

Article

Research and Development as a Moderating Variable for Sustainable Economic Performance: The Asian, European, and Kuwaiti Models

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Abstract: The research and development (R&D) expenditure in Kuwait is insufficient to lead to innovation and a knowledge economy. Investment in R&D has been shown to sustain elevated economic performance. The objective of this study is to explore the association between three competing dimensions of R&D indicators that lead to sustainable economic performance within any given country, namely, R&D expenditure, the number of researchers, and the number of patent rights, using time-series data collected over a 20-year period (1996–2016) by the World Bank Group. R&D indicators were compared between high- and middle-income countries including models from Asian (South Korea, Singapore, and Malaysia) and European (Finland and Ireland) countries as well as the State of Kuwait. Moreover, a case study describing R&D investments in Kuwait is presented. Overall, the results reveal higher R&D spending, number of researchers, and gross domestic product (GDP) per capita for the Asian and European models. Current R&D expenditure in Kuwait is estimated at 0.08% of GDP (2016), which is significantly lower than the mean of the middle-income countries (1.58%). Furthermore, the number of researchers (per million) in Kuwait (386) is less than half of the mean number of researchers in middle-income countries (775) (2015). Low R&D investments in the State of Kuwait has gradually led to a decreased GDP per capita. Regression analysis shows that GDP per capita can be predicted solely based on the number of researchers ($\beta = 0.780$, $R^2 = 0.608$). The number of researchers is the most crucial variable to predict GDP per capita, and the R&D expenditure is a good indicator of the number of researchers. These findings offer invaluable insight into the sustainable development goals (SDG 9). To our knowledge, this paper presents the first application of the effect of R&D on sustainable economic performance with reference to the SDG target 9.5 “Research & Development”. Thus, in order to enhance scientific research (both academic, professional, and industrial), countries need to increase the number of researchers, and these actions are necessary to introduce sustainable growth to GDP.

Keywords: research and development; economic growth; sustainable economic performance; researchers; knowledge economy; Kuwait

1. Introduction

Research and development (R&D) contribute to economic growth and economic diversity [1] in part by directly and indirectly impacting science, technology, and innovation [2]. During the last two

decades both high- and middle-income countries have increased R&D expenditures in an effort to promote economic diversification and growth [3]. While developing countries have increased financing for economic infrastructure, investments in scientific research and innovation are still lagging behind [4].

The 2030 Agenda for Sustainable Development calls for enhancing scientific research and substantially increasing the number of R&D workers per 1 million people [5]. Specifically, sustainable development goal 9 (SDG 9) promotes R&D expenditure as a proportion of the gross domestic product (GDP) and the number of researchers per million inhabitants [5–7]. Sustainability is defined as a path or system trajectory moving in various dimensions including economy, ecology, society, energy, and time [8]. Sustainability can be viewed in the context of macro-, meso-, and micro-scales [9]. To achieve sustainability in a broader sense, organizations are required to assess their productivity and align their strategies to three dimensions: economic, environmental, and social performances [10]. Optimizing these three dimensions leads to enhanced financial performance and economic growth [11–14]. These three dimensions must be harmonized in a comprehensive way to achieve a holistic sustainable development. The harmony of the economy and environment is a crucial factor in achieving sustainability [15].

In this study, the focus is to interpret how the investments in R&D can improve the economic sustainability at the micro- and meso- (national) scales. One way to support sustainable economic growth is through government supported R&D investment. Specifically, R&D expenditure, the number of researchers, and GDP per capita are three moderating variables that influence sustainable economic performance.

Innovation is one of the key success factors in a knowledge economy, and it is R&D that determines innovation [16]. R&D plays a significant role in the outcome and impact of business innovation, and R&D investment within a given country is one of the most powerful markers for ascertaining the level of innovation within that country [17]. Romer highlighted that investing in R&D increases the likelihood of developing high-level technologies, resulting in higher national income and greater economic growth [18]. In fact, R&D investments are closely linked to economic and social development [19,20]. Total R&D investments have positive and significant effect on the economic growth of the organization for economic co-operation and development (OECD) [21]. Investment in R&D is an important strategic factor for sustainable economic growth and it is a core element of a nation's and corporation's social responsibilities [22,23]. SDG target 9.5, which is related to “research and development”, was shown to be the sixth most influential target out of 34 SDG targets in Sweden [24]. For instance, it reinforces resilience against economic and social change (SDG target 1.5), achieves and sustains economic growth (SDG target 10.1), and enhances macroeconomic stability (SDG target 17.13). The connections between the targets need to be better understood [25]. R&D can lead to novel ideas and technologies to sustain business practices [26]. The improvement of the economy is closely linked to environmental sustainability [15,27,28]. The improvement and stabilization of the economic situation of countries are linked to the restrictions that are imposed by the natural environment [27].

The proportion of global GDP invested in R&D increased from 1.52 to 1.68% from 2000 to 2016, while the mean R&D expenditure of high-income countries was estimated at 2.49% of GDP in 2016 [3]. While middle-income countries have, on average, significantly increased their R&D expenditure from 0.65% in 2000 to 1.58% in 2016, the State of Kuwait decreased its R&D from 0.21% in 1997 to 0.08% in 2016 [3]. In fact, the level of R&D expenditure in the Gulf Cooperation Council (GCC) countries (the State of Kuwait, the Kingdom of Bahrain, the United Arab Emirates (UAE), the Kingdom of Saudi Arabia, the Sultanate of Oman, and Qatar) is lower than 1.0% of the average GDP for these countries [3]. Among GCC country expenditure values, the State of Kuwait has the lowest, while the UAE has the highest, amounting to more than ten times the R&D expenditure in the State of Kuwait. In terms of the number of researchers, although the State of Kuwait has doubled the number of researchers from 158 per million people in 2000 to 386 per million people in 2015, that value is still far behind the corresponding average value for both high- and middle-income countries [29]. High-income countries have increased the number of researchers from 3079 per million people in 2000 to 4157 per million people in 2015, and middle-income countries increased the number of researchers to 775 per million

people [29]. During the last several decades, the global economy has steadily increased. Since 1996, not only high-income countries but middle-income countries as well have made significant progress in the context of economic growth [30], with middle-income countries increasing their GDP per capita by 131%, reaching USD 5187 in 2018 and high-income countries increased their GDP per capita by 36%. Meanwhile, the State of Kuwait decreased its GDP per capita by 19% during the same period [30]. The reduction in the Kuwaiti GDP per capita has been most significant (32.3%; constant 2010 USD) since 2007 decreasing from USD 49,577 in 2007 to USD 33,538 in 2018. During the same period (2007–2018), high-income countries increased their GDP per capita by 9% from USD 39,920 to USD 43,512 [30].

In contexts within which private R&D expenditure is higher than public sector R&D expenditure, productivity growth is observed [31]. Therefore, government investments in R&D play a vital role in fostering national competitiveness in fast-changing and turbulent markets [31]. Although the R&D expenditure by the government sector is complementary to R&D expenditure by the private sector, in the case of the State of Kuwait, the economy heavily relies on the oil sector, which accounts for 60% of the national income [32]. The private sector, which is composed of small and medium enterprises (SMEs), is too weak and small to increase R&D investment. Thus, diversification of the local economic portfolio and development toward the knowledge-based economy are acknowledged necessary components of the national strategy, but investments in R&D are rare. Therefore, investment in R&D by the government sector in the State of Kuwait is essential to encourage diversification of the economy and drive the transition towards a knowledge-based economy in the State of Kuwait.

The effect of R&D expenditure on GDP growth has been the subject of many studies [33]. A strong correlation exists between R&D expenditure and the global competitiveness index (GCI) [34]. Increased R&D expenditures have a positive and significant impact on economic growth [17], affecting technological developments, employment capacity, and export and import activities [33]. However, the paths, including the number of researchers, to contribute to GDP growth due to the R&D expenditure are less clear.

This study explores the relationship between three economic sustainability indicators that foster innovation and economic growth: R&D expenditure, the number of researchers, and the number of patent rights. Two prediction models using multiple regression estimation were assessed: the first model used the GDP per capita as the dependent variable, and the number of researchers, the R&D expenditure, and the number of patents as the predictors. The second model used the number of researchers as the dependent variable, and GDP per capita, the R&D expenditure, and the number of patents as the predictors. Our hypothesis is that higher R&D expenditure, and consequently a higher number of researchers in a given country, will lead to higher growth of GDP per capita within that country. Comparisons are made between high- and middle-income countries, and between Asian and European countries and Kuwait.

2. Materials and Methods

We selected 101 countries that regularly provide time-series data of GDP per capita, R&D expenditure, the number of researchers, and the number of patents from the World Bank Group database (<https://data.worldbank.org>) [35]. The World Bank Group divides country economies into four income groupings: low, lower-middle, upper-middle, and high, based on a measure of national income per person, or Gross National Income (GNI) per capita [36]. The low-, middle-, and high-income group thresholds were established in 1989 based largely on operational thresholds that had previously been established [37]. The 101 countries were composed of 47 high-income countries, 26 upper-middle-income countries, 22 lower-middle-income countries, and 6 low-income countries. The data were obtained through statistical surveys which are regularly conducted on the national level covering R&D performing entities in the private and public sectors. Kuwait's R&D data were collected from two sources: annual reports published by the Kuwait Foundation for the Advancement of Sciences (KFAS) [38], and scientific reports published by the Kuwait Institute for Scientific Research (KISR) [39,40]. KFAS is a private non-profit organization that was established in 1976 [38]. KFAS's charter represents the commitment

by local shareholding companies to contribute 5% of their annual net profits to fund the foundation, which over the years has been reduced to 1% [38]. KISR is a governmental research institution and it is the main national institute of scientific excellence in Kuwait [39]. The main objectives of KISR are to carry out applied scientific research and develop technology in Kuwait. KISR is home to over 580 researchers and engineers and over 100 laboratories, housed at 9 locations, with growth expected through the implementation of a new strategic plan [39].

The gross domestic expenditure on R&D indicator consists of total expenditure (current and capital) on R&D by all resident companies, research institutes, universities, and government laboratories [3]. R&D covers basic research, industrial research, and experimental development.

Researchers are professionals engaged in the conception or creation of new knowledge, products, processes, methods, and systems, as well as in the management of these projects [29]. Students studying at the master's or doctoral level engaged in R&D are included in this category. According to the definition provided by the World Bank Group, data concerning researchers are obtained through statistical surveys that are conducted on the national level and that cover R&D-performing entities in the private and public sectors.

GDP per capita is the gross domestic product divided by midyear population [30]. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. Data are in constant 2010 U.S. dollars.

$$\text{GDP per capita} = \frac{\text{Gross domestic product}}{\text{population}} = \frac{(\text{Gross value added} + \text{Taxes on products} - \text{Subsidies on products})}{\text{population}}$$

Patent applications are those for which the first-named applicant or assignee is a resident of the state or region concerned. Data on patents granted only distinguish between patents awarded to residents and to non-residents.

Time-series data collated over a 30-year period (1996–2016) were collected and investigated. To perform statistical verification from visually presented raw data, we conducted correlation, multiple regression, prediction models, and trend analyses. To model the relationship between the three R&D variables investigated, we are assuming that a linear model is appropriate, although it is likely that a more complex model (curvilinear) may be possible. To determine the multiple linear relationships, we tested two prediction models in which two dependent variables were predicted: one is GDP per capita, and the other is the number of researchers: 1. GDP per capita was predicted from the number of researchers, the R&D expenditure, and the number of patents; 2. the number of researchers was predicted from GDP per capita, the R&D expenditure, and the number of patents. For empirical validations, we reviewed and analyzed the time-series data from five countries: South Korea, Singapore, Malaysia, Finland, and Ireland. The Supreme Council for Planning and Development of Kuwait recommended three countries from Asia and two countries from Europe. Al-Mahmood stressed that the economic growth and economic diversity of Finland and Singapore are directly related to R&D investments, while those of South Korea, Ireland, and Malaysia are related to high public expenditure, which is indirectly related to R&D investment [41]. We defined the models as operational definitions for just this study: we define Singapore, Malaysia, and South Korea as the Asian Model, while Finland and Ireland are referred to as the European Model for ease of reference throughout the discussion. The World Bank Group classifies countries into seven groups: East Asia and Pacific, Europe and Central Asia, Latin America and the Caribbean, Middle East and North Africa, North America, South Asia, and Sub-Saharan Africa [42]. Within this classification scheme, the State of Kuwait is classified in the Middle East and North Africa region. It is not included within the Asia Model described in this study. A case study is presented which describes how the investments in R&D are distributed in the State of Kuwait.

Data analysis was performed using IBM Statistical Package and Services Solutions (SPSS) software version 25 (IBM Corp, Armonk, New York, NY, USA). A p value < 0.05 was considered statistically significant.

3. Results

3.1. R&D Sustainability Indicators in High- and Low-Income Countries (1996–2016)

Empirical data collected over a twenty-year period (1996–2015) showed that the mean percentage of R&D expenditure in high-income countries has slightly increased from 2.16% (1997) to 2.47% (2015). The number of researchers also showed a steady increase from 2.84 to 4.19 researchers (per 1000 people) in the same period. The growth of GDP per capita increased by 30% from USD 32,000 (1996) to USD 41,600 (2015) (Figure 1).

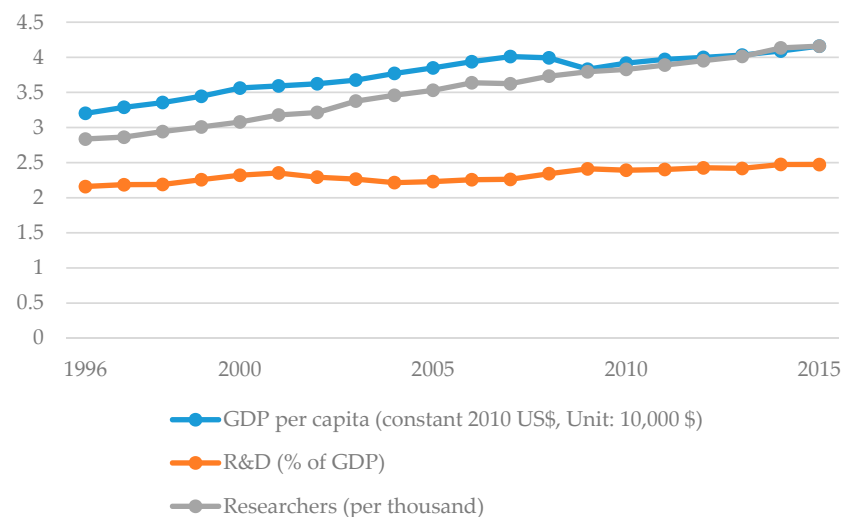


Figure 1. Gross domestic product (GDP), research and development (R&D) expenditure, and number of researchers in high-income countries (1996–2015).

A strong relationship exists between R&D expenditure, the number of researchers, and GDP growth in middle-income countries (Figure 2). Results show that R&D expenditure more than doubled (from 0.64% to 1.39%) in the period between 2000 and 2015. The number of researchers increased from 0.49 to 0.77 researchers per thousand people, and the growth of GDP per capita almost doubled from USD 2484 to USD 4694 during the same period.

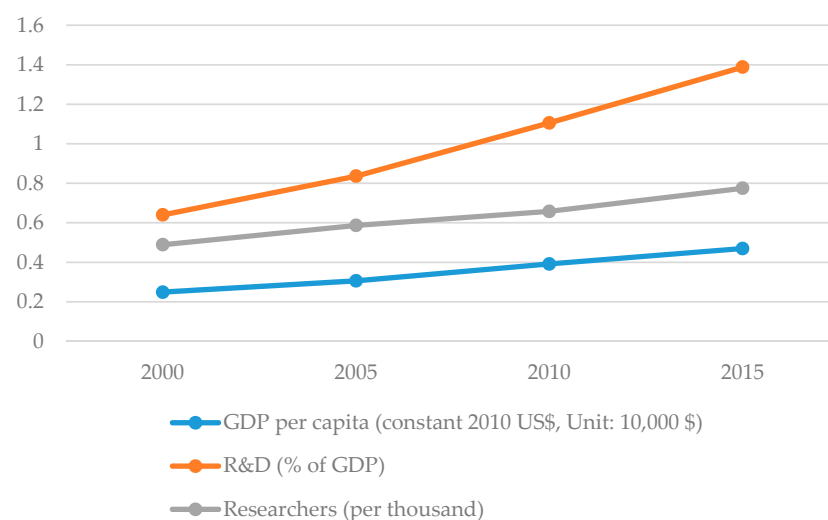


Figure 2. Gross domestic product (GDP), research and development (R&D) expenditure, and number of researchers in middle-income countries (2000–2015).

3.2. R&D Sustainability Indicators in the 101 Countries Analyzed (2016)

The mean GDP per capita of a total of 101 countries was estimated at USD 20,420 (constant 2010 USD) in 2016, while the mean R&D expenditure was estimated at 1.12% (Table 1). The mean number of researchers per million people was 2153, and the mean number of patents per million people was 184. The results, which include data derived from across all income level (high-, upper middle-, lower middle-, and low-income) countries, showed wide variations in the sustainability indicators of the 101 countries (i.e., large standard deviation (SD)).

Table 1. Sustainability indicators of R&D (101 countries) (2016).

Characteristics (<i>n</i> = 101)	Mean (SD)
GDP (per capita) *	20,420.45 (21,337.40)
R&D expenditure (% of GDP)	1.12 (0.97)
Researchers (per million people)	2152.55 (1988.42)
Patents (per million people)	184.42 (420.10)

* constant 2010 USD; SD: standard deviation.

3.3. Multiple Correlations and Prediction of R&D Sustainability Indicators (2016)

Strong positive correlations exist between the GDP per capita, the R&D expenditure, the number of researchers, and the number of patents (Table 2). Furthermore, R&D expenditure is strongly correlated with GDP, the number of researchers, and the number of patents (0.601, 0.851, 0.677, respectively). The number of researchers was shown to strongly correlate with the R&D expenditure (0.851), the GDP per capita (0.775), and the number of patents (0.455). However, R&D expenditure and the number of researchers show the strongest correlation. Correlation only tests whether there is a relationship between these variables, not whether changes in one of the variables actually cause changes in the other.

Table 2. Correlations between R&D sustainability indicators (2016).

	GDP ¹	R&D ²	Researchers ³	Patents ³
GDP ¹	-			
R&D ²	0.601 *	-		
Researchers ³	0.775 *	0.851 *	-	
Patents ³	0.242 **	0.677 *	0.455 *	-

*, $p < 0.001$, **, $p < 0.01$, ¹ per capita, ² % of GDP, ³ per million people.

To determine which variable contributes the most to successful prediction of R&D performance, two prediction models using multiple regression estimation were assessed to test our hypothesis: the first model was designed to predict the GDP per capita from the number of researchers, R&D expenditure, and the number of patents; the second model was designed to predict the number of researchers from the GDP per capita, the R&D expenditure, and the number of patents. The results revealed that the 60.8% of GDP growth per capita was predicted by the number of researchers (beta = 0.780). Adding the R&D expenditure and number of patents to the model did not significantly increase the GDP prediction (beta = 0.914, $R^2 = 60.6\%$). Therefore, results from this analysis demonstrate that the number of researchers is the only variable that can independently successfully predict the growth of GDP per capita (Table 3).

The R&D expenditure and GDP per capita were shown to be significant predictors for the number of researchers with a higher relative predictor value for R&D than GDP (beta = 0.692 versus 0.385) (Table 4). These two variables (R&D expenditure and GDP per capita) in model 2 account for 83% of the variance in the number of researchers ($F = 168.617$, $p < 0.001$). We can also conclude that the R&D expenditure alone can successfully predict the number of researchers fairly well, as presented in model 1 (beta = 0.851, $R^2 = 72.5\%$).

Table 3. Prediction model for GDP per capita (2016).

Variables	GDP ¹			
	Model 1		Model 2	
	B	Beta	B	Beta
Constant	2303.889		2935.394	
Researchers ²	8.360 *	0.780	9.81 *	0.914
R&D ³			−2426.051	−0.111
Patents ²			−5.021	−0.099
R ²	0.608		0.606	
F	158.253 *		52.329 *	

* $p < 0.001$, ¹ per capita, ² per million people, ³ % of GDP.**Table 4.** Prediction model for the number of researchers (2016).

Variables	Researchers ¹			
	Model 1		Model 2	
	B	Beta	B	Beta
Constant	213.539		−63.648	
R&D ²	1738.387 *	0.851	1413.146 *	0.692
GDP ³			0.036 *	0.385
Patents ¹			−0.504	−0.107
R ²	0.725		0.839	
F	260.516 *		168.617 *	

*: $p < 0.001$, ¹ per million people, ² % of GDP, ³ per capita.

3.4. R&D Sustainability Models from Select Asian Countries (South Korea, Singapore, and Malaysia) (1996–2016)

South Korea and Singapore showed typical patterns in the growth of R&D expenditure, the number of researchers, and the GDP per capita (Figure 3). The South Korean model showed higher sensitivity, with similar trends between the three R&D sustainability indicators. The South Korean model also supports the assumption that the expansion of R&D expenditure leads to hiring more researchers and higher growth of the GDP per capita (Figure 3a). During the last two decades (1996–2016), South Korea almost doubled its R&D expenditure from 2.26% to 4.23%. During the same period, the number of researchers almost tripled from 2170 to 7110 per million people, and the GDP per capita more than doubled from USD 12,848 to USD 25,484 (constant 2010 USD).

Since 1996, Singapore showed a steady increase in R&D expenditure from 1.32% (1996) to 2.16% (2014), with a peak in 2008 at 2.62% (Figure 3b). The number of researchers steadily increased from 2004 to 2014 (4.89 to 6.73 per million people). Sensitivity analysis showed a similar trend for GDP per capita with an increase from USD 30,414 in 1996 to USD 53,884 in 2015 (constant 2010 USD). The Singaporean model clearly shows that GDP growth is strongly associated with the number of researchers.

Malaysia transitioned its focus toward a knowledge-based economy after the concept of knowledge economy was introduced in the country's Vision 2020 agenda [16]. Since 2007, Malaysia had increased its R&D expenditure dramatically, more than doubling it from 0.61% to 1.30% over a 10-year span (2006–2015) (Figure 3c). During the same period the number of researchers increased more than six times from 370 to 2270 researchers per million people. As a result, the GDP per capita in Malaysia increased by 36% during the same period going from USD 8255 (2006) to USD 11,220 (2016). The Malaysian model shows that R&D expenditure is closely linked to the number of researchers, which consequently results in GDP growth. The speed of growth of the Malaysian GDP per capita was impressive especially during the global recession.

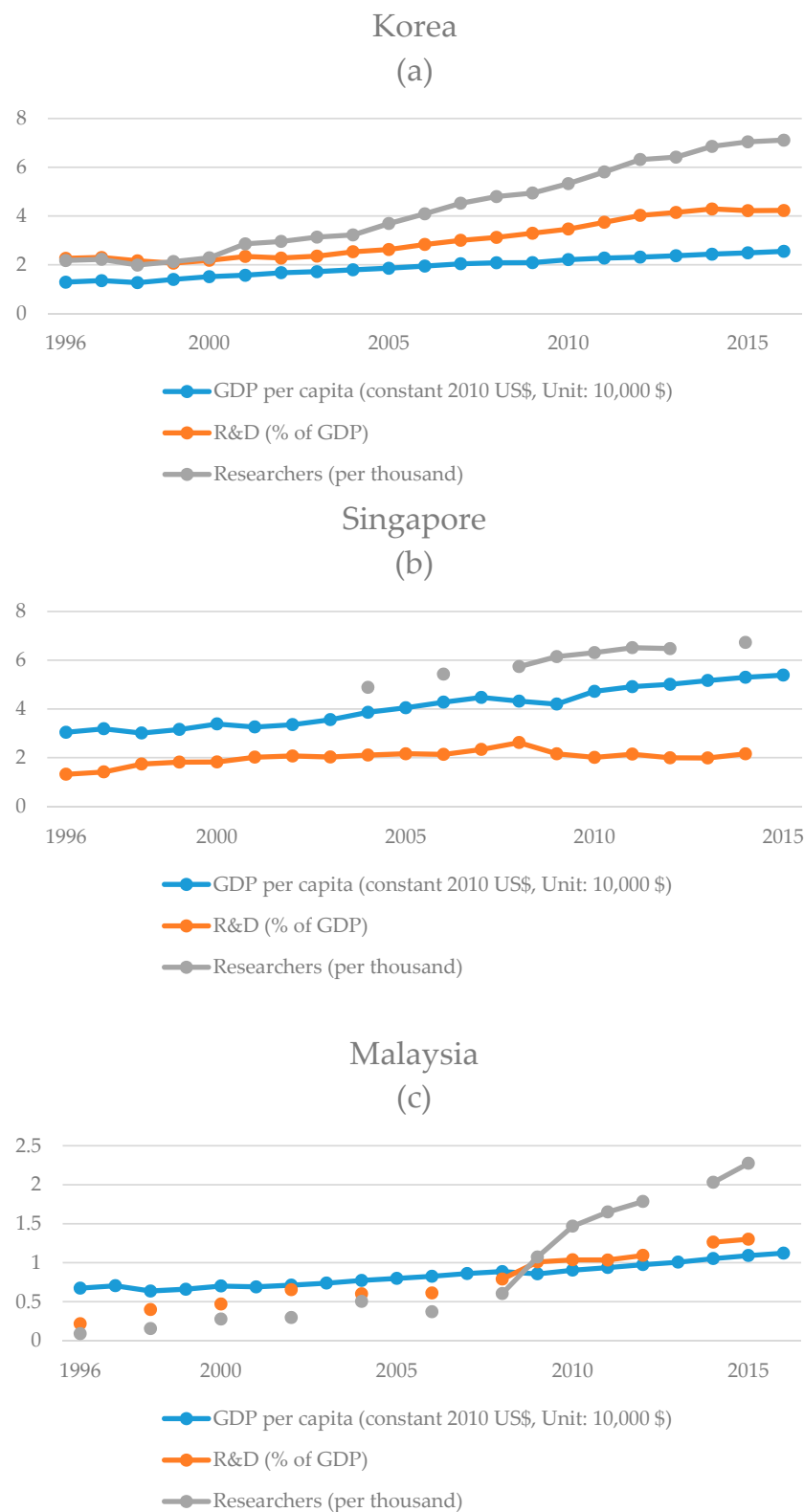


Figure 3. Research and development (R&D) sustainability models of Asian countries: South Korea (a), Singapore (b), and Malaysia (c) (1996–2016). Source: World Bank Group (2019).

3.5. R&D Sustainability Models from Select European Countries (Finland and Ireland) (1996–2016)

The Finnish model reflects the country's current experience of economic growth. Before the 2007 global recession, both R&D expenditure and GDP per capita were growing steadily in Finland (Figure 4a).

After the recession, as the R&D expenditure decreased, the GDP per capita gradually decreased as well going from USD 49,364 in 2008 to USD 46,438 in 2016. The decrease in R&D expenditure in 2009 resulted in a reduction in the number of researchers. The R&D per capita decreased by 1% of GDP from 3.75% in 2009 to 2.75% in 2015. Consequently, the number of researchers dropped by 12% from 7650 to 6800 researchers per million. One possible explanation of the reduction in the number of researchers and R&D in Finland is that the impact of Nokia's loss. Nokia influenced Finland's innovation system and R&D efforts. Nokia's expenditure on research and development had reduced from EUR 5.97 in 2009 to EUR 4.78 in 2012, which is the year before Nokia sold its business to Microsoft in 2013 [43]. The Finnish model displays a close relationship between R&D expenditure per capita and the number of researchers in the country.

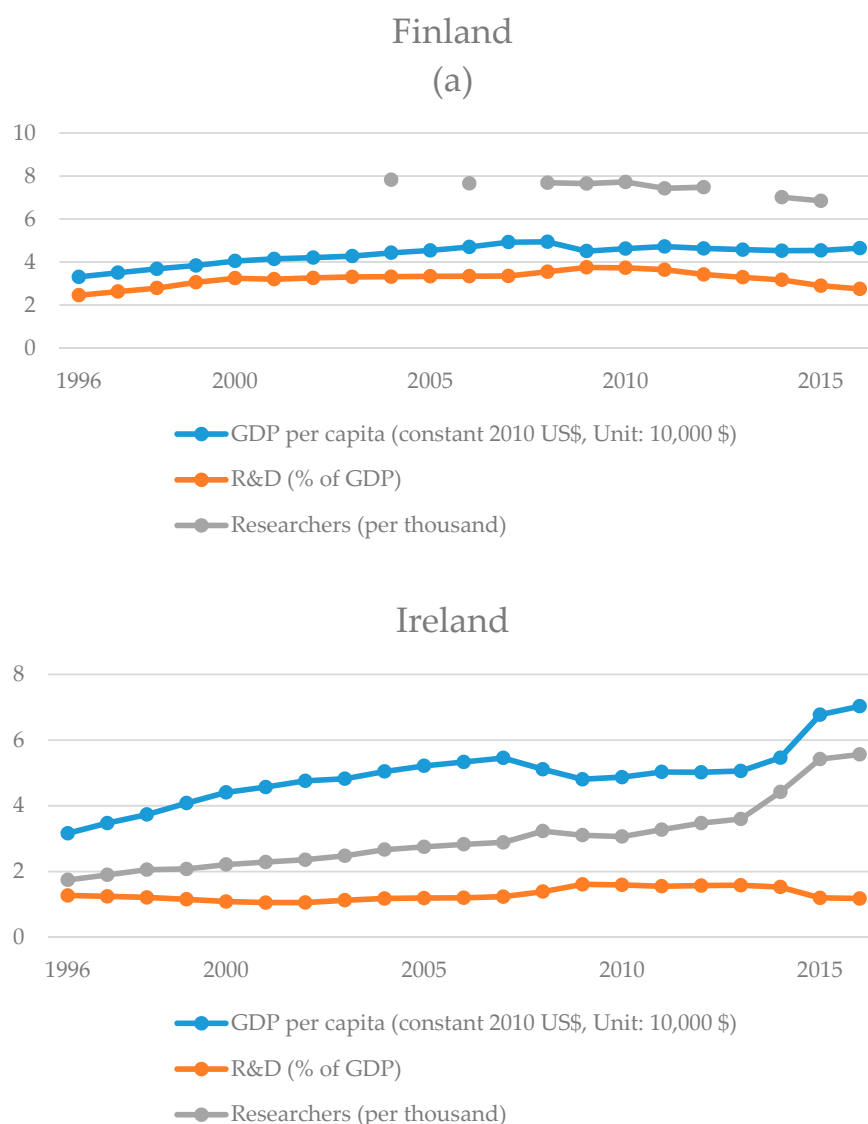


Figure 4. Research and development (R&D) sustainability models of European countries: Finland (a) and Ireland (b) (1996–2016). Source: World Bank Group (2019).

The Irish R&D sustainability model appears to be different from both the Finnish and the Asian R&D models. R&D expenditure, the number of researchers, and the GDP per capita in Ireland increased steadily from 1996 until the global recession hit in 2008 (Figure 4b). After 2008, the GDP per capita and the number of researchers increased gradually until 2013, while the R&D expenditure did not change significantly during that same period. During the following four years (2013 to 2016), however,

the number of researchers increased by about 55% (3.59 to 5.56), and the GDP per capita increased by 39% (USD 50,583 to USD 70,299). The Irish model displays a close relationship between the number of researchers and the GDP per capita.

3.6. R&D in Kuwait—Case Study (2006–2018)

Out of the six GCC countries, the State of Kuwait's investment in R&D is the lowest at 0.08% (2016) (Figure 5). In 2007, the GDP per capita of Kuwait was USD 49,577 (constant 2010 USD), but in 2018, the level dropped to USD 33,538. Furthermore, the total number of researchers in the State of Kuwait is very low, at only 386 in 2015. This number of researchers is significantly lower than the corresponding number in high- and middle-income countries (4157 and 775, respectively). Although, there has been a continuous increase in the number of R&D projects that were financed by KFAS since 2006, the allocated budgets dropped sharply since 2015 (Table 5 and Figure 6). The average number of R&D projects that were financed by KFAS in the period between 2006 and 2018 was 49; that number grew in 2018 to 84, an increase of 27% compared to the previous year, and 170% compared to 2006. The average KFAS R&D budget during the period of 2006–2018 was USD 8,423,678; the budget increased in 2018 to USD 8,453,112, an increase of 21% compared to the previous year, and 180% compared to 2006. The number of researchers significantly increased during the period from 2006 to 2018 with a positive trend of 4.0 ($p = 0.01$). Although there has been a positive trend in R&D financing during that same period (2006–2018), the positive trend was not significant (trend = 709,723, $p = 0.102$). The minimum R&D finance budget was recorded in 2006 and peaked during 2014 and 2015. The R&D budget then sharply declined from 2016 to 2018. Table 6 shows the major R&D divisions within KISR. The total number of researchers in 2008 was 168, with a total of 175 R&D projects and a total budget of USD 18,227,862. In 2013, KISR combined the two biggest divisions, the “Environment & Urban Development” and “Food Resources” divisions into a single division, named the “Environment & Urban Development”. This division has 10 departments with a total number of 117 researchers and acquisition funds about USD 2M. In 2019, the total R&D funds generated were less than USD 3 M (Table 7). During the five year period between 2016 and 2020, the government investment in R&D was roughly USD 8.5 M, which is equivalent to only USD 1.7 M per year. This amounts to only 35% of the total requested funds of USD 24 M (Table 8).

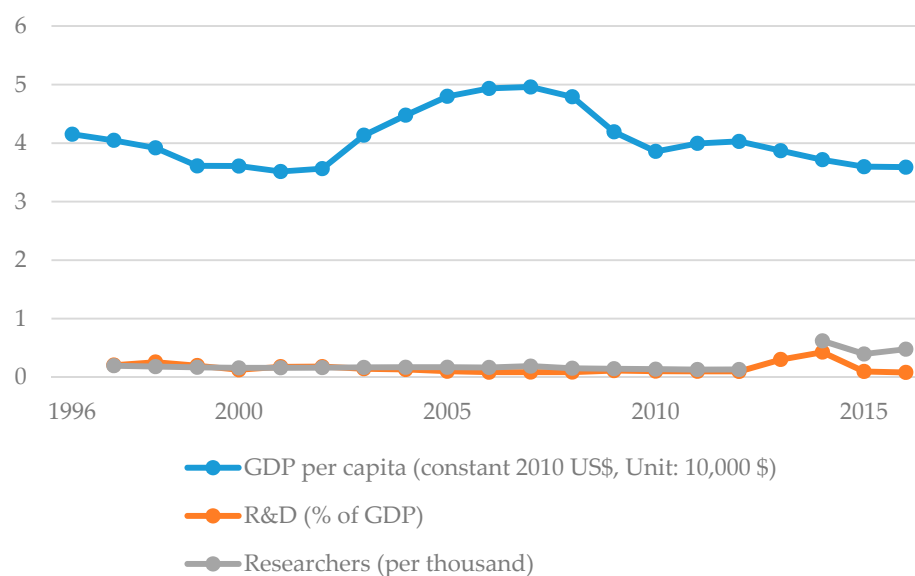
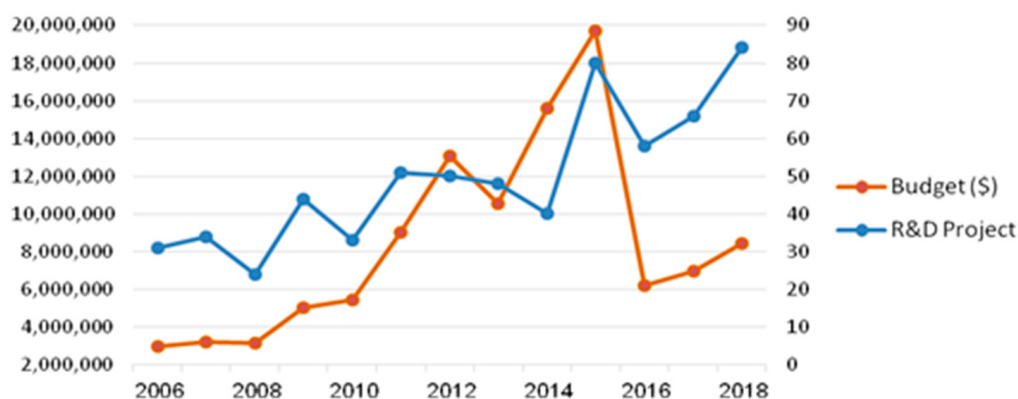


Figure 5. Research and development (R&D) sustainability models of Kuwait (1996–2016). Source: World Bank Group (2019).

Table 5. R&D Indicators for all projects funded by Kuwait Foundation for the Advancement of Sciences (KFAS) (2006–2018).

R&D indicator	Mean	SD	Min	Max	Trend ^a
Number of R&D Projects	49	19	24	84	4.0 *
Total budget USD	8,423,678	5,125,645	3,018,636	19,684,749	709,723 **

^a Slope of linear trend on annual scale (2006–2018); * positive significance ($p = 0.01$); ** positive non-significance.

**Figure 6.** Kuwait Foundation for the Advancement of Sciences (KFAS) allocated budget and number of R&D projects funded by KFAS (2006–2018).**Table 6.** Kuwait Institute for Scientific Research (KISR) R&D divisions (2008), including the “Environment & Urban Development” departments (2013).

R&D Divisions (2008)	No. of Researchers	Total No. of Projects	USD Total Budget
1. Petroleum Research	29	32	7,010,658
2. Water Resources	13	38	2,484,056
3. Environment and Urban Development	49	61	3,987,091
4. Food Resources	68	37	4,366,616
5. Techno-Economics	9	7	379,441
Total	168	175	18,227,862
Environment and Urban Development Departments * (2013)	Conference Papers	Journal Papers	USD Funds to Generate
Aquaculture	5	7	103,500
Coastal Management	5	7	103,500
Biotechnology	12	18	373,750
Crisis Decision Support	3	5	103,500
Arid and Agriculture Production	11	14	189,750
Biodiversity for Terrestrial Ecosystems	7	11	270,250
Air Quality	3	5	103,500
Food and Nutrition	7	11	230,000
Ecosystem-Based Management of Marine Resources	9	14	276,000
Environmental Management	10	15	270,250
Total	72	107	2,024,000

Table 7. Completed R&D “Environment & Urban Development” Projects in Kuwait (2018/2019).

R&D Project	Project Duration	USD Budget Request *	USD Government Fund	% Funded
Sea Breakers	2016–2018	317,000	75,000	23%
Greenhouse Gases	2014–2018	693,000	510,000	73%
Indoor/Outdoor Air Pollution	2015–2017	769,000	450,000	58%
Microplastics in Sea	2017–2018	222,000	70,000	31%
Bio-hydrocarbons in Sea	2016–2018	154,000	154,000 **	100%
Microbial in Soil and Plants	2015–2018	433,000	221,000	50%
Planting Fruit	2017–2018	201,000	81,000	40%
Coastal Plants	2016–2018	225,000	94,000	41%
Indigenous Plants	2015–2018	286,000	133,000	46%
Crop Feeds	2016–2018	622,000	150,000	24%
Palm Watering	2015–2018	551,000	152,000	27%

Table 7. Cont.

R&D Project	Project Duration	USD Budget Request *	USD Government Fund	% Funded
Crops Photosynthesis	2016–2018	305,000	305,000 **	100%
Soil Rehabilitation	2016–2018	110,000	4000	4%
Poultry production	2017–2019	300,000	30,000	10%
Vegetable Enzymes	2016–2018	160,000	160,000 **	100%
Fish Virus	2016–2018	256,000	120,000	46%
Fish Feed	2017	216,000	216,000 **	100%
Coral Reefs	2014–2017	750,000	750,000	100%
Sea Bacteria	2016–2018	348,000	348,000 **	100%
Sea Ecology	2016–2018	340,000	340,000 **	100%
Hydrocarbons in Soil	2018	181,000	107,000	58%
Total ***		5,916,000	2,947,000	49%

* rounded to nearest thousand; ** internal funding; *** total excludes internal funding.

Table 8. Ongoing R&D “Environment & Urban Development” Projects in Kuwait (2016–2020).

R&D Project	Project Duration	Budget Requested *	Government Fund	% Funded
Coastal Management	2017–2020	2,312,000	1,875,000	81%
Radiation Database	2016–2019	933,000	107,000	11%
Disease Early Warning	2018–2020	440,000	131,000	29%
Methanol Exposure	2017–2018	823,000	139,000	17%
Radiation Dose	2016–2019	514,000	66,000	13%
Dust Fallout	2017–2019	654,000	299,000	45%
Fire Simulation	2018	156,000	156,000 **	100%
Persistent Pollutants	2017–2019	640,000	194,000	30%
Air Pollution	2016–2019	580,000	270,000	46%
Dust Microorganisms	2018–2019	553,000	147,000	26%
Sea Acidification	2017–2019	379,000	70,000	18%
Sea Algae	2017–2019	378,000	172,000 **	45%
Air Pollution	2017–2019	329,000	80,000	24%
Safety Toy	2018–2020	484,000	102,000	21%
Fish Degradation	2018–2020	375,000	117,000	31%
Mercury in Air	2016–2019	778,000	298,000	38%
Fish Larvae	2017–2019	253,000	253,000 **	100%
Lead Concentration	2018–2020	247,000	73,000	29%
Fish Oil-Polluted	2018–2020	312,000	147,000	47%
Soil and Water Oil Pollution	2017–2018	505,000	210,000	41%
Plastic Bio-degradable	2017–2019	624,000	299,000	47%
Environmental Impact Water	2018–2019	333,000	186,000	55%
Swimming Pool Quality	2018–2019	74,000	74,000 **	100%
Chemical Desorption	2018–2020	397,000	183,000	46%
Tin in Sea	2018–2019	75,000	15,000	20%
Solar System	2018–2019	268,000	180,000	67%
Livestock Feed	2016–2018	453,000	206,000	45%
Insecticides Technology	2016–2019	363,000	150,000	41%
Seeds and Plants	2017–2020	474,000	125,000	26%
Poultry Feed	2017–2020	768,000	210,000	27%
Livestock Wild Feed	2017–2020	454,000	143,000	31%
Local Lamb	2017–2020	372,000	144,000	38%
Lamb Vaccination	2017–2020	756,000	122,000	16%
Poultry Local Deed	2017–2019	731,000	124,000	17%
Mixed Agricultural Feed	2018–2020	506,000	144,000	28%
Wool Production	2016–2018	396,000	255,000	64%
Expired Lamb	2016–2019	326,000	27,000	8%
Local Plants	2018–2020	339,000	60,000	17%
Desert Soil	2018–2019	342,000	342,000 **	100%
Soil Fertilization	2017–2019	461,000	105,000	22%
Greenhouse Technology	2017–2019	240,000	240,000 **	100%
Newborn Body Composition	2016–2019	239,000	131,000	54%
Wastewater Technology	2016–2019	1,191,000	802,000	67%
Food Value	2018–2019	296,000	74,000	25%
Fish Quality	2017–2019	300,000	300,000 **	100%
Chicken Salmonella	2018–2019	270,000	43,000	16%
Vitamin D Meals	2018–2019	193,000	193,000 **	100%
Dietary Fiber Bread	2018–2019	219,000	219,000 **	100%
Halal Food	2017–2019	963,000	109,000	11%
Agriculture Viruses	2018–2020	337,000	337,000 **	100%
Hydrocarbon Genetic	2017–2019	300,000	300,000 **	100%
Poultry Feed	2019–2020	489,000	66,000	13%

Table 8. Cont.

R&D Project	Project Duration	Budget Requested *	Government Fund	% Funded
Plant Tissue Culture	2017–2020	447,000	133,000	29%
Chicken E-Coli	2019–2020	539,000	42,000	7%
Nutrition from Algae	2017–2019	349,000	349,000 **	100%
Larvae Feedings	2017–2019	424,000	57,000	13%
Fish Production	2018–2019	267,000	50,000	18%
Fish Disinfection	2018–2020	148,000	148,000 **	100%
Fish multi Production	2018–2020	282,000	282,000 **	100%
Fish Vaccination	2018–2020	249,000	249,000 **	100%
Fish Algae Prime	2018–2019	212,000	212,000 **	100%
Sea Bacteria	2018–2020	365,000	365,000 **	100%
Total ***		24,079,000	8,510,000	35%

* rounded to nearest thousand; ** internal funding; *** total excludes internal funding.

4. Discussion

The number of researchers is the most crucial variable to predict GDP per capita, and R&D expenditure is a good indicator of the number of researchers. The results showed strong correlations between the R&D expenditure, the number of researchers, and the economic growth. The previous studies support these results that public and private R&D expenditure predict national productivity [33], and empirical R&D expenditure leads the economic growth [31]. Both high- and middle-income countries showed the same pattern of positive correlation between the three variables, although the intensity of correlations were slightly different. Innovation and sustainable economic growth in the State of Kuwait require hiring more intellectual researchers capable of conducting high-quality research. When the “market for research” is activated, such advanced human capital is nurtured. Without such a “market”, human capital is not cultivated.

Improvements in R&D will be different in different countries and depend for example, on the natural resources, manpower education, governance arrangements, availability of technology, and political stability. By highlighting how the R&D indicators influence and interact with each other, countries can set priorities of actions to better allocate their resources to promote scientific R&D. The objectives stated in the SDG 2030 Agenda recommends that each government sets its own targets, taking into account their national priorities and circumstances [5]. Countries need to understand how R&D can influence other SDG targets and how its systemic impact can be very significant [24]. Results of this study show that countries should set high priorities for R&D and apply policy interventions to promote and allocate more resources for R&D in order to achieve systemic economic sustainability. Decision makers may opt for political or “short-term” economic resources to allocate initial resources for R&D, however, a coherent and integrated policy with comprehensive implementation strategies should be set to efficiently enhance R&D expenditure and number of researchers to achieve long-term economic sustainability. It is important to note that it is not always true that rich countries have higher spending on R&D or that R&D spending makes rich countries; however, we concluded that consistent investments in R&D and high number of researchers will lead to sustainable economic growth. For instance, although Kuwait is considered a rich country, its R&D expenditure is very low (0.08% of the GDP). Kuwait’s high GDP per capita is mainly dependent on crude oil sales (over 92%), and if the international demand on crude oil is substantially reduced, the economy of the country becomes wavering. Kuwait not only has a low private research expenditure, but it also lacks a well-developed private sector beyond the oil industry. This “resources curse”, as a major source of the economy may make countries totally dependent on a single resource and may harm the economy in the event of global political or economic turmoil. Moreover, the drop in the number of researchers in Finland and the flattening of the GDP per capita from 2009 to 2015 is likely related to Nokia’s loss of competitiveness in the telecommunications industry, which suggest the vulnerability of small countries with one or a few firms or “resources” dominating the economy.

In both the Asian and the European models, the results showed that the expansion of R&D expenditure leads hiring more researchers, and consequently the higher number of researchers leads to

economy growth. Data from both the Asian and European models unequivocally support the hypothesis that the number of researchers influences economic growth. Furthermore, economic expansion and the investment in R&D have been shown to improve environmental and economic sustainability in European countries [44].

Within the GCC, the State of Kuwait and the UAE have different types of indicators that are related to research capacities [35], with significant gaps among these indicators between the two countries. The UAE invests over 12 times more than the State of Kuwait in R&D expenditure, and it has 5.2 times the number of researchers. Furthermore, the level of GDP per capita in the UAE was USD 41,045 (constant 2010 USD) in 2016, which is USD 5158 higher than that of the State of Kuwait [35]. Kuwait's R&D expenditure was very low at 0.08% of its GDP in 2016, and its number of researchers was only 467 per million people. The State of Kuwait's GDP fluctuated for twenty years (1996–2018) and showed a decline from USD 41,309 (1996) to USD 33,538 (2018). Although the number of R&D projects in the State of Kuwait increased linearly from 2006 to 2018, the total allocated R&D budgets did not correspond well with this sharp increase. A non-significant correlation was shown between the number of R&D projects and the allocated funds ($r = 0.56$, $\text{Sig} = 0.93$) between 2006 and 2018. The R&D projects in the State of Kuwait during the period between 2016 and 2020 demonstrated the lack of a commonly shared research framework. Research subjects were intermixed with no clear view or guidance to align efforts with the nations' research priorities. Projects were conducted under segregated research programs without "matrixing" among them. These classical disciplinary approaches to R&D are outdated and transdisciplinary projects that engage teamwork are required to achieve economic sustainability and growth. It is important to note that the R&D budgets reported for the State of Kuwait are inflated by the researchers' man-power costs, even though the government pays the researchers' salaries; this practice has been historically employed to enlarge superficial R&D budgets. This practice should be abandoned and actual required government funds should be allocated. For instance, the on-going R&D environmental project funds for the five-year period (2016–2020) was over USD 24 M, whereas only 35% of this budget was actually required. The upper management at local research institutions set annual key performance indices (KPIs) for each segregated research program based on the number of researchers within each program. KPIs target the generation of funds and the number of publications without consideration for the relevance of the R&D areas to tackle national priorities. The R&D environmental programs are broad in scope and multidisciplinary with other programs. Although Kuwait relies on its' economy to natural resources heavily, if it invests in diverse R&D, it can avoid the so-called "natural curse", because well-functioning institutions eliminate the potentially negative effect of natural resources [45]. For more robust R&D-driven economic growth, multidisciplinary sustainability research should be conducted [46–48].

Over the last few decades, the global economy has gradually become a knowledge-intensive economy. In today's globalized economy, R&D is a key component behind technology and economic growth. Grossman and Helpman stressed that improvements in technology are the best option to overcome the limits of economic growth [49]. Athina et al. analyzed 14 years (2000–2014) of data from the European Union on R&D and economic growth, and they concluded that private R&D spending, public R&D expenditure, total R&D spending, and the number of researchers and patents positively affected the per capita GDP of the countries [17]. While in developing countries an increase of 1% in R&D expenditure introduces a 0.3–0.4% increase in economic growth, a rise of 1% in R&D spending in developed countries leads to a 1% increase in economic growth [17]. In a knowledge economy, it is crucial to develop the R&D and service sectors to achieve economic sustainability. The level of development of the service sectors, particularly the knowledge-intensive segments, is a key determinant of a nation's competitiveness [16]. In economies with a strong emphasis on services, people tend to climb the "value-chain ladder" much more rapidly. It is generally believed that in the knowledge economy, the information-related industries and knowledge-intensive industries play the dominant role in promoting a sustainable economy [16].

The limitations of this study are the intrinsic restrictions associated with use of metadata, namely the lack of consistency between the various pieces of information collected from each country. However,

our analysis included data for 20 years (1996–2016) from the recent published World Bank Group (2019) report. The other limitation is that the results, despite showing significant correlations, do not determine the causation between variables. Nevertheless, the results are meaningful and can be used to draw universal conclusions through analysis of empirical data collected from each country by international organizations. Since various factors are affecting economic growth, it is necessary to conduct a longitudinally study to consider the growing numbers of factors and their interrelationships. Another limitation in this study includes the lack of explicit efforts to show the various types of R&D products or services and their links to national development and economic growth of the countries. We have looked at the overall context of the R&D indicators, excluding the means of how to achieve them.

5. Conclusions

This study was performed by applying a holistic approach to assess how countries can sustain economic performance through investment in R&D. Three R&D-moderating variables (R&D expenditure, number of researchers, and GDP per capita) were shown to be interrelated and can collectively lead to sustainable economic growth. High-income Asian and European countries were shown to invest heavily in R&D and, as a result, increased their GDP per capita. On the other hand, low investment in R&D in the State of Kuwait has been associated with lower economic flourishing. Based on the analyses performed in this study, the number of researchers was shown to be the most crucial variable in predicting GDP per capita, and the R&D expenditure is a good indicator of the number of researchers. Thus, in order to drive national innovation and sustainable economic growth away from a resource-dependent economy, it is necessary to make substantial R&D investments.

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