Proceedings of the Australasian Conference on Business and Social Sciences 2015, Sydney
(in partnership with The Journal of Developing Areas)
ISBN 978-0-9925622-1-2

CREDITING ENVIRONMENT IN MACROECONOMICS

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ABSTRACT

The aim of this paper is to highlight the shortcoming of the standard macroeconomic framework when environment is ignored in the implementation of traditional policy practices. Valuing the environment provides an understanding of the economy as a subsystem. This allows an appreciation for the close-knit relationship between a subsystem and the ecosystem. Often, the environment is not accounted due to an absence of markets to price it as a capital. Even with the presence of markets, pricing the environment may not address the challenges of optimality and sustainability. Furthermore, attaching a price to the environment does not resolve the accumulated degradation that has occurred to the ecosystem. It serves only to offer some form of provision towards the depletion of the environment as a capital. Therefore, the key is to ensure that valuation of environmental degradation is easily internalized in macroeconomic frameworks for the formulation of sustainable policies. Reference is made to a leading Gulf State to show the ease with which environmental degradation is internalized in macroeconomic framework and the respective policy recommendations. The paper concludes with implications to the framework towards sustainable economic growth.

JEL Classifications: E00, E01, E23, E61, Q51, Q56
Keywords: Macroeconomics General; Measurement and Data on National Income and Product Accounts; Production; Policy Objectives; Valuation of Environmental Effects; Sustainability, Environmental Accounts and Accounting
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INTRODUCTION

Macroeconomics (as practiced) is about a circular flow of isolated systems, where values are exchanged between firms and households. Such exchanges are conducted in a close loop system which does not rely on the external system. That is, the circular flow is isolated and deemed not to depend on the environment. If there was no dependence on the environment, there would be no environmental degradation nor natural resource depletion which effectively means that there will be no pollution. However, pollution is observed in our daily lives and it reduces quality of life. As there is no market to price the environment as a capital, it is convenient to not account for the environment. Attempts to assign proper pricing of pollution are based on individual economy's efforts towards clean energy options. Valuation of the environment provides a much needed understanding of an economy as a subsystem. Different economies use different methods and justifications to set the price of pollution. Although there are several proxies in place, the concern is whether a selected proxy provides a comprehensive representation of environmental degradation. Resource depletion also tends to be overlooked. A ton of coal mined now means one less ton of coal for mining in the future. As it is not easy to quantify environmental degradation and resource depletion into a comprehensive measure of Gross Domestic Product (GDP) (Frank and Bernanke, 2009), both environmental degradation and resource depletion are not fully represented in GDP. Nevertheless, it does not mean that quantification of environmental degradation and resource depletion should be overlooked.

Thus, there is a clear need for advanced macroeconomic modelling and analyses that explicitly incorporate the environment, such that meaningful and efficient policies can be formulated. Changes to the macroeconomic framework require that the macro economy behaves as an open subsystem of the finite natural environment. Standard macroeconomic frameworks do not consider the inclusion of environment as a capital (Daly, 1991) because environmental capital is not easily internalized into macroeconomic models. There are a few suggested ways on how the environment could best be internalized but unfortunately, there is no one universally agreed method to value the environment. As such, the exclusion of the environment could lead to unsustainable economic growth for an economy as the rate of environmental degradation outpaces the rate of economic growth.

The aim of this paper is to highlight the shortcoming of the standard macroeconomic framework when environment is ignored in the implementation of traditional policy practices. An illustration (with reference to a leading Gulf State) is used to demonstrate the ease with which environment can be internalized in macroeconomic framework. This paper is structured as follows. Section II provides an overview of sustainable growth, options to grow and impact on natural ecosystem. This is followed by Section III. which discusses accounting and valuing the environment, and proxies of the environment. An empirical case is used to illustrate the internalization of environment in a simple Keynesian framework in Section IV. A brief discussion on policy implications is also included. The implications of this framework conclude this paper.

ECONOMICALLY SUSTAINABLE GROWTH

Sustainable Growth

Since the 1970s, environmental impacts and economic growth have been major issues of concern for the environment and sustainable growth. But this has been ignored by mainstream economics (Daly, 2013). Without economic growth, unemployment may rise. But with economic growth, there could be a strain on the environment. This is evident with rising occurrences of natural disasters and an observation of erratic weather. Thus, for growth to be sustainable an economy must grow within the environmental boundaries. From a scientific angle, sustainable growth can be explained by the laws of thermodynamics. The first law of thermodynamics states that matter cannot be created nor destroyed; it can only be re-arranged (Guggenheim, 1985). Matter is re-arranged as the environment provides material for energy input and absorbs waste. Energy is transformed from a state of low entropy (high energy) to that of high entropy (low energy) to do work. This is the second law of thermodynamics. When an economy consumes, matter goes through phases of arrangement and re-arrangement. These phases use up the available energy levels with no recycling option. Consumption involves a rearrangement of energy within the economy as well as the environment (Daly, 1997). As a result of this non-recycling, some of the matter will become residual waste. The combination of the two laws results in absolute scarcity of resources (Daly, 1991)[1]. Such scarcity implies that the environment must be used in an efficient manner to allow for sustainability.

Over the past decades, scholars (selected) had made attempts to discuss and provide frameworks for measuring sustainability. See Norton and Toman (1997), Moffatt *et al*. (2001), and Pezzey and Toman (2005). The trend has been skewed towards theoretical debates as opposed to empirical work. Pezzey and Toman (2005) argued that this was the case of ideological pre-convictions triumphing over a greater ability to identify future limits to growth. There are other measures; such as ecological footprint that measures the resources necessary to produce the goods and services for individual consumption. But ecological footprint has been criticized as an ineffective proxy for sustainability. See Fiala (2008). Similarly, Ferng (2014) argued for both planetary boundaries and impacts of international trade documented for ecological footprint to be a suitable tool for measuring sustainable development.

With the internalization of environmental capital in standard macroeconomic frameworks, policy options should include environmental and sustainability policies. Hanley (2000) had reviewed the policy need for indicators of sustainable development but concluded that there is no current available single macroeconomic measure of sustainability. Even though there is no current available measure of sustainability, Randall (2008) argued that a weak sustainability policy suffices for now to ask more out of the status quo. Gray (2009) added that the challenge is a nuanced understanding of what "sustainability" actually is and what it represents empirically. Thus, it is crucial to measure the impact of economic activities on the ecosystem.

Growth Options

Growth of an economy differs in the short and long run. In the short run, growth is driven by the level of aggregate demand which constitutes consumption, investment, government expenditure, and net exports. In the long run, an economy can attain growth by increasing its productive capacity for instance, increase in factors of production (raw materials), increase in factor productivity, increase in labor participation and technological improvement. The discussion will start with increasing productive capacity followed by increases in level of aggregate demand (consumption).

One way an economy could grow is via the production of goods and services. The production process determines an economy's productive capacity. Production function in most economic textbooks (Dornbusch *et al.*, 1995; Frank, 2003; Pindyck *et al.*, 2006; Dornbusch *et al.*, 2008; Mankiw *et al.*, 2008; Blanchard, 2009; Frank and Bernanke, 2009) considers labor and manufactured capital to be the only two factors of production.

The price of labor is the wage paid to each unit of labor, and the amount of labor can be determined through demand and supply in the labor market. Note that it has been argued that population (source of labor) cannot continue to grow forever (Boersema, 2011) and at some point in time, rate of technology advances needs to outstrip that of the population growth rate. Manufactured capital refers to goods used for future production and can be priced as rent, assuming that it is not owned and supply is fixed. With technological advancement, rent can be discounted for depreciation. Thus, both labor and manufactured capital can be priced easily through their respective markets. However, production does not rely on labor and manufactured capital alone; it is also dependent on the natural environment. For example, air, land and water are essential requirements in the production process.

The natural services provided by the environment are external to the economy (Daly, 2007). The economy is a subsystem of the larger ecosystem. Given that the ecosystem is finite, non-growing and materially closed, the economy is dependent on the ecosystem for both its sink and source functions. Therefore, limit to growth is the threshold of the ecosystem to absorb wastes and replenish raw materials in order to sustain the economy in a closed-loop system. This limit is analogous to borrowing from the future, and deferring present maintenance and replacement. Limits to growth are physical and biological in their origin, but their effects are felt long before any physical damage is apparent. The subsystem has an optimal point, beyond which growth is no longer possible. Theoretically, optimal point can be explained using a production possibility function (PPF). Assume that an economy produces two goods namely, X and Y. This is represented in Figure 1 below.

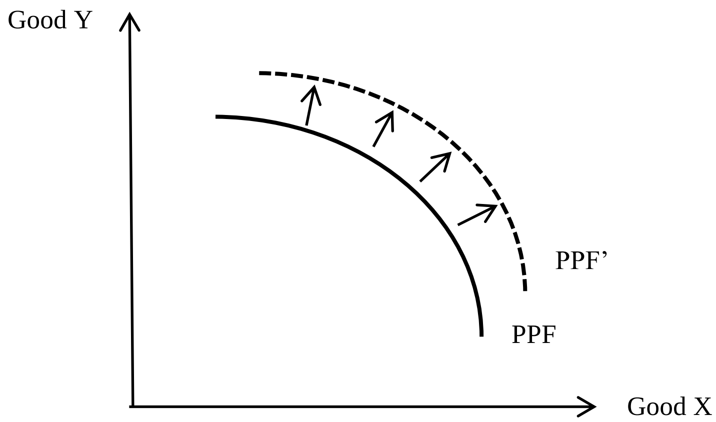


FIGURE 1. OPTIMAL POINT OF THE SUBSYSTEM

Growth[2] is illustrated by an outward shift of PPF to PPF’. This shift involves the services of the ecosystem which may not be attainable at the current time period, implying that PPF is the optimal point of the subsystem. This is because costs exceed benefits (in economic terms) beyond this optimal point. In reality, it is unlikely that optimality in economies can be achieved. The challenge is to include these limits in economic terms that would aid decision-making and not just market provision to price the environment.

In the short run, economic growth is driven by the level of aggregate demand for example, increase in consumption. Georgescu-Roegen (1971) and Daly (1977) argued that greater economic growth would entail more production and consumption activities to satisfy human wants. Kolstad and Krautkraemer (1993) pointed out a dynamic link between the environment, resource use and economic activity. While resource use (especially energy sources) yields immediate economic benefits, it also has a negative impact on the environment but this downside is observable only in the long run. England (2000) explored the relationship between capital accumulation and economic growth, and between capital accumulation and the natural world. He found that modern growth models were silent about the natural foundation of production. Land was not considered as an asset, raw materials were not considered as commodities, and no energy was required to drive the production process. However, if an economy is to grow by consumption, nature will play an important role.

Growing by consumption may not necessarily represent a greater level of well-being. Manner and Gowdy (2010) explored the usage of consumption as a proxy for well-being, but challenges by behavioural research have found that well-being is a function of much more than economic consumption. There are other factors that affect well-being. Besides, it has been found that consumption is the principal driving force behind environmental impacts (Rothman, 1998). Hence, economic growth through consumption has failed to explain an economy's well-being. Instead, it has attributed to the degradation of the environment. As economies grow, a population's welfare may be at risk should the environment continue to be neglected. It is important that the environment be kept intact to provide future generations with a set of life opportunities undiminished relative to present opportunities (Howarth, 1997). Arrow *et al*. (2004) reconciled the conflicting intuitions of consumption (towards economic growth) by using both ecological and economic insights to raise questions that might not have been raised. Consumption increases the use of natural resources, reflecting a higher demand from a growing world population. With the increase in the use of natural resources, an increase in investments has also been witnessed[3] (Arrow *et al.*, 2004). Despite stresses on the ecosystem, such investment was necessary to ensure higher (or at least similar) real living standards in the future.

The Natural Ecosystem

The natural ecosystem refers to the environment that living organisms interact and live in. It encompasses the air, soil, sunlight, and water. These are public goods as no property rights have been assigned. Consuming one more unit does not reduce the amount available for consumption (non-rivalry) and does not exclude (non-excludability) another individual from consuming. Notwithstanding the public goods characteristics, there are two other challenges. Firstly, it is not easy to arrive at a mutually agreeable price as there is obviously a market (or governance) failure. Secondly, the span of the natural ecosystem means that one price for all will not accurately reflect the socially optimal marginal cost. The challenge is compounded as there are different measurement methods for different facets of the natural ecosystem. Stiglitz *et al.* (2009) argued that placing a monetary value on the natural environment is often difficult and separate sets of physical indicators will be needed to monitor the state of the environment. This is particularly the case when it comes to irreversible and / or discontinuous alterations to the environment. And climate change (due to increases in atmospheric concentrations of greenhouse gases) is unique in that it constitutes a truly global issue that cannot be measured with regard to national boundaries (Stiglitz *et al.*, 2009). Costanza *et al.* (2014) made it clear that expressing the value of ecosystem services in monetary units does not mean that they should be treated as private commodities to be traded in private markets. The value in monetary terms is an estimate of their benefits (or costs) to society expressed in a form that appeals and is understood by a broad audience.

There are several scholars who have considered the ecosystem as a production input. Frank (2003) discussed natural resources as inputs to production (p577). His discussion was focused on the awareness of renewable and exhaustible (non-renewable) resources, and transition from exhaustible to renewable energy sources. Frank's collaboration with Bernanke in a later textbook (Frank and Bernanke, 2009) presented the production function to include technology and land (p574) with the numerical illustration focusing only on labor and manufactured capital. Mankiw *et al.* (2008) included labor, manufactured capital, human capital, and natural resources in their production function (p567). Similar to Frank and Bernanke (2009), the numerical illustration focused on labor and manufactured capital based on their returns to scale. However, as per Frank (2003), their natural resource discussion was limited to renewable and non-renewable resources. Most discussions stopped short of accounting for natural resources and attributed economic growth to non-resource factors. Even when resources are recognized as a necessity for production, the amount of resources used can be small because labor and manufactured capital can be substituted in sufficient quantities and be substituted smartly.

An analysis of the natural environment as inputs to production made by Samuelson and Nordhaus (2010) grouped factors of production into three categories: land, labor, and manufactured capital. Land and labor are the primary or original factors of production. Land can be a derived demand as it depends on the product produced. Manufactured capital was added only as a produced factor of production and can be grouped as structures, equipment, and inventories. In line with the above discussions, a United Nations report published in 2012 also identified nature (as well as labor and manufactured capital) as capital and included land, forests, fossil fuels and minerals as wealth assets. If natural resource is considered an input of production in the production function, an economy is unlikely to continue growing indefinitely. These discussions suggest that the ecosystem is critical for economic growth.

A transition to new economic growth requires a change in both habits of consumer consumption and production methods of producers to attain an optimal point for the subsystem. This implies different development paths from present and involves a transition from current business-as-usual practices to a nuance form of environmental-friendly path. A review of existing economic growth frameworks, starting with accounting and valuing the environment.

ACCOUNTING AND VALUING THE ENVIRONMENT

Accounting for the environment

Accounting for the environment as a capital comes in the form of green accounting. This approach of accounting extends national accounts to include the value of environmental degradation as a result of economic growth. The fundamental goal of accounting for the environment is to ensure that there is some form of allowance allotted to the depletion of natural capital. There have been significant developments by international agencies to date. When measuring the income of an economy, the United Nation's (UN) System of National Accounts (SNA) recognizes land, minerals, timber and environmental resource as economic assets in a nation's capital stock (Hanley *et al.*, 1997; Hecht, 2005) for resource accounting. A World Bank-led partnership (launched in 2010) incorporated the value of natural capital in national accounts in the form of Wealth Accounting and Valuation of Ecosystem Services (WAVES). This is based on the System of Environmental-Economic Accounting founded on SNA and will feed into developing an UN's handbook of ecosystem accounting.

As economies continue to grow, there is a need to account for the degraded environment. However, no depreciation estimate even in terms of a universally agreed-upon valuation method can be considered as truly accountable. For instance, expenditure that protects and maintains the environment should be considered. But such expenditures could contribute to further environmental degradation. To this end, Sustainable Net National Product (NNP) is a measure of true income which has been adjusted for expenditures that do not reflect any increase in the net product available for consumption without eventual impoverishment (Daly, 1996). Bartelmus (2010) termed this Green NNP since it offered a quantifiable sustainability concept of produced and natural capital maintenance.

Methods of Valuing Environmental Capital

Price signals are typically used in discussions of whether an asset should be used or preserved. The non-existence of a market implies no precedence to value costs and benefits of using or preserving an asset. It is a myth that markets solve all valuation problems. Even when a market exists, the economic framework may not always be practical for valuation (Ison *et al.*, 2002). Hence, a no market scenario seems a convenient excuse not to value a natural resource. The absence of a market is one of many considerations for not providing a fair valuation to a natural asset. For example, there are other considerations like valuing mobile underwater resource (fisheries) and considering if there is a spatial component provision (land and water) (Hecht, 2005).

Market prices reflect the relative scarcity of individual resources but do not measure the absolute scarcity of resources in general. Therefore, income derived in this manner does not necessarily correspond to well-being. Perhaps, a better choice for an objective measurement of well-being might be consumer surplus that is, the difference between the maximum price an individual is willing to pay and the actual price paid. Unfortunately, consumer surplus is not included in the calculation of National Income Accounting. In the absence of markets, there are other factors that can be considered to contribute to national income such as, the life of an asset, the resource rent it provides, and the discount factor that can be used to value future returns at the present time.

Welsch (2009) proposed that environmental valuation (in monetary terms) be a basic ingredient to the cost–benefit analysis of environmental policy. By correlating people's reported subjective well-being with both environmental amenities and income, it permits the identification of the utility function over environmental quality and income directly; and the estimation of the implied utility-constant trade-off between them. But estimation of such is subjective to individuals. Likewise, the Centre for Social and Economic Research on the Global Environment (CSERGE) developed approaches to environmental valuation but had issues ensuring that environmental issues were taken into account in economic accounting and appraisal. See Barbier *et al.* (1990); Pearce and Turner (1990); Pearce and Warford (1993); Turner *et al.* (1994).

Valuation techniques (with time taken into consideration) may be a better estimation than the use of traditional statistical methods because degradation is a cumulative continuing process in a time continuum, not a one-off occurrence in a particular time period. An option is to base asset valuation on the principle of replacement cost, or the willingness to pay (WTP). The replacement cost is simply the cost of replacing a damaged environmental asset, and WTP is the amount to be paid for an environmental benefit. In both instances, there are no markets to attach a price to the cost or benefit.

Familiar techniques of environmental valuation are classified into stated preference and revealed preference methods. Stated preference methods rely on hypothetical markets. In this case, individuals are directly asked to value the environmental good in question. One prominent stated preference method is Contingency Valuation (CV), which attempts to elicit the valuation of hypothetical changes in environmental conditions. Market approaches offers a powerful incentive for cost-saving innovation with price adjustments without intervention from the authorities. As markets will have its ups and downs, the key for policy makers is to establish limits on a tolerable level and enforce the required limits. Revealed preference methods rely on actual markets and use complementarity or substitutability relationships between environmental goods and market goods to infer the value attributed to environmental conditions from observed behavior with respect to market goods. Examples include hedonic price analysis (which assumes that differences in environmental conditions are reflected in wages and housing prices), the travel cost approach, and the averting or mitigating behavior method. Both stated and revealed preferences have their weaknesses. Stated preference studies make strong requirements concerning people's cognitive ability to value hypothetical goods. Revealed preference approaches are based on stringent assumptions concerning the rationality of agents and the functioning of markets. A discussion of a popular valuation method is illustrated next as it provides a "shadow price[4]" for resources that are non-market tradable.

Contingency Valuation (CV) Method

The CV method is based on WTP to value environmental damages when the environment is considered a consumption good. This method is the most widely used method as other valuation methods are unable to identify and measure passive or non-use values of biodiversity (Nunes and van den Bergh, 2001). This is evident with its application in various scenarios of environmental valuation (Carson, 2007). It is a popular method because it is easy to apply and has a wide range of contextual applicability (Thampapillai, 2002). The effectiveness of CV is dependent on the survey sample and how the questions are framed which could lead to varying interpretations. See Rathzel and Uzzell (2009) where the manner in which questions is framed can lead to quite different interpretations of the findings.

Biasness cannot be avoided as in the case of preserving the Kariba lake shore in Zambia (Thampapillai *et al.*, 1992), where there were respondents willing to contribute in excess of 50% of their income whilst others were unwilling to contribute. Knetsch (1994) argued that the correct measure for CV should be the sum total compensated to individuals for the environmental damage. This is the willingness to accept (WTA), an amount which will normally be far larger than WTP. Outcomes of such demonstrate that WTP biasness may be inherent in nature, leading to inappropriate environmental policies and distorted incentives as losses are valued more than gains. It is argued that loss schedules might be implemented faster as it provides deterrence incentives and predict incurable outcomes. For that reason, it is deemed more appealing and not reliant on rational behaviour alone.

A study by Sinden (1994) found that the estimation for un-priced goods and services usually meets several objections. Valuations serve to account explicitly for factors that are otherwise overlooked, implicitly valued and wrongly valued. As a result, the consistency in the findings across the body of valuation studies adds more value than the findings from each individual study. When the market for a certain good is competitive, economic activities can be studied by the market pricing mechanism. But because this is not feasible in the case of environmental goods, classical CV and closed-version of discrete choice methods are preferred (Verbič and Slabe-Erker, 2008).

Environment Proxies

There are several proxies to environmental degradation. Thampapillai *et al.* (1998) used energy consumption expenditures, and the air shed was used a decade later in Thampapillai (2007) for Sweden and the United States (US). Apart from energy consumption expenditures and the air shed of an economy, there are other proxies to environmental degradation. Loss of forest cover, loss of marine biodiversity, degradation of soil quality, rising sea levels, frequencies of cyclones and floods are some examples. Loss of forest cover can lead to landslides and loss of biodiversity. Rising sea level suggests higher sea surface temperatures which is a pre-condition for the formation of tropical cyclones (Harvey, 2010). For example, high sea-surface temperatures and large amounts of moist air over the Indian Ocean may have triggered the Pakistani floods and the Russian heat wave in 2010 (Ananthaswamy, 2010). Reducing emissions from deforestation and degradation (REDD) have called for better land use and planning as it serves to maintain the environment as well as create jobs. Some viable options include: forestry, ranching, vineyards, and wetland restoration. Debates over procedural hurdles meant a lack of progress in the REDD-plus Partnership (which includes forest conservation, sustainable management of forests and carbon stock enhancement) (Haverkamp, 2010; Kant, 2010). An effect from over-utilizing assimilative capacity is the diminishing services of nature. Of late, Liu and Borthwick (2011) used natural resources capacity, environmental assimilative capacity, ecosystem services capacity, and society supporting capacity as proxies of environmental degradation. But more work is required on improving the representation of ecosystem services.

As there is a range of proxies for environmental degradation, a feasible policy option might be one with a portfolio of solutions for maintaining each proxy. That is, carbon reduction; renewable energy consumption; air shed quality; marine biodiversity; reforestation; and wetland restoration. An array of environmental degradation proxies offers some relief to environmental accounting and valuation. But there remain two questions to be answered. One, which of these proxies can be assigned a fair monetary value. And two, how easy would it be to internalize the degradation of environment into selected macroeconomic frameworks. These are critical questions as they are vital towards the formulation of developmental policies and sustainable economic growth. For the purpose of this paper, the emphasis will be on consumption-led economic growth.

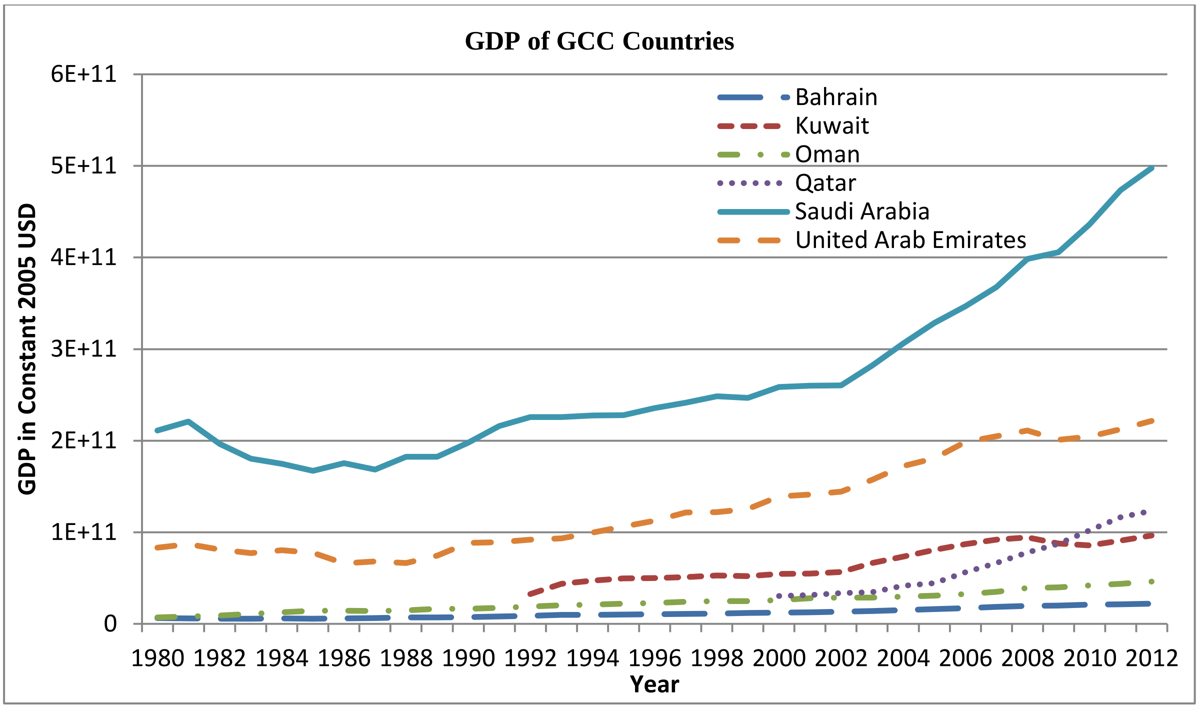
The next section presents a simple macroeconomic framework which allows internalization of environmental degradation and discusses some policy implications with reference to a leading Gulf State.

EMPIRICAL CASE

"30 years from now, there will be a huge amount of oil – and no buyers. The Stone Age came to an end not because there was a lack of stones."

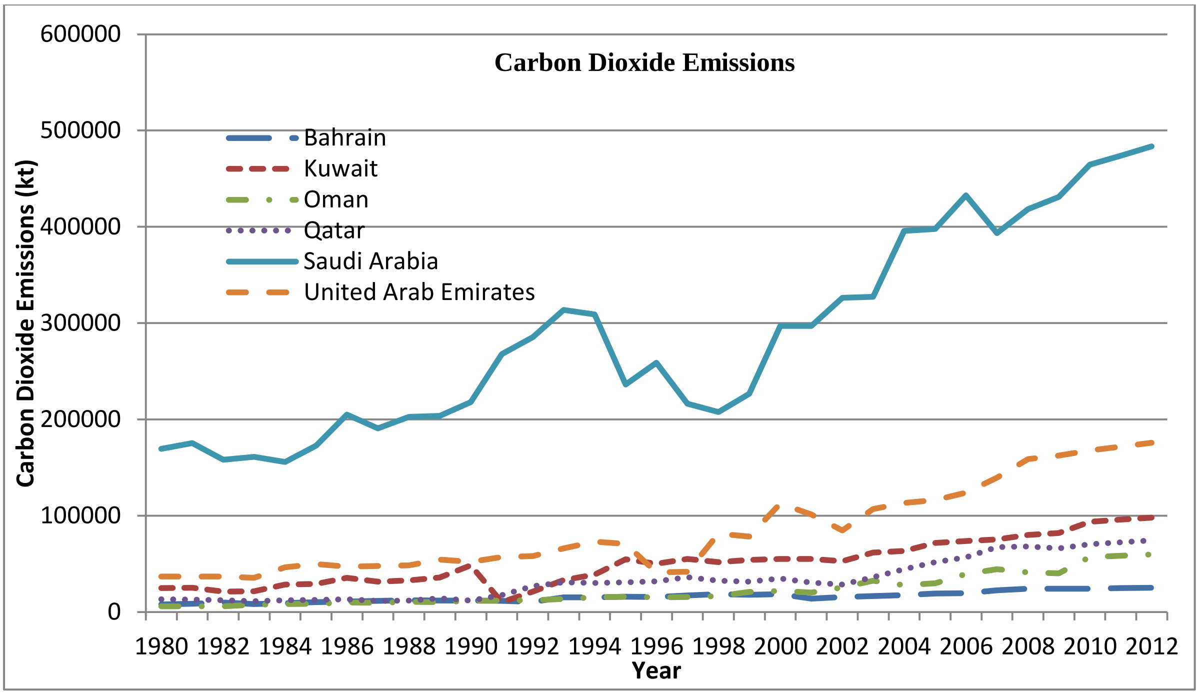
Sheikh Ahmed Zaki Yamani (2000)
Minister of Oil (Petroleum) and Mineral Resources (1962 –1986)

Saudi Arabia's economic growth has increased exponentially over the past 30 years. This is largely due in part to the oil and natural gas resource which the Kingdom is endowed with. Amongst the Gulf Cooperation Council (GCC), Saudi Arabia has the highest level of Gross Domestic Product (GDP) (See Figure 2) but it also emits the highest level of carbon dioxide (CO_2) (See Figure 3) and evidence suggests an increasing dependence on non-renewables (oil and gas) for power generation (See Figure 4). Therefore, the Kingdom is a classic example of a leading economy whose economic growth has been highly dependent on non-renewables.



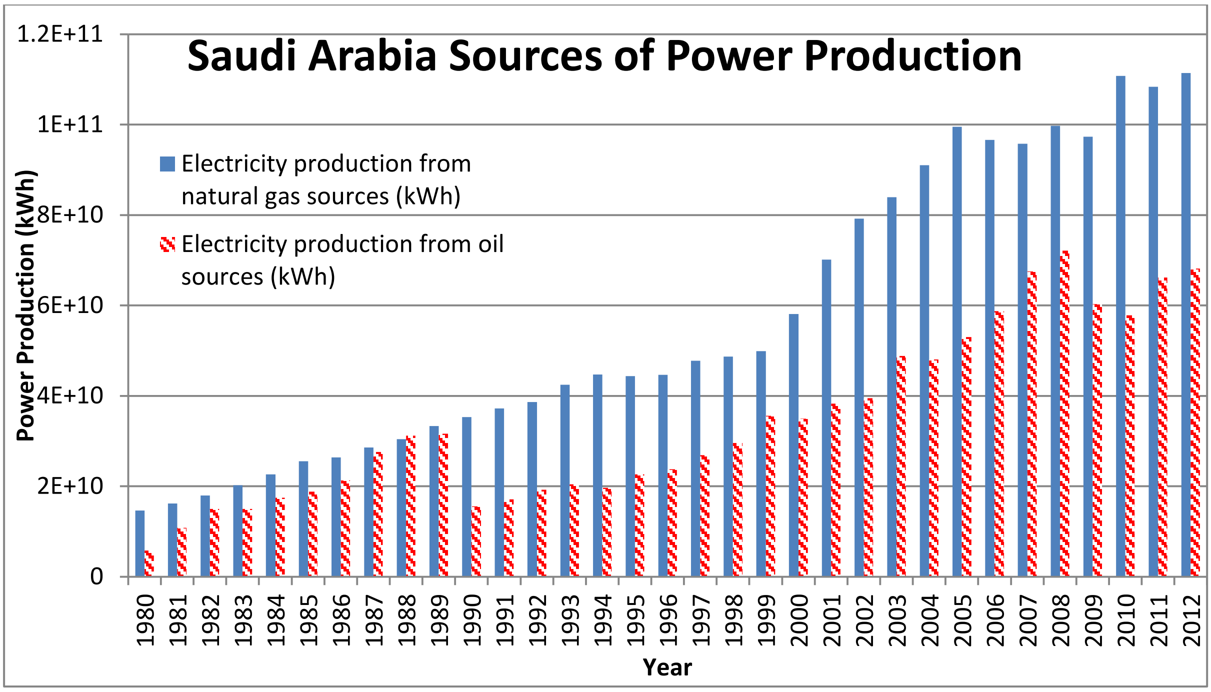
Source: World Development Indicators, 2014

FIGURE 2. GDP OF GCC COUNTRIES IN CONSTANT 2005 USD FROM 1980 – 2012



Source: World Development Indicators, 2014

FIGURE 3. CARBON DIOXIDE EMISSIONS IN KILO TONS FROM 1980 – 2012



Source: World Development Indicators, 2014

FIGURE 4. SAUDI ARABIA SOURCE OF POWER PRODUCTION (kWh) FROM 1980 – 2012

There are plans to further develop and modernize the oil and natural gas industry. For instance, an investment valued at USD17 billion (to replace declining production from mature fields as opposed to increasing capacity) has been allocated to develop the offshore Manifa field (Makan and Hume, 2013). This bodes well for future growth of the industry in the form of continuous direct employment in the oil and natural gas industry; as well as the auxiliary industries which support the industry. More importantly, such development ensures that the accumulated expertise and skillsets of the labour force are preserved.

To enjoy sustainable economic growth, it is crucial that Saudi Arabia adopts innovative energy and environment policies. A transition to alternative forms of energy is important as the supply of non-renewables is not indefinite. There must be a strong sense of urgency to address innovative use of current energy sources; and the reliability of renewables. The "El Serafy[5] Method" (first published in 1981) suggests that only part of the proceeds from the sale of resource assets can be considered income (El Serafy, 2002). By applying this to the Kingdom, not all revenues from exporting oil can be calculated as income. This is because there is depletion to the asset stock – which is irreversible, and no allowance has been made for the depletion.

The following describes a simple Keynesian framework to show that the Kingdom's income will not be sustainable when environmental degradation is included in consumption-led economic growth.

A Simple Keynesian Aggregate Expenditure Framework

The following analysis is based on a simple Keynesian framework where aggregate income (Y) is determined by aggregate expenditure. Aggregate expenditure is limited to GDP with the assumption that all components of GDP are fixed, barring consumption (C) and investment (I). Hence, the sum of government expenditure (G) and net exports (NX) is assumed to be contained in a constant (denoted by Φ) during a given time period. The methodology employed relies on the analytics of point estimates.

The assumed functional definitions of C and I are as follows:

$$C = \alpha + \beta Y \quad (1)$$

$$I = \bar{I} + \delta Y \quad (2)$$

In (1), α and β represent respectively autonomous consumption and the marginal propensity to consume. By assuming $\alpha = 0$, the point estimate value of β is $\left(\frac{C}{Y}\right)$. In (2), $\bar{I}$ represents fixed investment which is assumed to be contained in Φ such that ($\Phi = \bar{I} + G + NX$) and point estimate values of δ (propensity to invest) are defined as $\left(\frac{I - \bar{I}}{Y}\right)$.

A simple definition for the equilibrating value of Y within standard framework based on $Y \equiv GDP$ is given by:

$$Y^{*} = \frac{\Phi}{[1 - \beta - \delta]} \tag{3}$$

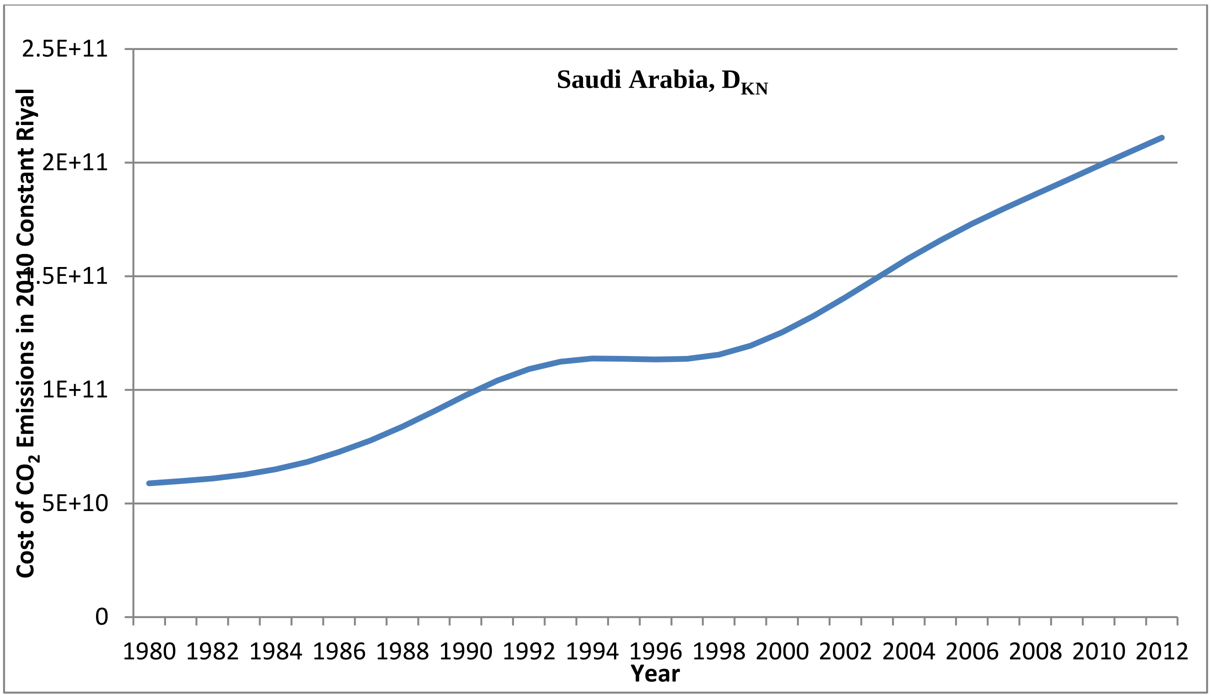
For the sustainable framework, equilibrium for income determination is redefined as ($Y \equiv GDP - D_{KN}$), where D_{KN} is the depreciation of environmental capital (KN). In a simple Keynesian framework, KN can be afforded a similar measurement to manufactured capital (KM), analogous to that of an income-bearing asset. That is, KN will undergo the same depreciation treatment as KM to account for the loss in its ability to generate future income. If the depreciation of environmental capital (D_{KN}) is a simple linear proportion γ of GDP, it follows that γ is defined as:

$$\gamma = \frac{D_{KN}}{GDP} \tag{4}$$

With the consideration of γ, the revised equilibrating value of income Y^{**} will be:

$$Y^{**} = \frac{\Phi(1 - \gamma)}{[1 - (1 - \gamma)(\beta + \delta)]} \tag{5}$$

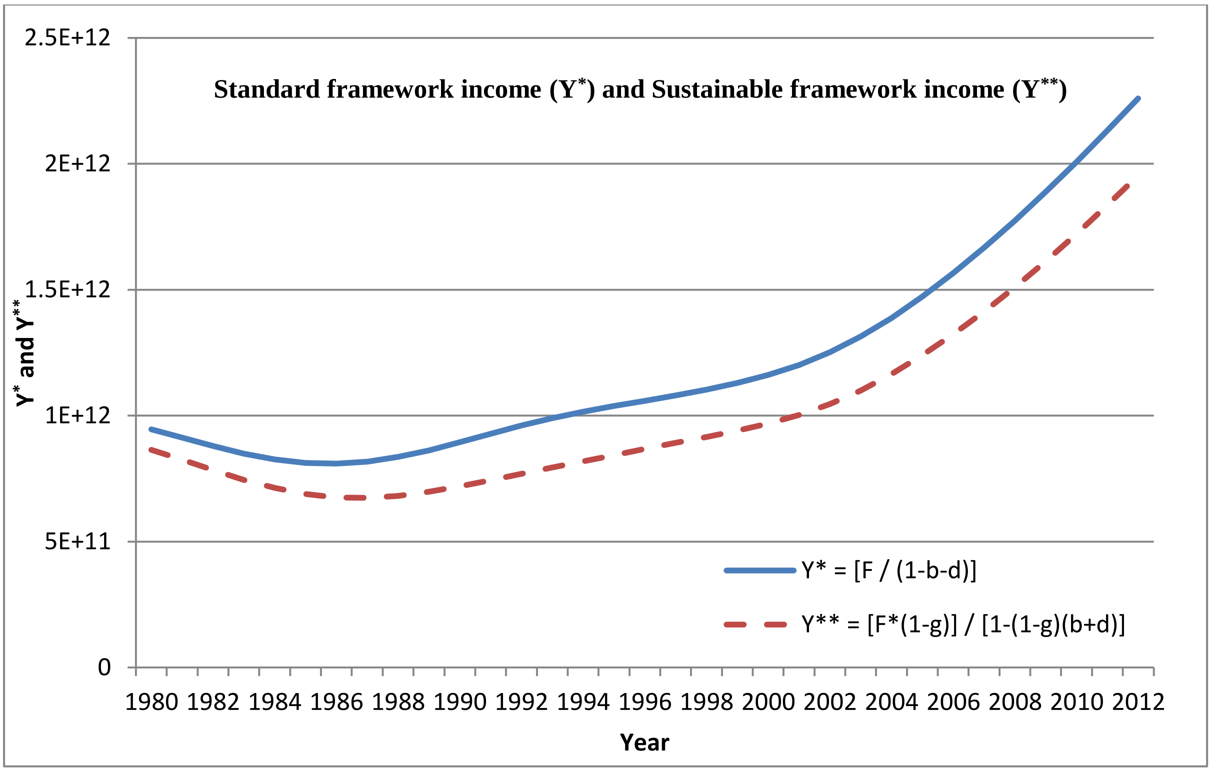
An illustration with reference to Saudi Arabia using data from World Development Indicators is presented. Please see Appendix. In the first instance, point estimates for Φ, β, δ and γ from 1980 to 2012 are obtained. The data required to measure Y^{*} and Y^{**} [Consumption (C), investment (I), and depreciation of environmental capital (D_{KN})] have been smoothed by the Hodrick-Prescott (HP) filter. This allows the separation of business cycles from actual data and ensures that the time series is smoothed, and is less sensitive to short-term fluctuations and more sensitive to long-term fluctuations. For illustrative convenience, the analysis of environmental capital is confined to the depreciation of the air shed in terms of air pollution from CO_2 emissions. The use of CO_2 is preferred as it is uncomplicated with reliable time series data. In this simple framework, the value of D_{KN} is restricted to the cost of CO_2 abatement. The greenhouse gases are CO_2, methane (CH_4), nitrous oxide (N_2O), and other greenhouse gases (GHG) [which includes hydrofluorocarbons (HFC), perfluorinated compounds (PFC), sulphur hexaflourinated compounds (PFC) and sulphur hexafluoride (SF_6)]. All of the gases are measured in tons of CO_2 equivalent, at a cost of USD100 / tonne (2010 constant prices)[6].



Data Source: World Development Indicators, 2014

FIGURE 5. SAUDI ARABIA D_{KN} IN 2010 CONSTANT RIYAL

The depreciation of environmental capital (D_{KN}) determined in monetary terms is presented in Figure 5 for Saudi Arabia. On a trend basis, the depreciation of environmental capital is rising for the observed time period. There is an improvement in the rate of environmental depreciation over a five-year period (1993 – 1998). Despite environmental capital being used more efficiently, environmental capital remains scarce towards end of observed time period.



Data Source: World Development Indicators, 2014

FIGURE 6. STANDARD FRAMEWORK (Y^{*}) VERSUS SUSTAINABLE FRAMEWORK (Y^{**})

Figure 6 displays the comparison of the incomes determined from the standard framework income (Y^{*}), and the sustainable framework income (Y^{**}). The difference between the two is that sustainable income (Y^{**}) takes into account environmental depreciation. An observation of significant importance is the clear divergence of Y^{*} and Y^{**}. Y^{*} is overstated relative to Y^{**}. This supports the observation that Saudi Arabia's standard income (Y^{*}) is not sustainable for future economic growth. To appreciate the extent of environmental degradation and ensure growth beyond the depletion of the non-renewables, it is recommended that the Kingdom uses income Y^{**} derived from the sustainable framework to measure economic progress.

Policy Implications

The policy implications for Saudi Arabia range from technology innovation, energy sources and human capital enhancement.

Increased energy use is the main driver for economic growth (Stern, 2010) and economic activity is closely related to energy supply (Murphy and Hall, 2010). Stern (2010) argued that declining energy return on investment (EROI) would threaten growth and the output level of an economy. Thus, the first step would be to review existing energy policies which the Kingdom has as this is likely to affect the sustainable growth of the economy. Saudi Arabia is blessed with rich and accessible natural resources in oil and natural gas. As such, investments could be aimed towards advanced and productive oil and natural gas extraction. In addition, the continued use of non-renewable resources must be offset by exploration towards renewable resources and investment in renewables production which can be achieved with incentives for innovation in energy efficiency and non-petroleum energy technologies.

Saudi Arabia is diversifying its energy mix to nuclear and solar for instance, 17 new nuclear reactors are planned over the next 20 years and a USD109 billion plan has been drawn out for solar power. According to Bloomberg, the goal is to create a solar industry that will generate a third of the Kingdom's electricity by 2032 (Mahdi and Roca, 2012). The move towards renewables serves two purposes. One, it allows for more oil to be exported. Two, it aids towards goal of generating half of energy required from renewable fuels by 2020 (Komnenic, 2014). In the case of solar, it was reported that Saudi Arabia will be investing more than USD100 billion in solar power to add 41GW of power capacity, which is sufficient to cover a third of the Kingdom's power needs by 2032 (Komnenic, 2014). The move away from fossil fuels suggests an appreciation for long term sustainable growth.

However, there are aspects of the usage which ought to be considered such as, the quality of the sun rays, façade of buildings, land uses and aviation consideration. Quality of the sun rays is determined by the angle which it lands on the panels because this determines how much of the rays can be collected for usage. Hence, the positioning of the solar panels is important. The positioning of the solar panels will also affect the façade of a building. In the past, solar panels' preferred placement would be atop building rooftops. Architects of recent times have started to innovate designs of buildings where solar panels can be placed anywhere from rooftops to windows. Even though there are innovative methods to capture sun rays, large scale solar photovoltaic (PV) farms are still required to power energy requirements of an economy. This may result in conflicting land use for food production and natural sinks to maintain the ecosystem. Financers of such large-scale and untested investment will need to be assured of justifiable returns. Another consideration is the aviation industry as the reflected sun rays from solar panels could possibly blind pilots of commercial and military aircrafts en route their landing strips. It has also been found that solar systems are not emission free technologies and are responsible for greenhouse gas emissions (Nugent and Sovacool, 2014). Thus, even though direct solar energy has favourable EROI (Murphy and Hall, 2010) it is not likely to replace fossil fuel usage in the near future (Stern, 2010).

For transition to non-fossil fuel usage, realistic targets must be set for the percentage of solar produced electricity towards the total power generated in decades ahead. Coupled with transfers and subsidies to both producers and consumers, pricing for electricity powered by non-renewables should be greater than renewables to influence consumer switching. Other considerations include avenues made available for consumers to sell excess back to grid, and the reliability of solar energy supply to consumers. This is in line with El-Katiri (2014) where the main concern with renewables (including solar) relates to scale and feasibility. And once a policy to install solar panels and build PV farms is announced, implementation should not be overlooked as it is critical to policy success. There must be an implementation framework with timely audits and follow-throughs so that major stakeholders and financers are kept aware of progress at every project milestone.

The final policy implication is to enhance human capital in Saudi Arabia and identify labour force comparative advantage via capacity building and research (for example, King Abdullah City for Atomic and Renewable Energy). An immediate action is to enhance tertiary education (specifically in Engineering) and offer apprenticeships in leading oil and natural gas firms. This is a capital intensive industry where a large portion of budget goes to integrating plant equipment solutions. Thus, apprenticeships will offer a supply of highly skilled labor required to operate the sophisticated machineries. There is no doubt that this action serves to provide jobs and employment. However, the focus is not solely on job creation, the focus should be on quality local job creation where jobs are moving up-stream towards the fields of research, development and technology in the oil and natural gas industries. A highly trained and educated workforce (with inclusion of women in the workforce) can increase productivity. This allows for a flexible economy with a lower level of risk for example, German automobile makers have succeeded with their highly popular apprenticeship schemes – See Bryant (2012). A low carbon environment is a global public good where the Kingdom can lead in new technology investment towards a low carbon economy and make the patent available globally[7].

Jobs can also be created in other sectors for example, eco-tourism. Every year pilgrims from all over the world descend to Mecca for the annual Hajj which is a significant event on the tourism calendar for Saudi Arabia. Tourism has multiple touch points and several linkages with numerous auxiliary industries which offers employment and a portfolio of skillsets distinct from the oil and gas industry. By utilizing the current infrastructure, eco-townships could be developed where tourism related activities continue throughout the calendar year. Employment in the tourism sector may be less affected by seasonal swings for instance, at Blackwater Coal Centre in Australia and Oil Sands Discovery Centre at Fort McMurray in Canada (Hegarty, 2013) where tourism jobs were created from past economic drivers.

The simple framework proposed in this section provides evidence that Saudi Arabia's income is inflated when it fails to internalize the environment as a capital. Although this is a simple framework, it seeks to prompt a switch away from traditional sources of economic growth by exploring renewable sources of energy and enhancing human capital. Policies should focus on restoring and maintaining environmental capital for future consumption by investing in environmental technologies and reviewing energy policies which can potentially expand an economy's capacity through aggregated expenditure.

FRAMEWORK IMPLICATIONS AND CONCLUSIONS

It is a common belief that pricing an environmental resource allows the purchase of the environmental damage as cost of damage is embedded in the purchase. This belief is false as accumulated degradation inflicted on the environment remains in the ecosystem. Moreover, pricing the environment may not address the challenges of optimality and sustainability. Valuation of the environment serves two broad objectives; it offers some form of provision towards the depletion of the environment as a capital and allows an appreciation for the close-knit relationship between a subsystem and the ecosystem.

The aim of this paper is to highlight the shortcoming of the standard macroeconomic framework when environment is ignored during policy formulation. Following the empirical case review, two key challenges are observed. Firstly, environment is ignored because there is no universally agreed-upon method of valuation; and secondly, a standard macroeconomic framework may not accommodate continuous growth without environmental internalization and allowance for the depreciation of the environment towards the formulation of sustainable policies.

In the book "Slow Death by Rubber Duck" by Smith and Lourie (2009), the human body was used as an analogy to the environmental sink. The toxins that humans consume from their daily routines remain in the body and pose long-term health risks. On a wider scale of the environment, most of us know and are more than aware that the environment is "sick". Oceans are polluted, fish stocks are dwindling, coral reefs are damaged. Ecosystem which acts as both a sink and source is being compromised as a result of human activities. Sharks are adapting to cope with climate change (Coopes, 2012) but the world's best-known fishes and whales are in danger of extinction (Clark, 2012); and bark beetles are adjusting to climate change (Hicke *et al.*, 2012) but tree lines on Swiss Alps are rising (Gehrig-Fasel *et al.*, 2007).

Bees create honey as it has a price on the market. Bees also pollinate floras – which unfortunately, is a service that is not priced. It is on this note that assets such as land, natural resources (oil and coal), and environment assets (clean air, national reserves and white sandy beaches) be accounted for (Samuelson and Nordhaus, 2010):

"The land gives us food and wine from fertile soils. Our waters give us fish, recreation, and a remarkably efficient medium for transportation. The precious atmosphere yields breathable air, beautiful sunsets and flying space for airplanes." Samuelson and Nordhaus (2010) (p268)

This may help account for the extent of the "sickness", but this will not convince policy makers of the value in practicing such accounting. Quantifying the know and aware may be difficult to accept for some. Hence, the options are: price the environment like a capital in order to appreciate the relationship between subsystem and ecosystem; and ensure ease with which a selected proxy of environmental degradation can be internalized into macroeconomic frameworks towards the formulation of sustainable policies.

ISBN 978-0-9925622-1-2

APPENDIX

National currency, current prices, millions of riyals	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
GDP (current LCU)	547381	623367	525334	446288	421558	376318	322020	320931	330519	357065	437334	491853	510459
Household final consumption expenditure, C	137089	165605	190952	201245	201226	200264	176974	171154	176027	183142	204131	217589	226782
General government final consumption expenditure, G	86981	121864	137555	132834	127048	120051	111633	113040	102240	119958	127824	169128	152692
Gross capital formation, I	125402	131899	135817	153302	138392	80732	62663	56863	65074	69431	65901	95640	114959
Gross fixed capital formation, $\bar{I}$	113438	132262	130767	120238	106050	83873	72695	71660	62556	66392	83251	100480	103955
Changes in inventories	11964	-363	5050	33064	32342	-3141	-10032	-14797	2518	3039	-17350	-4840	11004
Exports of goods and services, X	347345	391591	266511	171681	145530	113163	85989	99045	103531	120494	177685	189694	200772
Imports of goods and services, M	149437	187591	205502	212775	190639	137892	115239	119170	116352	135961	138207	180199	184746
GDP Deflator	0.571816859	0.621709731	0.589194817	0.545211452	0.531221077	0.497023251	0.40470815	0.420074373	0.399748931	0.431585623	0.487966711	0.503005147	0.498939346
<u>Constant Values</u>													
C (HP)	260224.3842	289833.6643	318822.2918	345858.6023	369770.5517	390090.7947	406625.5747	419570.1056	430048.7647	438818.2703	446947.3146	455066.0619	462937.478
I (HP)	236558.8046	230531.4712	223981.2795	215828.5168	205191.3982	193168.4556	182534.7474	175133.8951	171970.1349	172842.5583	177271.9855	184416.5597	192155.038
G	180125.7538	197276.3305	213578.0476	228143.8023	240689.0564	251398.7802	260411.6755	267567.6933	273174.1828	277584.7813	280625.4399	282133.0909	281378.8137
X - M	269162.9668	194766.7783	122702.1309	59341.79662	10478.07079	-22179.0055	-39810.1108	-44431.5362	-39043.336	-26750.9176	-10448.4549	6694.523822	24276.71785
GDP Expenditure = C + I + G + X - M	946071.9095	912408.2444	879083.7497	849172.718	826129.0771	812479.025	809761.8868	817840.1579	836149.7463	862494.6922	894396.2851	928310.2363	960748.0476
$\bar{I}$	213939.918	209457.0805	204502.7819	198705.0175	192220.2401	185866.4055	180686.141	177203.4147	175909.9866	177097.1749	180467.7596	185019.5378	189451.5245
CO_2 Emissions (T)	169404399	175491619	158091704	161050973	155715488	172653361	204878957	190706002	202554079	203738520	217948145	267768007	285534622
HFC gas emissions (t of CO_2 equivalent)											100	7640	15180
Methane emissions (t of CO_2 equivalent)											29672100	30884640	32097180
Nitrous oxide emissions (metric tons of CO_2 equivalent)											5523500	5570030	5616560
Other greenhouse gas emissions, HFC, PFC and SF_6 (metric tons of CO_2 equivalent)											2441400	2331270	2221140
PFC gas emissions (t of CO_2 equivalent)											0	0	0
SF_6 gas emissions (t of CO_2 equivalent)											2441300	2323630	2205960
Total tons of CO_2, HFC, Methane, NO_2, GHG, SF_6	169404399	175491619	158091704	161050973	155715488	172653361	204878957	190706002	202554079	203738520	258026545	308885217	327690642
Total cost of GHG (CO_2, HFC, Methane, NO_2, GHG, SF_6) @USD100/ton	16940439900	17549161900	15809170400	16105097300	15571548800	17265336100	20487895700	19070600200	20255407900	20373852000	25802654500	30888521700	32769064200
Total cost of GHG (CO_2, HFC, Methane, NO_2, GHG, SF_6) @3.75 riyals/ton 2010 prices (D_{KN}) (HP)	58785506355	59813862834	60985890321	62626941470	65010808288	68343621370	72630980999	77769438642	83782776910	90505242422	97533960664	1.04039E+11	1.09166E+11
<u>Estimating Coefficients</u>													
$\Phi = \bar{I} + G + X - M$	2.36034E+11	2.87106E+11	3.33557E+11	3.67143E+11	3.60616E+11	3.17174E+11	2.78575E+11	2.69397E+11	2.80785E+11	3.06139E+11	3.14605E+11	3.81877E+11	3.90478E+11
$\beta = C / GDP$	0.015789222	0.015019068	0.014593166	0.012935252	0.014336089	0.024587524	0.031693344	0.034943636	0.030549836	0.028647146	0.03019681	0.02081765	0.017327917
$\delta = (I - \bar{I}) / GDP$	4.26960495	4.728845556	3.830772289	2.695489948	2.812416903	4.700230392	5.299012176	5.904155602	5.040430894	5.098961559	6.899500766	5.193360519	4.344635914
$\gamma = D_{KN} / GDP$	0.062136404	0.065556031	0.06937438	0.073750534	0.078693282	0.084117398	0.089694245	0.095091245	0.100200684	0.10493426	0.109050051	0.112073185	0.113625744
<u>Income</u>													
$Y^* = [\Phi / (1-\beta-\delta)]$	9.46072E+11	9.12408E+11	8.79084E+11	8.49173E+11	8.26129E+11	8.12479E+11	8.09762E+11	8.1784E+11	8.3615E+11	8.62495E+11	8.94396E+11	9.2831E+11	9.60748E+11
$Y^{**} = [\Phi^*(1-\gamma)] / [1-(1-\gamma)(\beta+\delta)]$	8.64381E+11	8.24651E+11	7.8407E+11	7.45498E+11	7.12704E+11	6.88675E+11	6.75461E+11	6.73301E+11	6.81413E+11	6.97648E+11	7.19591E+11	7.44271E+11	7.69365E+11

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
494907	503055	533504	590748	617902	546648	603589	706657	686296	707067
237749	240477	250280	259486	261428	251418	252216	258126	259550	260400
130976	122552	125923	144783	161795	155192	154095	183804	188695	184517
121707	99878	105584	106906	113077	122555	127617	132227	129592	139109
108824	93002	103316	102848	109241	112959	118196	123324	126095	128066
12883	6876	2268	4058	3836	9596	9421	8903	3497	11043
171065	172123	200437	237812	243384	163099	210231	308473	273677	291155
166590	131976	148720	158239	161782	145616	140570	175973	165219	168114
0.483612264	0.488324227	0.5168432	0.553567785	0.5643803	0.485535402	0.54015377	0.603053682	0.582489058	0.599350808
469643.0746	474009.5367	475529.237	474253.4585	470497.671	464410.6344	455920.3445	446573.142	438249.1055	432266.4472
198539.5309	202781.292	205701.358	208173.8196	211029.891	214644.6613	219069.7715	225501.3288	235656.3716	251062.8804
279273.1436	277473.7179	277382.277	279597.2483	283694.527	288702.9755	293741.8437	298867.583	303880.2216	308759.2185
42265.97875	60867.83743	79287.44	97376.78056	115617.423	135896.0487	160977.2051	190598.5172	223527.5473	259414.1788
989721.7278	1015132.384	1037900.31	1059401.307	1080839.51	1103654.32	1129709.165	1161540.571	1201313.246	1251502.725
192909.3969	195111.5731	196749.618	198373.8776	200630.107	203782.7683	207882.052	213852.8635	222951.5361	236150.9588
313818193	309018090	236253809	258750854	216239323	207680545	226459252	296935325	297214017	326407004
22720	30260	37800	45340	52880	60420	67960	75500	99780	124060
33309720	34522260	35734800	36947340	38159880	39372420	40584960	41797500	43697820	45598140
5663090	5709620	5756150	5802680	5849210	5895740	5942270	5988800	6080340	6171880
2111010	2000880	1890750	1780620	1670490	1560360	1450230	1340100	1506220	1672340
0	0	0	0	0	0	0	0	0	0
2088290	1970620	1852950	1735280	1617610	1499940	1382270	1264600	1406440	1548280
357013023	353251730	281526259	305062114	263589393	256069425	275886942	347401825	350004617	381521704
35701302300	35325173000	2.8153E+10	30506211400	2.6359E+10	25606942500	27588694200	34740182500	35000461700	38152170400
1.12419E+11	1.13717E+11	1.1363E+11	1.13297E+11	1.1361E+11	1.15497E+11	1.19438E+11	1.25322E+11	1.32555E+11	1.40693E+11
3.81608E+11	3.69905E+11	3.7847E+11	4.08327E+11	4.2706E+11	4.16206E+11	4.15732E+11	4.50833E+11	4.51742E+11	4.5596E+11
0.016375393	0.019964357	0.01889491	0.018670608	0.01766053	0.016302884	0.015664057	0.015125504	0.015440768	0.014391592
3.960528154	4.967850778	5.03140627	5.487905263	5.43051195	4.382130472	4.655868732	5.276940413	5.268836039	5.003443343
0.113586184	0.11202191	0.10948113	0.106944318	0.10511292	0.104649948	0.10572472	0.107893209	0.110341971	0.112418877
9.89722E+11	1.01513E+12	1.0379E+12	1.0594E+12	1.0808E+12	1.10365E+12	1.12971E+12	1.16154E+12	1.20131E+12	1.2515E+12
7.93985E+11	8.18613E+11	8.4343E+11	8.68006E+11	8.9207E+11	9.1568E+11	9.40196E+11	9.68162E+11	1.00229E+12	1.04547E+12

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
804648	970283	1230771	1411491	1558827	1949238	1609117	1975543	2510650	2752334
269980	294854	324154	367360	434187	523947	591814	639417	681761	785404
198148	221798	262650	311082	322086	345098	357015	400173	488062	551179
159473	192743	248306	313565	412666	532060	510336	607347	672400	724950
148098	185872	237691	288680	368686	444499	414452	483921	568793	614906
11375	6871	10615	24885	43980	87561	95884	123426	103607	110044
371088	494702	702164	844522	934321	1210701	757711	981867	1410841	1497824
194041	233814	306503	425038	544434	662568	607759	653261	742414	807023
0.62986642	0.699246483	0.826965203	0.898296756	0.935977485	1.07942926	0.875073863	1	1.17054989	1.182565428
430165.763	433554.4257	443993.2874	462683.1844	489248.7996	521686.589	557224.4448	591990.4409	625721.0555	659589.9352
272849.543	301570.397	337183.5999	378861.6552	424658.222	471724.066	517701.9176	560876.4647	601516.94	641300.7742
314092.086	320439.1317	328375.67	338378.7307	350599.0229	365427.356	383058.1212	402300.159	422717.5992	443810.1127
296777.081	332494.81	362970.4531	385837.5199	402228.8821	415736.186	430385.2318	452991.5991	482521.5955	514172.2677
1313884.47	1388058.764	1472523.01	1565761.09	1666734.927	1774574.2	1888369.715	2008158.664	2132477.19	2258873.09
254227.797	277277.613	304817.1272	336015.7864	369516.0225	403516.266	436953.9996	469017.4497	500005.9159	530670.3211
327272416	395834315	397642146	432739003	393535106	418239685	431026514	464480555	473941155	483401755
148340	172620	196900	220100	243300	266500	291250	316000	331786	347572
47498460	49398780	51299100	52580633.33	53862166.67	55143700	57726950	60310200	61811200	63312200
6263420	6354960	6446500	6555400	6664300	6773200	6511000	6248800	6190811	6132822
1838460	2004580	2170700	2309900	2449100	2588300	2731150	2874000	3027120	3180240
0	0	0	0	0	0	0	0	0	0
1690120	1831960	1973800	2089800	2205800	2321800	2439900	2558000	2687190	2816380
384711216	455597215	459729146	496494836.3	458959772.7	485333185	500726764	536787555	547989262	559190969
3.8471E+10	45559721500	45972914600	49649483633	45895977267	4.8533E+10	50072676400	53678755500	54798926200	55919096900
1.4925E+11	1.57816E+11	1.65828E+11	1.73118E+11	1.79716E+11	1.8605E+11	1.92317E+11	1.98591E+11	2.04807E+11	2.10985E+11
4.795E+11	5.23523E+11	5.97419E+11	7.03327E+11	8.00253E+11	9.5661E+11	1.04471E+12	1.16302E+12	1.27343E+12	1.44663E+12
0.01256012	0.010397265	0.008074714	0.006397398	0.004863497	0.00377401	0.003936622	0.003309475	0.002990779	0.002775364
4.97434048	4.998427958	4.913920727	4.42206879	3.670879113	3.49899823	2.965170006	3.049520291	3.579778406	3.644789296
0.1135946	0.11369572	0.11261498	0.110564544	0.107825194	0.10484226	0.101843081	0.098892088	0.096042027	0.093402696
1.3139E+12	1.38806E+12	1.47252E+12	1.56576E+12	1.66673E+12	1.7746E+12	1.88837E+12	2.00816E+12	2.13248E+12	2.25887E+12
1.0998E+12	1.16505E+12	1.23992E+12	1.3229E+12	1.41311E+12	1.5097E+12	1.61228E+12	1.72165E+12	1.8364E+12	1.95348E+12

ISBN 978-0-9925622-1-2

ENDNOTES

*Acknowledgement
The author would like to thank the Editor, Managing Editor, and anonymous referees for their constructive feedback. With the usual disclaimers, the author remains grateful to R. Rajan, J. Huang, and L. Ewe.

[1] Daly wrote on his blog http://www.neweconomics.org on the 8th November 2011 that the first and second laws of thermodynamics should be called the first and second laws of economics.
[2] Growth could also be a movement from a sub-optimal point within PPF to the PPF. This is technical efficiency when there is maximum output from minimum inputs. A movement from PPF to PPF' is explained by technological change where there is technological development and progress.
[3] The implicit assumption is that the entire utilization of natural resources goes to investment (I). However, a large part of this utilization also contributes towards consumption (C).
[4] Shadow price is the price of the factor of production when the market is perfect, for example when all resources are fully employed.
[5] El Serafy proposed the user cost approach to compute the Hicksian income which is defined as "the maximum value which can be consumed during a week and still expect to be as well off at the end of the week as was in the beginning" (Hicks, 1946).
[6] The literature has proposed for a cost of USD100 / ton of CO_2 emissions. See Stern (2007), Ackerman *et al*. (2009), Hope (2011), and Karstad (2012).
[7] One concern is if an industry becomes dominant, the government (or the entire economy) may be held hostage. Moreover, its monopolized position may create inertia for investing in research and development.

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