

Middle East and Central Asia Department
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The Future of Oil and Fiscal Sustainability in the GCC Region

*Prepared by an IMF staff team of the Middle East and
Central Asia and Research Departments, comprised of
Tokhir Mirzoev, Ling Zhu, Yang Yang,
Andrea Pescatori, and Akito Matsumoto;
supervised by Tim Callen*

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Abstract

The oil market is undergoing fundamental change. New technologies are increasing the supply of oil from old and new sources, while rising concerns over the environment are seeing the world gradually moving away from oil. This spells a significant challenge for oil-exporting countries, including those of the Gulf Cooperation Council (GCC) who account for a fifth of the world's oil production. The GCC countries have recognized the need to reduce their reliance on oil and are all implementing reforms to diversify their economies as well as fiscal and external revenues. Nevertheless, as global oil demand is expected to peak in the next two decades, the associated fiscal imperative could be both larger and more urgent than implied by the GCC countries' existing plans. At the current fiscal stance, the region's financial wealth could be depleted by 2034. Fiscal sustainability will require significant consolidation in the coming years. Its speed is an intergenerational choice. Fully preserving current wealth will require large upfront fiscal adjustments. More gradual efforts would ease the short-term adjustment burden but at the expense of resources available to future generations.

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Introduction

There are growing signs that the oil market is changing. Rising concerns about the global environment have been steadily permeating both policy discourse and commercial activity. International and national policy efforts have led to the tightening of environmental standards while innovation in energy efficiency and renewable energy has been picking up speed (UN 2019). Meanwhile, technological progress in the oil industry has been expanding its capacity. Both volume and productivity of conventional oil reserves have been rising, and their output has been complemented by the rapidly growing shale oil industry. This combination of rising supply amid the global push to reduce reliance on fossil fuels is expected to continue, heralding what has been dubbed “the age of oil abundance.”

Anticipating and preparing for what comes next will be critical for oil-exporting regions, including countries of the Gulf Cooperation Council (GCC). The GCC region is home to the largest concentration of oil exporters, collectively producing over one-fifth of the global oil supply. Oil remains critical to both external and fiscal revenues and overall GDP. And although the importance of non-oil sectors has increased in recent decades, many of them rely on oil-based demand either in the form of public spending of oil revenue or private expenditure of oil-derived wealth. The 2014–15 oil price shock, which notably slowed non-oil growth in most of the region, was a stark reminder of this dependence. Recognizing this challenge, the GCC countries are all implementing programs to diversify their economies as well as fiscal and external revenues away from oil. The success of these programs will be central to achieving strong and sustainable growth in the years to come (Mazarei 2019).

This paper examines three questions:

- What is the long-term oil market outlook?
- What does this outlook mean for public finances in the GCC region?

- What will it take for the GCC countries to ensure long-term fiscal sustainability?

The next section estimates that growth of global oil demand will significantly decelerate, and its level could peak in the next two decades. In assessing the long-term oil market prospects, it is useful to look beyond the geopolitical and cyclical factors and focus on trends that are robust to temporary shocks. Econometric analysis of past oil market developments reveals a strong and sustained declining trend in the global oil demand, after accounting for income and population growth. Reflecting a range of factors, such as long-term improvement in energy efficiency and substitution away from oil, this trend has so far been veiled by the effects of economic and population expansion. But it is poised to become more visible in the coming years, resulting in a path of gradually slowing—and eventually declining—global demand for oil. The latter would peak by around 2040 in our benchmark projection or much sooner in scenarios of stronger regulatory push for environmental protection and faster improvements in energy efficiency. Growth of global demand for natural gas is also expected to slow, although it is expected to remain positive in the coming decades.

This outlook spells a significant fiscal sustainability challenge for the GCC region (Chapter 3). A legacy of sharply rising fiscal expenditure during 2007–14 followed by a steep decline in hydrocarbon revenues have weakened fiscal positions in the region. The decline in oil revenues sparked a period of intensive reforms, including sizable fiscal consolidations. Nevertheless, the effect of lower hydrocarbon revenue is yet to be fully offset. And the resulting fiscal deficits have lowered the region's net financial wealth during 2014–18. A path of prolonged deceleration in hydrocarbon revenue growth would add to this decline in wealth. At the current fiscal stance, the region's existing financial wealth could be depleted in the next 15 years.

The fiscal policy need implied by this challenge is both larger and more urgent when compared to countries' existing plans (Chapter 4). In the context of broader goals of sustainability and sharing of exhaustible oil wealth with future generations, all GCC countries have recognized the lasting nature of their challenge and are already planning continued fiscal adjustment in the context of their broader strategic long-term visions. However, the expected speed and size of these consolidations in most countries may not be sufficient to stabilize their wealth. These adjustments need to be accelerated and sustained over a long period of time, in line with the expected path of hydrocarbon revenue. In illustrative simulations, long-term fiscal sustainability in the GCC requires the average non-oil primary fiscal deficit to decline from the present level of 44 percent of non-oil GDP to mid-single digits by 2060.

Managing the long-term fiscal transition will require wide-ranging reforms and a difficult intergenerational choice. Continued economic diversification will be important but would not suffice on its own. Countries will also need to step up their efforts to raise non-oil fiscal revenue, reduce government expenditure, and prioritize financial saving when economic returns on additional public investment are low. While fiscal starting positions are still strong in a global context in four of the six GCC countries, the longer-term fiscal challenges are substantial. The intergenerational distribution of wealth would be helped by an early start. Gradual fiscal adjustment would ease the burden on the current generation, but the size of required fiscal consolidation would be made larger and its burden transferred onto future generations who would inherit a lower stock of wealth. A notion of the level of wealth that countries intend to leave to future generations would help anchor their long-term fiscal strategies.

2 The Future of Oil

Shifting Market Fundamentals

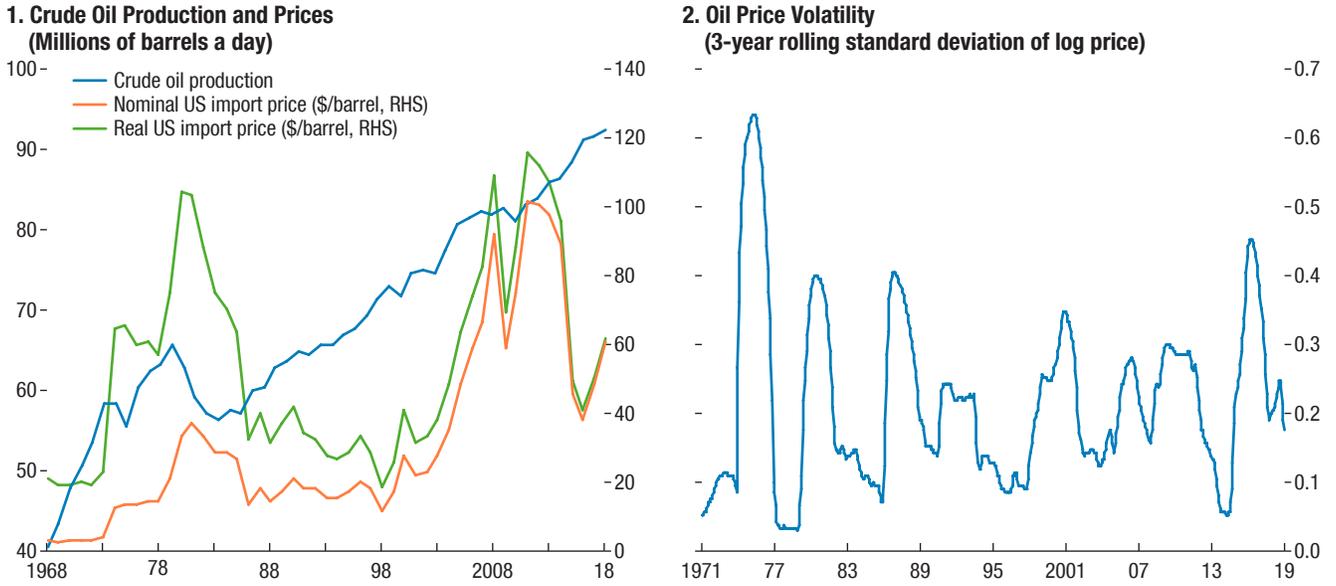
The oil market has experienced a significant turnaround in recent years. The sudden and unexpected oil price decline of more than 50 percent during 2014–15 was among the largest in the past century (Figure 1). It amounted to a transfer of nearly \$6.5 trillion from oil-exporting to oil-importing countries, in the form of cumulative oil revenue decline, between 2014 and 2018. Many oil-exporting countries are still adjusting to the effects of this oil price decline.

Since then, fiscal policies in oil-exporting countries have been adjusted based on the “lower for longer” oil price expectation. Although the possible causes of the 2014–15 oil price shock have been debated in recent studies,¹ there appears to be a broad consensus about the aftermath—that lower oil prices are likely to remain, at least in the medium term.² This expectation has been validated so far as the oil price has remained well below its pre-2014 level despite some recovery from the initial plunge. Consequently, recalibration of policies in response to the oil price decline involved formulating annual budgets and medium-term fiscal plans based on lower oil price assumptions and conservative revenue projections. Amid substantially higher—although not unprecedented—volatility of the oil price (Figure 1, panel 2) and medium-term uncertainty (Figure 2), this approach to fiscal planning has made policies more prudent.

¹Oversupply, owing to increased competition between traditional and new oil producers, has been the most oft-cited reason (for example, Husain and others 2015 and Arezki 2016). Baumeister and Kilian (2015) and Prest (2018) attribute a significant part of the price decline to weaker global demand. Tokic (2015) argues for the importance of exchange rate developments owing to divergent growth prospects in the US and Europe.

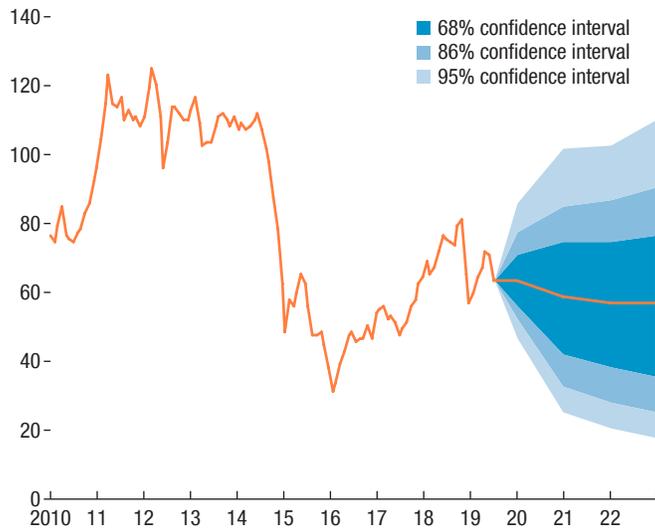
²The likely duration of “lower-for-longer” is also debated. For example, Arezki and others (2017) anticipate a period of lower oil prices to be followed by a period in which oil prices overshoot their long-term trend.

Figure 1. Oil Output, Price, and Price Volatility



Sources: BP; International Energy Agency; and IMF staff estimates.

Figure 2. Brent Crude Futures (US dollars a barrel)



Sources: Bloomberg, LP; and IMF staff calculations.

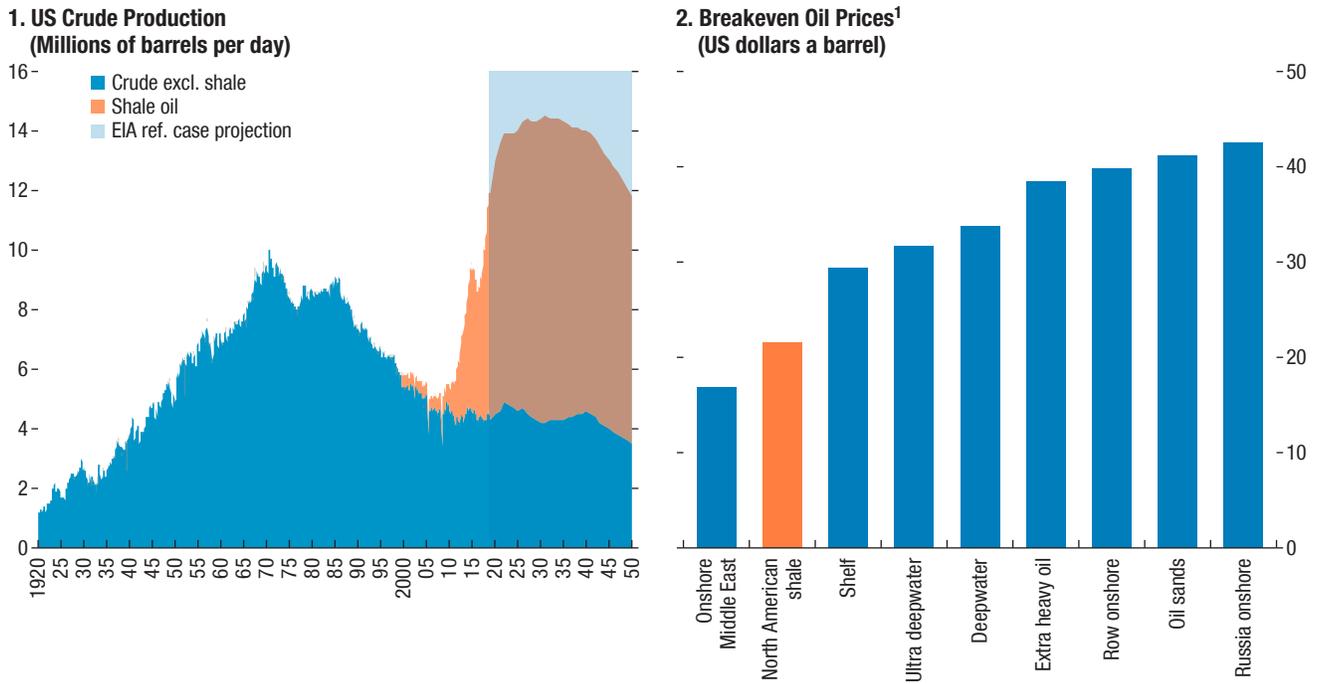
However, the lower oil price alone may not fully capture the new oil market reality. If the oil price decline and subsequent developments are symptomatic of more profound changes in the oil market fundamentals—as argued by Dale (2016) and Arezki and Matsumoto (2016) among others—these changes and their long-term consequences must also inform policy formulation. To this end, it is useful to look beyond the short-term outlook—which is clouded by generally unpredictable and transitory, albeit persistent, geopolitical and cyclical factors—and focus on key long-term trends that are robust to temporary shocks.

There are growing signs that the oil market has been experiencing significant long-term shifts over the past several decades. In the background of global expansion and market volatility, technological progress and environmental concerns have enabled two fundamental changes that will arguably shape the long-term future of oil:

- *Increased availability of oil.* Technological innovation has given rise to the shale oil industry, which has reshaped the market landscape. In just a few years, the US shale oil has become the second-cheapest source of oil in the world (Figure 3, panel 2) and its output doubled, making the country the largest oil producer and (soon to be) a net oil exporter. According to the U.S. Energy Information Administration (EIA), even with the current technology, shale oil output is expected to continue expanding rapidly in the next decade (Figure 3, panel 1). Other countries, notably China, could follow suit. Technology has also significantly increased productivity of existing conventional oil wells and made oil exploration cheaper. For example, proven reserves in the GCC countries have increased over the past decade despite sizable extraction (Figure 4).³ These developments have significantly augmented both current and future potential global oil supply, obviating fears of oil depletion which prevailed in earlier decades. They have also made the market more competitive and the supply curve more price-elastic.
- *Substitution away from oil.* Whether in response to bouts of high oil prices, regulations, or societal concerns over climate change, many economies have been making efforts to reduce their consumption of oil helped by improved technology. The impact of these efforts has thus far been submerged underneath the sustained growth of oil demand fueled by global economic and population expansion. But it is expected to become more prominent and could significantly accelerate with faster innovation and stronger regulatory push for environmental protection.

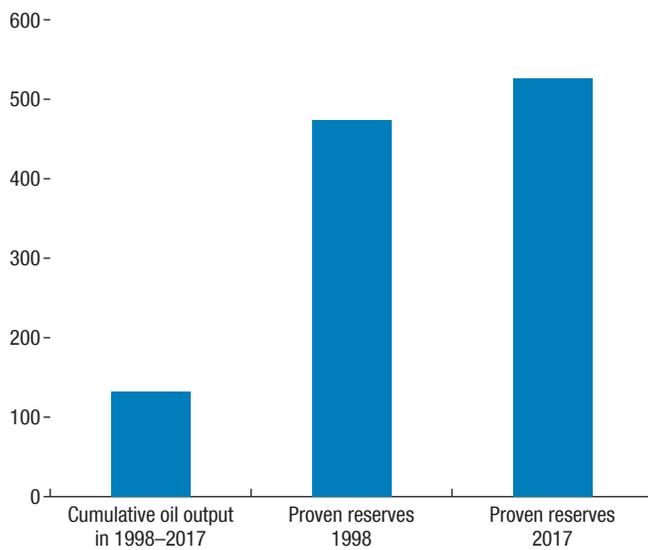
³Dale (2016) estimates that for every barrel of oil consumed worldwide over the past 35 years, another two have been added in proven reserves.

Figure 3. The Shale Revolution



Sources: US Energy Information Administration; Rystad Energy; and IMF staff estimates.
¹Breakeven prices are based on currently operating and sanctioned projects.

Figure 4. Oil Output and Proven Oil Reserves in the GCC Countries¹
 (Billions of barrels)



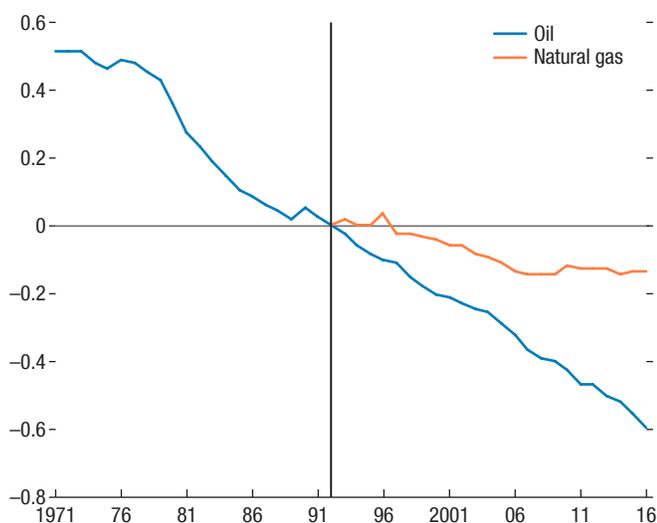
Sources: *BP Statistical Review*; and IMF staff calculations.
¹Bahrain is not included as data are unavailable.

Global Oil Demand Outlook

Econometric analysis of global oil demand reveals—in addition to usual determinants—a strong and sustained declining trend. The estimated model examines the long-term determinants of oil consumption during 1971–2016 in a panel data set of 137 countries (see Annex for full results).⁴ Historically, population and per capita GDP growth have

been the primary drivers of global oil demand. The former has been raising growth of oil demand almost one-for-one, but the influence of per capita GDP growth has been non-linear.⁵ It has been stronger in countries with lower incomes, where growth tends to be more energy-intensive, and weaker in countries with higher per capita GDP owing to larger service sectors and greater means to invest in energy efficiency. In addition to these two determinants, there is also a strong downward time trend in global oil demand (Figure 5). This trend has been subtracting 2½ percent from global oil demand annually between 1971 and 2016 with a cumulative impact of more than 100 million barrels per day in 2016. Among other things, it captures such factors as improved energy efficiency and substitution toward alternative sources of energy. Together, these three determinants explain more than 95 percent of variation in oil demand during the past four and half decades. Finally, the price elasticity of oil demand appears to be small, especially for

Figure 5. Energy Efficiency and Substitution Trends
(Index; 1992 = 0)



Sources: BP; US Energy Information Administration; International Energy Agency; Rystad Energy; and IMF staff estimates.

Note: Trends in energy efficiency and substitution for oil and natural gas are proxied by year fixed effects estimated from regressions with oil consumption and natural gas consumption as dependent variables respectively (see Table 1).

⁴Model specification follows IMF (2018b), which also documents the S-shaped relationship between oil demand and per capita income and the declining time effects in energy demand.

⁵Nonlinearity is captured by the inclusion of quadratic and cubic terms. Lower oil intensity of growth in high-income countries can be explained by greater importance of services and increased ability to invest in energy efficiency by economic agents. Interestingly, including the oil price in the model yields a very small (although statistically significant) coefficient and does not improve model fit.

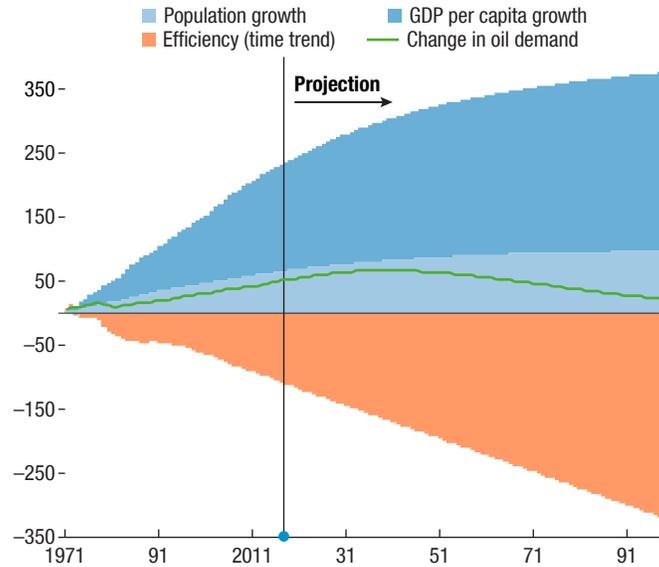
relatively modest oil price fluctuations (see Cooper 2003 and Hamilton 2008, among others).

The declining time trend is weaker in the global demand for natural gas. Estimation of a similar model of global consumption of natural gas during 1992–2016 also reveals a declining time trend, but it has been much more gradual compared to that of oil demand, especially in the past decade (Figure 5). This can be explained by the relatively low carbon footprint of natural gas which—together with easy access, especially to its liquified form (LNG), and relatively low cost of conversion—makes it an appealing cleaner alternative to carbon-heavy fuels such as coal and oil where transition to renewable energy sources requires high setup costs (IMF 2019). Moreover, the estimated model suggests that, unlike in the case of oil, the impact of per capita GDP growth appears to be linear, country size plays a more important role while the influence of population growth is smaller (see Annex). Thus, the long-term future of natural gas may differ from that of oil, at least for some time.

Current trends in key determinants point to continued downward pressure on global demand for oil and natural gas. First, population growth has been slowing and is expected to continue doing so in most of the world. According to the median projection in the United Nations 2019 World Population Prospects, the rate of global population growth is expected to decline from 1.1 percent in 2018 to 0.6 percent by 2046. Second, per capita income is expected to continue rising in the largest oil-importing countries and, as they grow richer, their additional growth is expected to require less oil. In addition, according to the International Energy Agency (IEA), global per capita GDP growth is expected to slow from 3.2 percent over the next decade to 1.8 percent in the long term with the maturing of emerging market economies. Finally, the declining time trends in both oil and gas demand are expected to continue and could accelerate with faster improvements in energy efficiency and quicker adoption of renewable energy sources.

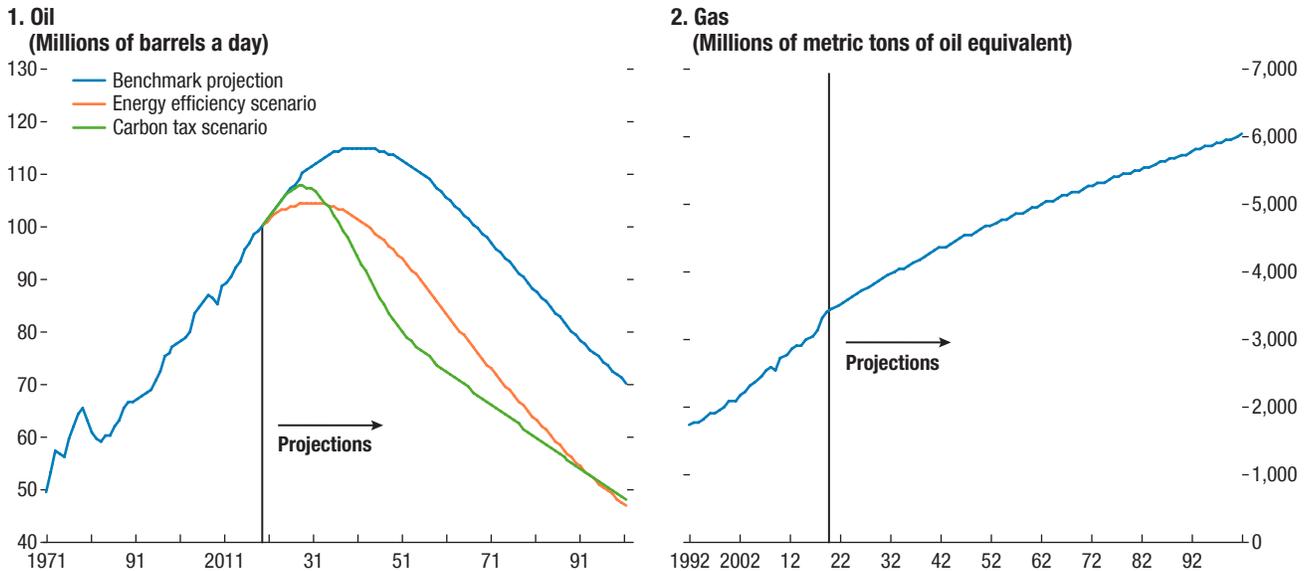
Global oil demand could peak in the next two decades. The benchmark projection of long-term oil demand applies the econometric results discussed (Annex Table 1.1) to the current trends in key determinants. It predicts that global oil demand will peak around 2041 at about 115 million barrels a day and gradually decline thereafter as the demand-reducing effects of improvements in energy efficiency and increased substitution away from oil begin to dominate the weakened positive impact of rising incomes and population (Figures 6 and 7). By contrast, improvements in energy efficiency will have a more moderate effect on natural gas and its global demand will likely continue to grow (Figure 7, panel 1).

Figure 6. Contribution to Cumulative Change in Oil Demand Since 1971
(Millions of barrels a day)



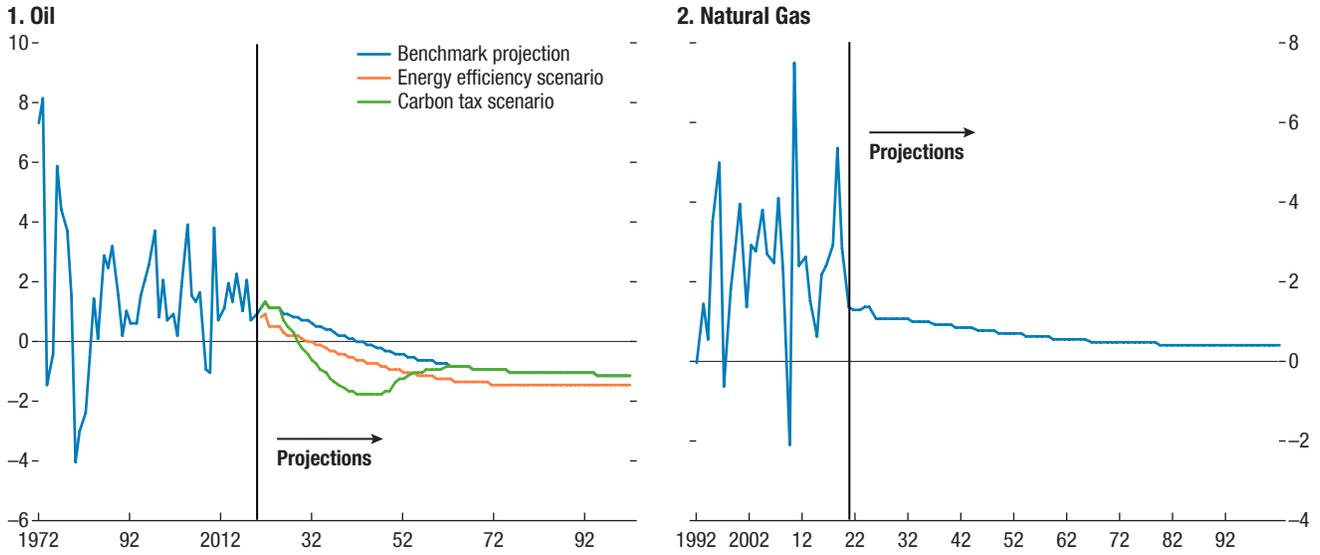
Sources: International Energy Agency; United Nations; *World Economic Outlook*; and IMF staff calculations.

Figure 7. Projected Global Demand for Hydrocarbons



Sources: BP; International Energy Agency; Rystad Energy; United Nations; and IMF staff estimates.

Figure 8. Projected Annual Growth of Hydrocarbon Demand (Percent)



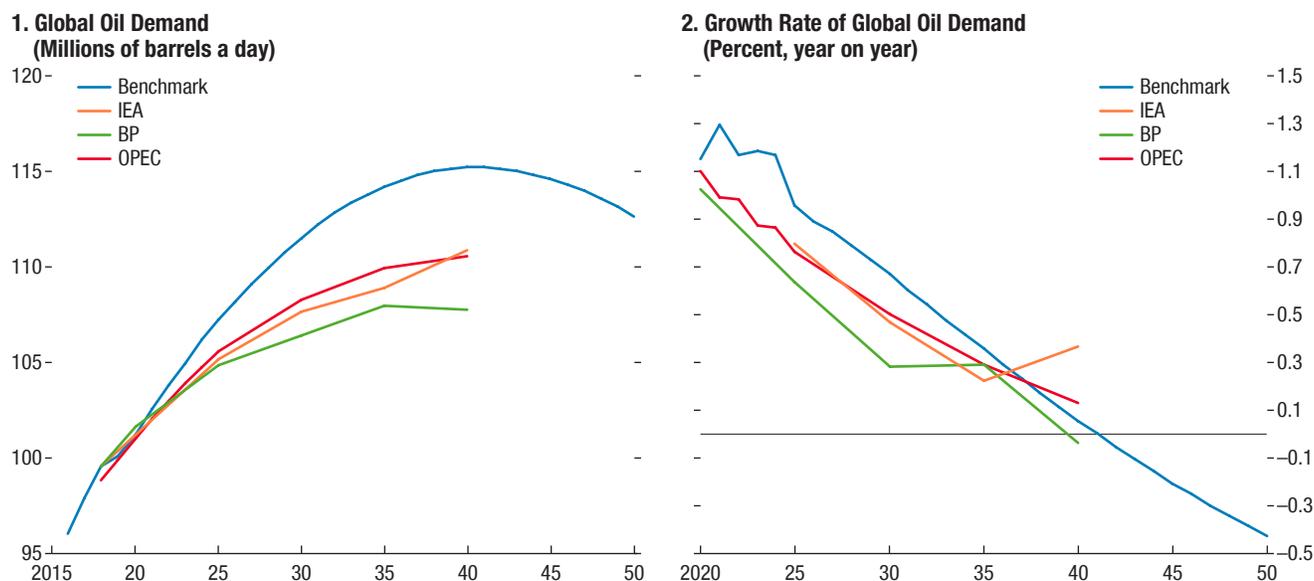
Sources: BP; International Energy Agency; Rystad Energy; United Nations; and IMF staff estimates.

Faster technological innovation and regulatory response to climate change would bring this process forward (Figure 8).⁶ In the scenario of faster improvements in energy efficiency—constructed by assuming an additional 0.6 percentage point acceleration of the time trend—global oil demand could peak as early as 2030.⁷ In line with the October 2019 *Fiscal Monitor* (IMF 2019), the scenario of stronger regulatory action in response to climate change is approximated by assuming a carbon tax that is gradually increasing (starting in 2022) to a level that would bring the cost of CO₂ emissions to \$50 per ton by 2030 and \$150 per ton by 2050. This is consistent with curbing the long-term increase in global temperature at 2 degrees Celsius according to the IEA’s sustainable scenario (see IEA 2013). The carbon tax scenario brings the peak in oil demand forward to before 2030 and implies a steeper decline thereafter.

While the exact timing of the oil peak is uncertain, growth of global demand for oil (and gas) will most likely slow down. Estimates of when oil demand will peak are sensitive to the underlying assumptions and vary significantly across scenarios. Regardless of when (or whether) the peak in oil demand occurs, nearly all scenarios predict a significant deceleration in the growth of oil demand throughout the projection period (Figure 9). This is consis-

⁶These scenarios would also affect demand for natural gas but were not modeled here due to insufficient data.

⁷On the other hand, slower pace of improvements in energy efficiency would delay the peak in oil demand.

Figure 9. Benchmark Projection and Forecasts by Other Energy Institutions

Sources: BP (2019); International Energy Agency (2018); Organization of the Petroleum Exporting Countries (2019); IMF staff calculations.

tent with projections by other prominent agencies (see Figure 9).⁸ For example, the central scenario in BP (2019)—the “evolving transition” scenario—also envisages a peak in oil demand by 2040. In the central projection in IEA (2018)—the “new policies scenario”—global oil demand is not expected to peak before 2040 but its annual growth slows to 0.4 percent by 2040 compared to 2.1 percent during 1995–2017. Similarly, OPEC (2019) forecasts annual growth of oil demand to decelerate to 0.1 percent by 2040. These studies do not specify their underlying models of oil demand, which precludes a detailed comparison with the projections presented here.

Within overall oil demand, there will be changes in composition. Several recent studies point to two opposite trends that are expected to change the composition of global demand for oil.⁹ On one hand, it will be helped by the petrochemical industry, which IEA (2018b) expects to expand by 40–60 percent by 2050 (or about 5 million barrels a day) depending on assumptions. Due to a relatively low starting base (14 percent of current oil demand), this expansion will only partially offset the expected decline in the oil intensity of larger consumers of oil, such as transportation (see Cherif, Hasanov, and Pande 2017; Lewis 2019). Nevertheless, it will provide some support to oil demand in the long term.

⁸Similarly, growth of global demand for natural gas, while remaining positive, is also expected to slow.

⁹The econometric analysis described above uses aggregate oil demand from all sectors, including from the petrochemical industry, and can be interpreted as aggregation of these compositional trends.

Finally, the likely evolution of the long-term oil price is less certain (Box 1). The discussion that follows is based on a real oil price of \$55 a barrel, which corresponds to its historical average but is also subject to significant uncertainty. Perhaps more importantly, a precise price forecast is of limited consequence for the projections discussed in the following sections: alternative assumptions would only affect their timing but not their general predictions (see following discussion).

Box 1. The Long-Term Oil Market Equilibrium

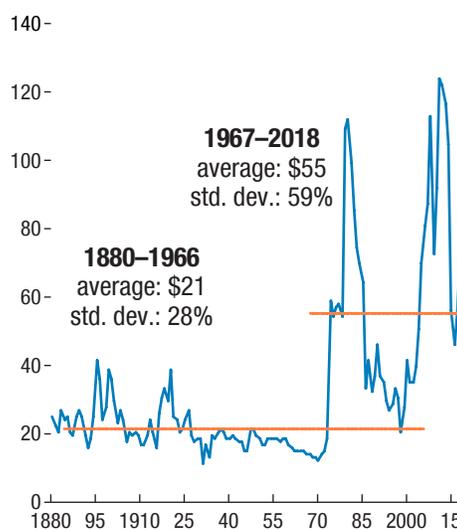
The simulations in the paper are based on a benchmark real oil price of \$55 a barrel. This assumption is motivated by its consistency with the historical average over the past five decades. During this period, global oil supply has adjusted and, on average, met the changing demand at this price. For this average price to hold going forward, supply must continue to rise until the peak in demand and contract thereafter.

Is this assumption plausible? Rystad Energy projects quantities that would be supplied by each existing oil field under different prices based on the expected evolution of marginal costs. To project total oil supply, these data have been combined with an assumption about new discoveries. If new discoveries were to expand capacity by about 20 percent over the next 20 years—which is consistent with robust growth of proven reserves in the past—global oil supply would be able to meet the demand before the peak at the assumed price. Closer to the peak, investment in oil would decline triggering gradual contraction of supply thereafter.

Is this assumption probable? Predicting the oil price is notoriously difficult. While sensible as a central projection, the real price assumption—which implies a nominal price of about \$100 a barrel by 2050—is also subject to significant uncertainty because demand and supply could evolve differently or adjust at a different pace for various reasons (Dale and Fattouh 2019). For example, faster contraction of demand in the energy efficiency or carbon tax scenarios would reduce the real oil price to below \$37 a barrel. The changing market structure could also affect the long-term oil price: the real \$55 a barrel average corresponds to the period of increased monopolization; but in a more competitive market before that, the real oil price was lower. Finally, even if the average real price remains at \$55, deviations from this average could be large and persistent.

What if the actual price is significantly different from the assumed benchmark? Effects of different price assumptions on the GCC countries would be partly offset by market share implications. Because they enjoy the lowest average cost of oil extraction in the world, the GCC countries' market share would be higher at lower oil prices—which would make oil wells unprofitable in higher-cost regions—and contrariwise. Whereas the oil price is the primary determinant of near-term developments, in the long term, quantities will arguably be more important and the focus on the long-term oil price is likely to be misplaced. Importantly, barring extreme scenarios, alternative price assumptions (e.g., IEA and Rystad Energy projected prices to be higher) would not change the main qualitative findings of this paper.

Figure 1.1. Historical Real Oil Price
(2017 US dollars)



Source: BP Statistical Review of World Energy, 2019.

What Does It Mean for the GCC Region?

Oil Wealth in the GCC: Looking Back

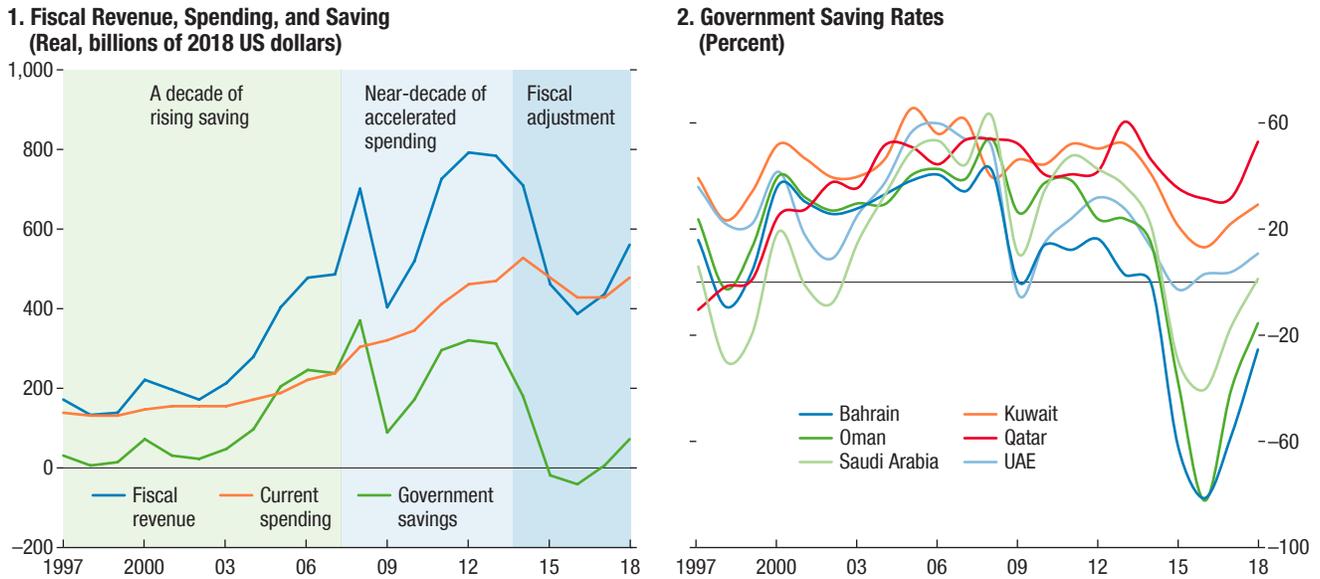
The evolution of government wealth in the GCC region tells a story of two different periods between 1997 and the 2014 oil price decline (Figure 10):

- *A decade of rising saving* (1997–2007). Against the background of a rapidly rising oil price and revenues, countries' current expenditures grew more gradually resulting in rapid wealth accumulation in the form of both infrastructure capital and financial investment. As saving outpaced spending, saving rates (the fraction of fiscal revenue saved) more than doubled, reaching an average of 40 percent in 2007.
- *A (near-) decade of accelerated spending* (2008–14). Since the global financial crisis, oil prices and average annual oil revenue have somewhat declined amid increased volatility. By contrast, current spending in the GCC region continued to grow largely unabated until the 2014 oil price shock—with a notable acceleration in the wake of the Arab Spring in 2011—rising from 20 percent of GDP in 2007 to 30 percent of GDP in 2014. Consequently, government saving rates plummeted and wealth accumulation slowed—a salient feature across all GCC countries.

The 2014 oil price decline resulted in large fiscal deficits and sparked significant reforms. Recognizing the need to accelerate efforts to reduce their dependence on oil, all countries have adopted new (or modified existing) strategic “visions” for their economies envisaging faster diversification and private sector development. To this end, governments have begun to roll out wide-ranging structural and fiscal reforms.

There has been a significant recalibration of fiscal policies. Most GCC countries have begun to improve their public financial management while also making efforts to strengthen their fiscal positions. The latter involved deploy-

Figure 10. GCC: Government Saving, 1997–2017



Sources: Country authorities; and IMF staff calculations.

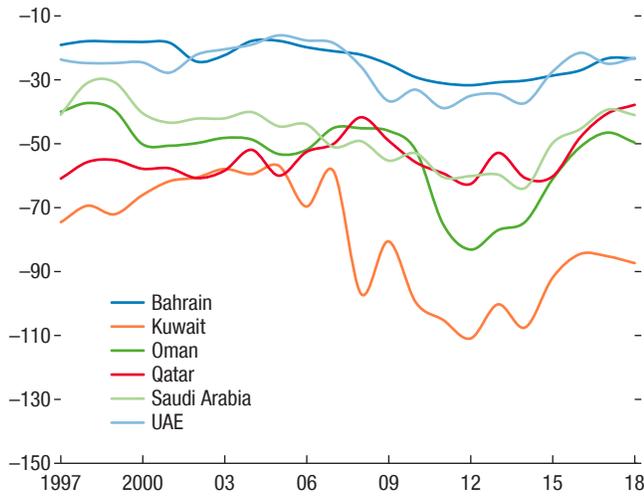
ing a variety of quick fixes—such as short-term freezes and cuts in various discretionary items—as well as more substantive reforms, such as phasing out of inefficient energy and water subsidies and the introduction of new taxes and fees. The introduction of excise and value-added taxes in Bahrain, Saudi Arabia, and UAE was a significant change that other GCC countries are expected to follow.¹ As a result of these efforts, the average non-oil primary fiscal balance (NOPB) in the GCC has improved from a deficit of more than 60 percent of non-oil GDP in 2014 to 44 percent in 2018—a remarkable effort in any international comparison (Figure 11).

But overcoming the legacy of nearly a decade of strongly rising spending will require more time and effort. Although the fiscal consolidations to date have managed to stop the rising trend in current spending, they have yet to fully offset the decline in oil revenue. During 2014–18, most GCC countries were running overall fiscal deficits that required increased borrowing and/or drawing down central bank and sovereign wealth fund (SWF) assets. Consequently, aggregate public wealth accumulation in the GCC region came to a halt while public net financial wealth declined during this period (Figure 12). Government saving rates during this period differed across countries: in Bahrain and Oman, they remained negative; in Saudi Arabia and the UAE, the saving rates recovered from the initial plunge to slightly positive territory;

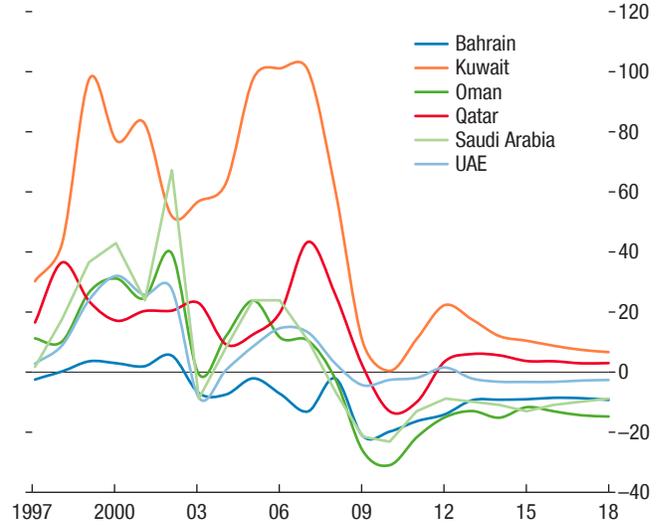
¹Qatar also introduced excise taxes on several product categories.

Figure 11. Non-Oil Primary Balance and Overall Fiscal Balance

1. Non-Oil Primary Balance
(Percent of non-oil GDP)



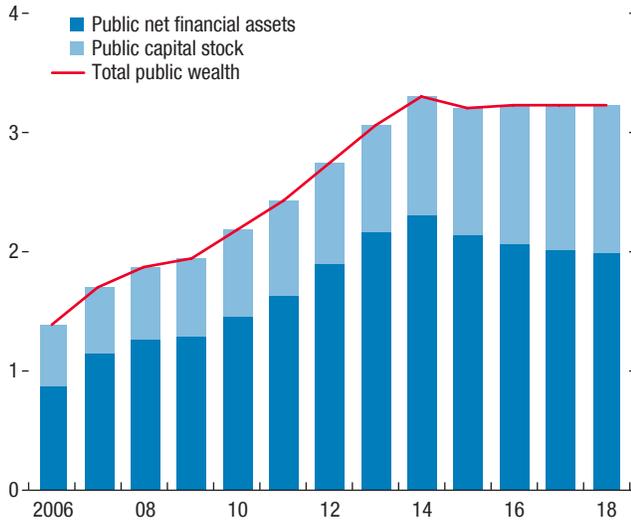
2. Overall Fiscal Balance
(Percent of non-oil GDP)



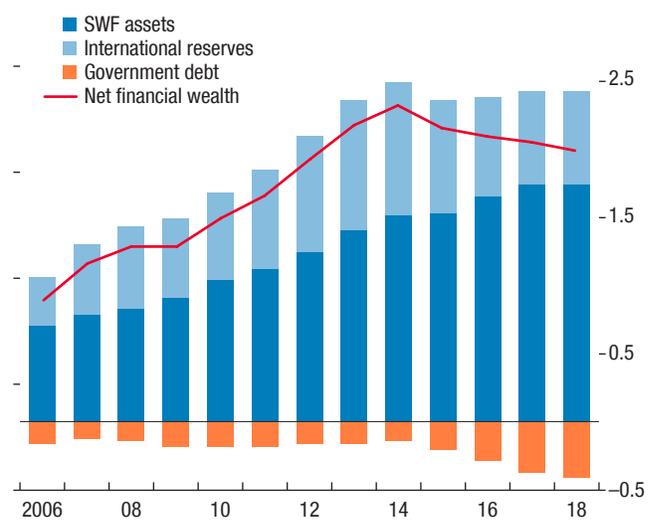
Sources: Country authorities; and IMF staff calculations.

Figure 12. Accumulation of Non-Oil Public Wealth

1. Real Non-Oil Public Wealth
(Trillions of 2018 US dollars)

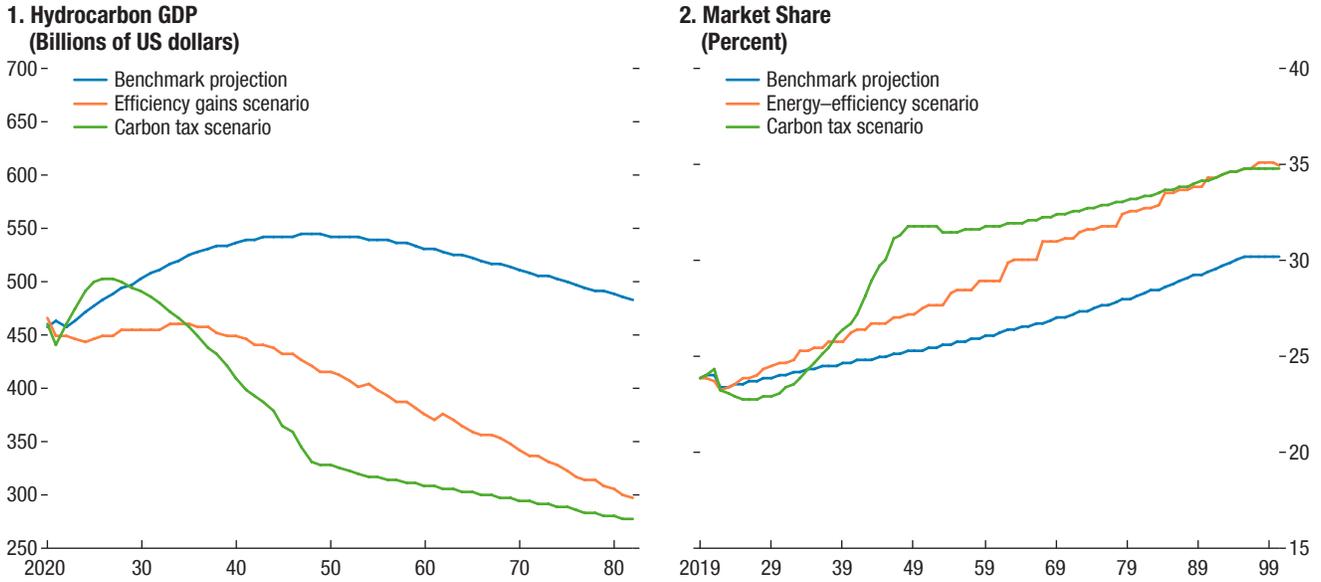


2. Real Net Financial Wealth
(Trillions of 2018 US dollars)



Sources: Country authorities' data; and IMF staff calculations.

Figure 13. GCC: Long-Term Projections of Hydrocarbon GDP and Market Share



Sources: BP, International Energy Agency; Rystad Energy; and IMF staff estimates.

while Kuwait and Qatar managed to maintain fiscal surpluses and positive saving rates.

Mounting Challenges Ahead

The long-term shifts in the oil market would pose additional fiscal challenges for the region. The GCC countries’ hydrocarbon GDP will likely follow the hump-shaped path of global oil demand, but with a more gradual deceleration owing to the expected gain in market share from higher-cost producers (Figure 13).² Continued growth of demand for natural gas will benefit Qatar and Oman, where it accounts for 75 and 25 percent of hydrocarbon revenue respectively, as well as other countries with sizable gas reserves (e.g., Saudi Arabia). In the benchmark projection, these factors will delay the peak in hydrocarbon GDP by about a decade. Hydrocarbon GDP is expected to be lower in the alternative scenarios. The lower producer price effect arising in the scenarios of stronger regulatory response to climate change (carbon tax, see Annex) and faster improvements in energy efficiency will expand

²Market share projections were constructed based on the forecasted extraction costs from Rystad Energy that allows us to project which of the existing oil wells will become unprofitable over time at the assumed real oil price.

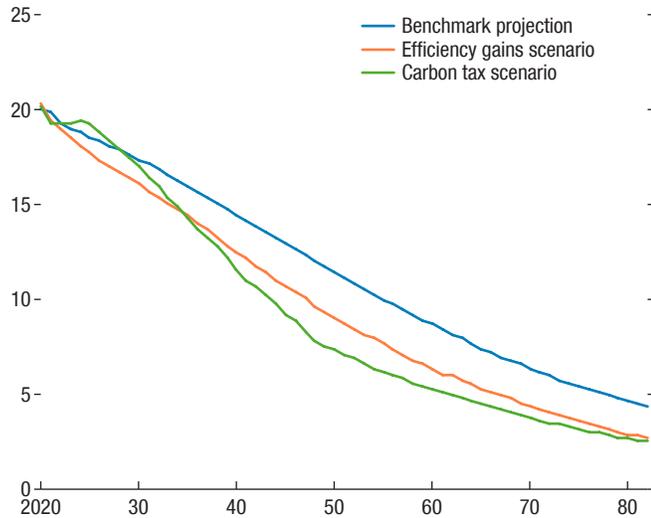
the GCC region's market share. But these gains would be more than offset by the decline in demand.³

These developments would be mirrored in a decelerating path of fiscal revenue. In the benchmark projection, hydrocarbon revenue will peak by about 2048. Assuming continued annual non-oil real GDP growth rate of three per-

cent, this implies a path of a persistent decline in hydrocarbon fiscal revenue in percent of GDP (Figure 14). In the benchmark projection, this ratio would halve by 2050 from the present level of 23 percent. The decline would be steeper should the alternative scenarios of faster improvements in energy efficiency and stricter environmental protection policies materialize.

The fiscal sustainability impact would be significant: at the current fiscal stance, the region could exhaust its financial wealth in the next 15 years. Holding the current levels of expenditure and nonhydrocarbon revenue constant in percent of nonhydrocarbon GDP provides a reference point for assessing fiscal sustainability implications of the benchmark oil revenue projection (see Annex for technical details). When projected forward, it implies a steady widening of fiscal deficits and a corresponding erosion of the region's financial wealth at an accelerating pace. In this illustrative simulation, the region's aggregate net financial wealth, estimated at \$2 trillion at present, would turn negative by 2034 as the region becomes a net borrower (Figure 15). Total non-oil wealth would be depleted within another decade. This timeline would be brought forward in the alternative scenarios of faster improvement in energy efficiency and introduction of a carbon tax. Specific timing would vary across countries, reflecting differences in their initial con-

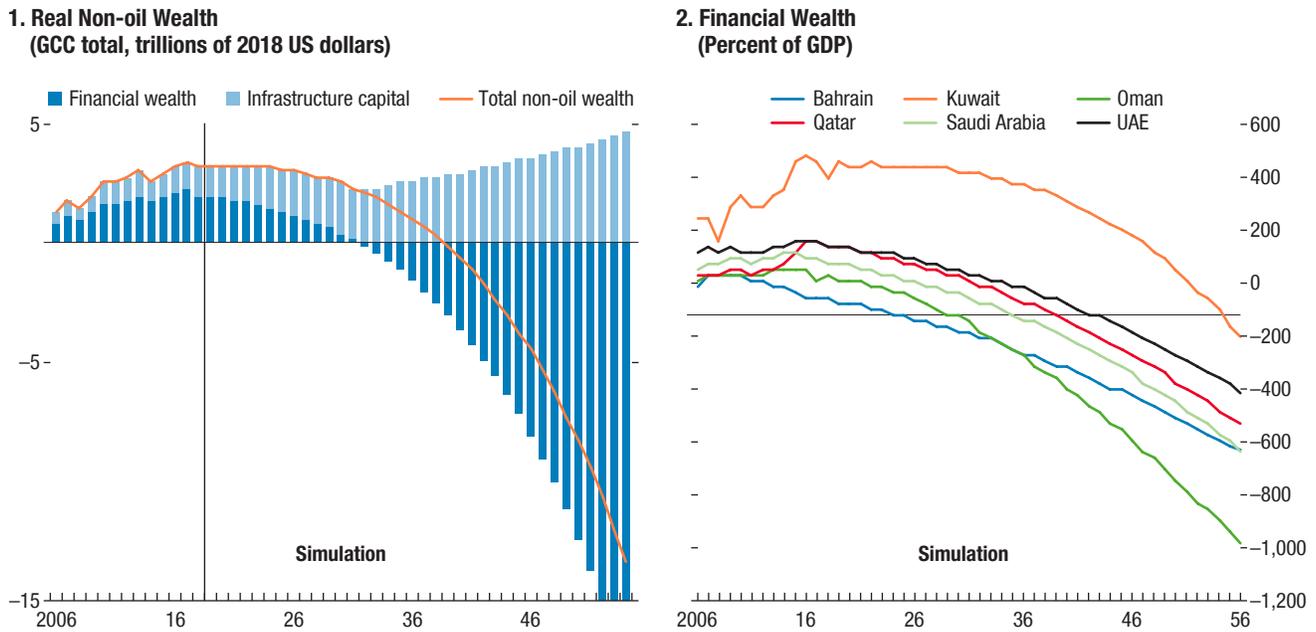
Figure 14. GCC: Aggregate Hydrocarbon Revenue
(Percent of GDP)



Source: IMF staff calculations.

³In the carbon tax scenario, oil revenue initially overshoots because producers cut output and investment upfront, in anticipation of falling demand, while the carbon tax is raised gradually. This leads to a temporary boost to oil prices and revenues, which dissipates over time.

Figure 15. Public Wealth Under the Current Fiscal Stance: Benchmark Projection



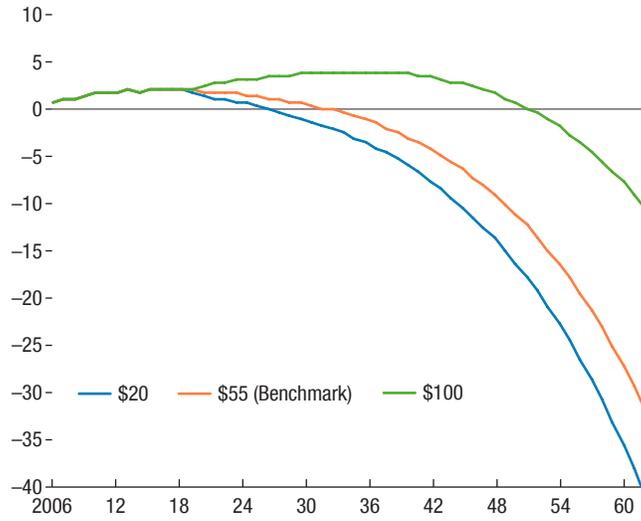
Sources: Country authorities; and IMF staff calculations.

ditions. For example, Bahrain and Oman are most vulnerable to this downturn, while Kuwait’s large SWF will help keep its net financial wealth positive until about 2052.

How would different price assumptions affect these projections? Alternative price assumptions would not change the general outcome—that financial wealth would be depleted under the current fiscal stance—but it would affect its timing. The per-barrel revenue loss from a lower oil price would be limited by the GCC countries’ gain in market share because production by higher-cost producers would be unprofitable. Similarly, the expected revenue gain from a higher oil price would be reduced by the GCC countries’ market share decline owing to improved viability of higher-cost producers and potentially lower oil demand. These offsetting effects would limit the overall impact of alternative price assumptions. For example, a real oil price of \$100 a barrel would delay the time of wealth exhaustion only until 2052, while a real oil price of \$20 a barrel would bring it forward to 2027 (Figure 16).

Figure 16. Real Financial Wealth Under Alternative Price Assumptions¹

(GCC total, trillions of 2018 US dollars)



Source: IMF staff calculations.

¹Prices are in real terms (for example, a real price of \$100 implies a nominal price of \$244/barrel by 2050). Alternative assumptions take effect starting 2020.

What Would It Take?

Agreeing the Goal Posts of Fiscal Policy

A fiscal strategy to respond to the changing oil market needs to be anchored to countries' long-term goals of fiscal sustainability and intergenerational equity. The main fiscal policy task in oil-exporting countries is to convert subsoil wealth into the sustainable well-being of their populations by using some of the hydrocarbon proceeds to finance current needs while saving the rest for future generations. A fiscal path is *sustainable* in the long term when these savings (including their financial returns) are sufficient to meet the future fiscal needs without continuously depleting financial wealth. Consequently, for any given set of fiscal policy and other macroeconomic assumptions, stability of net wealth—including the value of underground oil and gas, net financial assets, and infrastructure capital—either in per capita terms or in percent of GDP is a key indicator of long-term fiscal sustainability.¹ Furthermore, the level at which wealth is sought to be stabilized captures the degree of *intergenerational equity* in how oil-based wealth is managed over time.

One possible fiscal strategy in oil-exporting countries is full preservation of wealth as prescribed by the Permanent Income Hypothesis (PIH).² In the absence of shocks, PIH ensures both fiscal sustainability and intergenerational equity as every generation inherits the same amount of wealth and benefits

¹Debt sustainability frameworks, which seek to stabilize long-term debt, are usually guided by thresholds which correspond to probabilities of an adverse event (crisis or loss of market access) when the debt burden is too high. This approach is not directly applicable where net wealth is significantly positive.

²This is achieved by limiting expenditure to the estimated annuity value of total wealth while saving a significant portion of oil receipts in revenue-generating assets whose dividend income is meant to replace oil revenue in the future. IMF (2012, 2015) discuss alternative fiscal frameworks in which temporary deviations from PIH can be justified by productive public investment.

from equal level of fiscal expenditure.³ As in many resource-rich regions, meeting the PIH benchmarks has been a challenge in the GCC countries, which have so far opted for fiscal balances that are not sufficient to meet the saving rates implied by the PIH. The lower oil price environment has made this challenge more difficult: fiscal balances have turned negative and countries have been unable to save any portion of their oil receipts. This means that total wealth in the GCC has been declining.

Alternative fiscal paths could also be considered as fiscally sustainable but at the cost of intergenerational inequity. For example, gradual fiscal consolidation followed by accelerated adjustment efforts down the road could stabilize wealth at some lower level. Such a strategy would ease the burden of adjustment on the current generation and could still be sustainable since the government's net asset position would not spiral downward, e.g., as in Figure 15. However, the cost of such fiscal gradualism would be transferred onto future generations who will need to implement a larger (and steeper) fiscal adjustment while inheriting a lower stock of wealth.

In practice, countries' intergenerational goals are likely to be highly subjective. Academic research (see Arrow 1973 and Solow 1974, 1986) and policy discussions (IMF 2012) usually focus on intergenerational equity. But what is equitable across generations cannot be defined in economic terms alone. It ultimately reflects preferences of the current generation and the various socioeconomic challenges it faces. Whatever the circumstances, some (however subjective) notion of the level of wealth (debt) that a country is aiming to leave to future generations would help anchor its long-term fiscal strategy (Mirzoev and Zhu 2019).

Illustrative Fiscal Paths

Examination of fiscally sustainable paths starts with estimating countries' net wealth. Measuring wealth in the GCC is difficult owing to data limitations. In general, a comprehensive measure of net wealth should include the value of natural resources that are underground; net financial assets; and government's real assets, such as infrastructure capital. The discussion that follows is based on estimates that rely on several assumptions. First, underground hydrocarbon wealth is estimated based on countries' current level of proven reserves and assuming their gradual exhaustion over time.⁴ Second, public investment is treated as saving while current expenditure is treated

³Mirzoev and Zhu (2019) discuss limitations of the PIH in the presence of uncertainty.

⁴This traditional approach is followed for the lack of a better alternative while recognizing its two problematic features. First, proven reserves are highly uncertain and tend to increase over time; at the same time, they are often self-reported using countries' own definitions and thus cannot be easily verified or compared. Moreover, if demand for oil declines, oil revenue could diminish long before countries exhaust their reserves, that is, global

as spending of wealth.⁵ Public physical capital stock is approximated by its book value, i.e., the sum of past public investment less an assumed depreciation rate of 5 percent. Finally, net financial wealth is measured by the sum of publicly available estimates of SWF assets and central bank reserves less government debt.

A fiscal strategy to meet the PIH would require a large and immediate fiscal adjustment. For all generations to equally share the initial level of wealth, the nonhydrocarbon fiscal balance must be immediately improved to a level that is consistent with keeping wealth constant over time. The magnitude of the estimated adjustment is large, averaging 32 percent of nonhydrocarbon GDP or more than double the fiscal adjustment achieved by the GCC region during 2015–18.⁶ The benefit of preserving initial wealth is that its larger stock generates higher dividend income which, in turn, creates additional fiscal space in the future. The downside of such a strategy is the difficulty of implementing it in one go.

Alternative fiscally sustainable strategies involve intergenerational tradeoffs:

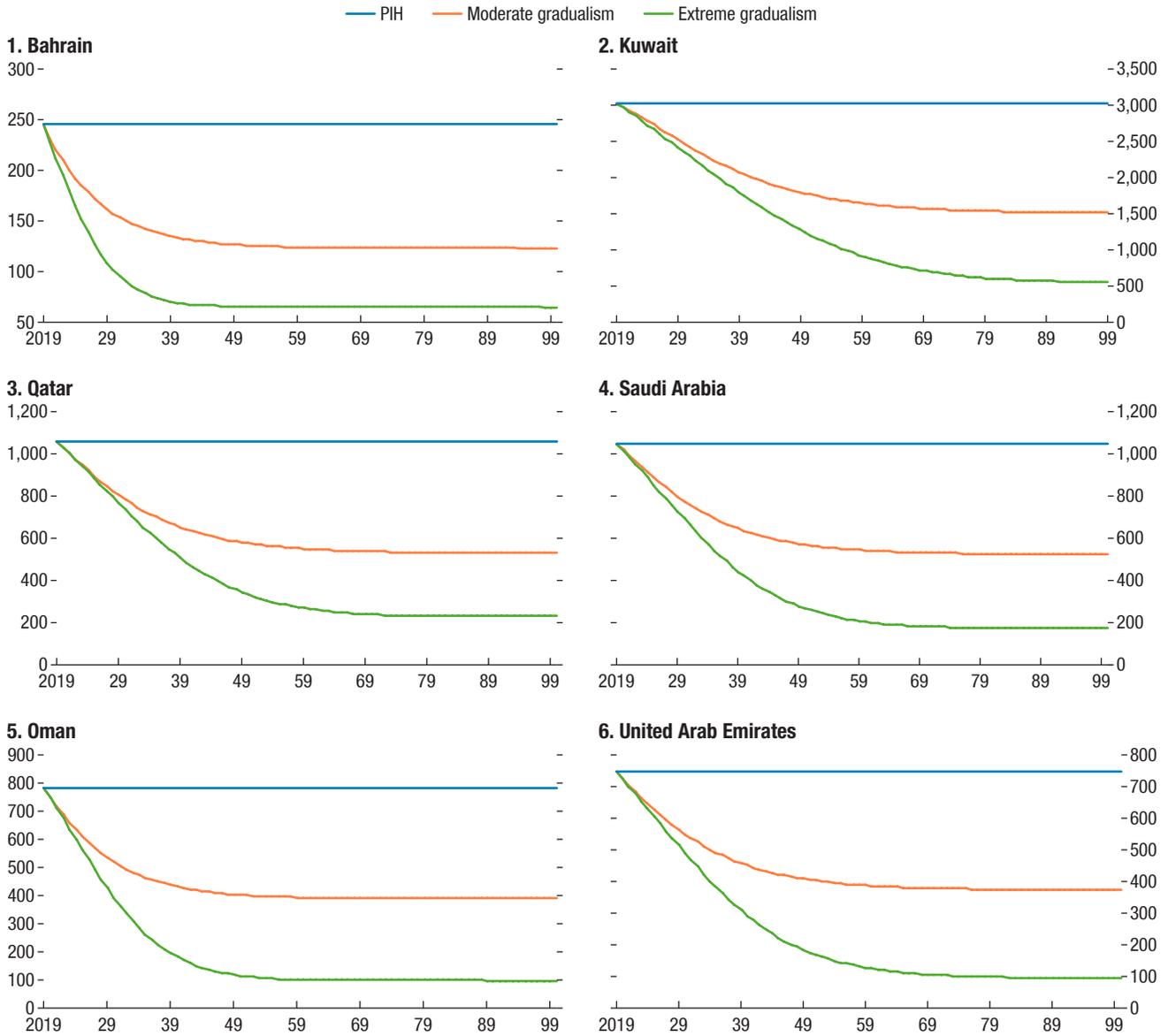
- *More gradual adjustment paths would ease the burden on the current generation at the expense of future generations.* Figures 17 and 18 contrast the PIH strategy with two alternative fiscal paths: moderate gradualism that stabilizes long-term wealth at half of its initial level and what could be described as an example of extreme gradualism that results in near-depletion of net wealth. Average fiscal adjustment under moderate gradualism is reduced to 5.5 percent of non-oil GDP in the first five years and is about 1 percent of non-oil GDP under the extreme scenario. The loss of wealth that enables this measured pace of reform represents the cost of fiscal gradualism.
- *Gradualism would not reduce the overall long-term fiscal adjustment—it would make it larger.* In the gradual adjustment scenarios, wealth declines while the non-oil primary balance remains below the level that is needed to stabilize it. Lower wealth inherited by future generations also means that

demand, rather than available reserves, is more likely to be the dominant long-term constraint and some oil reserves may remain unextracted.

⁵In conventional *budget accounting*, the fiscal stance is usually assessed using the overall non-oil primary balance (see Medas and Zakharova 2009), where both current and capital expenditure are treated as spending. By contrast, because countries' non-oil wealth includes physical capital (for example, infrastructure) and financial assets (for example, SWF holdings or central bank reserves), *wealth accounting* requires treating capital expenditure as equivalent to financial investment as both represent a transformation of oil revenue into productive saving.

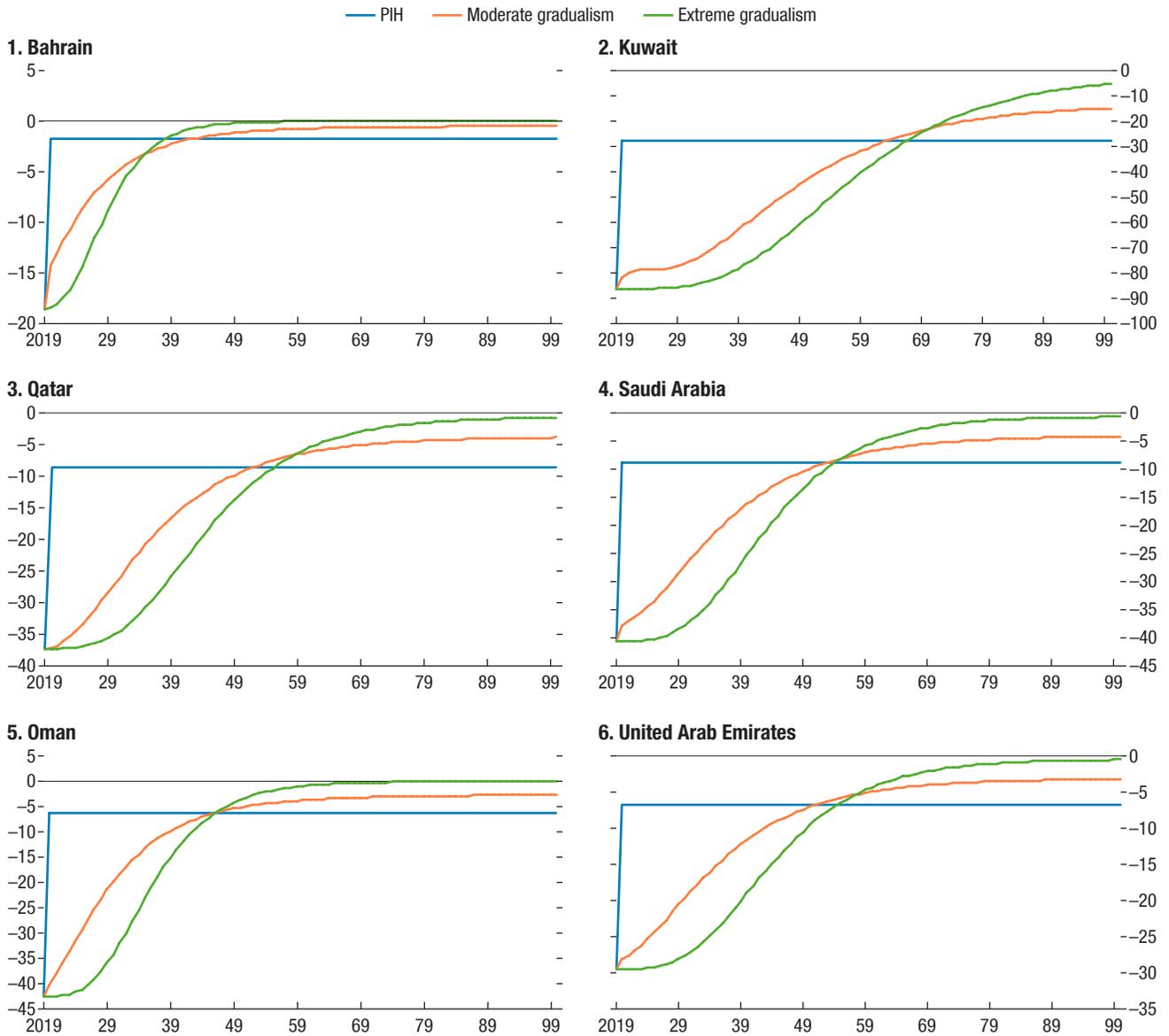
⁶Alternative price assumptions would affect the magnitude of the required adjustment under PIH: at the real oil prices of \$20 and \$100, average adjustment is 35 and 28 percent of non-oil GDP, respectively. In these calculations, public investment is assumed to maintain the stock of infrastructure capital in percent of non-oil GDP and remains constant as a share of non-oil GDP. Therefore, fiscal balance excluding public investment and NOPB imply the same fiscal adjustment.

Figure 17. Government Wealth in Simulations of Illustrative Fiscal Paths, 2019–2100
(Percent of non-oil GDP)



Source: IMF staff calculations.

Figure 18. Non-Oil Primary Fiscal Balance Under Illustrative Fiscal Paths, 2019–2100
(Percent of non-oil GDP)



Source: IMF staff calculations.

they would be deprived of the associated dividend income. The latter could be significant—it currently ranges between 2 and 4 percent of GDP in Kuwait, Qatar, Saudi Arabia, and the UAE—and represents a permanent loss of fiscal space. Fiscal sustainability requires the overall long-term fiscal consolidation to be larger to compensate for this loss.

- *After a gradual start, the fiscal adjustment path must also be steeper.* Smaller initial fiscal adjustment means that a higher long-term fiscal balance needs to be achieved from a later starting point which requires a faster average annual effort. This increased burden on future generations raises the overall sustainability risk—the probability that the needed fiscal consolidation would not be achieved.

In sum, the GCC countries face a potentially difficult policy choice. Notwithstanding its desirability, the PIH requires an adjustment that may not be feasible due to socioeconomic constraints. At the same time, significant fiscal adjustment is unavoidable in the long term and an early start would improve both the intergenerational distribution of wealth and facilitate long-term fiscal sustainability.

What Can Be Done?

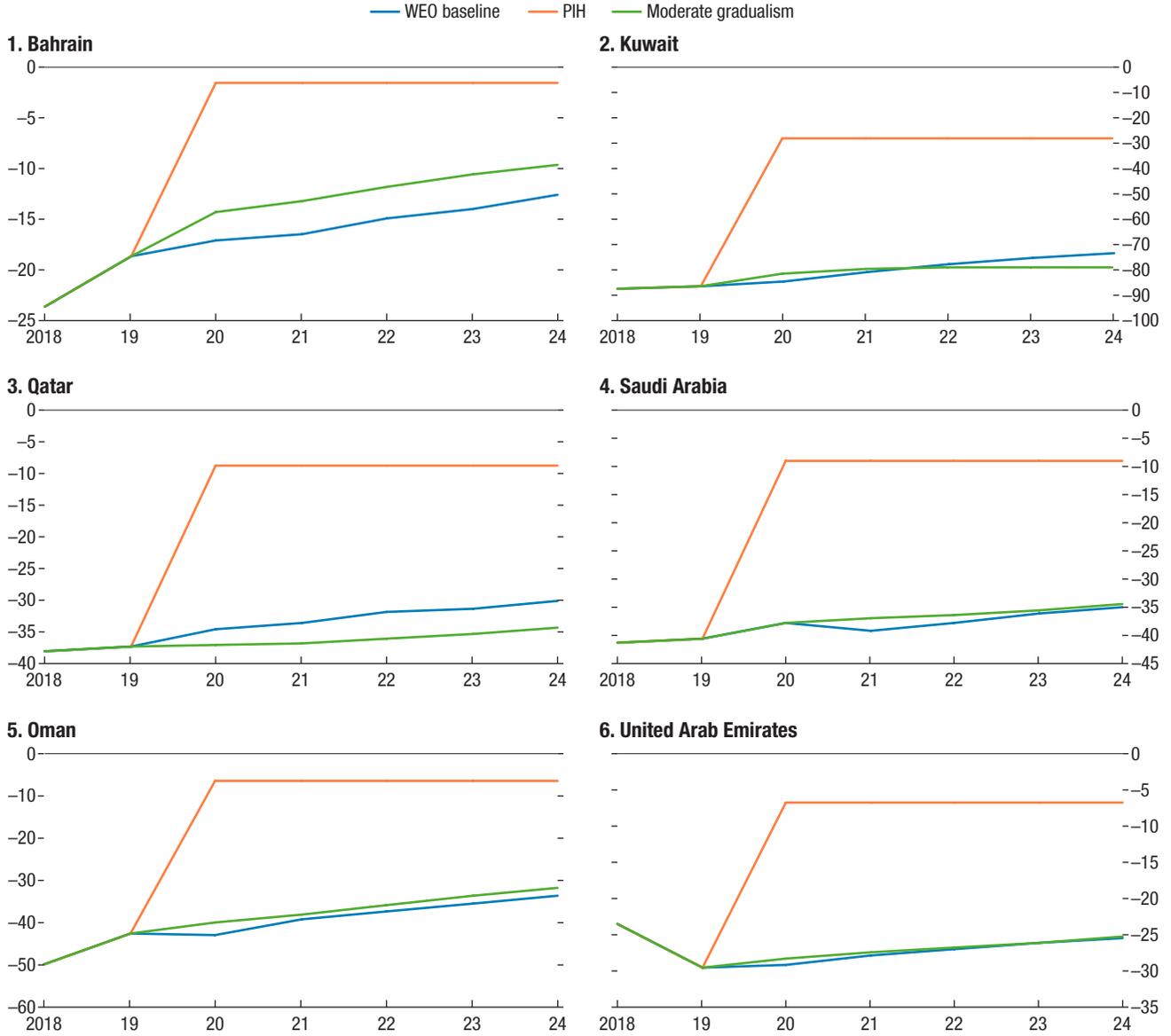
Ongoing reform efforts in the region will provide momentum over the next five years, but they need to be accelerated. Current IMF staff projections envisage continued fiscal consolidation in all GCC countries. These projected fiscal paths appear to be more consistent with fiscal gradualism (Figure 19). Consequently, should the peak in oil demand begin to materialize, net wealth in these countries would decline further in the coming years unless fiscal adjustment accelerates. The urgency of continued reforms is greater in countries with more vulnerable financial positions than those with larger financial savings (Kuwait, Qatar, UAE).

Accelerating and sustaining adjustment in the long term will require broadening the scope of fiscal reforms. The measures to deliver the required fiscal consolidation and how to split them between revenue and expenditure require a tailored country-specific approach.⁷ That said, three general considerations apply to the GCC region:

- *Faster economic diversification will not resolve the fiscal challenge on its own: countries will also need to increase their non-oil fiscal revenue.* The fiscal revenue GCC governments generate from the hydrocarbon industry (about 80 cents from a dollar of hydrocarbon GDP) is much higher than what is

⁷The fiscal strategies discussed in Danforth, Medas, and Salins (2016) could be helpful in identifying feasible measures.

Figure 19. Non-Oil Primary Balance: Current Projections and Illustrative Fiscal Paths
(Percent of non-oil GDP)



Source: IMF staff calculations.

generated from nonhydrocarbon industries (about 10 cents from a dollar vs. 14½ cents globally). Thus, even full replacement of the hydrocarbon industry with non-oil activity would still create a significant revenue short-fall. While this has begun to change with the recent introduction of VAT and excises in some countries, there is significant potential to build on this progress. As the region transitions toward a nonhydrocarbon economy, moving from wide-ranging fees toward fewer broad-based taxes, for example, could provide much-needed revenue diversification while also reducing distortions and facilitating SME development.

- *Governments will likely need to downsize.* Additional non-oil revenue could help alleviate future fiscal pressures, but this alone will not be sufficient. Replacing the declining oil revenue in the long term would require eventually raising the effective tax rate on non-oil GDP to a prohibitively high level of 50 percent in the long term (assuming continued non-oil GDP growth of 3 percent)—on par with the top five most heavily taxed economies in the world. This may not be feasible and could be too disruptive to growth. Thus, wider reforms, spending restraint and optimization toward areas with highest economic impact will be critical. Progress has already been achieved in some areas, such as reduction of energy and water subsidies in several countries. But there remains significant scope for rationalizing other categories of spending, including reforming the region's large civil service and reducing public wage bills which are high by international standards (see IMF 2018d).⁸ Besides strengthening public finances, these reforms would also reduce labor market distortions and facilitate private sector development.
- *Countries should re-evaluate their approach to saving.* In the past, a significant portion of oil proceeds were used for public investment which created nonfinancial wealth and supported rapid economic development. But the impact on nonhydrocarbon growth has been typically short-lived and, as the economies have developed, growth multipliers from these investments have begun to decline (see Fouejieu, Rodriguez, and Shahid 2018).⁹ Therefore, from the optimal portfolio allocation and wealth preservation perspectives, financial saving will be more important going forward. Meanwhile, emphasis could be made on sustained structural reforms to generate lasting non-oil growth momentum.

⁸Significant progress in this area has been elusive in the region. Bahrain's voluntary retirement scheme is the most recent step in this direction, although the outcome is yet to be fully assessed.

⁹Moreover, as discussed above, the additional non-oil growth facilitated by these investments has not been generating a similar growth of non-oil fiscal revenue.

This paper presents a case that oil-exporting countries may need to be ready for a post-oil future sooner rather than later. With continued improvements in energy-saving technologies, adoption of renewable sources of energy, and a stronger policy response to climate change, the world's demand for oil is expected to grow more slowly and eventually begin to decline in the next two decades. If these expectations materialize, they would reshape the economic landscape of many oil-exporting countries, including those in the GCC.

The transition to a post-oil future will involve potentially significant challenges. Faster progress with economic diversification and private sector development will be critical to ensure sustainable growth down the road, and it needs to be supported by wide-ranging reforms.¹ Ongoing reforms are moving the GCC region in the right direction, but they need to accelerate. Even with rapid diversification, sizable fiscal adjustment will be needed in the long term. Achieving this adjustment will require countries to step up their efforts to raise non-oil fiscal revenue, reduce government expenditure, and prioritize financial saving. The economic well-being of future generations would be helped by a strong early start with these reforms, although they will entail greater effort by the current generation.

The biggest challenge will be managing the broader economic transition. The long-term future of oil outlined in this paper would have a multitude of socioeconomic consequences affecting employment, household incomes, and business confidence and investment. More work is needed to fully understand these consequences, design mitigation strategies, and build the social consensus required for their implementation.

Annex 1. Technical Notes

Econometric Analysis

Data. Estimation of oil demand is based on a panel data set of 135 countries from 1971 to 2016. Estimation of global demand for natural gas is based on a shorter sample period (1992–2016) due to abnormal patterns in the data (structural breaks) in earlier years.

Benchmark model. The baseline regression specification takes the following form:

$$\ln(\text{oil}_i^t) = c + \beta_1 \ln(\text{pop}_i^t) + \beta_2 \ln(\text{gdppc}_i^t) + \beta_3 \ln(\text{gdppc}_i^t)^2 + \beta_4 \ln(\text{gdppc}_i^t)^3 + \ln(\text{land}_i) + \text{exp}_i + \mu_t + \epsilon_i^t,$$

where:

oil_i^t	oil consumption of country i in year t (source: International Energy Agency);
pop_i^t	population of country i in year t (source: World Development Indicators);
gdppc_i^t	GDP per capita of country i in year t . Its square and cubic terms capture non-linear effect of income growth on oil demand.
land_i	land area of country i ;
exp_i	dummy variable indicating whether the country is an oil exporter.
μ_t	time fixed effects.

Appendix Table 1. Determinants of Global Oil and Gas Demand: Regression Results

	Oil		Natural Gas
	(1) (time fixed effects)	(2) (linear time trend)	(3)
Population	0.983*** (0.007)	0.975*** (0.007)	0.460*** (0.026)
Land Size	0.047*** (0.006)	0.051*** (0.006)	0.324*** (0.020)
GDP per Capita	29.639*** (1.129)	29.647*** (1.211)	0.795*** (0.033)
(GDP per Capita) ²	1.183*** (0.127)	1.172*** (0.136)	
(GDP per Capita) ³	20.049*** (0.005)	20.042*** (0.005)	
Oil Exporter (Dummy)	0.172*** (0.027)	0.191*** (0.027)	
Oil Price		20.108*** (0.026)	
Year		20.018*** (0.001)	
Observations	5,225	4,815	2,057
R-squared	0.962	0.963	0.714

Sources: IEA; BP; and IMF staff estimates.

Notes: The model was estimated in logs. The dependent variable is oil consumption in models (1) and (2) and natural gas consumption in model (3). Time fixed effects are included in the regressions in (1) and (3); global oil price and a linear time trend are used in (2). The oil price included in model (2) is the 5-year average real oil price (using contemporaneous price did not produce a statistically significant coefficient). Heteroskedasticity robust standard errors are in parentheses (** $p < 0.01$, * $p < 0.05$, $p < 0.1$). The sample periods are 1971–2016 for oil and 1992–2016 for natural gas.

Estimation of global demand for natural gas—using data from *BP Statistical Review of World Energy*—did not reveal non-linear effects from growth of GDP per capita and its square, and cubic terms were not included.

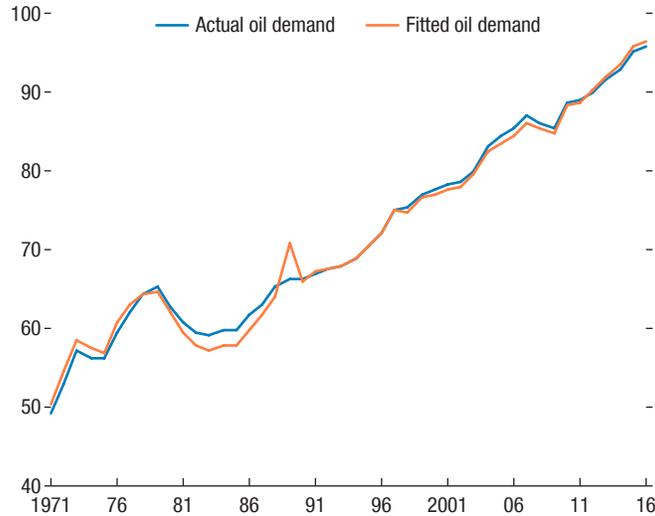
Projections are based on the following assumptions:¹

- Per capita GDP growth follows projections in the *World Economic Outlook* for 2019–24, and gradually converges to 1.8 percent for all countries in the long term (IEA).
- Population growth projection is based on the United Nations World Population Prospects (medium scenario).
- The estimated declining time trend is assumed to continue.

Price elasticity of oil demand appears to be small. To gauge the potential magnitude of price effects in our model, a five-year average price was included in one specification (model 2) and a second-stage regression was

¹Small adjustments were made to account for international bunker fuel, which is not included in the IEA data set.

Annex Figure 1.1 Actual vs. Fitted Value
(Millions of barrels a day)



Sources: US International Energy Agency; and IMF staff calculations.

used to estimate the relationship between year fixed effects and the oil price. The estimated price elasticity in both cases about 0.1, which is consistent with those found in other studies.²

Diagnostics were performed to ensure the validity of regression results. A specification using (log) levels was preferred to first differencing in order to retain low-frequency information that is essential to estimating long-term relationships. At the same time, concerns about non-stationarity and spurious correlations were addressed in several ways. First, time fixed effects were included in the baseline regressions to control for time trends. Second, coefficients obtained from regressions based only on cross-sectional variation were similar to those from the baseline model, suggesting that the time dimension of the data did not bias the estimates. Finally, several commonly used unit-root tests for panel data confirmed stationarity of model residuals.

Alternative Oil Market Scenarios

Modeling. The alternative scenarios were examined using a stylized equilibrium model of the oil industry, constructed by the IMF's Research Depart-

²Estimates of price elasticity of demand in the short term typically range from 0 to 0.25 in other studies. In theory, price elasticity could be larger and non-linear in the long term; however, good estimates of long-term price elasticity are scarce reflecting difficulties with identifying supply-side shocks.

ment, which allows to examine the impact of policy and technological changes as deviations from a baseline equilibrium prices and quantities.

The model features investment decisions by forward-looking producers and an oil demand with non-constant price elasticity. The model abstracts from inventory changes. Oil supply is specified as a function of installed capital in the oil sector which, in turn, is a function of past investment. Investment reacts to past and expected future producer prices of oil. The oil sector is further divided into conventional and non-conventional oil subsectors where the latter reacts faster to investment. A carbon tax introduces a wedge between producer and consumer prices of oil.

The model's baseline is calibrated to a benchmark scenario that is derived by fitting an empirically estimated model of oil demand (see above) driven by fundamental factors such as population, per capita income and efficiency gains in end-use of oil, coupled with control variables. Specifically, the benchmark scenario assumes (1) exogenous projections of income and population of 135 countries based on IMF and United Nations projections and (2) a 2.6 percent annual efficiency gains, which is linearly extrapolated from the empirical model implying the speed of energy transition and efficiency gain stay the same as seen in past 45 years; and (3) a long-term real oil price of \$55 a barrel.

Alternative Scenarios

Energy efficiency scenario: the declining time trend accelerates by an additional 0.6 percentage points (or two standard deviations above the average annual rate of change) faster than under the benchmark. This brings the real oil price gradually down to \$36 per barrel.

Carbon tax scenario: this scenario follows IEA (2013, sustainable scenario) in assuming a carbon tax will be introduced in 2024 and gradually increased to a level (100 percent) that would bring the cost of CO₂ emissions to \$150 per ton. This level of carbon tax is consistent with curbing the long-term increase in global temperature at 2 degrees Celsius in the long term. In this scenario, producers and consumers are assumed to share the tax burden: the producer price of oil in real terms gradually declines to \$37 a barrel whereas the consumer price rises above \$55.

Illustrative Fiscal Paths

Framework and Assumptions

The analysis of the impact of oil revenue scenarios on countries' fiscal sustainability focuses on net financial wealth, in percent of nonhydrocarbon GDP. It evolves as follows:

$$a_t = \frac{1+r^*}{(1+r_t^{NO})} a_{t-1} + \tau^O y_t^O + nopb_t, \quad (1)$$

where a_t is net financial wealth in percent of nonhydrocarbon GDP, r^* is the real return on financial assets, r_t^{NO} is the real growth rate of nonhydrocarbon GDP, $\tau^O y_t^O$ is the hydrocarbon revenue in percent of nonhydrocarbon GDP, $nopb_t$ is the nonhydrocarbon primary balance in percentage of nonhydrocarbon GDP.

Total wealth (w_t) consists of net financial wealth, hydrocarbon wealth (q_t), and capital infrastructure (k_t):

$$w_t = a_t + k_t + q_t,$$

where k_t is capital infrastructure in percent of nonhydrocarbon GDP, q_t is estimated value of underground hydrocarbon wealth in percent of nonhydrocarbon GDP, calculated as the net present value of the hydrocarbon revenue stream.

For simplicity, the stock of public capital infrastructure is assumed to grow at the same rate as nonhydrocarbon GDP. Hydrocarbon revenue projection is based on the projected global hydrocarbon demand and each country's expected market share (estimated using data on breakeven prices from Rystad Energy). Real rate of return on financial assets is assumed to be fixed at 4 percent per year.³ Real nonhydrocarbon growth is assumed to be 3 percent in all countries, under a neutral fiscal stance—when the primary nonhydrocarbon fiscal balance is unchanged. Changes in $p b_t$ are assumed to affect nonhydrocarbon growth, both contemporaneously and in the medium term. Specifically, fiscal consolidation (expansion) is assumed to reduce (increase) contemporaneous nonhydrocarbon growth with a short-term elasticity of γ and the long-term multiplier of $\frac{1}{1-\gamma}$, with γ set to 0.2 in line with estimates

³Data on actual profitability of GCC's sovereign wealth funds are limited. This assumption is consistent, for example, with the 6–7 percent nominal return during a 30-year period reported by the Abu Dhabi Investment Authority.

in Fouejieu, Rodriguez, and Shahid (2018). For example, a fiscal consolidation of 10 percentage points of nonhydrocarbon GDP at time t reduces real nonhydrocarbon growth by 2 percentage points at time t , a further $\frac{1}{2}$ percentage point decline at time $t+1$, and so forth with the impact waning over time. Real nonhydrocarbon GDP growth can be expressed recursively as follows:

$$r_t^{NO} = (1 - \gamma) r^{NO} + \gamma(r_{t-1}^{NO} - \Delta nob_t). \quad (2)$$

Illustrative Scenarios

The benchmark projection assumes that countries maintain a constant primary nonhydrocarbon balance in percent of nonhydrocarbon GDP, set at its initial level⁴: $nob_{t+i}^b = nob_{t-1}^b, \forall i \in [0, T]$. In addition, three policy adjustment scenarios are examined:

- *Permanent Income Hypothesis*. This policy targets maintaining total wealth constant (in percent of non-hydrocarbon GDP) at its initial level:

$$w_t = w_0, \forall t > 0.$$

The fiscal path associated with this policy is:

$$nob_t^{PIH} = \frac{r^* - r^{NO}}{1 + r^{NO}}(a_0 + q_0), \quad \forall t > 0 \quad (3)$$

- *Moderate gradualism*. This policy based on a fiscal path that allows a gradual decline of wealth to w_L below its initial level (w_0). The wealth path is assumed to follow a Gompertz curve modified as follows:

$$w_t = w_0 - (w_0 - w_L) \left(\frac{e^{-v_1} e^{-v_2 t}}{e^{-v_1}} - 1 \right) \frac{e^{-v_1}}{1 - e^{-v_1}}, \quad \forall t > 0 \quad (4)$$

Under this policy, wealth starts out at the initial level w_0 and converges to the targeted (lower) level over time $\lim_{t \rightarrow \infty} w_t = w_L$. In other words, its long-term sustainability is imposed. Parameters v_1 and v_2 control curvature of the wealth path and the speed of its convergence.

⁴Year 2019 is set to be the initial year.

- *Extreme gradualism.* In these scenarios, the fiscal path is captured by a Gompertz curve of the following form:

$$nopb_t = nopb_0 - (nopb_0 - nopb_H) \left(\frac{e^{-v_1} e^{-v_2 t}}{e^{-v_1}} - 1 \right) \frac{e^{-v_1}}{1 - e^{-v_1}}, \quad \forall t > 0 \quad (5)$$

Under this policy, nonhydrocarbon primary balance starts out at the initial level $nopb_0$ and converges to a higher level over time $\lim_{t \rightarrow \infty} nopb_t = nopb_H$, where $nopb_H > nopb_0$. Parameters v_1 and v_2 control the curvature of the adjustment path and the speed of convergence they were chosen to mimic near-depletion of wealth for illustrative purposes.⁵

⁵Note that, in this case, convergence of wealth is not always guaranteed.

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