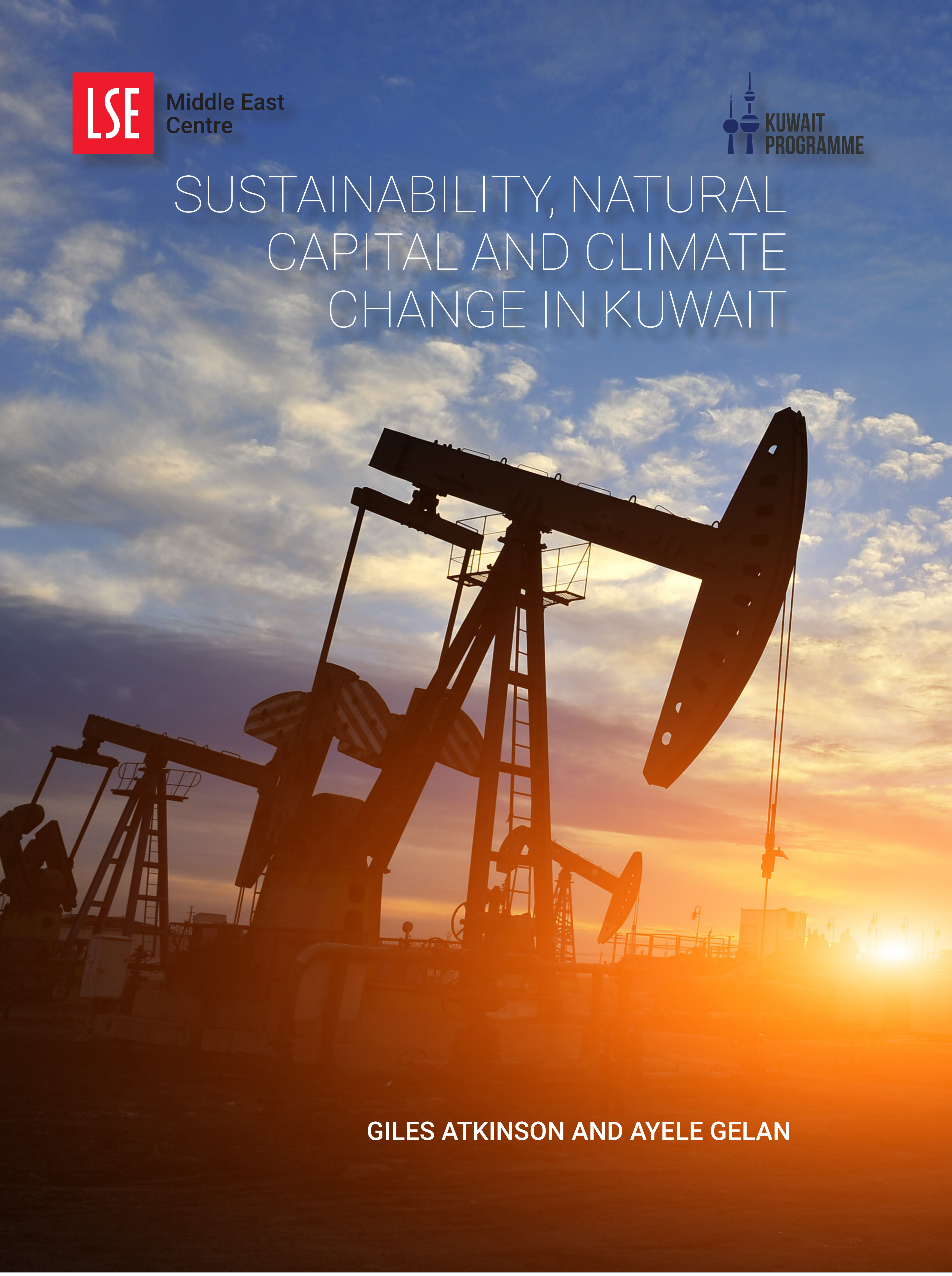

LSE Middle East Centre

KUWAIT PROGRAMME

SUSTAINABILITY, NATURAL CAPITAL AND CLIMATE CHANGE IN KUWAIT

GILES ATKINSON AND AYELE GELAN

LSE Middle East Centre Kuwait Programme Paper Series | 12 | July 2021

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About the Authors

Giles Atkinson is Professor of Environmental Policy in the Department of Geography and Environment at the London School of Economics. He has long-standing research interests in sustainability and development as well as more recently on distributional issues and natural capital.

Ayele Gelan is Research Economist in the Techno-Economics Division of the Kuwait Institute for Scientific Research (KISR). His research interests encompass resource economics, agricultural policy, and regional development, focusing more recently on energy and environmental economics using multi-sectoral modelling techniques.

Abstract

We explore the challenge of sustainability in Kuwait and, in doing so, explore three distinct (but related) questions surrounding this. First, we assess development prospects in Kuwait using metrics of national wealth and natural capital. Secondly, we construct a comprehensive greenhouse gas (GHG) emissions inventory for Kuwait. Third, we provide a risk assessment for Kuwait of climate change impacts by combining an economic model with different climate scenarios relevant to Kuwait's food security. Our findings on wealth accounting and our GHG inventory point to the importance of strengthening, and extending, statistical systems in Kuwait. The benefits of this would be improved sustainability benchmarks (against which official national savings commitments can be evaluated) and a more robust basis for judging GHG reduction strategies (given our finding that existing data sources underestimate Kuwait emissions). Moreover, understanding climate risks for Kuwait is crucial to prudent assessment of development prospects. We show that food security is a useful starting point for this and investigate the impacts of changing world food prices on the cost of imports and scope for substituting for domestic activities in both the food production and processing sectors.

1. Introduction

The challenge of sustainability should feature prominently on any 'risk register' of development prospects of any country (and indeed for the world as a whole). In this report, we explore a number of aspects of this challenge for Kuwait. Of course, this begs an initial, more basic, question: what is meant by *sustainability*? Specifically, here, it is development that should be sustained although there is no unified theory of what *sustainable development* is. For example, it could be understood as it is in the United Nations Sustainable Development Goals or SDGs as comprising *three pillars* – society, the economy and the environment – as well as more detailed themes (and sub-themes) reflecting development outcomes and processes.[1] It could also be understood as a nexus of critical resources such as water, energy and food.[2] This emphasises resource security alongside resource scarcity as well as resource interdependencies as limiting factors for development.

Our starting point to thinking about sustainability, in this report, is not unrelated to these approaches. It does, however, have a further distinct perspective: *sustaining wealth* as one means of boosting prospects that development will be sustained. From a national perspective, this is concerned with how a country is managing its national wealth. From a global perspective, this is how planetary wealth is managed. A critical component – in both cases – is *natural wealth*, or natural capital: stocks of resources and ecosystems (and natural processes) that provide flows of nature services that sustain human well-being and development in a multitude of ways.[3]

Our emphasis on wealth and sustainability is highly relevant to Kuwait in at least three ways. First, Kuwait's development – past and present – is heavily reliant on non-renewable natural capital (i.e. petroleum resources): a special, yet challenging, case for sustainability with respect to national wealth management. Secondly, its resource depletion and use contribute to a global climate liability. Thirdly, a changing climate has implications for national wealth in Kuwait in other ways, too: notably, the costs of climate change to the domestic economy including its produced capital and human capital.

[1] See, for example, 'The Sustainable Development Goals Report', *United Nations* (New York, 2020). The interpretation of sustainable development as three pillars can also be traced to the WCED, Brundtland Report: *Our Common Future* (Oxford University Press: Oxford, 1987).

[2] Christian Siderius, Declan Conway, Mohamed Yassine, Lisa Murken and Pierre-Louis Lostis, 'Characterising the Water-Energy-Food Nexus in Kuwait and the Gulf Region', *LSE Middle East Centre Kuwait Programme Paper Series* 1 (London, 2019).

[3] See, for example: Kirk Hamilton and Cameron Hepburn (eds), *National Wealth: What is Missing, Why it Matters* (Oxford: Oxford University Press, 2017); 'The State of Natural Capital', *UK Natural Capital Committee* (London, 2015).

Our contribution in this project can also be seen in these three ways, specifically:[4]

- We assess development prospects in Kuwait by reviewing existing metrics of national wealth and natural capital. Our contribution is deliberately circumspect and is mostly used as a means to explain the wealth-based approach to sustainability. Nevertheless, what emerges is also a general point about established statistical frameworks for natural capital accounting as yet to be introduced in Kuwait as well as a more specific point about how this throws light, for example, on whether sufficient wealth is being sustained via payments into Kuwait's Future Generations Fund.
- We construct a comprehensive greenhouse gas (GHG) emissions inventory for Kuwait using one of the hierarchy of options for applying the Intergovernmental Panel for Climate Change (IPCC) methodology. The resulting inventory is a crucial ingredient in assessing Kuwait's contribution, via its domestic emissions, to the global climate liability. It is also a basic input for: e.g. (a) assessing a nation's domestic emissions and (b) modelling climate policies which seek to reduce GHG emissions from this baseline.
- We provide an exploratory risk assessment of the impact of climate change on the Kuwaiti economy by applying a computable general equilibrium (CGE) model with different climate change scenarios. The focus here is on food security only and so our assessment is inevitably partial. However, it provides an initial assessment of the impacts of global climate change on an essential element of the domestic economy.

The remainder of this report is organised along the above lines: Section 2 discusses wealth and sustainability; Section 3 summarises our GHG emissions inventory; Section 4 is an overview of climate scenarios and illustrating their implications for food security in Kuwait; lastly, Section 5 provides some concluding remarks.

2. Wealth and Sustainability

For countries such as Kuwait – with substantial reserves of non-renewable natural capital – a critical question is how to manage resource revenues to ensure the sustainability of wealth. At a very general level, guidance typically draws on the Hartwick rule - a rule of thumb for investing resource revenues in produced capital.[5] Conceivably, this could be any alternative asset yielding a sustained return. As such, it includes investment in financial assets abroad in portfolios such as sovereign wealth funds. But the

[4] These work packages are detailed in three separate background papers prepared as part of this research project. These are as follows: (a) Wealth Accounting and Kuwait; (b) Greenhouse Gas Emissions Inventory for the State of Kuwait: Baseline Year 2015; and (c) Greenhouse Gas Emissions Scenarios and Food Security in Kuwait: Simulation Experiments Using a Recursive Dynamic CGE model. These are available on request from the authors.

[5] John M. Hartwick, 'Intergenerational Equity and the Investment of Rents from Exhaustible Resources', *American Economic Review* 67/5 (1977), pp. 972–4. The relevance here is investment rules for managing exhaustible resources while assuming an overarching development objective of sustaining consumption. Specifically, what has become known as the Hartwick Rule showed that future consumption can be sustained when exhaustible resources are extracted if other investments offset the value of resource depletion.

general point stands: this is the requirement for an investment strategy that sustains (overall) wealth as the means to safeguard development prospects.[6]

A number of contributions have elaborated further on the theoretical foundations for this guidance. These explore the circumstances in which well-being cannot be sustained if 'net' investment, which subtracts the value of resource depletion, is negative. This includes a generalisation of the Hartwick rule that allows for consumption and well-being to be growing over time (i.e. not just sustained) even in economies with non-renewable natural capital.[7] Just as important has been measurement frameworks for constructing practical metrics based on such insights. Under the broad heading of *wealth accounting*, this has involved rethinking the statistical systems on which development is evaluated at the macroeconomic level.[8]

Practical foundations for this are now provided by the resource accounting principles laid out in the Central Framework of the United Nations System of Environmental and Economic Accounts (UN SEEA-CF).[9] The Central Framework is a statistical standard, meaning that it has been adopted at the end of a lengthy UN statistical process as the official template for how countries (specifically, their official statistical agencies) should undertake this national accounting activity. At present, however, the Central Statistical Bureau (CSB) in Kuwait does not appear to publish accounts along the lines of the SEEA-CF. For example, the single accounting item for resource extent in CSB[10] is value-added in the oil and gas sector. This is a broader measure of resource dependence and abundance than the resource metrics in the SEEA-CF.

A sense of the additional information provided, were the SEEA-CF to be implemented in Kuwait, is summarised in Table 1. The initial five rows correspond to summary aggregates in the conventional UN System of National Accounts (SNA) based on existing data

[6] There is a debate about the relative importance of different assets. Practical discussion tends to focus on a balanced wealth portfolio as critical for sustainability: see, for example, Edward B. Barbier, *Nature and Wealth: Overcoming Environmental Scarcity and Inequality* (Palgrave MacMillan: London, 2015). This might also entail a focus on protecting elements of natural capital such as ecosystem assets. This represents a greater development challenge because current human actions would be significantly more constrained (as certain development paths would be effectively 'off-limits'). A key argument for observing such constraints is that natural capital is non-substitutable (i.e. cannot be easily replaced, if at all).

[7] Kirk Hamilton and Michael Clemens, 'Genuine Savings Rates in Developing Countries', *World Bank Economic Review* 13/2 (1999), pp. 333–56; Partha Dasgupta and Karl-Goran Mäler, 'Net National Product, Wealth and Social Welfare', *Environment and Development Economics* 5/1 (2000), pp. 69–93; Kirk Hamilton and Cees A.A.M. Withagen, 'Savings, Growth and Path of Utility', *Canadian Journal of Economics* 40/2 (2007), pp. 703–13.

[8] There is also a connection from this work to the 'Beyond GDP' debate. This concerns how novel metrics might: (a) reflect better the sustainability of development and (b) broaden the notion of well-being that is being evaluated along a development path. What this means exactly has led to voluminous proposals. The myriad metrics supporting the various objectives (and sub-objectives) of the SDGs is an exemplar in this respect.

[9] 'System of Environmental-Economic Accounts 2012 – Central Framework', *United Nations* (New York, 2014).

[10] Various years, *CSB* (Kuwaiti Central Statistical Bureau). Available at https://www.csb.gov.kw/Pages/-Statistics_en?ID=55&ParentCatID=3 (accessed 23 June 2020).

published by the CSB. This includes GDP and gross saving.[11] Subtracting the consumption of fixed capital (i.e. the depreciation of produced capital) from these respective aggregates provides estimates of net domestic product (NDP) and net domestic saving. The remaining rows of the table provide information added by the SEEA-CF.

Table 1: Resource Accounting in Kuwait, 2010–17 (current Kuwaiti dinar, millions) [12]

	2010	2011	2012	2013	2014	2015	2016	2017
SNA								
Gross domestic product	33,079	42,512	48,722	49,392	46,285	34,473	33,056	36,261
Gross saving	15,234	16,636	18,862	20,514	21,632	22,663	23,448	24,875
Cons. of fixed capital	2,515	2,672	2,948	3,001	2,871	2,881	3,035	3,235
Net domestic product	30,564	39,839	45,774	46,391	43,414	31,593	30,021	33,026
Net domestic saving	12,718	13,964	15,914	17,513	18,761	19,783	20,413	21,641
SEEA-CF								
Resource asset value	2,391,157	3,410,954	3,550,968	3,450,287	3,104,125	1,593,578	1,262,143	1,692,416
Resource rent	19,980	32,805	38,384	36,530	32,204	16,513	13,527	17,033
Depletion value	3,508	6,429	8,184	7,671	6,684	3,427	2,900	3,434
Natural resource income	16,473	26,375	30,199	28,859	25,521	13,086	10,628	13,599
Depletion-adjusted NDP	27,056	33,410	37,590	38,720	36,731	28,166	27,122	29,592
Depl-adj, net saving	9,211	7,534	7,729	9,841	12,077	16,355	17,514	18,206

[11] GDP minus final consumption expenditures.

[12] Source: *CSB* (various years); 'World Development Indicators', *World Bank* (Washington DC, various years).

Resource asset values are calculated as the present value of resource rents – the difference between the value of resource production and the economic cost of extraction – up to the point of exhaustion.[13],[14] The magnitude of these asset values – the resource wealth of the economy – provides important guidance regarding *future* prospects.[15] Another important question is when resources are extracted, in a given year, what is the actual contribution to the *current* economy?

An answer to this in the SEEA-CF starts with a decomposition of the estimate of current resource rents into two components: *depletion value* and *natural resource income*.[16] The former is equivalent to the depreciation of the resource asset and natural resource income is the (net) return on that asset. Table 1 provides an illustration of this. Over the period 2010–2017, it is evident that natural resource income is substantially higher than depletion values. The proximate reason for this disparity is reasonably straightforward: relatively high reserve lifetimes in Kuwait.

A practical link between saving and sustainability is that the depreciation of non-renewable natural capital – i.e. the *depletion value* in Table 1 – should be reinvested when this finite asset is used up. Two depletion-adjusted economic aggregates defined in the SEEA-CF reflect this insight and construct metrics which are *net* of depreciation: [17]

- *Depletion-adjusted net domestic product* (*aNDP*): This is defined as GDP minus the value of depreciation of produced capital and resource depletion. Note then this means that natural resource income counts positively in *aNDP*, while depletion values are subtracted.
- *Depletion-adjusted net saving*: This is defined as GDP minus consumption (i.e. gross saving in the economy) minus the value of depreciation of produced capital – i.e. consumption of fixed capital in the SNA terminology[18] – and the total value of resource depletion.

[13] The economic cost of extraction includes all current extraction costs, depreciation and the opportunity cost of produced capital (used in the extraction process).

[14] The resource lifetime used to calculate the point of exhaustion is defined in terms of the ratio of the extent of physical reserves (typically measured as the sum of proven and probable resources) to current production. Resource rents are typically fixed at the current year and held constant up to the point of exhaustion. A final ingredient in this present value calculation is a discount rate.

[15] The fall in resource prices after 2014 results in a significant fall in these metrics.

[16] The value of resource depletion is measured as the unit value of depletion times the quantity extracted. This unit value is equal to the current resource asset value divided by the current physical stock. Each depletion unit is therefore valued according to its average value. Specifically, it is estimated as the average price – in effect the average rent – of the resource in situ (i.e. in the ground).

[17] The empirical link between saving and sustainability was first explored by David W. Pearce and Giles Atkinson, 'Capital Theory and the Measurement of Sustainable Development: An Indicator of "Weak" Sustainability', *Ecological Economics* 8/2 (1993), pp. 103–8. This took the form of a metric of 'net' savings: that is, net of changes in assets including the value of resource depletion. Kirk Hamilton, 'Green Adjustments to GDP', *Resources Policy* 20/3 (1994), pp. 155–68, subsequently named this metric as 'genuine saving' and this terminology has largely stuck. However, World Bank (various years) label their analogous metric as 'Adjusted Net Saving'. This has been published in its 'World Development Indicators' for over 150 countries since the late 1990s. *UN* (2014) refer to depletion-adjusted net saving, as discussed elsewhere in this section.

[18] This, in turn, refers to e.g. physical wear and tear on fixed assets such as machinery and buildings

Table 1 describes this data for Kuwait. Depletion-adjusted net saving is positive over the years described. It is important to note that this is a partial measure of net saving given it does not consider investment in human capital or depreciation in other categories of natural capital (such as climate change damage, although see below for further discussion). Notwithstanding such caveats, on the face of it, it appears that for the economy as a whole net saving exceeds what would be required to satisfy the basic sustainability advice exemplified by the Hartwick rule. That said, depletion-adjusted net saving as a proportion of GDP is broadly declining over the period.

These highly aggregated insights take us only so far. Relating this wealth accounting to the public finances is also important given that a critical pathway for boosting savings from resource depletion arises from appropriating these benefits through state revenues. In the case of Kuwait, a critical channel is its wealth funds, specifically the *Future Generations Fund*. A comparison of depletion values (such as in Table 1) and payments into the fund provides a preliminary assessment of actual investment vis-à-vis a benchmark established by wealth accounting.

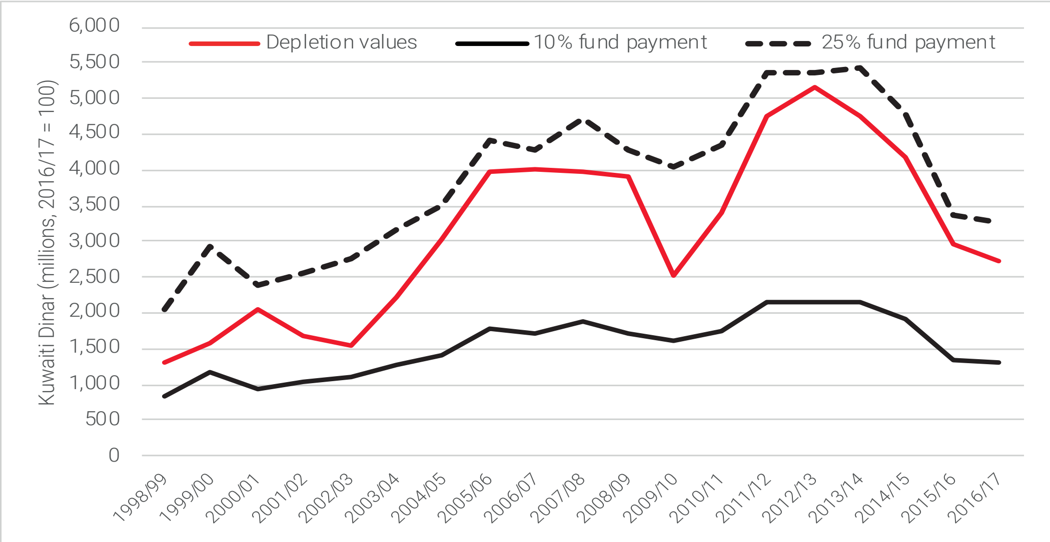
Figure 1 illustrates this comparison. Published data on payments into the fund are partial and appear to go back to 2008/09 only.[19] Fund payments are based on a proportion of state revenues: typically, this has been 10 percent although from 2013 to about 2016 this was raised to 25 percent.[20] The Figure describes simulated and actual fund payments based on two possible fiscal rules – of 10 percent and 25 percent of total state revenues – over the period 1998/99 to 2016/17.[21] In effect, depletion values are a benchmark since this is what sustaining wealth, in theory, requires to be invested.

[19] The *Kuwaiti Ministry of Finance* (various years) publishes data for 2017/18 to 2019/20, outside of the period covering our estimates of depletion values. See https://www.mof.gov.kw/MofBudget/MofBudget-Detail.aspx-#mofBudget2 (accessed 23 June 2020).

[20] Rolando Ossowski and Hårvard Halland, *Fiscal Management in Resource Rich Countries: Countries: Essentials for Economists, Public Finance Professionals, and Policy Makers* (Washington DC: World Bank Group, 2016).

[21] *World Bank* data on depletion values and *CSB* data on government revenues are measured by calendar year and fiscal year respectively. We have therefore adapted the former for more easy comparison in Figure 1.

Figure 1: Comparison of Fiscal Rules for Fund Payments with Depletion Values[22]



What seems clear is that the 10 percent rule (i.e. paying 10 percent of state revenues in the *Future Generations Fund*) falls short of this benchmark while the 25 percent rule exceeds it although tracks depletion values relatively better. There are several caveats of course. The depletion value is a basic sustainability benchmark only: additional development objectives provide reasons why countries might wish to save more (economic growth) or less (current distributional concerns). There are also different pathways whereby resource revenues generate benefits in the domestic economy; some of which will be consumption but some of which can also be construed as investment.[23]

Sustainability, so far in this section, has been defined in terms of how exhaustible resources – specifically petroleum resources – are depleted, as well as how proceeds of this economic activity are reinvested. Of course, a further – and increasingly more prominent – sustainability challenge is the pollution emissions arising from use of these resources in economic activity. Most notably the use of fossil fuels in economic production and consumption augments the stock of carbon dioxide (CO2 and greenhouse gases, GHGs, more generally). This creates a liability, which in turn can be construed as diminishing a corresponding asset: namely, global climate stability.

One important line of enquiry that follows this reasoning is focused on obsolescence in national wealth or 'stranded assets' and the extent to which carbon taxes and binding carbon budgets will render petroleum reserves 'unburnable' *in the future*.[24] What this

[22] Authors' calculations based on *CSB* (various years) and *World Bank* (various years).

[23] See Laura El-Katiri, Bassam Fattouh and Paul Segal, 'Anatomy of an Oil-Based Welfare State: Rent Distribution in Kuwait', *LSE Kuwait Programme on Development, Governance and Globalisation in the Gulf States* 13 (London, 2011).

[24] See, for example: Glenn-Marie Lange, Quentin Wodon and Kevin Carey, 'The Changing Wealth of Nations 2018: Building a Sustainable Future', *World Bank* (Washington DC, 2018); Christophe McGlade and Paul Ekins 'The Geographical Distribution of Fossil Fuels Unused When Limiting Global Warming

means is that the resource asset values in Figure 1 overestimate the *global* value of these same assets (because of the prospective climate liabilities). Moreover, given the context of a changing global climate, consideration of climate damage as part of the economic analysis of projects which exploit remaining petroleum reserves is clearly desirable.[25]

A separate question arises for wealth accounting: given current production of petroleum reserves, how is the global liability arising from resource use and associated GHG emissions to be accounted for in specific countries? There are a number of answers to this question.[26] This includes:

- *Depletion emissions*: resource depleting countries account for emissions embodied in the fossil fuels that they produce in a given year. In effect, this accounts for emissions at original source.
- *Production emissions*: resource using countries' account for emissions produced as a result of combustion of fossil fuels within their own borders.
- *Consumption emissions*: countries account for GHG emissions embodied in their final consumption of goods and services.

These different perspectives all involve different standpoints on responsibility for the global climate liability and, as a result, different accounting rules and procedures. As a practical matter, each arguably provides interesting and distinct insights on GHG emissions along winding supply chains.[27] Moreover, this general setting is also a way of understanding where the contributions in the remainder of this report are situated. Our GHG emissions inventory (Section 3) is the basis for better understanding Kuwait's responsibility for climate change damage arising from its own domestic emissions. Our climate risk assessment (Section 4) provides an initial analysis of climate change damage in Kuwait.

to 2°C', *Nature* 517 (2015), pp. 187–90.

[25] Giles Atkinson and Kirk Hamilton (2020) 'Sustaining Wealth: Simulating a Sovereign Wealth Fund for the UK's Oil and Gas Resources, Past and Future', *Energy Policy* 139 (2020).

[26] See, for a review, Matthew Agarwala, 'Natural Capital Accounting Perspectives for Measuring Sustainable Development', unpublished PhD dissertation, *London School of Economics and Political Science* (London, 2020).

[27] According to data in *World Bank* (various years), in 2017 it accounted for about 3 percent of global oil production and 6 percent of oil (proven plus probable reserves). 'BP Statistical Review of World Energy 2019', *British Petroleum* (London, 2019) estimates that Kuwait exported just over two thirds of crude oil production in this same year.

3. Constructing a Greenhouse Gas Inventory

Our GHG emissions inventory was conducted within an overarching criterion of strict adherence to the relevant IPCC protocols.[28] This is important for purposes of transparency and replicability. This does entail some exercise of choices as the IPCC methodology has a degree of inbuilt flexibility. Specifically, three 'tiers' represent a hierarchy of levels of complexity in data and parameters at which national inventories can be estimated.[29] Higher levels of complexity are clearly desirable in principle but so too are practical matters. For Kuwait, given the available data and project resources, it was only feasible to construct an inventory using the lowest tier in the IPCC hierarchy.[30] The background paper on GHG inventory provides details of data sources, methods and outputs. It may suffice here to state that this study relied on international databases such as the International Energy Agency (IEA) (for energy) and the Food and Agriculture Organization of the United Nations (FAO) (for livestock numbers) and national sources (for the remaining sectors and industries). The methodology developed in the inventory remains an important step forward in constructing a rigorous and replicable framework that can be built on.

The construction of the inventory is detailed in a separate (background) report prepared for this project.[31] For the purposes of the current summary report we focus on: (a) our inventory findings only and its contribution and (b) brief recommendations for the future process of 'official' estimation of an inventory for Kuwait.

The background paper on our GHG inventory discusses details of the evolution of emission inventory reports produced by the Kuwait Environmental Public Authority (KEPA). Three key stages, and associated documents, are worth noting. The first was published in May 2018, although this was relatively outdated; that is, it was produced in 2012 with a considerable lag in the base year for the inventory (1994).[32] A second publication followed in April 2019, this time with a baseline inventory year of 2000: a longer lag than the initial

[28] 'Inventory Software User Manual Version 2.691', *IPCC* (2020). Available at https://www.ipcc-nggip.iges.or.jp/software/files/IPCCInventorySoftwareUserManualV2_691.pdf (accessed 29 April 2021).

[29] Taka Hiraishi and Buruhani Nyenzi, 'Chapter 7: Methodological Choice and Recalculation' in *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (Kanagawa, Japan: Institute for Global Environmental Strategies, 2000).

[30] What this means is that we use one-year baseline data, which focuses on ensuring consistencies between a range of relationships between variables included in the inventory process as well as other indicators in the economy. Most obviously in terms of limitations is that it is not possible to examine trends in GHGs nor is more complex specification of parameters possible.

[31] See footnote 1 of this report. Background paper (b) cited there sets out the steps and data required for GHG inventory construction and so can be regarded as a draft/preliminary manual for future use and refinement.

[32] 'Kuwait's Initial National Communications under the United Nations Framework Convention on Climate Change', *Kuwait Environment Public Authority* (November 2012). Available at https://epa.org.kw/Portals/0/PDF/Initial%20national%20communication%20for%20state%20of%20kuwait.pdf (accessed 29 April 2021).

report. Our own study report was compiled using the KEPA 2000 inventory[33] as a reference point, bringing forward KEPA's estimates to 2015 and comparing with our results. However, a third KEPA publication was produced in September 2019.[34] What is notable is that the baseline for this third report was 2016, a relatively short lag compared to the previous two summaries of KEPA inventories.

These improvements are to be welcomed and indicate enhanced commitments by the Kuwaiti authorities to strengthen the evidence base for climate change mitigation and adaptation policies. Our own study results have been compared and contrasted with the latest KEPA emission report (as shown below in Table 4). Unfortunately, we can compare only results but not methods. KEPA assert that they have utilised the IPCC protocol in compiling their inventory. Yet it is unclear whether this refers to IPCC primary data collection instruments or a full utilisation of IPCC software to generate the KEPA quantitative results.

By contrast, our study – and resulting inventory – offers explanations of sources of data inputs (mostly secondary sources), data entry procedures and computations in the IPCC software and reporting results in standard IPCC procedure. To that extent, our study lays down foundations in applying the IPCC protocol in constructing our GHG emissions inventory for Kuwait. An advantage in our application is that this allows consistent data entry and reporting styles and, in turn, means our inventory is replicable and can be improved on in a transparent way.

Turning now to our results, Table 2 summarises our inventory in terms of the three most significant GHGs: carbon dioxide (CO_2), methane (CH_4) and, nitrous oxide (N_2O). The data in the first row is presented, for purposes of comparison, in CO_2 equivalent units (i.e. based on the global warming potential of each gas relative to CO_2). This data refers to gigagrams (Gg) or '000 tonnes of these gases in total for the entire economy. The rest of the table disaggregates this total for four domestic sectors plus Kuwait's share of international emissions. This data refers to the percentage of the total Gg of CO_2, CH_4 and N_2O. For example, the energy sector accounts for 93.1 percent of CO_2 emissions. The waste sector accounts for just over 17 percent of CH_4 and N_2O in total.

[33] 'State of Kuwait Second National Communication', *Kuwait Environment Public Authority* (originally posted with April and later updated to July 2019 as its publication date). Available at https://unfccc.int/sites/default/files/resource/94235106_Kuwait-NC2-2-KUWAIT%20SNC%20%20final%20v2.pdf (accessed 29 April 2021).

[34] 'First Bi-Annual Update Report of the State of Kuwait', *Kuwait Environment Public Authority* (September 2019). Available at https://www4.unfccc.int/sites/SubmissionsStaging/NationalReports/Documents/391865_Kuwait-BUR1-1-State%20of%20Kuwait%20-%20BUR.pdf (accessed 29 April 2021).

Table 2: Summary of a Greenhouse Gas Inventory for Kuwait (Gg or '000 tonnes CO_2 equivalent) – 2015 Baseline

Categories	CO_2	CH_4	N_2O	Total GHGs
National: Total Emissions and Removals	108,012	25,033	529	133,575
1 - Energy	93.1%	75.6%	73.6%	93.1%
1.A - Fuel Combustion Activities	88.4%	0.7%	58.4%	88.4%
1.B - Fugitive Emissions from Fuels	4.7%	74.9%	15.2%	4.7%
2 - Industrial Processes and Product Use	6.9%	6.5%	0.0%	6.9%
2.A - Mineral Industry	1.6%	0.0%	0.0%	1.6%
2.B - Chemical Industry	3.7%	6.5%	0.0%	3.7%
2.C - Metal Industry	0.0%	0.0%	0.0%	0.0%
2.D - Non-Energy Products from Fuels and Solvent Use	1.6%	0.0%	0.0%	1.6%
3 - Agriculture, Forestry, and Other Land Use	0.0%	0.6%	9.0%	0.0%
3.A - Livestock	0.0%	0.6%	9.0%	0.0%
4 - Waste	0.0%	17.3%	17.4%	0.0%
4.A - Solid Waste Disposal	0.0%	14.6%	0.0%	0.0%
4.D - Wastewater Treatment and Discharge	0.0%	2.6%	17.4%	0.0%
International bunkers: Aviation	5.5%	0.0%	9.6%	5.5%

It is worth benchmarking our findings against existing data sources on Kuwait's GHG emissions. The most prominent of these is arguably the data published by KEPA.[35] Table 3 provides a comparison of this data and our inventory.

For energy emissions, the CO2 emissions estimated by KEPA are about four fifths of total CO2 in our inventory. For CH4, accounting for fugitive emissions is of critical significance and offers the main basis for comparison between our inventory and these existing sources.

[35] Other existing sources are: the *International Energy Agency*, *World Bank* and the *Kuwait Carbon Atlas*. Many of the comments we make in the context of *KEPA* also apply to these sources.

For Industrial Processes and Product Use (IPPU), while KEPA does include these emissions the estimate in our inventory appears to be more comprehensive. As Table 2 previously indicated, these emissions amount to around 7 percent of both CO2 and total GHG emissions. Nor does KEPA estimate emissions from CH4 in the IPPU sector. As illustrated in Table 3 (and in Table 2), such emissions are substantial.

In the waste sector, perhaps due to our emphasis on fuller measurement of CH4 emissions, this yields an estimate which is more than twice as large as that in KEPA (as discussed in detail in the background paper). Our estimates for the agriculture and land-use (LU) sector are the closest to those provided by the KEPA source.

The uses that this inventory might potentially address are also significant. For wealth accounting, this provides the basis for a more accurate picture of global damage caused by Kuwait's GHG emissions. For example, assuming a relatively conservative value of the social costs of carbon of USD 30 tonnes of CO2,[36] gives an estimate of this damage equivalent to around 3.5 percent of Kuwaiti GDP in 2015. In terms of policy analysis, a GHG inventory can provide the baseline for modelling the impacts of energy policies, for example, on the path of GHG emissions and/or on the broader economy.

Table 3: Comparison of GHG Inventory for this Study with KEPA

	CO_2	CH_4	N_2O	Totals
KEPA				
Total National Emissions and Removals	83,911	2,383	407	86,701
Energy	81,985	273	329	82,587
IPPU	1,932	0	0	1,932
Agriculture & LU	-10	164	13	167
Waste	4	1,946	65	2,015
LSE-KISR (Current study)				
Total National Emissions and Removals	108,012	25,033	529	133,575
Energy	100,540	18,930	390	119,860
IPPU	7,472	1,637	0	9,109
Agriculture & LU	0	148	47	195
Waste	0	4,319	92	4,411

[36] This is the unit value used in *World Bank* (2019), for example. While there is considerable debate about exactly what this social cost is, reviews typically place this in a range of about USD 10 to 100 per tonne of CO_2.

Improving any official inventory of Kuwait's GHG emissions is a matter of importance at two levels. First, this means improvements in the evidence base for decision-making regarding environmental policy at the country level. Second, improvements in the quality of emission inventory means accurate data would be submitted to IPCC, a contribution to strengthening the evidence base for climate change and global warming policies on a global scale. While our study illustrates the likely outcome in terms of GHG estimates and the mechanical steps to reach that point, this will also entail attention to issues of process. Specifically, it will entail the work of, and coordination between, a number of government actors each responsible for a specific aspect of the GHG exercises.

This points to several considerations regarding capacity building in organisations such as KEPA. The CSB of the State of Kuwait is also well placed to assist with addressing remaining gaps in any GHG emissions inventory but this will entail necessarily boosting its environmental data programme. Other actors are critical to particular economic sectors. Notably, this includes the Kuwait Petroleum Corporation (KPC) in the case of energy, the Public Authority of Agriculture Affairs and Fish Resources (PAAFR) in the case of agriculture and the Public Authority for Industry (PAI). Moreover, opportunities for cost-effective GHG mitigation may well exist in the waste management sector. If so, then the Kuwait Municipality (KM) is well placed to assist in understanding how to make a GHG inventory more responsive to such opportunities.

Above all, however, there is a critical need for all these organisations to coordinate and work together. In this regard, the coordination framework established in the latest KEPA emissions report is a step in the right direction. The capacity built with regard to data collection, organisation and storage procedures outlined in the KEPA report may need to be accompanied by a strong technical team of experts to undertake the actual estimation of the GHG emissions. Such a technical team led by KEPA will strengthen Kuwait's capacity to construct a robust and replicable GHG emissions inventory while taking account of crosscutting sectoral challenges that inevitably arise. This would also leverage the assistance of further organisations. For example, in the course of this study, the Kuwait Institute for Scientific Research (KISR) has evolved substantial expertise in constructing GHG inventories.

4. Economic Impacts of Climate Change: The Example of Food Security

Climate change will undoubtedly present numerous risks to development prospects in Kuwait. Understanding these risks is crucial. In this section, we explore the implications of one example: food security. Kuwait's geographic location in an arid zone necessitates it being heavily dependent on food imports (81 percent).[37] This is a question of degree. While Kuwait is not an agricultural economy, there is still significant activity in domestic sectors in vegetables (45 percent), dairy and poultry products (39 percent).[38] Nonetheless, it remains true that imports constitute the bulk of the country's food

[37] 'Food Balance', *FAO* (2017). Available at http://www.fao.org/faostat/en/#data/FBS (accessed 29 April 2021).
[38] Ibid.

supply. As a result, Kuwait's food security status is greatly influenced by what happens in world markets. A changing climate can be viewed, in turn, as an exogenous shock to this status, unfolding over the long term.[39]

Our analysis of Kuwait's food security combines IPCC climate/economy scenarios with a computable general equilibrium (CGE) model for Kuwait. These global scenarios are long-term projections intended to represent pathways for socioeconomic development outcomes and climate mitigation/adaptation actions (technically speaking from a baseline as 1990 through to 2100).[40] These projections are described below. Each has been given a technical label by the IPCC (i.e. a numbered SSP or shared socioeconomic pathway) but corresponds to storylines involving possible future worlds with plausible permutations of socioeconomic outcomes, climate policy and climate-related outcomes.

SSP1: a green economy pathway, characterised by relatively straightforward implementation of mitigation and adaptation options.

SSP2: an intermediate pathway, where there are moderate challenges to global mitigation and adaptation.

SSP3: a pathway where there are substantial challenges to mitigation and adaptation.

SSP4: entails low challenges to implementing mitigation but high challenges for adaptation.

SSP5: a pathway where economic growth is assigned primacy with corresponding low priority assigned to climate mitigation, but adaptation is adopted.

In what follows, we present results for each of these scenarios. Clearly, however, some of these appear more distinguishable than others. In this respect, we view SSP5 as a baseline, which can be taken as the highest end scenario in terms of its implications for Kuwait.[41] SSP1 is the clearest contrast to this pathway, where a global green economy entails far fewer political and economic obstacles. Detailed descriptions of the scenarios are provided in Table A1.1 in Annex 1. The importance of these scenarios for current purposes is that they have been used to generate food production and agricultural land-use for each of these scenarios. The projection scenarios were obtained from the SSP database.[42,43]

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[39] The COVID-19 pandemic has provided a glimpse of these issues in the Kuwaiti context.

[40] The projections are produced by modelling at a global scale and then focusing on broad regional groups (OECD, ASIA, ALM); ALM denoting Africa, Latin America and the Middle East. Put this way, these scenarios represent a high level of aggregation and as such represent a first look at the way in which classes of climate risk affect an individual economy such as Kuwait.

[41] See: 'Explainer: The High-Emissions "RCP8.5" Global Warming Scenario', *Carbon Brief*, 21 August 2019. Available at https://www.carbonbrief.org/explainer-the-high-emissions-rcp8-5-global-warming-scenario (accessed 29 April 2021).

[42] See Shared Socioeconomic Pathways website: https://tntcat.iiasa.ac.at/SspDb (accessed 23 June 2020). See: Keywan Riahi et al., 'The Shared Socioeconomic Pathways and their Energy, Land Use, and Greenhouse Gas Emissions Implications: An Overview', *Global Environmental Change* 42 (2017), pp. 153–68.

[43] These particular scenarios apply to 2005 to 2100. Given the base year of the Kuwaiti economic model we use is 2013, it has been necessary to change the base year to 2010 given this is closer to 2013. In order to show the position of the Middle East and Africa region relative the world average, the projected

We investigate impacts of Kuwait food security by using a CGE model for Kuwait. The model was calibrated on the Kuwaiti social accounting matrix (SAM)[44] which was constructed with 2013 as its base year.[45] This model was additionally adapted for the purposes of this project in other important respects. The objective of these adaptations was: (a) to better align the CGE model with the long-term nature of the IPCC scenarios;[46] and (b) the specification of the production process to better reflect the supply chain describing the use of energy commodities in the economy.[47]

The connection of this model to our foregoing discussion of IPCC/SSP scenarios is how these effects play out via food prices in the world market. That is, climate change shapes demand and supply relationships for food products by influencing agricultural productivity across the global economy. Changes in food prices in the world market occur because of excess demand for food, where the latter is defined in terms of the balance of changes between demand and production. Specifically, we make use of this relationship to construct a world food price index (WPI) from estimated excess demand for crops. This WPI then can be used as an exogenous variable to shock the Kuwaiti national model through the influence on the world food price path on food imports. Since the WPIs are separately constructed for each of the five SSP scenarios, the impacts of each scenario on Kuwait's food security status were separately quantified.

figures were converted to indices as changes from the 2010 baseline year scenario.

[44] A SAM is a matrix format based on the sequence of accounts in the System of National Accounts. The CGE model we use consolidates the Kuwaiti SAM into a matrix of 146 by 146 individual accounts, describing generation of output and income in the economy as well as its (re)distribution and final use.

[45] Ayele Gelan et al., 'Designing and Constructing a Social Accounting Matrix (SAM) for the State of Kuwait, Final Project Report' (Project No. P114-17IA-01). Submitted to the *Kuwait Foundation for the Advancement of Sciences* (October 2018).

[46] Our model uses a recursive dynamic formulation. This involves period-by-period updating of stock variables (population, labour force and capital stock), replicating the SAM for each period.

[47] For details of the CGE model equations see: Ayele Gelan, 'Economic and Environmental Impacts of Electricity Subsidy Reform in Kuwait: A General Equilibrium Analysis', *Energy Policy* 112/2 (2018), pp. 381–98; Ayele Gelan et al., 'Designing and Constructing a Social Accounting Matrix (SAM) for the State of Kuwait, Final Project Report'.

Figure 2: Import Price Effects Under Each SSP Scenario

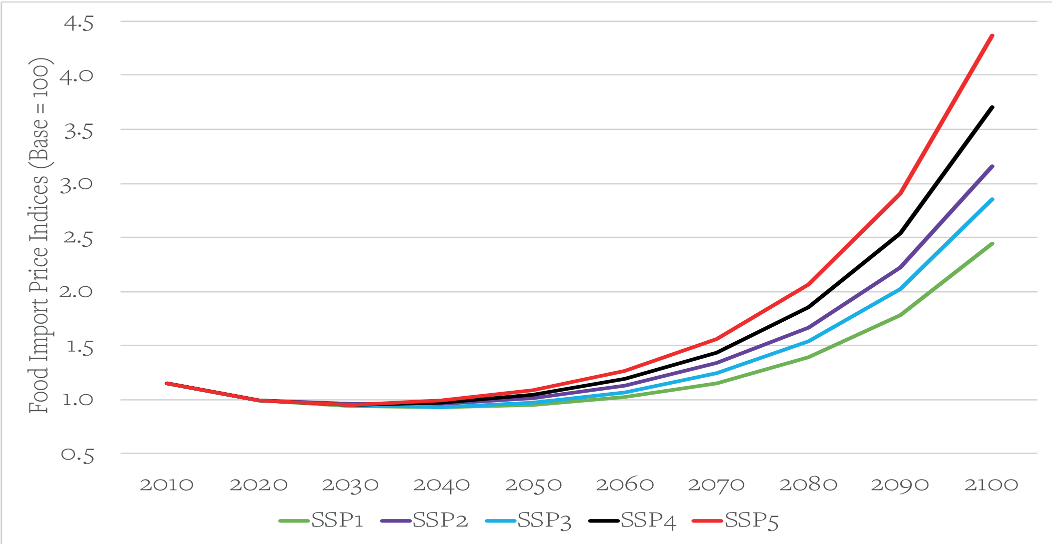


Figure 2 begins by summarising the implied import price path – based, in turn, on the WPI – and changes for each SSP scenario. These are increases in import prices from baseline levels (=1.0). All SSP scenarios show sharp increases in the prices of imported food products in the Kuwaiti domestic market beyond 2030. SSP5 projects a nearly 4.5-fold increase from the 2010 level while SSP1 is the least steep entailing a nearly 2.5-fold increase in imported food prices. The other scenarios fall in between these two extremes.

Before proceeding to our discussion of the results arising from these price paths on the Kuwaiti economy, we emphasise two modelling considerations which contextualise these findings. First, it is important not to rule out, by assumption, substitution of domestic production for food imports. We assume, however, that there is limited scope for this and our model limits substantial switching to domestic output as a result of escalating import prices.[48] Secondly, the purpose of this study is to isolate and examine climate scenario effects on food security. All else, in effect, remains equal. As a practical matter this means that existing government policy such as subsidies is assumed to be left in place. But clearly changing these policies may also create additional impacts on our results. Moreover, a changing climate may make agricultural production more challenging in Kuwait to an extent not reflected in relatively broad brush IPCC scenarios that we use.

[48] Specifically, we assume that the substitution parameter between imports and domestically produced food is inelastic. We vary this assumption in our sensitivity analysis.

Figure 3: Primary and Processed Food Production Effects

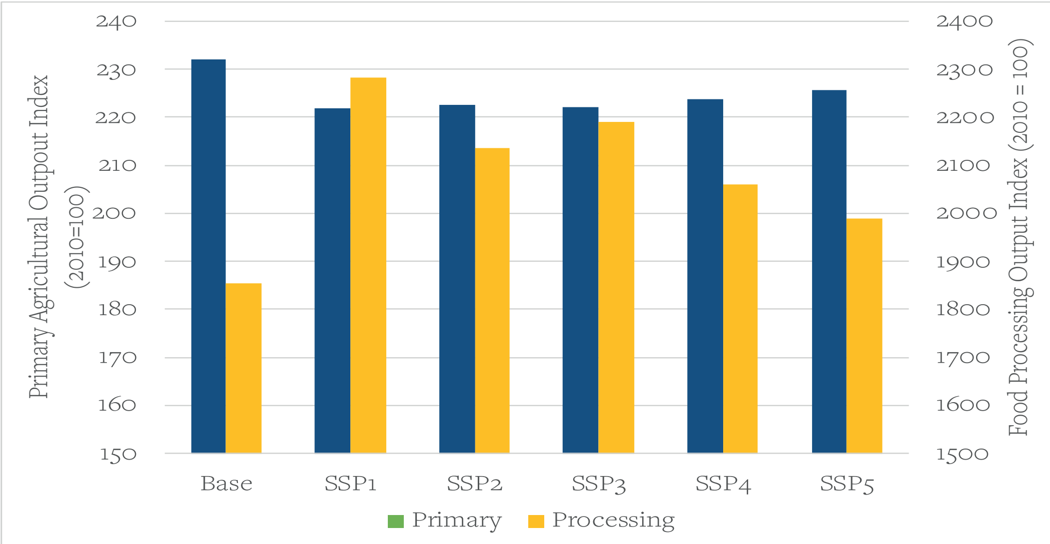


Figure 3 disaggregates the impacts of import price changes on two components of domestic food production: primary and processed food. This distinction is important because as the figure shows, the fortunes for these products are divergent under the scenarios. In terms of the overall picture, however, what happens in the processed food sector is critical as its weight in the composition of domestic food production is relatively large.

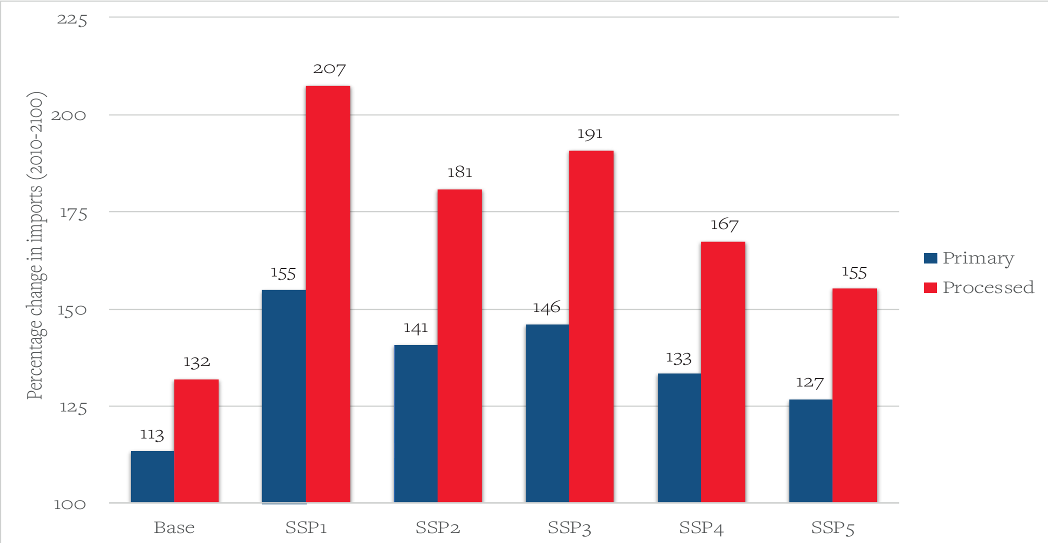
But Figure 3 further emphasises that higher import prices have contractionary effects on food processing. The reason is that this increases costs of production due to higher prices for intermediate inputs which are imported (e.g. cereals for flour mills, powdered milk for dairy processing plants and so on). By contrast, rising world market prices for primary farm products mean that domestic production of primary products becomes more feasible, within the limits of what is technically possible (i.e. substitution) as we have previously discussed. It should be recalled, however, that we assume here that comparatively generous government subsidies stay in place. If this system is judged to be unsustainable (perhaps due to falling oil revenues and fiscal probity) then this will circumscribe further the scope for expanding domestic food production. Energy policy and concerns about water scarcity are important considerations too.[49]

Next we turn to impacts on food imports. This is especially critical given that ultimately Kuwait is bound to rely on imports to feed a growing population. Figure 4 presents percentage changes in level of food imports from between the initial and final periods, 2010 and 2100. An increase in primary food imports is projected to rise from 127 percent (SSP5) to 155 percent (SSP1). The corresponding percentage increases for processed food would be 155 percent and 207 percent respectively. These results are likely to represent conservative estimates of Kuwait's future food imports. The results reported in

[49] Siderius, Conway, Yassine, Murken and Lostis, 'Characterising the Water-Energy-Food Nexus in Kuwait and the Gulf Region'.

this study hinged on projected world market prices. It is likely that prices of food would increase by larger proportions, causing food import increases to be much higher than the results we report in this study.

Figure 4: Primary and Processed Food Import Effects



CGE models are calibrated to baseline data as well as the underlying SAM and a variety of assumed values for parameters in production and demand functions. It is important, therefore, to explore the sensitivity of results to changes in these assumptions. We conducted sensitivity analysis, particularly of one key parameter: the elasticity of substitution between domestic and imported food products. Our main assumption is that import demand for food is not overly sensitive to changes in prices of goods in the world market.[50] This reflects the reality of Kuwait's arid environment which limits its capacity to switch to local production and so move away from reliance on imports. We conducted sensitivity analysis by varying this assumption within the inelastic range it might take, that is, we further assume that substitution is lower and higher than we model previously.[51] As would be expected, the higher the possibility to substitute domestic product for imports, the greater the stimulating effects of price increases in socioeconomic pathways on the domestic economy.

It is worth briefly considering the policy implications of this sensitivity analysis. It is important to note that the exogenous shock applied to the model was an increase in the price of food in the world market. The impact of this shock on import-domestic food supply composition would depend on the value elasticity of import demand. This essentially encapsulates the possibility of switching to local food products in response to price rises in foreign products. The results suggest the importance of shifting consumer

[50] Specifically, we assume an elasticity of substitution of 0.5. This is in the middle of the range of inelastic values for this parameter (i.e. between 0 and less than 1).

[51] That is, elasticities take a value of 0.2 and 0.8 respectively.

preferences to local products. In practice, the actual shift to local food is constrained by two factors: (a) capacity to produce locally and supply to the domestic market and (b) consumer taste or preference for local goods. As far as domestic production is concerned, the most important thing to do is to shift from the current material intensive agricultural production systems to a sustainable mode of food production within the limits set by the natural environment.[52]

In summary, all this makes clear that our simulation experiments serve only to frame thoughts on food security.[53] Actual outcomes are contingent on a number of factors, although a number of the most important are arguably within the reach of policy-making. Much else is framed by the SSP scenarios themselves. For example, SSP5 is the most challenging of these scenarios whereas SSP1 is associated with a more favourable transition for food security concerns. The latter offers a relatively cheaper food import scenario. This means less costly intermediate inputs, or cheaper primary food products which will be processed domestically. Cheaper primary agricultural products, however, also mean less favourable conditions for local primary producers. Given that we have judged SSP5 to be 'business as usual', in effect, Kuwait would expect to pay less for food imports with alternative SSP scenarios than if current trends (i.e. SSP5) continue to prevail in the long term.

5. Overall Conclusions

Our focus on the challenge of sustainability in Kuwait, especially in the context of climate change, has led us to examine three, related but distinct, elements of this wide-ranging debate:

- *Wealth accounting*: the importance of extending existing metrics of national wealth and non-renewable natural capital in assessing development prospects in Kuwait;
- *Greenhouse (GHG) emissions inventory*: the centrality of constructing robust, yet replicable, building blocks for understanding Kuwait's contribution to climate change;
- *Climate risk assessment*: the criticality of assessing development risks arising from climate change on the Kuwaiti economy, starting with the example of food security.

In what follows, we provide some brief conclusions for each of these strands of our work, and finally we draw together collective implications and possible future directions.

With regards to *wealth accounting*, estimating depletion values and natural resource income arising from the production of non-renewable natural capital provides important development insights. For example, depletion values are an important sustainability

[52] Notably, Kuwait has proven capacity for self-sufficiency in vegetables. See also: Afaf Al-Nasser and M. Razzaque, 'Kuwait Food Security within the Context of Climate Change: Animal Production Systems', *Kuwait Institute for Scientific Research* (Kuwait City, 2014).

[53] We have also explored, as is standard in CGE models, the GDP effect on our food price shocks. These are reported in our background report but we do not summarise here. These were negligible, even after accounting for intersectoral feedback effects.

benchmark against which official savings commitments can be evaluated (such as the amount set aside each year to be invested in a sovereign wealth fund). This underlines the importance of official statistical systems (i.e. those of the Kuwaiti CSB) in implementing the Central Framework of the UN's System of Environmental-Economic Accounting.

With regards to a *GHG emissions inventory*, we have shown that existing data sources describing Kuwait's emissions of carbon dioxide, methane and nitrous oxide are likely to be underestimated (perhaps by at least one quarter to one third). In doing so, we show the empirical importance of including previously ignored emissions sources from sectors otherwise well assessed (e.g. fugitive emissions in the energy sector) and a more comprehensive coverage of emissions from less well studied sources such as in the waste sector. This inventory construction, moreover, strictly follows the IPCC guidelines. It is therefore easily replicable and a more robust and comprehensive inventory in official policy processes is clearly of some importance.

With regards to our climate risk assessment, understanding risks as a result of climate change is crucial to prudent assessment of development prospects. Food security, as we show, provides a useful starting point for this in the context of Kuwait (given its dependence on imported food products). By linking IPCC climate change scenarios to an economic model for Kuwait, we show the impacts of changing world food prices on the cost of imports and scope for substituting for domestic activities in both the food production and processing sectors.

What does all this imply for judgements about the sustainability of Kuwait's current development trajectory? Clearly our picture here is incomplete. But our results on the proportion of resource depletion values that are invested in the Future Generations Fund raises questions about sustaining wealth in this context. Whilst a robust emissions inventory is an essential input to economic models that seek to understand the implications of policies such as Kuwait's energy strategy, in terms of contribution to the global climate liability these domestic (production) emissions are a small share. Nonetheless, assessing climate risks to the domestic economy is the other side of this coin. While food security is only one critical risk in this regard, our partial assessment suggests that challenges for climate adaptation in Kuwait also need to be urgently considered.

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Annex 1

Table A.1 Summary of SSP Narratives[54]

	SSP1	SSP2	SSP3	SSP4	SSP5
RCPs (Climate change conditions W/m2)[a]					
8.5	X	X	X	X	Baseline
7.0	X	Baseline	Baseline	X	X
6.0	Baseline	√	√	Baseline	√
4.5	√	√	√	√	√
3.7	√	√	√	√	√
2.6	√	√	X	√	√
Reference Scenarios[b]					
2100 Population (billions)	Peak and decline (~7)	Medium growth (~9)	High growth (~13)	Medium growth (~9)	Peak and decline (~7)
2100 GDP (trillion 2005 PPP)[4]	565	539	270	352	1031
Income inequalities	Low	Medium	High	High	Low
Land-use change and regulation effectiveness[c]	High	Medium	Low	High	Medium
Material intensity in production and consumption	Low	Medium	High	High[3]	High[3]
Barriers to international trade	Low	Medium	High	Medium[3]	Low
Crop Yield Improvement[d]	High	Medium	Low	Low/Medium	High
Challenges to mitigation	Low	Medium	High	Low	High
Challenges to adaptation	High	Medium	High	High	Low

54 Source: a) Fujimori et al., 'SSP3: AIM implementation of Shared Socioeconomic Pathways', *Global Environmental Change* 42 (2017), pp. 268–83; Ayele Gelan, 'Simulating Impacts of Reducing Subsidies to Kuwait's Electricity Sector', *Oxford Energy Forum* 95 (2014), pp. 32–5 (Fig. 1, p270); b) 'IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems: Summary for Policymakers', IPCC (2019), pp. 14–15, available at. https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/ (accessed 10 June 2020); c) Popp et al., 'Land-Use Futures in the Shared Socio-Economic Pathways', *Global Environmental Change* 42 (2017), pp. 331–45 (Table 1); d Riahi et al. (2017) (in SSP database).

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Middle East Centre
London School of Economics
Houghton Street
London, WC2A 2AE

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