from West Virginian Department of Transportation and US Census' Topological Integrated Geographic Encoding and Referencing Database to provide detailed maps of the roads, to Zillow marketplace.

Taking a bottom-up approach for the Produced Capital, the authors made an assumption that buildings and infrastructure account for more than 70% of physical capital. The buildings were defined as residential and non-residential, and infrastructure mostly included roads, such as highways, US routes and roads. To estimate the values for the former group, the authors used the average prices for rental per zip code. To look up the value of the infrastructure, for instance, the roads, the authors used 10 million USD, 8 million USD, 5 million USD and 2 million USD per mile of highways as used by the work of cost estimation created by the states of Florida and Arkansas. Other infrastructure services, such as railroads, tunnels, bridges, pipelines, power and energy grids, and other urban and regional structures such as water, and sewage systems came at a price of the annual ecosystem service calculated per unit area (dollars per hectare).[15]

For the Natural Capital, the subsoil resources, which in the case of West Virginia has been coal, was taken from the available databases. However, the other, surface resources were estimated by identifying the land cover use. For instance, cultivated and non-cultivated soils, as well as the water resources (taken as the ground water and water of the lakes). A Global Information System (GIS) was then used to map the results of these calculations to the regions. The result was a very detailed map of the inclusive wealth capital distribution across the all 55 counties of the state.

The authors acknowledge the challenge in assessing the Human Capital. The chosen approach has been modified from the original IWR2012 and IWR2014, by using the following Equation:

$$h_a^e = w_a^e y_a^e + (1 - s_a^e) p_{a,a+1} \frac{1+g}{1+r} + \sum_{m=1}^{M_e} (\frac{s_a^e}{M_e}) p_{a,a+m} h_{a+m}^{e+1} (1+g)^m / (1+r)^m \tag{5.1}$$

e = educational attainment level;

a = age;

h_e^a = average human capital per capita for individual with age a and educational level e;

m = number of years;

w_a^e= probability of engaging in paid employment for an individual with age a and educational level e;

y_e^a = annual labour income for paid workers for an individual with age a and educational level e.

$pa,a+1$ = the probability of surviving for one more year from age a.

s_a^e= school enrollment rate for an individual with age a and educational level e.

Me = number of years that the individuals with educational level e spend to complete higher educational level $(e+1)$.

g = real income growth rate.

r = discount rate.

The approach that was chosen for the study was to apply the Jorgenson-Fraumeni formula to West Virginia geo-demographic, labor rates and educational attainment data. The data was taken from the American Community Survey. The results of this study provides data for assets-based management for regional development of the state.

5.4 Middle East

To date, there have been very few attempts to disaggregate the global development indices in the Middle East, due to a general lack of data on the regional level. However, an interesting attempt to overcome that had been achieved using night lights analysis. In 2012, Elvidge et al. developed a *Night Light Development Index*(NLDI), that gauges human development using night-time satellite imagery and population density.[65] The authors based their measurements on a well-established methodology from Lorenz curves to derive *Gini* coefficients of social inequality. Normally, the *Gini* coefficients would be calculated using national level data, however, in this method, the authors measured the brightness of satellite-observed lights versus population count. They found positive correlations between *Ecological Footprint, International Poverty Rate* and *the Multidimensional Poverty Index.* The NLDI was

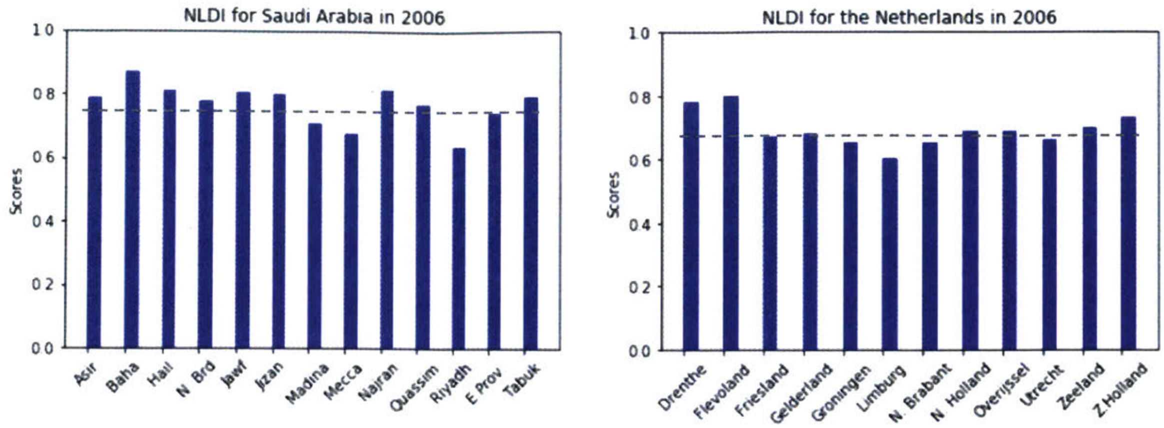

Figure 5-2: NLDI values produced for the provinces of the Saudi Arabia and the provinces of the Netherlands in 2006, with their average values (dashed line). Based on the data from National Centers for Environmental Information of National Oceanic and Atmospheric Administration.[66], [69]

found to be poorly correlated with the *Human Security Index*, and the percent of the population living in the urban areas. One of the conclusions was that the 'urbanisation' component needs to be developed.

The authors also made the subnational data available for 2006 globally. Using this dataset, provinces of Saudi Arabia could be compared with the provinces of the Netherlands, for example, to capture differences between a sparse land and highly urbanized developed land (fig.5-2). The NLDI index was lower for the Netherlands in overall, whereby the only Saudi provinces that reached the average levels of the country was Riyadh, Medina and Mecca.

Beyond being a proxy for the development activity, night-lights have also been shown to be a good estimate for *Gross Domestic Product* in developing countries by measuring the density of infrastructure and intensity of human activity.[68]

In this context, Saudi Arabia presents a promising case for the use of night-lights. As its economy is in transition, a lot of its activities are focusing on the secondary sector: from the oil drivers to mining and agriculture, rather than the services sector. Therefore, a night-lights study could be a valid alternative to estimate and map regional economic activity in case of insufficient data.

5.5 Conclusion

Subnational indices allow for more precise policy-making. This chapter reviewed efforts done in Europe on the indices, such as the *Competitiveness Index* and the *Human Development Index.* They acknowledged the problems with data availability and standardization. In China, an effort has been done to regionalize the H*uman Development Index.* In the USA, the latest Inclusive Wealth Index has been successfully implemented on a subnational level for the state of West Virginia using a bottom-up approach. However, when it comes to the regions with little data available, such as the Middle East, the latest sustainability assessments that had been done on a regional levels is *Night-Lights Development Index.* The Index looks at the night-lights concentration and correlates it against the population information. In conclusion, *Inclusive Wealth Index* regionalization is best to be done with a bottom-up approach, however even where data is available, there may be issues with its reliability. If no data is available, using the Night Lights as a proxy for economic or human activities could be a viable approach.

Chapter 6

Regionalizing IWI for KSA

This chapter presents a methodology to disaggregate the Inclusive Wealth (IW) model from a national to a regional level for the Kingdom of Saudi Arabia. This analysis will allow us to see how the sustainability varies by province across KSA as measured by IWI.

To adapt the IWI to a subnational level for Saudi Arabia an appropriate scale has been defined. Three levels were explored:

- 4 large regions: Central, Eastern, Southern and Western regions, whereby they are more inter-linked by electric grids and roads.
- 13 provincial regions: these are administrative regions that have much data already assigned to this level
- Subregional: data is insufficient, except for major cities such as Riyadh and Jeddah.

The finest resolution that allows a reasonable data collection is the provincial level as the Saudi Arabia General Investment Authority (SAGIA) and the Saudi Arabian Monetary Authority (SAMA) have been releasing detailed information since 1999. Since 2015, the Saudi Government has been centralizing their data collection efforts. We choose to regionalize the IWI by provinces, which gives us the best trade-off between best data availability and regional sensitivity.

6.1 Methodology Adaptations

This section described methodological adaptations implemented in order to regionalize the IWI to a provincial level.

6.1.1 Natural Capital

Regarding the Natural Capital, the available regional datasets are of rather good quality for crops, but not for pastures. Besides, while Saudi Arabia is very active regarding the fossil fuels and minerals industries, the location of these resources was not readily available. As such, the decisions about these allocations were made top-down.

Agriculture

For the crops stocks, the same method as described in Chapter 4 was applied to each province separately. The pastures land was regionalized using the livestock data as a proxy. Assuming the pasture lands to be fully utilized by the livestock, we could estimate how much pastures land is available from a comprehensive set of data for livestock available for each province: camels, cows, goats, sheep, chickens per province from 1996 until 2012. Using the livestock information from FAO (Table 4.1), we know that the average density of livestock units (LU) is 12 units per sq. km. FAO suggests estimates for cattle, sheep, goats, camels, and chickens for Near East and North Africa [95] to be 0.7, 0.1, 0.1, 0.75, and 0.1 LU respectively. Using these parameters, we assigned land areas in each province.

Table 6.1: Key variables and data sourced used in the measurement of Agricultural Capital stocks for Regional Level

Variables	Data available regionally	Source
Quantity of crops produced	yes	SAMA [71]
Price of crops produced	–	FAO [30]
Rental Rate	–	GTAP [29]
Harvested area in crops	yes	SAMA [71]
Discount rate	assumed at 5%	assumed at 5%
Permanent crops land area	yes	SAMA [71]
Permanent pasture land area	n/a but there is regional data on livestock	SAMA [71]

Fossil fuels: Oil and Natural Gas

The allocation of the resources was done using a top-down approach, using information from an interview with a representative of Saudi ARAMCO and publicly available maps from International Atomic Energy Agency, (fig.6-1).[51]

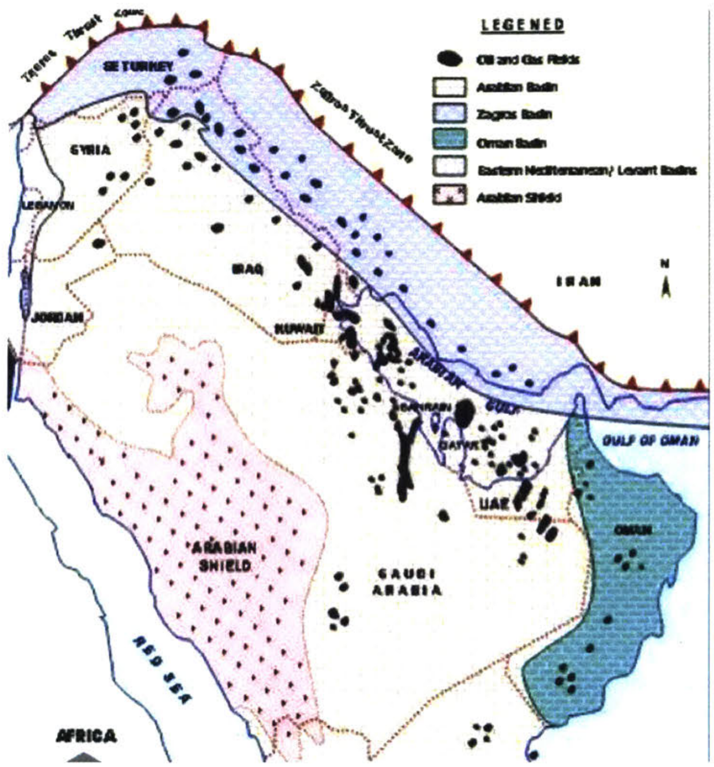

Figure 6-1: An example of locations search. Source: International Atomic Agency[51]

Mining and Minerals development

Mining is an important sector for the KSA, and the approach to data was a quasi-top down. For these calculations, each mineral deposit was identified by searching for the major mining sites and their products (see Table6.2), and studying the geological maps. For instance, we assumed that the metallic minerals (i.e. tin) were contained in the Precambrian rocks in the western part of the country. As for the non-metallic (i.e. feldspar) reserves, these were assigned to the Precambrian and Phanerozoic rock. Marble and Granite quarries location were identified using the International Builders Marketplace.[73] Gypsum was assumed to be similar to kaoline, whose locations were publicly available. The prices were taken from US Geological Survey, with the exception of magnesite. However, a market study in 2000 estimated the prices to be growing by 7.5% annually, which we applied here. [74]

Table 6.2: Variables used for Minerals information and their sources

Materials Selection	Source	Location
Feldspar, Limestone, Gypsum, Granite, Bauxite, Copper, Gold, Iron, Lead, Nickel, Phosphate, Silver, Tin, Zinc, Marble	Prices, reserves: USGS [34],[74]	Geologic Framework of Water Atlas, p. 16 [86]
Uranium	Reserves: IEAI. [51] Prices: NYMEX - CME Group [52]	IEAI [51]
Rental Prices	GTAP [29] (*vfm* parameter)	-

The information for Uranium deposits was gathered through the publicly available International Atomic Energy Agency's list of quarry stations, separately assigned to provinces using their addresses.

Fishing

No regional information was available. Therefore, we allocated the overall production between the provinces based on their respective coastline by the Red Sea or the Arabian Gulf.

Forests

The forests were allocated based on the maps from the Perry-Castaneda Library from the University of Texas Libraries [75]. Most of the stocks were in the west of the country in the mountainous regions.

6.1.2 Human Capital

The Human Capital approach was bottom-up for the data that was available from the Saudi sources, such as population, mortality rates and labor force participation (Table 6.3). The methodology applied was the same as discussed in Chapter 4.

Table 6.3: Key variables and data sourced used in the measurement of Human Capital Capital Stocks

Variables	Data available regionally	Source
Educational attainment	no	Barro and Lee [41]
Population by age, gender, time	yes	SAMA [71]
Mortality rates by age, gender, time	yes	SAMA [71]
Labor Force rates by age, gender, time	yes	SAMA [71]
Market rate of interest	no	Klenow and Rodriguez-Clare [40]
Discount rate	–	assumed 8.5%
Employment	yes	SAMA [71]
Compensation of Employees	no	GTAP [29]

The calculation was performed for each region separately and summed up to obtain the total wealth of the nation.

6.1.3 Produced Capital

The data exists on the national level, as we had calculated in the Chapter 4. However, due to the lack of data at a provincial level, we developed a top-down approach using the night-lights data for the regions of the country (Fig.6-2).

The Nation Centers for Environmental Information's Earth Observation Group gathers night-time observations and combustion sources worldwide. The group has been publishing the data from Defense Meteorological Satellite Program (DMSP) and Visible Infrared Imaging Radiometer Suite (VIIRS). Despite VIIRS having a higher resolution, the DMSP's

Table 6.4: Key variables and data sourced used in the measurement of Produced Capital Capital Stocks

Variables	Data available regionally	Source
Investment level	no	WB [7]
Discount rate	4%	4%
Night-lights breakdown	yes, for 1992-2012	NCEI[66]

dataset goes back to 1992 until 2013. Therefore the work in the retrospective IWI analysis will be more complete with this dataset.

The data archive is acquired from 4 satellites (3 day/night, 1 dawn/dusk) which have a 101-minute, sun-synchronous near-polar orbit, 830 km above the Earth's surface. The ground sample distance is, done by Operational Linescan System (OLS), at 2.7 km through a scanning telescope with three single detector focal planes. The signal is then intensified using a photomultiplier tube (PMT) and the collected data is processed by the laboratory.

We used the cloud free coverage data, and if the data was available from 2 satellites at each time, an average of the results had been taken. Using ArcGIS 10, the data was projected onto World Mercator 1984 and over-layered by a map of the provinces of the same projection (fig. 6-2). Based on the datasets, histograms were then extracted per region with values of brightness from 0 to 64. These values were separated into two ranges: 0-1 represented the 'black pixels'; and 2-64 represented the 'white pixels'. Using the regional 'white pixels' proportions out of the total 'white pixels' number for the country per year, we split the total Produced Capital by provinces in a top-down approach based on the density of night-lights.

Figure 6-2: Night-lights over Saudi Provinces in 2006. Image rendered using ArcMAP 10 software

6.2 Regional Inclusive Wealth Index Results

The results of the regional breakdown of the Inclusive Wealth show how spatially different the rates of change had been over the past two decades. Using the methods discussed in the previous section, the overall inclusive wealth is presented by the Natural Capital (calculated with and without fossil fuels), Human Capital (Expats and Saudis), and Produced Capital.

6.2.1 Regional Natural Capital

Overall Natural Capital is given in the following table (fig.6-3). However, the results with or without fossil fuels will be further discussed below.

	Natural Capital															
	Total *($ Bln 2005)*		Crops (%)		Pastures (%)		Forests (%)		Fisheries (%)		Oil (%)		Natural Gas (%)		Mineral (%)	
Regions	1999	2013	1999	2013	1999	2013	1999	2013	1999	2013	1999	2013	1999	2013	1999	2013
Al-Baha	3	2	0.01	0.01	0.1	0.0	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Al-Jouf	1	1	0.00	0.00	0.3	0.2	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Asir	11	20	0.00	0.00	0.7	1.0	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eastern Province	5162	4655	0.01	0.01	0.6	0.7	0.000	0.000	0.0	0.0	60.8	57.4	28.5	31.0	0.0	0.0
Hail	4	6	0.00	0.00	0.3	0.5	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jazan	2	1	0.00	0.00	0.2	0.1	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Madinah	8	8	0.01	0.00	0.3	0.2	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Makkah	59	78	0.02	0.01	1.6	1.5	0.002	0.002	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Najran	0	0	0.00	0.00	0.1	0.1	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Northern Border	89	88	0.03	0.01	0.0	0.0	0.000	0.000	0.0	0.0	0.0	0.0	1.5	1.6	0.0	0.0
Quassim	18	24	0.00	0.00	1.8	2.6	0.000	0.000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Riyadh	53	50	0.00	0.00	1.7	1.4	0.000	0.000	0.0	0.0	0.7	0.6	0.0	0.0	0.0	0.0
Tabuk	356	308	0.02	0.02	0.1	0.1	0.000	0.000	0.0	0.0	6.1	5.7	0.0	0.0	0.0	0.0
Total	5767	5242	0.11	0.07	7.7	8.4	0.005	0.005	0.0	0.0	67.6	63.7	30.0	32.7	0.0	0.0

Figure 6-3: Overview of the Natural Capital by regions

Natural Capital with the fossil fuels by regions

When looking at the results for the Natural Capital that do include the Fossil Fuels, the wealth of the nation is then concentrated in the Eastern Province, followed by the Tabuk and Mecca provinces (fig. 6-5).

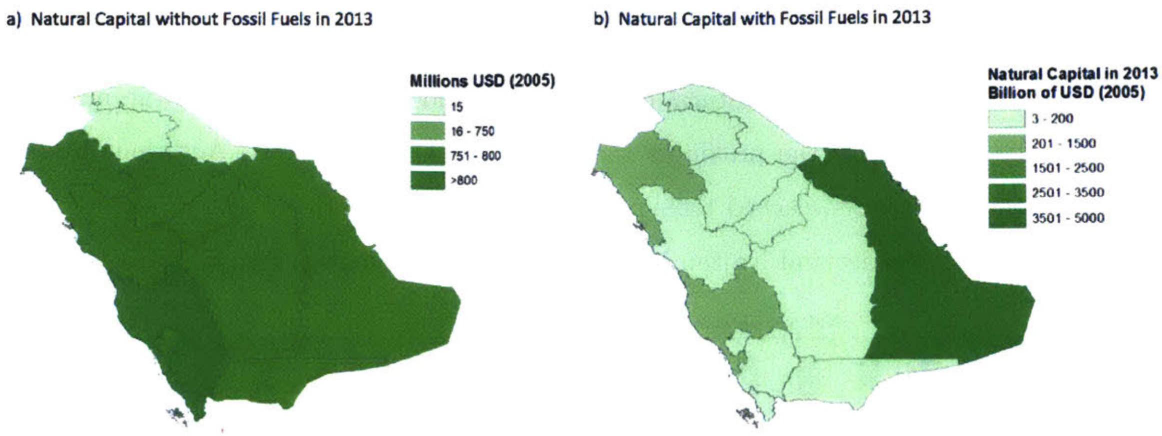

Figure 6-4: Map of the Natural Capital by regions without and with Fossil Fuels for 2013

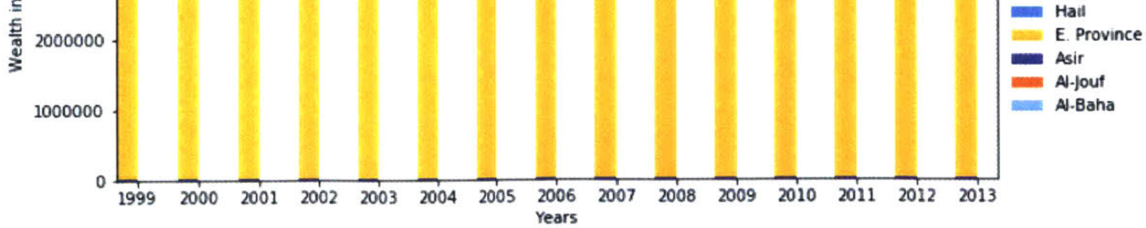

Figure 6-5: Natural Capital by regions, 1999-2013

Development of Natural Capital without fossil fuels

The Tenth Development plan, *Vision2030*, considers the diversification of the economy as critical for successful sustainable development. Therefore, the study of the Inclusive Wealth Natural Capital without the fossils was conducted. With this approach, the main contributor to the wealth becomes the agricultural capital: crops and pastures. Besides, the minerals could also be a factor for the provinces that have had little pastures. Additionally, one could note that the stocks reached their peak around 2006, with the Western regions, such as Mecca being the leader and Najran having the least of the capital (see figs.6-6).

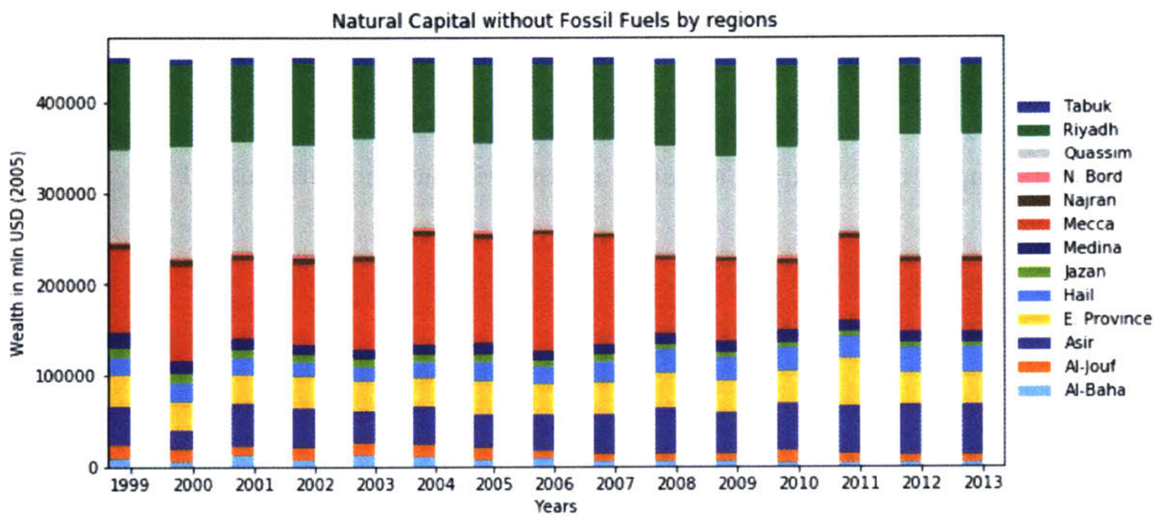

Figure 6-6: Natural Capital without Fossil Fuels, 1999-2013

6.2.2 Human Capital

The human capital has been steadily growing (fig.6-7) and has nearly doubled in 15 years, where most of the wealth is concentrated in Asir, Riyadh, Eastern Province, and Mecca.

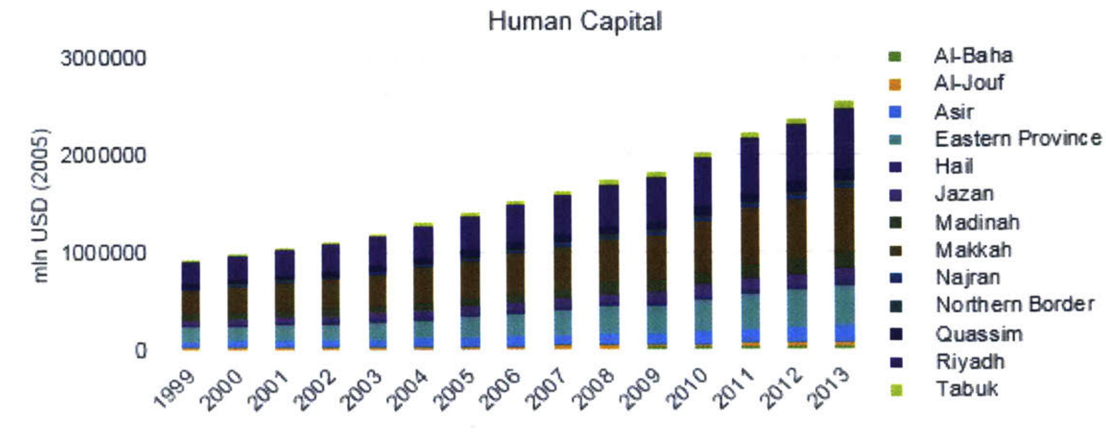

Figure 6-7: Human Capital by regions, 1999-2013

From the maps in fig. 6-8 one can see that the largest Saudi Human Capital is in Riyadh, Medina and the Eastern Province, whereas the largest Human Capital concentration for Expats is in Medina. More exact calculations in fig.6-9 show that the largest Human Capital was aggregated in Mecca and Riyadh at 489 and 482 billion USD (2005) respectively. The share of the Saudi Human Capital increased the largest in Riyadh (at 15.2%) and among the non-Saudi Human Capital in Mecca (10.5%). Eastern Province has lost its share of Saudi capital from 10.5% to 10.4%, whereas the non-Saudi Human Capital proportion has rise from 4.4% to 5.1%. Furthermore, the non-Saudi share has risen in Riyadh, Al-Jouf, Jazan, Medina, Mecca and Tabuk, but dropped in other places. The Saudi share has increased only in Al-Baha, Al-Joufe, Najran and Northern Border, apart from Riyadh.

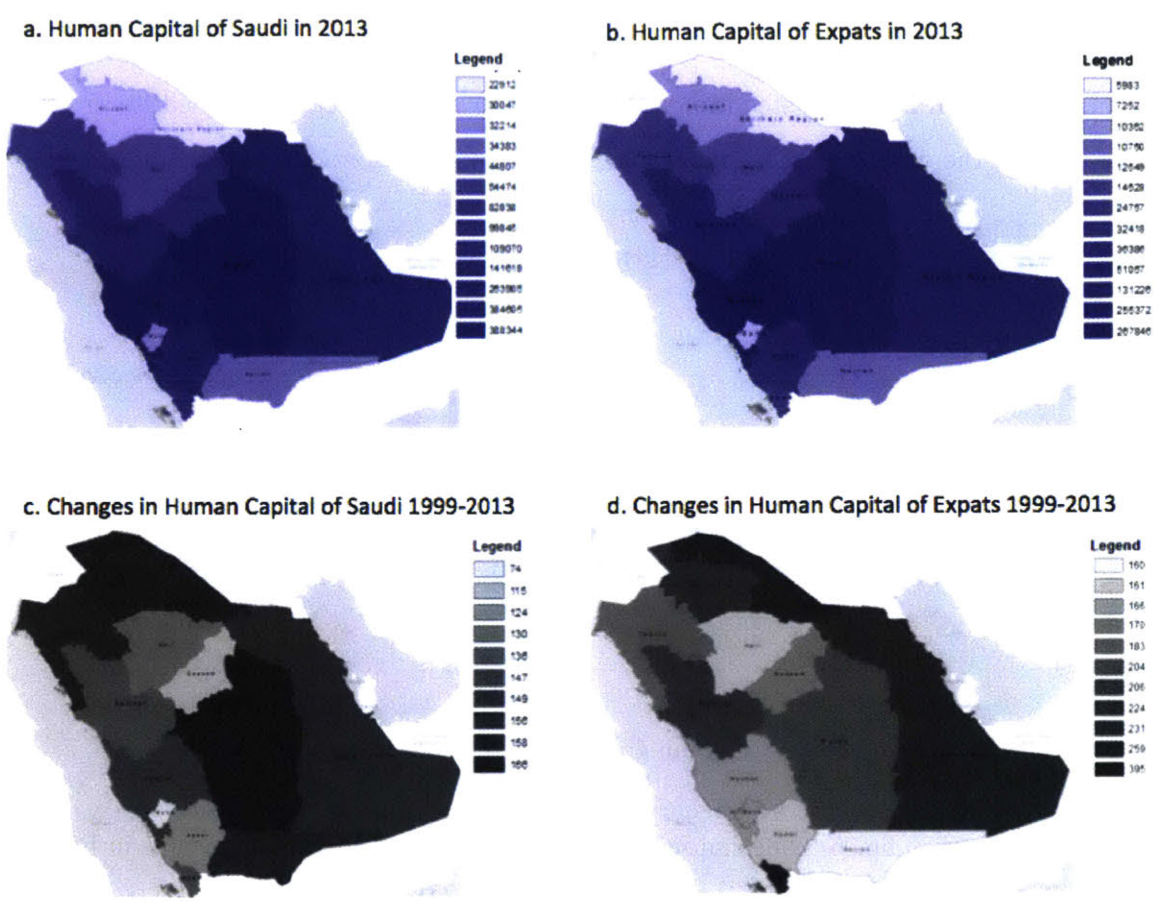

Figure 6-8: Maps Human Capital Variation for the Saudi and Expats Capitals and their changes between 1999 and 2013

	Human Capital					
	Total *($ Bln 2005)*		Non-Saudi (%)		Saudi (%)	
Regions	1999	2013	1999	2013	1999	2013
Al-Baha	27	30	0.3	0.3	1.9	1.3
Al-Jouf	18	30	0.3	0.4	1.2	1.2
Asir	99	133	1.5	1.4	6.6	5.6
Eastern Province	184	296	4.4	5.1	10.5	10.4
Hail	30	43	0.5	0.5	2.0	1.8
Jazan	59	93	0.5	1.0	4.4	3.9
Madinah	78	120	1.7	2.0	4.6	4.3
Makkah	315	489	9.8	10.5	15.9	15.1
Najran	22	34	0.5	0.4	1.3	1.3
Northern Border	13	22	0.2	0.2	0.9	0.9
Quassim	66	86	1.3	1.3	4.0	3.2
Riyadh	284	482	8.4	10.0	14.7	15.2
Tabuk	33	52	0.5	0.6	2.2	2.1
Total	**1229**	**1909**	**29.8**	**33.8**	**70.2**	**66.2**

Figure 6-9: Overview of the Human Capital by regions, 1999-2013

6.2.3 Produced Capital

The Produced Capital has been increasing steadily until about 2005 followed by a faster rate thereafter (fig.6-11). Using the night-lights data, we can see the diversity of the Produced Capital across the nation (fig.6-12). In numbers (fig. 6-10) one can see that the largest portion of the Capital lies within the capital region, at 24% in Riyadh, which is consistent with the recent development plan. The other provinces that have a share of activities larger than 10% are Mecca and Eastern Province. As for the changes, only six provinces increase their relative economic activities by 2013 with respect to 1999; these are: Al-Jouf, Eastern Province, Hail, Medina, Najran and Northern Border.

	Produced Capital	
	Total (%)	
Regions	1999	2013
Al-Baha	2.5	2.2
Al-Jouf	2.6	2.9
Asir	10.5	9.9
Eastern Province	16.4	17.1
Hail	3.4	6.2
Jazan	4.5	3.6
Madinah	5.5	7.4
Makkah	16.3	12.1
Najran	2.1	2.6
Northern Border	1.4	1.7
Quassim	8.1	7.6
Riyadh	24.0	24.0
Tabuk	2.7	2.7
Total	**100**	**100**

Figure 6-10: Overview of the Produced Capital by regions, 1999-2013

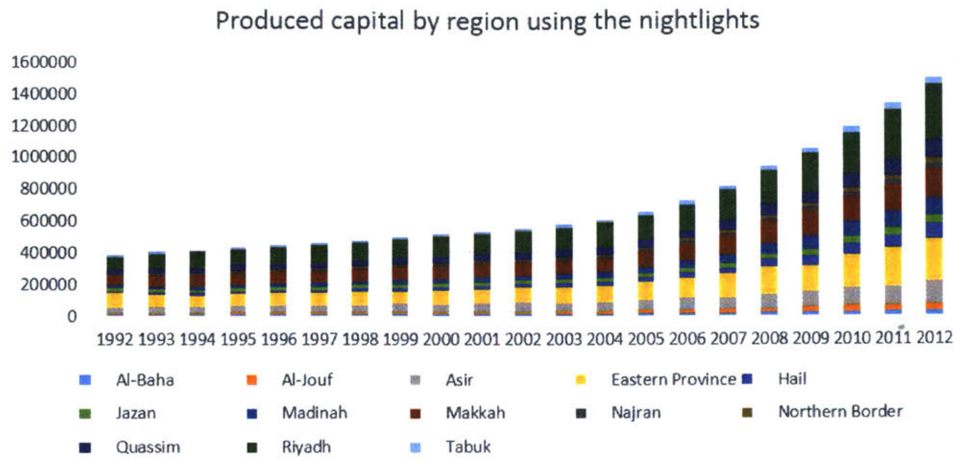

Figure 6-11: Produced Capital by regions, 1999-2013

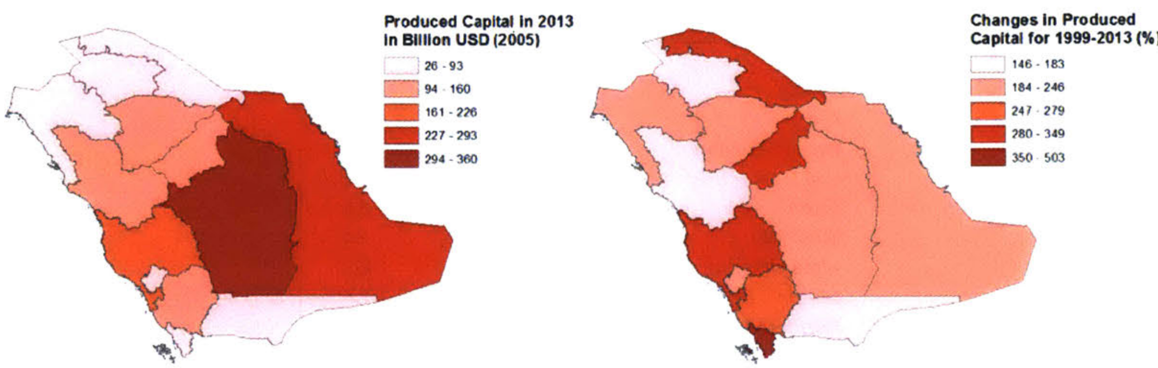

Figure 6-12: Map of the Produced Capital variation and changes in the Produced Capital, between 1999 and 2013

6.2.4 Overall IWI

The overall IWI has been growing for all the regions (figs.6-13 and 6-14).

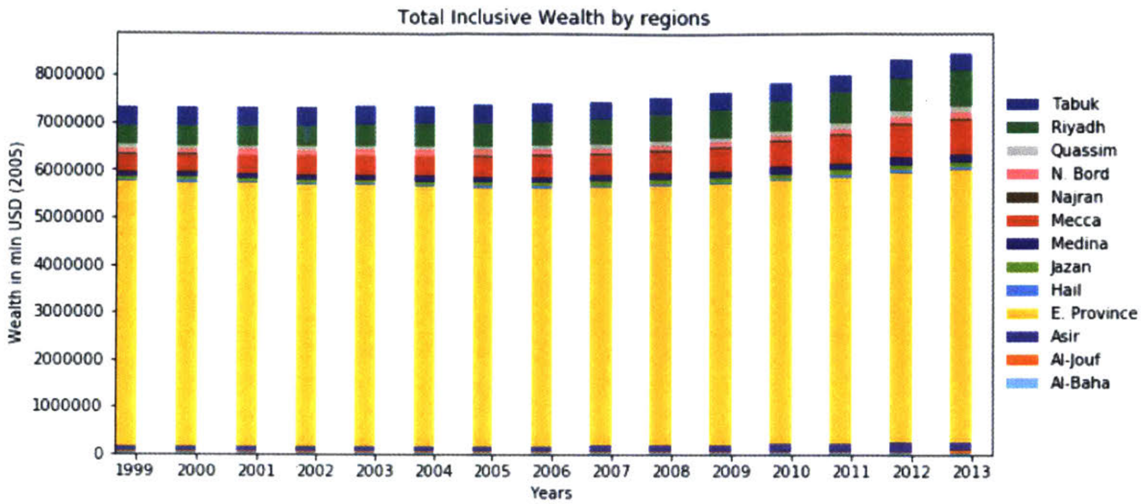

Figure 6-13: IWI by regions

However, the Inclusive Wealth *per capita* is uneven: it is growing in eight regions - Riyadh, Quassim, Medina, Mecca, Najran, Asir, Al Jouf, Hail - but it is decreasing in the others. The largest drop is in the Eastern province, followed by the Northern border, Tabuk and Al Baha. Additionally, the Eastern province shows the highest decline in terms of Natural Capital without any major compensation effect from other capitals (figs. 6-17 and 6-18).

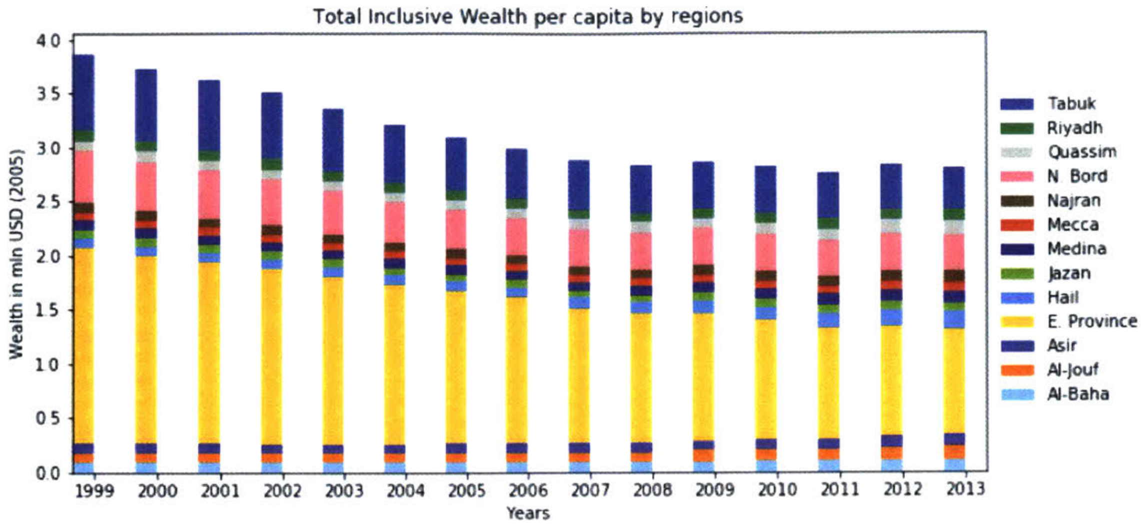

Figure 6-16: Inclusive Wealth breakdown *per capita*

The rates of change confirm that the Eastern Province has a huge impact at a national level. Indeed, its IWI drop in the absolute number is by far the most outstanding and is barely compensated by the other regions' performances. However, the relative rate of change *per capita* shows Eastern Province to be comparable to the other regions (see figs 6-17 and 6-18).

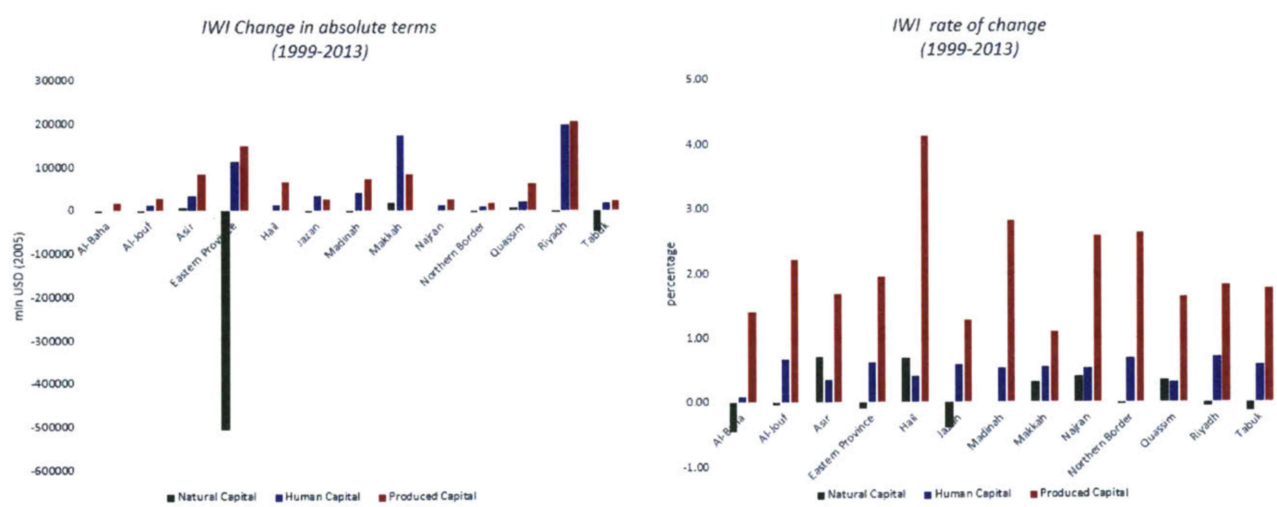

Figure 6-17: Comparison between the IWI calculations for Saudi Arabian regions in absolute changes: IWR2012, IWR2014 and IWI-KSA.[8],[9]

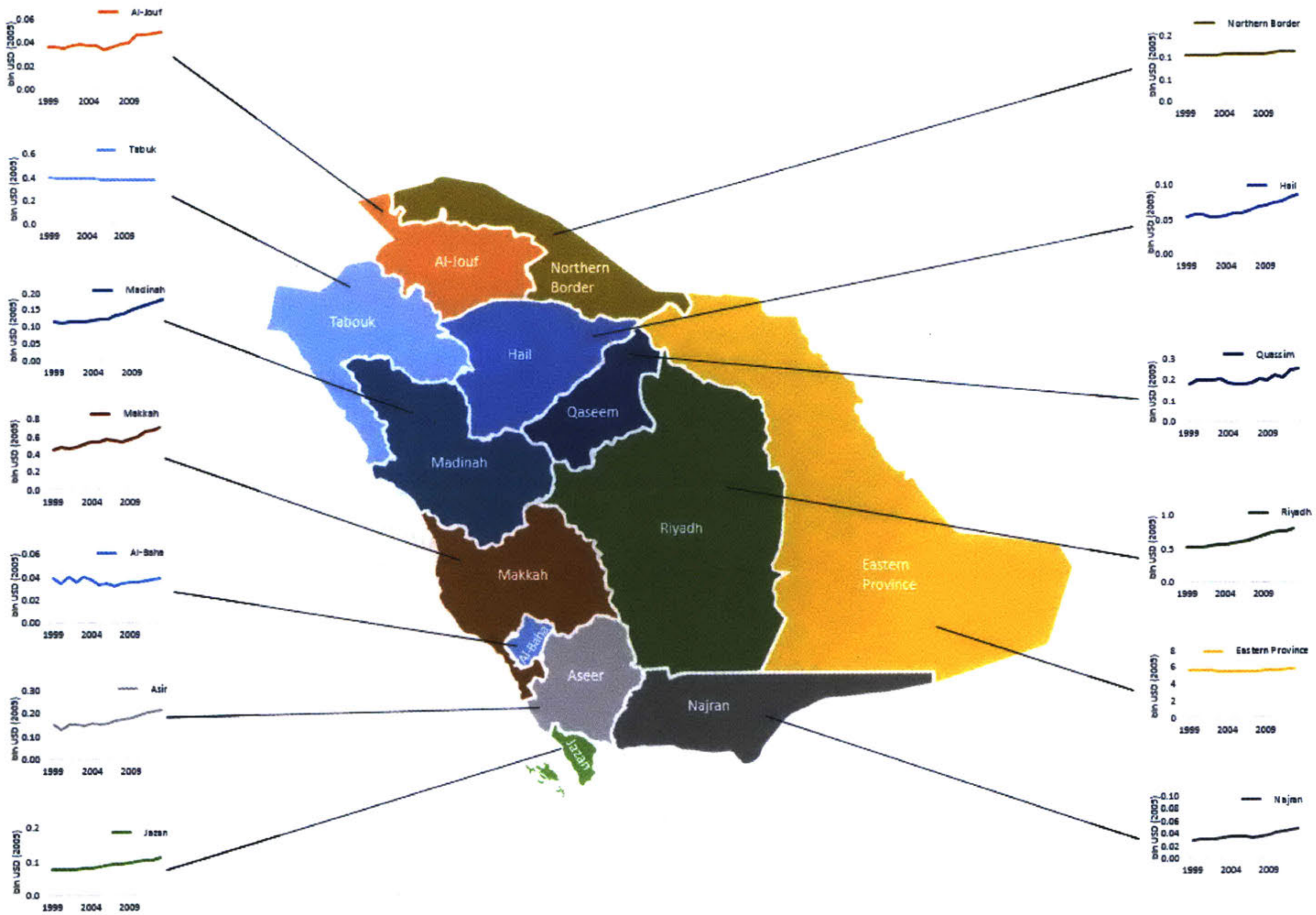

Figure 6-14: Inclusive Wealth breakdown across the provinces, 1999-2013

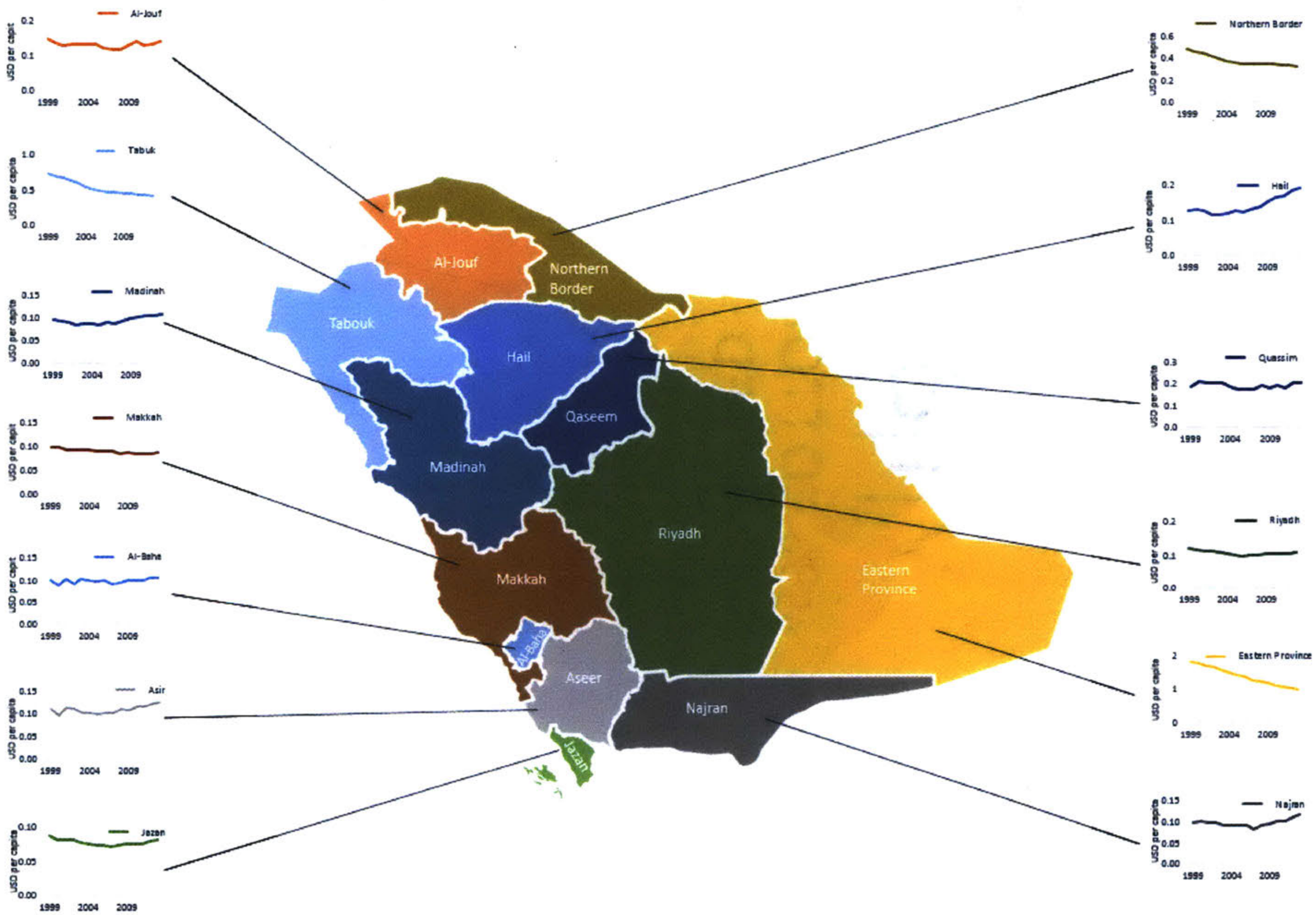

Figure 6-15: Inclusive Wealth *per capita* breakdown across the provinces, 1999-2013

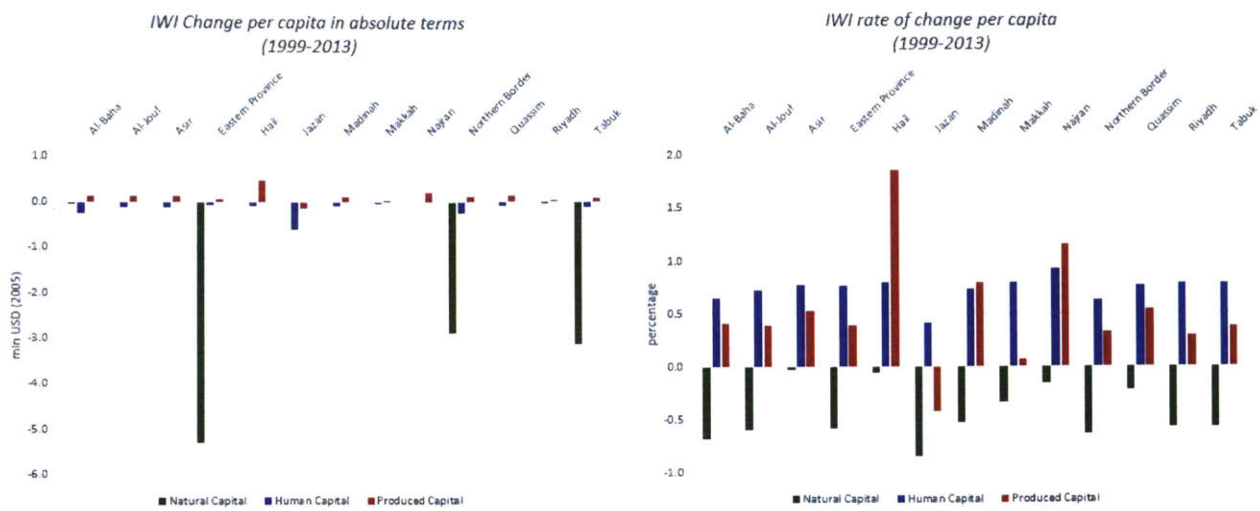

Figure 6-18: Comparison between the IWI *per capita* calculations for Saudi Arabian regions in absolute changes. IWR2012, IWR2014 and IWI-KSA.[8],[9]

6.3 Conclusion

The IWI has been successfully regionalized for the Kingdom of Saudi Arabia at the provincial level. Methodologically, we combined two approaches: bottom-up when good quality regional data was available (i.e. for Agricultural Capital) and top–down for other cases (i.e. for Produced Capital). The most available data was for Human Capital. The data availability for the Natural Capital was also quite reasonable for agriculture, even though some changes in the assumptions were needed for the top–down estimations for the fisheries, minerals, fossil fuels and forests.

There is a strong regional variation: the Eastern Province is showing the highest rates of overall IWI decline, whereas Riyadh is growing the fastest.

The policy implications for these findings will be addressed in the next chapter.

Chapter 7

Using Inclusive Wealth Index for policy-making in the Kingdom of Saudi Arabia

The Inclusive Wealth Index (IWI) is a tool to assist policy-making for the Kingdom of Saudi Arabia. There is literature suggesting applications of IWI as a metric for modeling forward-looking policies.[76] This particular work provides the dataset for validating such models. Policy)making, nonetheless, is deeply intertwined with context. Therefore this section provides the policy context, currently represented by *Vision 2030.* It then presents initial recommendations for the use of the IWI, such as insights from the regionalization of the Index; followed by a brief analysis of the limitations of the metric for practical policy-making.

7.1 Vision 2030

The most recent Saudi National Plan, *Vision 2030*, presents the overall goals of the policymaking in the upcoming years, for which a metric such as the IWI could be crucial. For instance, there is a strong push for achieving environmental sustainability "*by preserving our environment and natural resources, we fulfill our Islamic, human and moral duties. Preservation is also our responsibility to future generations and essential to the quality of our daily lives*"[3]. Achieving this goal implies management of the rates of depletion or repletion of the

Natural Capital stocks and doing so for the future generation. The IWI includes a detailed overview of the Nature stocks and it captures the intergenerational aspects as well.

Furthermore, there is an acknowledgment of the necessity to grow all Capitals - Natural, Produced and Human - in a complimentary way. For instance, similar to the example above, any other mentions of the natural resources within the text is always linked to the Human Capital: *"A vibrant society.. with strong roots. We have enormous untapped opportunities and a rich blend of natural resources, but our real wealth lies in our people and our society."* and *"Our country is rich in its natural resources.[...] But our real wealth lies in the ambition of our people and the potential of our younger generation".* [3] The potential and the younger generation employment is reflected within the Human Capital through the education, population size, and labor force participation as were shown in the previous chapters 3 and 4. For instance, *Vision 2030* states goals to lower the unemployment rate from 11.6% to 7% and to increase women's participation from 22% to 30%. [3]

Additionally, there is a push towards changing the production base from oil towards minerals: *"Diversifying our economy is vital for its sustainability. Although oil and gas are essential pillars of our economy, we have begun expanding our investments into additional sectors." "Gold, phosphate, uranium, and many other valuable minerals are found beneath our land."*[3] These ambitions would be reflected in Natural Capital stocks as well as Produced Capital, as the levels of associated investments are to be increased too. Overall, *Vision2030* identifies a need for a comprehensive development with a view for future generations too, making the IWI an extremely relevant approach to build the path towards the KSA's ambitions.

7.2 Insights into Regionalization of the Index

Vision 2030's more concrete strategic objectives lay out specific tasks for the Ministries aiming to support less developed regions. For instance, the Ministry of Energy, Industry and Mineral Resources is set to maximize the use of available hydrocarbon and mineral resources in less-developed regions with non-existing industries.

The Regionalized IWI shows progress in development within the central regions. In particular, the Northern and the Western regions would benefit from an increase in the minerals industry activity referred to in *Vision 2030.* However, just like fossil fuels, the minerals are another non-renewable resource. Therefore, the results from the IWI may, in fact, warn of the need to increase Human or Produced Capitals in the regions, otherwise, this development may not be sustainable over longer term. The index could call for the needs of additional investments in the economy, more educational and health-care facilities.

Furthermore, this regional development is far from being homogenous as there is an alarming disparity between the central regions and the Eastern Province. This inequality is a major area of concern due to the brewing conflict between the various Muslim groups: the Shi'a and the Sunnis. The majority of Shiites live in the Eastern Province (up to 15 percent)[77] whereas the rest of the country, including the most populated provinces of Riyadh, Mecca, and Medina are predominantly Sunni. Meanwhile, the Eastern Province is holding and losing most of its natural stocks, whereas the central regions are increasing in their wealth and as UN notes "the exploitation of high-value natural resources, including oil, gas, minerals, and timber has often been cited as a key factor in triggering, escalating or sustaining violent conflicts around the globe."[78] By following the policies to maintain the growth of the other regions at the expense of Eastern Region, the government is potentially worsening the conditions for an ongoing tension between the two groups, which may lead to a conflict escalation. The Regional IWI provides an objective metric to demonstrate this situation.

7.3 Questions of Interdependency of Resources: Water

Another important aspect of the natural resources is the development of the Agricultural sector, with a particular focus on the use of water. According to *Vision2030*, the use of water in agriculture will be "prioritized for those areas with natural and renewable water sources". The role of agriculture in the Saudi context is quite important. The history of increasing the agricultural stock in the Saudi shows its dependence on the subsidies more than the fertility of the soil. The agriculture in Saudi Arabia took off in the 1970s, following the introduction of the Food Independence Security policy. The policy declared a set of measures to boost the Kingdom's domestic production of crops and livestock to rely less on the imports. Substantial subsidies were initiated to import best technologies at the time, knowledge and seeds.[79] Consequently, the wheat production between the 1980s and 1992 grew almost 30-fold to 4.1 million tons in 1992. The wheat production had, in fact, exceeded the domestic demand and turned the nation into the 6th largest wheat exporter in the world at the time.[80]

However, in the 1990s, due to lower oil prices and the funds redirecting towards the military spending for the Gulf Wars, the subsidies on agriculture had to be cut. Accordingly, the production responded immediately, as seen in figure 7-1 by the sharp drop in wheat quantity. The crops had since then recovered, but since 2008 the government of Saudi Arabia changed the food policies. The state is to reduce the purchases of wheat from local farmers to 12.5% in order to rely entirely on imports by 2016.[80] Similarly, the domestic green fodder production, for instance, is to be terminated by 2019, scrapping the Food Independence Program.[81]

Additionally, studying the agricultural portfolio, one can see that Saudi Arabia's major crops are cereals, such as wheat and barley, others include fruits, vegetables and forage.[55] However, wheat is one of the more intensive crops [82], and as such, the Saudi decision to grow the crops has used large volumes of the water since the beginning of the policy (fig.7-2).

In the absence of precipitation, lakes or rivers, the water supply in an arid country such as Saudi Arabia is limited to two sources: desalination sea-water and the aquifers. The aquifers have been formed over during the Paleozoic age (250-525 million years ago), Mesozoic age (65-2500 million years ago) and the Tertiary age (1.8-65 million years ago) are considered *fossil water*[83]. Most of the demand, however is from the Agricultural domain, rather than residential or industrial.[84] Therefore, the Inclusive Wealth's treatment of the agricultural production as a renewable stocks may not be fully applicable to the Kingdom of Saudi Arabia, as it is ultimately reliant on a non-renewable resource such as water.

The current IWI methodology and results may encourage the Saudi to increase the agricultural sector, in agreement with the National Food Security program. However, it will be at odds with the question of sustainability. The IWI, therefore, needs to be adapted to take the endogenous value of water from arid regions. So far, the only two attempts to capture the value of water have been made: using the surface water in West Virginia [64] and the stocks of groundwater for aquifers in Kansas, USA.[85] The first method is inapplicable to the Saudi context due to the water sources being groundwater; the second case, however, uncovers another problem: the last estimates of the aquifers volume was done in 1984[86] before the peak of the water-intensive wheat production. Therefore, it is to be done in the future work to improve the IWI applicability for the KSA using the water stocks once the data becomes available.

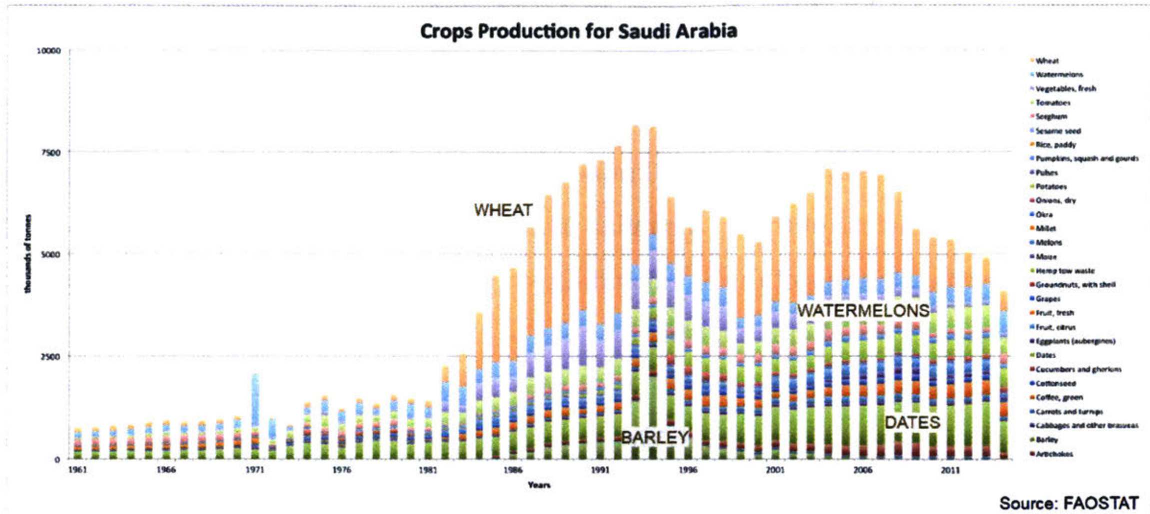

Figure 7-1: Historical overview of the crops production of Saudi Arabia. Source: FAO [30]

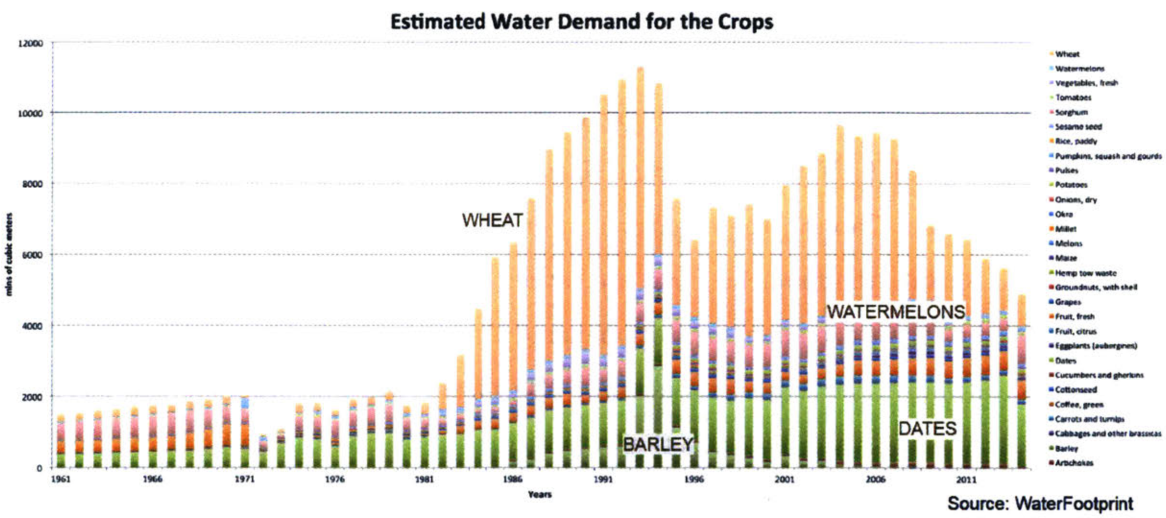

Figure 7-2: Estimation of the water use for the crops using the Water Footprint modelling data. Source: 'The green, blue and grey water footprint of crops and derived crop products. Vol 1.' [23]

7.4 Questions on Sovereignty of Wealth

One of the issues of the study and in the increasingly globalized world is the Sovereignty of Wealth. For instance, some of the policies that the Saudi are pursuing to overcome the Agricultural dependence (and its increasing rental rates) is purchasing agricultural land from Ukraine[87] and Tanzania[88]. Furthermore, in Tanzania, the land has been found to contain uranium, which is another strategic resource the Saudi are willing to exploit according to *Vision2030*. The renting of the land from another territory is then leading to the question of the sovereignty of a country's wealth: should the capital issued by these rented assets be allocated to Ukraine and Tanzania respectively, or to Saudi Arabia? On one hand, the capitals are under the sovereignty of Ukraine and Tanzania, on another hand, it is Saudi Arabia that is making use of them. A similar trend is noticeable for the Human Capital. By separating the contributions of the Saudi and Expat populations, and explicitly counting the Expat population, we exclude this contributions of the diaspora to the Human Capital of their countries of origin. For the current treatment of the IWI, we prioritize the sovereignty for the Natural Capital and Human Capital, yet this is a potential caveat for the IWI's application to the Saudi wealth.

Secondly, there is a question of the transfer of the capitals. For the UNEP *Inclusive Wealth Reports*, the non-monetary assets are evaluated in USD, deflated to the constant levels of 2005. Therefore, the transfers between the capitals should also be measured in USD, capturing the transactions. For instance when the oil reserves are depleted, the profit theoretically makes it back into the economy as an investment and therefore is to be captured as Produced Capital.[9] If this flow from Natural Capital depletion returns as sufficient Produced or Human Capital, the country is deemed to be developing sustainably. In the case of Saudi Arabia, the financial flows are rather complex and intractable. For instance, *Vision2030* sets forward a plan for nationalizing Aramco, the state company overseeing nearly total oil and natural gas production. The money will be turned to the Sovereign Wealth Funds, making it the largest in the world to date at over $2 trillion USD.[89] However, *Bloomberg* reports that the investments from those are rather difficult to track, providing no certainty what fraction of the profits will remain in the Saudi economy.

7.5 Conclusion

In conclusion, the historical analysis of the IWI on the national and subnational levels carries an important function to provide an insight into the sustainability of development of the country and regions. There is a recognized need for intergenerational treatment of the economy, natural resources and Human Capital within the government's policy plan, *Vision 2030*, and IWI can help to focus these efforts. For instance, while more investments are welcomed to the regions of Medina and the Northern province, the IWI results caution against levels of investment in Human and Produced Capitals to compensate for the depletion of the non-renewable minerals there.

The analysis could also provide additional insights regarding the potential conflict between the East and the Center of the country. The Eastern province is experiencing the most rapid depletion of the Natural Capital *per capita*, in contrast to the enrichment of the other provinces. Considering the simmering conflict between the Shi'a and Sunni populations, the results of the IWI analysis could highlight unintended consequences of policy that might worsen conditions.

Additionally, before applying the IWI for policy-making in the country, one has to be aware of the IWI inherently carrying an assumption that the agricultural stocks are renewable in nature. The study of the agricultural dependency on water indicates otherwise: due to the scarcity of water in the country, the agriculture is supported mostly by fossil water and supporting the sector may in fact hinder the sustainable development of country in the future.

Finally, the question of Sovereignty of the capitals has been addressed. Even though Saudi Arabia lends resources, such as land, from other nations, it has been decided to not reflect these transactions in the IWI recalculations. Another limit of the IWI model relies in the exclusion of the financial flows. Nonetheless, it may be inferred that if the financial gains from depletion of the Natural Capital, for example, are not reinvested in other Capitals then the development would not be sustainable.

Chapter 8

Summarizing Conclusions and Future Research

8.1 Conclusion

The Kingdom of Saudi Arabia has ambitious political goals for its development, and this work urges the government to consider other metrics than GDP to measure Sustainable Development. A candidate metric is the *Inclusive Wealth Index* (IWI) and this thesis investigated to what extent it is appropriate for sustainable development analysis of Saudi Arabia.

The study started with an overview of all the potential sustainability metrics, out of which only the *Inclusive Wealth* offered an overview into the state of the Economy, the Human Capital and the Environment over long-term, covering the intergenerational aspects.

Two global assessments were conducted by the UNEP in 2012 and 2014, using global databases. This study looked at how to adapt the methodology and data to the Saudi context to make it an appropriate policy-making tool for national development. The data sources were replaced by the Saudi data, where possible; and three modifications were made to the IWI calculation method.

First, minerals and fisheries were appended, although their impact on the IWI results was on the order of magnitudes of 103 to 108 respectively of the Natural Capital. The fossil fuels overshadow these contributions, however.

Secondly, the fossil fuels had to be revisited to emphasize the physical limit to the reservoirs. Due to new technologies, improvement in discovery techniques led to a steady increase in the oil and natural gas reserves despite continuous extraction activities. The recalculation for the fossil fuels allowed us to change the methodology to correct this paradox, incompatible with the definition of the non-renewable stocks. This method was revisited to capture all the known assets to date to be treated as the initial stocks.

Finally, we modified the methodology regarding the Human Capital to consider the split between the Saudi and non-Saudi populations, reflecting the effects of Saudi-specific strict policy-making regarding foreigners. The results showed that the IWI of Saudi Arabia is growing, while IWI *per capita* is declining, confirming the pattern presented in the Inclusive Wealth Reports 2012 and 2014.

To see if this pattern was the same across the whole country, this research investigated the extension of the IWI to a sub-national level. To date, this is the first application of a national development metric at a subnational level in the Middle East. While the Human Capital had much of the provincial data available, this was not the case for the Natural and Produced Capitals. For the Natural Capital, new datasets were developed by linking publicly available reports with geological maps of potential sites to estimate the resources' location across the country. The Produced Capital was disaggregating using an application of the night-light density.

Overall, the results showed a significant regional variation which needs to be considered to build an impactful and long-term policy-making vision. The Natural Capital is concentrated in the Eastern Province and is rapidly declining, whereas the other Capitals are mostly growing in the Central regions of the country, such as Riyadh, Mecca, and Medina. For the Human Capital, for instance, the increases for the Saudi population were the fastest in Riyadh; for the Expats in Eastern Province, Northern Province, and Jazan.

Additionally, the IWI illustrates a few caveats. First, a deeper analysis into another type of stocks of the Natural Capital reveals that specifically in Saudi Arabia, the Agricultural stock should not be considered as a renewable stock, because it is highly dependent on fossil water in the aquifers. Likewise, the Saudi government is considering expanding its minerals industry, but by doing so, it would only accelerate the depletion of the Natural Capital.

When combining the stocks from all the Capitals, one can see that the IWI is growing across all the regions. However, the IWI *per capita* is declining in five provinces: Tabuk, Northern, Al Baha, Jazan, and the Eastern Province. The rate of the Eastern Province's

IWI *per capita* decline is by far greater than in the other provinces, of 1 million USD *per capita*. As such, the development of the province can be sustainable only if the government increases its support the Human and Produced Capitals.

8.2 Future Research

The IWI sub-national analysis is a useful tool for policy-making. However, areas of improvement have been identified and could be addressed in future research. Firstly, water stocks for Saudi Arabia render the Agricultural Capital as non-renewable. Therefore, further investigation ought to be done in linking ground-water to the *Inclusive Wealth Index*, via the Agricultural Capital or as a stand-alone stock. There is some work done to this extent, but not in the Middle East context yet.

The subsequent work should also continue to expand to the forward-looking projection of various policies and their impact on the IWI at sub-national and national level. This work as shown that by diversifying into the minerals economy, the Saudi is, in fact, staying within the sector of non-renewable energy. Therefore, by furthering the Natural Capital decline, other Capitals need to be grown and these scenarios ought to be investigated. For instance, what would be the impact of investment in renewable energy sources, and investment in a knowledge economy? These policy recommendations could then support the government in decision-making to bring the country onto a positive IWI *per capita* trend.

Another important question this work raised is the question of inter-regional equity. The country is developing at the expense of the exploitation of the resources of the Eastern Province could be seen as an inter–regional subsidy. On another hand, the support of the Eastern Province to the national development should not penalize its local development. Indeed, the Natural Capital attracts new jobs and with it, potentially higher Human Capital via new educational centers, more population, provided that new universities and health-care facilities are built. The IWI has the capacity of measuring to what extent these assumptions hold, once more data would become available.

Finally, this work provides the first attempt to regionalize the IWI in an area with very limited data access. In particular, the night-lights use helped to disaggregate the Produced Capital of the Index. With the improvement in the sensor technologies and data, IWI could potentially be more reliant of the observational data collection for the Human and Natural

Capitals too, complementing statistical bureau reports. Generalizing this approach to the regionalization could provide a methodology that would be of high importance especially in remote or sparse areas and be of aid to the local governments for measuring their policies' impact at sub-national and national level.

Appendix A

List of Acronyms

ARAMCO .... Saudi Arabian Oil Company,

ArcGIS .... GIS software

BP .... British Petroleum

CME .... CME group

DMSP .... Defense Meteorological Satellite Program

EIA .... United States Energy Information Agency

FAO .... United Nations Food and Agriculture Organization

GDP .... Gross Domestic Product

GIS .... Geographic Information Systems

GSSD .... Global System for Sustainable Development

GTAP .... Global Trade Analysis Project

HDI .... Human Development Index

IEAI .... International Atomic Energy Agency

ILO .... International Labor Organization

IMF .... International Monetary Fund

IW .... Inclusive Wealth

IWI .... Inclusive Wealth Index

IWR2012 ...... Inclusive Wealth Report 2012

IWR2014 ...... Inclusive Wealth Report 2014

KACST .... King Abdulaziz City for Science and Technology

KSA .... Kingdom of Saudi Arabia

LU .... Livestock Units

MinMax .... Minimum-Maximum analysis

NLDI .... Night-Lights Development Index

OECD .... Organization for Economic Cooperation and Development

OLS .... Operational Linescan System

PIM .... Perpetual Inventory Method

SAGIA .... Saudi Arabia General Investment Authority

SAMA .... Saudi Arabian Monetary Authority

SAUP .... Sea Around Us Project

SDGs .... Sustainability Development Goals

UN .... United Nations

UNEP .... United Nations Environmental Program]

USD .... United States Dollar

USGS .... United States Geological Survey

VIIRS .... Visible Infrared Imaging Radiometer Suite

WB .... World Bank

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