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Discussion Paper

Energy Transition in Oil-Dependent Economies

Public Discount Rates for Investment Project Evaluation

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Abstract

The selection of welfare-enhancing projects necessitates the determination of the present value of cash flows from a public policy perspective. For an oil-exporting economy, the domestic energy transition often implies displacing oil from domestic consumption. Economic dependence on oil affects the public discount rate for oil-related cash flows in two opposite ways. On the one hand, it renders the economy more volatile, lowering the risk-free discount rate; on the other hand, it increases the correlation between consumption and the oil price, resulting in a higher risk premium. To study these opposite effects, we first derive the public discount rate for an oil-related investment project. Our framework considers economic uncertainty and an oil price-related risk premium, and it makes it possible to value oil at its opportunity cost. We illustrate our methodology using data from a panel of 26 oil-exporting countries. The results indicate that a risk-free discount rate of 3.1% is appropriate for our panel. However, to discount oil-related cash flows, a risk premium of 1.4% needs to be added to the risk-free rate, yielding a risk-adjusted real discount rate of 4.5%. We find significant disparities between country-specific public discount rates. Additionally, for each country, we assess the present value of reducing domestic oil consumption by a barrel per day from 2023 to 2040, decomposing the different effects. Oil-exporting countries can use our estimates to make investment or policy decisions.

Keywords: Public economics; risk premium; opportunity cost; public discount rate; oil-exporting countries; cost-benefit analysis

JEL codes: E6; Q3

1. Introduction

The domestic energy transition of an oil-exporting economy often implies investment in projects that displace oil from domestic consumption. Such projects can be, for example, a project that enhances energy efficiency in an oil-consuming sector or that develops renewable capacity, displacing oil in the power sector. At the same time, most oil-exporting economies pursue economic diversification and industrial development policies, ultimately leading to less dependence[1] on oil revenues.

In this context, selecting welfare-enhancing projects requires understanding how economic dependence on oil impacts the present value of oil-related cash flows from a public policy perspective. Gaining such an understanding raises the issue of using public discount rates that capture both the cash flow risk and the characteristics of the oil-exporting economy.

Economic dependence on oil impacts the public discount rate for valuing oil-related cash flows in two opposite directions. On the one hand, dependence on oil exports and the substantial share of oil in the gross domestic product (GDP) render the economy more sensitive to oil prices. As a result, due to fluctuations in oil prices, dependence on oil increases the volatility of the economy, which, through a precautionary effect, lowers the risk-free discount rate,[2] resulting in a higher valuation of future cash flows. On the other hand, economic dependence on oil leads to a stronger correlation between private or government consumption and the price of oil. This stronger correlation results in a higher risk premium, implying a lower valuation of future cash flows. In this paper, we investigate how the combination of these two opposite effects impacts the risk-adjusted discount rate. Such an investigation begs a series of related questions: Which effect holds greater significance in shaping the public discount rate for oil-related public investment projects? What is the magnitude of the risk premium? Does the size of the effect vary significantly between oil-dependent economies?

Our study begins with an overview of how a public discount rate can be derived for a project that aims to save barrels of oil consumed domestically, decomposing the effect into three distinct components: the wealth effect, the precautionary effect and the risk premium. Furthermore, this study recognizes that the barrel of oil freed from domestic use must be valued at its opportunity cost rather than at the prevailing international market price. Karanfil and Pierru (2021) show that for an oil-exporting country, the opportunity cost of domestic oil consumption can be influenced by numerous factors, including the market share of the country's oil exports, domestic oil pricing schemes and a variety of constraints[3] faced by the country's oil sector.

We use recent data from a panel of 26 oil-exporting countries and show that a risk-free discount rate of 3.1% can be employed in these countries if country-specific characteristics are overlooked. We show that governments should apply a distinct discount rate when evaluating cash flows correlated with aggregate consumption. Considering the inherent risk associated with oil-related cash flows, we find that the risk-free rate needs to be adjusted upward by adding, on average, a risk premium of 1.4%, which yields a risk-adjusted real discount rate of 4.5%.

However, our results indicate that there is a considerable disparity between country-specific discount rates. Based on this finding, we investigate the factors that can affect the public discount rates in oil-exporting countries and analyze their correlation with macroeconomic indicators, such as the level of oil reliance or the degree of export diversification. Furthermore, for various oil-exporting countries, using our calculated risk-free discount rates, risk premia and opportunity costs, we estimate the present value of the cash flows arising from reducing domestic consumption by a barrel of oil per day over the 2023-2040 period.

Using incorrect discount rates can lead to mistaken public policy decisions, compromising policymakers' ability to make accurate choices in regard to resource allocation and select efficient investment projects. Given the ongoing endeavors of oil-exporting countries to transition their energy systems and diversify their economies, it is essential to comprehend the factors influencing public discount rates. By discussing the elements that impact the public valuation of oil-related cash flows and providing numerical illustrations, this paper generates tangible insights that are applicable to public policymaking in these countries.

The next section briefly documents the literature and discusses the disparities observed in the current discounting practices among governments and international institutions. Section 3 presents the data. Section 4 outlines our methodological approach to valuing oil-related cash flows from a public policy perspective. Section 5 provides empirical insights and estimates. Section 6 concludes.

2. Literature Review and Discount Rates Applied in Practice

According to public economics, an investment project can be undertaken if the reduction in welfare due to the foregone current consumption is more than compensated for by the expected increase in welfare from the future benefits of that investment. Appropriately discounting future costs and benefits is critical for assessing the net present value (NPV) of investment projects from a public policy perspective.

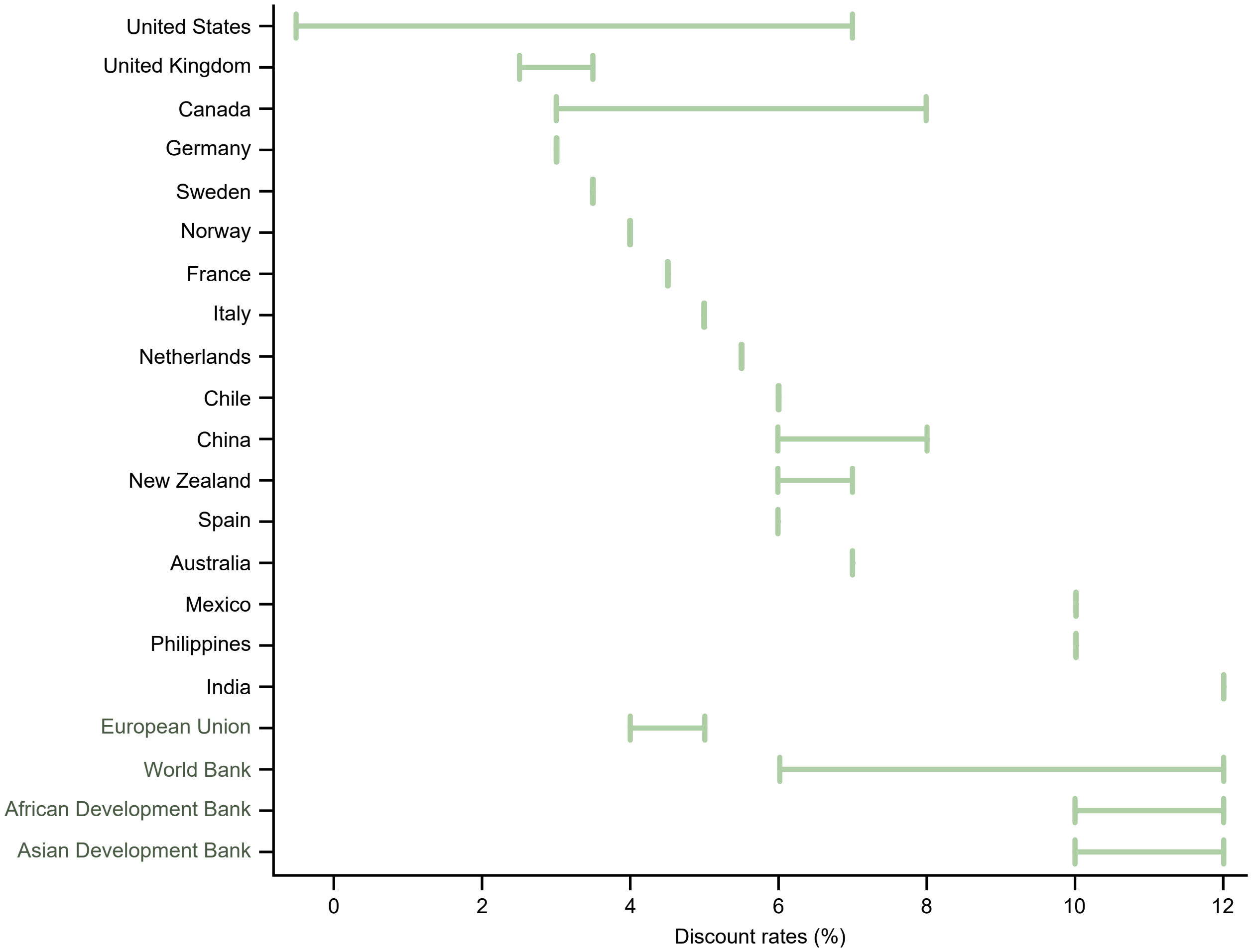
Many studies have attempted to address public decision-making in an intertemporal or intergenerational context. In "The Economics of Welfare," Pigou (1932) puts forth the idea that "the State should protect the interests of the future in some degree against the effects of our irrational discounting and of our preference for ourselves over our descendants" (Pigou 1932). According to this statement, to act as protectors of the interests of future generations, governments must use a "rational" public rate to discount the streams of costs and benefits of new investment projects.

Although economists have since made progress in both the theory and the empirical estimation of public discount rates, the question of which values to choose remains under debate in both academic and governmental circles. Figure 1 presents the discount rates utilized by multinational institutions and governments across a range of selected countries. It indicates that there is significant heterogeneity in the discount rates used. This disparity is attributable to several factors, such as differences in country-specific macroeconomic factors, time horizons and the perceived level of risk associated with the outcome of a project. For example, discount rate selection may rely on the characteristics of the sector or industry concerned, considering the economic, environmental and societal impacts of the project.

Figure 1 also suggests that, compared to national governments, multinational institutions focusing on development employ a relatively high social discount rate,[4] which implies that such institutions assign less weight to the benefits and costs that arise in the distant future. This approach tends to prioritize projects that yield immediate or near-term benefits. This preference for projects with earlier benefits is attributable to an urgent need to increase infrastructure investment and overcome existing constraints.

The literature exploring the determination of public discount rates provides various perspectives.[5] Factors such as social preferences, intra- and intergenerational equity, and uncertainty are commonly emphasized, particularly in areas such as infrastructure planning, economic diversification, energy policy, and climate change mitigation and adaptation. One perspective

Figure 1. Discount rates used by multinational institutions and governments in selected countries.



Source: Authors' elaboration based on data from Boardman et al. (2018), the European Union (2015), Lopez (2008), the World Bank (2020) and Zhuang et al. (2007).

centers on the valuation of private investments displaced by government programs, while another focuses on consumers' relative preferences for current income compared to future income. For example, Stern (2016) indicates that climate change impact models rely on two problematic assumptions: that people will be wealthier in the future and that future lives are less important than current lives. The first assumption ignores the risks and disruptions that climate change brings for future livelihoods and well-being, while the second assumption is discriminatory and difficult to defend. In accordance with this observation, due to the irreversibility and uncertainty associated with the impacts of climate change, Weitzman (2010) shows that a lower discount rate, significantly less than 6%, which is approximately the global average after-tax real rate of return on capital, should be used.

The literature stresses the necessity of using a discount rate that incorporates both the uncertainty related to the macroeconomy and the risk associated with the future outcomes of a given investment. This is particularly the case for public decision-making in oil-exporting countries, where a substantial portion of these countries' income is tied to volatile oil revenues. The reliance on such revenues carries a social cost, emphasizing the need to incorporate a risk premium when assessing the value of energy-related public investment projects (Pierru and Matar 2014). In a framework that focuses on maximizing the utility of society from consumption, the modified Ramsey rule provides a useful framework for determining the appropriate discount rate. According to this rule, the discount rate equals the sum of a risk-free rate (i.e., the minimum rate of return required for an investment with zero risk) and a risk premium that accounts for the risk to the economy generated by the investment. The modified Ramsey rule makes it possible to adjust discount rates based on the specific attributes of each project, recognizing that not all investments carry the same level of risk. Within this context, several studies have estimated country-specific social discount rates to evaluate public projects (see, e.g., Moore, Boardman and Vining (2020) and Schad and John (2012)).

Finally, in regard to promoting societal welfare across generations, the question of how to optimally allocate resources raises the concept of opportunity cost. Understood broadly, opportunity cost represents the value that society assigns to the most favorable alternative that is foregone or rejected. While earlier studies (e.g., Little and Mirrlees (1974), Squire and Van der Tak (1975)) have assumed that border prices accurately reflect the relevant opportunity costs for goods involved in international trade, subsequent research challenges this view and suggests that market distortions lead to opportunity costs deviating from observed prices (e.g., Hamilton and Clemens (1999), Karanfil and Pierru (2021)). Building upon these insights, our analysis integrates both the opportunity cost approach and the public discounting framework.

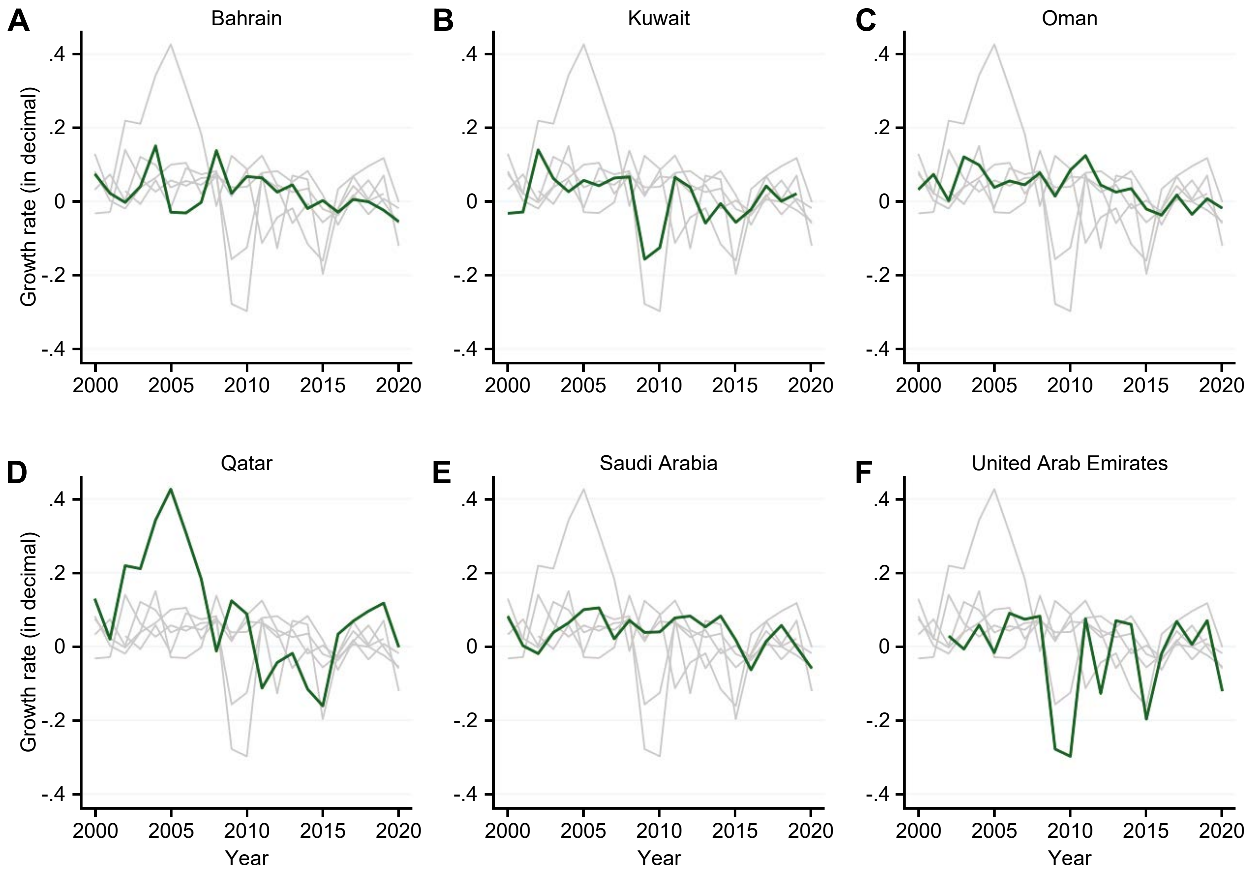
3. Data and the Per Capita Consumption Paradox

We consider gross consumption per capita as our main variable of interest. Data covering the 1999-2020 period are obtained from the World Bank and are given by the sum of final household consumption expenditures and final general government consumption expenditures.[6] We also use Brent crude oil price data from the U.S. Energy Information Administration. All data are yearly and in real US$ terms.[7] Our sample comprises 26 emerging and developing oil-exporting countries. In line with the World Bank (2018), we consider countries whose crude oil and natural gas exports account for at least 20% of their total exports.[8]

As explained further below, when determining public discount rates for a given country, the evolution of the country's economy is captured through changes in per capita consumption. We could be tempted to assume that economic growth mechanically increases per capita consumption. However, this is not necessarily the case for countries where expatriate workers represent a significant proportion of the total population. In such countries, when the economy experiences growth, it often triggers a surge in the number of expatriate workers and subsequently leads to an increase in population. Despite the growing economy, this increase could, paradoxically, lead to a decrease in the per capita consumption growth rate.

Conversely, an economic contraction can lead to a decrease in population (as a result of the departure of expatriate workers returning to their countries of origin), thus creating a positive per capita consumption growth rate. In our analysis, this circumstance is particularly important due to the dissimilar behavior and consumption patterns of foreign residents and the citizens of these countries. First, foreign residents typically have short-the term employment agreements with lower earnings than the local population. Second, their primary objective is to maximize the remittances that they send home since many have left their families in their countries of origin. Among the countries considered in our study, the Gulf Cooperation Council (GCC) member states (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) are particularly concerned with this statistical issue. As an illustration, in Figure A.1 in Appendix A, we provide the evolution of the total population and Emirati citizens in the United Arab Emirates. Despite the significant impact of the global financial-economic crisis in 2008, the Emirati economy managed to grow between 2005 and 2010 (with an average yearly real GDP growth rate of 3.3%). In the same period, economic growth was accompanied by a rapid influx of expatriate workers. As a result, the population more than doubled in the same period, leading to a decline in per capita consumption. To mitigate this potential bias, we exclusively include citizens (individuals holding citizenship in the country) when computing the consumption growth rate (defined as the logarithmic change in per capita consumption).

Figure 2. Growth rates of real gross consumption per capita in GCC countries.



Note: Each green line represents the growth rate for the country specified at the top of the chart, while gray lines represent the growth rates for all other GCC countries.

Source: KAPSARC

We adopt this methodology for all GCC countries.[9] The data obtained, which are utilized in the current study, are depicted in Figure 2.[10]

Figure 2 shows that the growth rates of GCC countries exhibit significant volatility. Certain countries have experienced notably pronounced fluctuations in the past two decades. For example, the Dubai debt crisis caused by a real estate bust in 2009 plunged the United Arab Emirates into a severe financial and economic crisis. In the subsequent sections, we return to this volatility issue and show how it affects discount rate estimates.

4. An Analytical Approach to Valuing Oil-Related Cash Flows From a Public Policy Perspective

4.1. The Ramsey Rule and the Opportunity Cost of Oil

Using the correct discount rate value is key since discounting may strongly impact the valuation of investments with a long lifetime, such as those related to energy transitions, as in the projects considered here.

We begin our analysis by considering a standard social welfare function for an oil-exporting economy that is written as follows:

$$U(C_0)+\sum_{t=1}^{\infty} e^{-\delta t} E\left[U(C_t)\right], \quad (1)$$

where C_0 and C_t are the current and future per capita gross consumption levels, respectively. δ is a constant rate of pure time preference, that is, the discount rate measuring the weight placed on the utility ($U(.)$) of future consumption. A higher value indicates that less importance is given to future utility. In this paper, in line with the bulk of the literature on public economics,[11] we take $\delta = 0$.

We consider an investment project that is small compared to the size of the economy. The project, which costs I per capita, aims to reduce domestic oil demand and export the oil freed from domestic consumption. The project is assumed to generate q barrels per year for T years on a per capita basis. Each barrel available in year t will be sold at international price P_t.

The cash flows generated by the project must be calculated based on the opportunity cost of a barrel of oil for the domestic economy. Karanfil and Pierru (2021) show that the opportunity cost of oil equals the marginal revenue generated by the export of an additional barrel and is given by a fraction (γ_t) of the international price of oil. These authors show that in an oil-exporting country, when the oil consumed domestically has a fixed administered price,[12] the opportunity cost of oil is given as follows:

$$\gamma_t P_t = \left(1 + \frac{1}{\varepsilon_{x,t}}\right) P_t \ , \tag{2}$$

where $\varepsilon_{x,t}$ is the price elasticity of international demand for the country's exports. By simple algebra, $\varepsilon_{x,t}$ can be written as follows:

$$\varepsilon_{x,t} = \frac{1}{\rho}(\varepsilon_{d,t} - (1-\rho)\varepsilon_{s,t}) \ , \tag{3}$$

where $\varepsilon_{d,t}$ and $\varepsilon_{s,t}$ denote the price elasticity of global demand and the supply of other producers, respectively. ρ represents the country's share in the global oil market. As $\varepsilon_{x,t} < 0$, we have $\gamma_t < 1$. Additionally, Equations (2) and (3), $\lim_{\rho \to 0} \gamma_t = 1$, suggest that for a small oil exporter, the opportunity cost is close to the international price.

The project is considered profitable if it enhances the country's welfare:

$$U(C_0 - I) + \sum_{t=1}^{T} e^{-\delta t} E[U(C_t + \gamma_t P_t q)] \geq \sum_{t=0}^{T} e^{-\delta t} E[U(C_t)]. \tag{4}$$

As in Gollier (2013a), by using first-order Taylor approximations, the above condition becomes the following:

$$-IU'(C_0) + \sum_{t=1}^{T} e^{-\delta t} E[\gamma_t P_t q U'(C_t)] \geq 0.$$

One way to express this relationship is as follows:

$$-I + \sum_{t=1}^{T} e^{-\delta t} \frac{E[U'(C_t)]}{U'(C_0)} \frac{E[\gamma_t P_t q U'(C_t)]}{E[U'(C_t)]} \geq 0. \tag{5}$$

Assume for now that the cash flow of the project is certain; that is, the opportunity cost of oil $g_t P_t$ is known. Then, the project has a positive NPV if the following holds true:

$$NPV = -I + \sum_{t=1}^{T} e^{-rt} \gamma_t P_t q \geq 0, \tag{6}$$

where the discount factor e^{-rt} is given by the expected marginal rate of substitution between current and future consumption, i.e., $e^{-rt} = \frac{E[U'(C_t)]}{U'(C_0)}$ (see Gollier 2013a; Gollier and Hammitt 2014). This implies the following:

$$r = -\frac{1}{t} \ln \frac{E[U'(C_t)]}{U'(C_0)}. \tag{7}$$

We now consider the utility function of a representative agent that is increasing and concave:

$$U(C_t) = \frac{C_t^{1-\alpha}}{1-\alpha}. \tag{8}$$

Here, α is the constant elasticity of the marginal utility of consumption or the relative aversion to the intertemporal inequality of consumption. Throughout the paper, we refer to α as the relative risk aversion. It is supposed to be positive and different from 1. However, when $\alpha = 1$, Equation (8) becomes $U(C_t) = \ln(C_t)$.

If we suppose that there is no uncertainty about future consumption, using Equation (8) in Equation (7), we can obtain the following:

$$r_t = \alpha \mu_t, \tag{9}$$

where μ_t is the average growth rate of consumption with $\mu_t = \frac{1}{t} \ln\left(\frac{C_t}{C_0}\right)$. Equation (9) is called the Ramsey rule (Ramsey 1928). It indicates that the socially efficient discount rate can be calculated by multiplying the average consumption growth rate from the present to date t by the degree of relative risk aversion, represented by α. When the consumption growth rate μ_t remains constant, the Ramsey rule produces a fixed discount rate, that is, $r = \alpha\mu$.

Determining the appropriate value for the coefficient of relative risk aversion has been a subject of ongoing debate. Estimates of a used in macroeconomics and public finance applications usually range from 1 to 4.

There is no specific study addressing the value of α for oil-exporting countries, but the value of 2 has often been used in economic literature or been recommended for public decision-making purposes (Pierru and Matar 2014). Therefore, in this study, we adopt a value of $\alpha = 2$ while also examining the sensitivity of our findings to $\alpha = 1$ and $\alpha = 3$.

4.2. Extending the Ramsey Rule With Economic Uncertainty

For long-term decision-making in the public sector, coping with uncertainty and asset or investment riskiness is a critical challenge. To take into account the effect of uncertainty, in line with the literature (see, e.g., Cherbonnier and Gollier 2022), we begin by assuming that consumption follows a geometric Brownian motion[13] and that its growth rate (g) has a constant mean μ and standard deviation σ. Using Equation (8), we can derive the expected marginal utility at date t as follows:

$$E[U'(C_t)] = C_0^{-\alpha} E[e^{-\alpha g_t}]. \tag{10}$$

Now, we can use the Arrow-Pratt approximation[14] to write the following:

$$E[e^{-\alpha g_t}] = e^{-\alpha(\mu - 0.5\alpha\sigma^2)}. \tag{11}$$

Combining Equations (7), (10) and (11), we obtain an extended Ramsey rule:

$$r_f = \alpha\mu - \frac{\alpha^2}{2}\sigma^2. \tag{12}$$

The risk-free discount rate (r_f) in Equation (12) should be applied when evaluating a project that carries no risk to the economy. According to Equation (12), the risk-free discount rate results from two opposing factors. The first factor is the wealth effect ($\alpha\mu$), which is determined by the expected rate of consumption growth multiplied by the relative risk aversion. When future consumption is anticipated to increase, the need for current investment decreases, resulting in a higher discount rate. Essentially, there is no need to overinvest in favor of an already promising future. The second factor, the precautionary effect $\left(\frac{\alpha^2}{2}\sigma^2\right)$, is given by half the relative risk aversion squared multiplied by the variance in the consumption growth rate. When future consumption is uncertain, the value of the discount rate decreases. Consequently, this decrease stimulates the current investment as a hedge against possible future declines in consumption.

The uncertainty of consumption is particularly striking in the case of economies that are highly dependent on oil export revenues. The real per capita consumption growth rates of GCC countries, shown in Figure 2, have an average standard deviation of 0.083. To provide a point of comparison, during the same period from 1999 to 2020, the standard deviation of the same variable was 0.014 for both Organisation for Economic Co-operation and Development (OECD) countries and the U.S., while it was slightly greater at 0.016 for the European Union. The high value of σ observed for oil-exporting economies is primarily caused by their dependence on the oil price (since gross consumption is often constrained by volatile oil revenues). Therefore, this dependence amplifies the precautionary effect and fosters a greater inclination toward investing, which lowers the risk-free discount rate.

4.3. Introducing the Oil Price-Related Risk Premium

The social discount rate obtained via Equation (12) can be used to evaluate safe projects. However, when the cash flows of a project affect the aggregate risk borne by the economy, a risk premium must be incorporated into the discount rate, which will occur in an oil-exporting economy when a new project generates cash flows that are a function of the international oil price. Undertaking such a project increases (or decreases) the exposure of the whole economy to fluctuations in oil prices. Let us illustrate this point.

Suppose that the project has a risky cash flow. In other words, the opportunity cost of oil in t is uncertain. Equation (6) becomes the following:

$$-I + \sum_{t=1}^{T} e^{-r_f t} \tilde{\gamma}_t \tilde{P}_t q \geq 0, \tag{13}$$

where $\tilde{\gamma}_t \tilde{P}_t q$ is the certainty equivalent of the cash flow. Using Equation (5), we can write the following:

$$\tilde{\gamma}_t \tilde{P}_t q = \frac{E[\gamma_t P_t q U'(C_t)]}{E[U'(C_t)]}. \tag{14}$$

If the cash flow $\gamma_t P_t q$ carries its own level of risk, which comes in addition to the risk associated with C_t, applying Equation (14) leads to the following:

$$\tilde{\gamma}_t \tilde{P}_t q = E[\gamma_t P_t q]. \tag{15}$$

This scenario implies that the risk premium is insignificant, and we obtain the risk-free discount rate specified in Equation (12). Nevertheless, it is improbable that the assumption of independence between consumption and cash flow, as stated in the Arrow-Lind theorem (Arrow and Lind 1970), holds true in the case under examination here. The reason is that gross consumption in oil-exporting countries is likely to exhibit a correlation with oil prices. When a positive correlation exists, project implementation leads to a higher level of overall risk. As a result, the project carries a positive risk premium. Consequently, the certainty equivalent of the future cash flow is given as follows:[15]

$$\tilde{\gamma}_t \tilde{P}_t q = e^{-\pi(\beta)t} q E[\gamma_t P_t]. \tag{16}$$

Here, $\pi(\beta) = \alpha\beta\sigma^2$ is the risk premium of the project with

$$\beta = \frac{\operatorname{cov}\left(\ln \frac{\gamma_t P_t}{\gamma_{t-1} P_{t-1}},\ \ln \frac{C_t}{C_{t-1}}\right)}{\sigma^2}$$

, which measures the dependence between oil prices and aggregate consumption.[16] It implies that the risk premium has the same sign as the covariance between the growth rates of consumption and cash flow. The impact of the project on the aggregate risk to the economy increases when the consumption β of the project increases. Conversely, a cash flow that exhibits a negative correlation with consumption will enjoy a negative risk premium, representing an economic gain generated by risk diversification.

From Equation (16), it follows that when the risk premium is positive (i.e., $\beta > 0$), the certainty equivalent of the cash flow decreases exponentially with t. Additionally, assuming that the elasticity of the country's oil exports remains constant (see Karanfil and Pierru 2021), it can be shown that the fraction γ of the international oil price has no effect on the β of the project. In other words, the risk premium is independent of γ.

Finally, using Equations (13) and (16), the NPV of the project is written as follows:

$$-I + \sum_{t=1}^{T} e^{-r_a t} qE[\gamma_t P_t], \tag{17}$$

where r_a is the risk-adjusted discount rate.

Undertaking the project increases welfare if the NPV (as described by Equation (17)) of the project is positive.[17] Using Equation (12), we write the following:

$$\begin{aligned} r_a &= r_f + \pi(\beta) = \alpha\mu - \frac{\alpha^2}{2}\sigma^2 + \alpha\beta\sigma^2 \\ &= \alpha\mu - \frac{\alpha^2}{2}\sigma^2 + \alpha \operatorname{cov}\left(\ln \frac{\gamma_t P_t}{\gamma_{t-1} P_{t-1}}, \ln \frac{C_t}{C_{t-1}} \right). \end{aligned} \tag{18}$$

Equation (18) can also be written as follows:

$$r_a = \alpha\mu + \alpha\sigma^2\left(\beta - \frac{\alpha}{2}\right). \tag{19}$$

From Equation (18), a high level of uncertainty generates a precautionary saving motive and reduces the risk-free discount rate. Conversely, from Equation (19), if consumption β is greater than $\frac{\alpha}{2}$, the risk premium dominates the precautionary effect (Gollier 2016). If $\beta = \frac{\alpha}{2}$, the risk premium and the precautionary effect offset each other, and the risk-adjusted discount rate is given by the original Ramsey rule, i.e., $r_a = \alpha\mu$.

5. Application to Oil-Exporting Countries

In this section, we provide illustrative examples specific to oil-exporting countries, building upon our previous analysis of the determination of discount rates for public investment projects considering economic uncertainty, oil price-related risks and the opportunity cost of oil. Since our methodology described above requires that the per capita gross consumption growth rate follows a normal distribution, we first test for normality for the countries in our sample. The results of the Jarque-Bera test presented in Table 1 reject the normality of the distribution for eight out of 26 oil exporters. Therefore, unless otherwise stated, we continue our analysis in this section with the remaining 18 countries.[18]

For gross consumption per capita, the countries listed in Table 1 exhibit an average standard deviation of 0.065, which is approximately five times greater than the average standard deviation observed in OECD countries (as discussed in Section 4.2). In the context of public policy in oil-exporting countries, such a substantial difference emphasizes the significance of uncertainty and the inherent risk associated with oil price fluctuations.

Table 1. Summary statistics and normality test results for per capita real gross consumption growth rate.

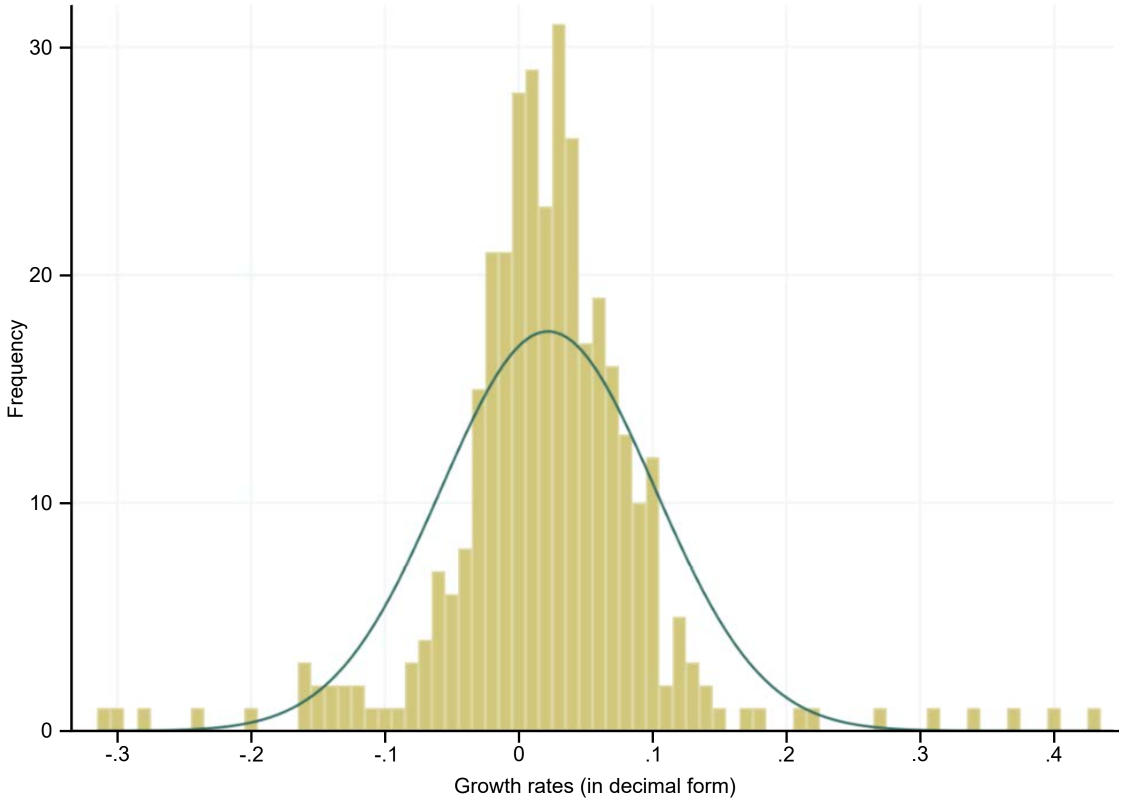
Country	Mean (μ)	Std. Dev. (σ)	J-B Test	P value
Algeria	0.020	0.022	2.40	0.30
Angola	0.005	0.051	0.14	0.93
Azerbaijan	0.029	0.147	26.35	0.00
Bahrain	0.022	0.054	3.35	0.19
Bolivia	0.017	0.027	86.74	0.00
Brunei	0.014	0.036	1.40	0.50
Cameroon	0.016	0.016	1.56	0.46
Chad	0.028	0.175	0.39	0.82
Colombia	0.020	0.024	16.06	0.00
Rep. Congo	0.0007	0.077	0.51	0.77
Ecuador	0.013	0.034	14.75	0.00
Eq. Guinea	0.044	0.107	27.42	0.00
Gabon	0.002	0.033	3.79	0.15
Ghana	−0.063	0.251	10.05	0.01
Iran	0.014	0.041	0.72	0.70
Iraq	0.016	0.066	3.42	0.18
Kazakhstan	0.052	0.046	2.12	0.35
Kuwait	0.007	0.070	1.34	0.51
Malaysia	0.044	0.026	21.06	0.00
Nigeria	0.036	0.138	7.72	0.02
Oman	0.038	0.047	0.66	0.72
Qatar	0.091	0.153	0.74	0.69
Russia	0.039	0.051	2.86	0.24
Saudi Arabia	0.038	0.048	1.61	0.45
Sudan	−0.001	0.058	1.17	0.56
United Arab Emirates	−0.020	0.124	4.31	0.12

Notes: Under the null hypothesis of a normal distribution, the Jarque-Bera statistic follows a χ^2 distribution with two degrees of freedom. The normality hypothesis is not rejected for the countries in boldface.

5.1. Pooled and Country-Specific Risk-Free Discount Rates

We initially investigate the risk-free discount rate, as outlined in Equation (12), and we can do so by utilizing cross-sectional or individual country-level data. First, we focus on a cross-sectional framework. The distribution of yearly growth rates of per capita gross consumption is plotted in Figure 3, revealing a normal distribution.

Figure 3. Frequency of gross consumption per capita (pooled data) for countries normally distributed.



Note: The blue curve is the normal distribution curve corresponding to the pooled data encompassing all years and the 18 countries highlighted in Table 1.

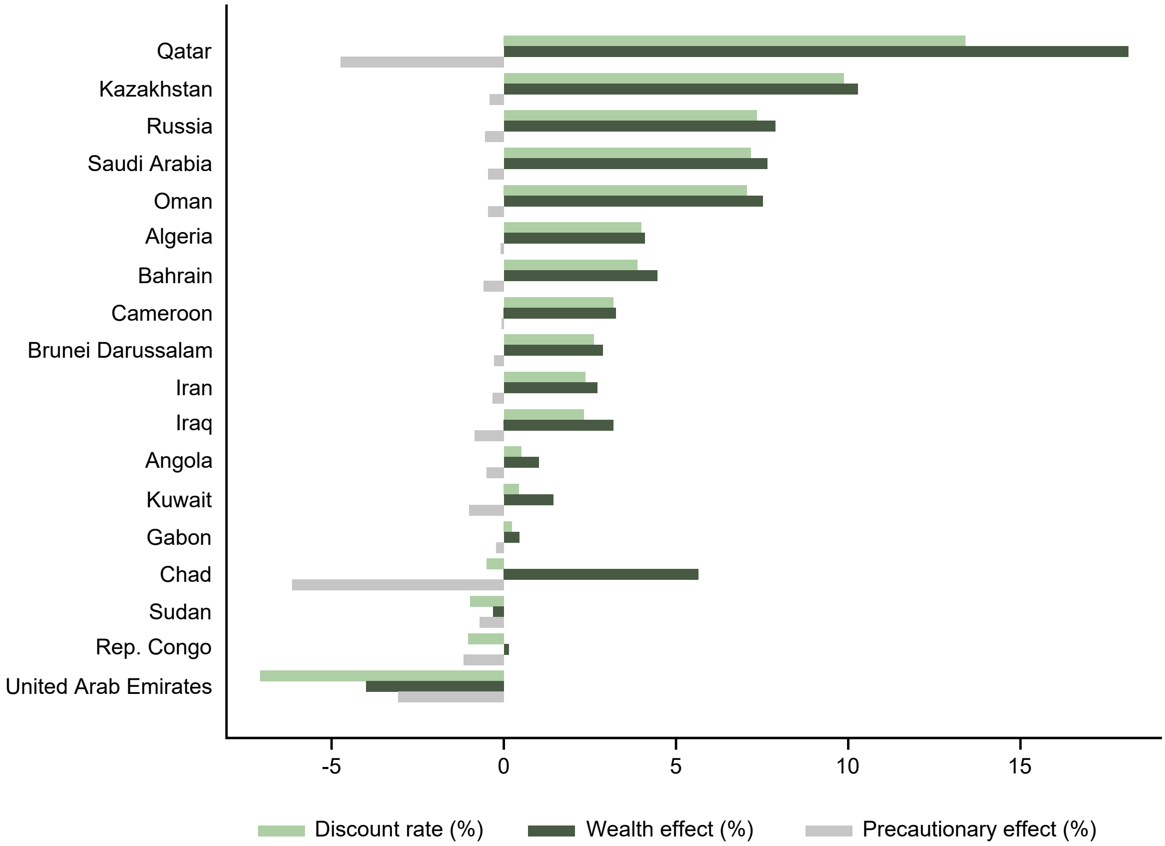
Source: KAPSARC

Using our pooled data, the obtained values for the risk-free discount rate, along with a breakdown of wealth and precautionary effects, are presented in Table 2.[19] Note that the expected consumption growth rate and the variance in it are calculated using historical (1999-2020) per capita consumption data. In other words, in our numerical illustrations, we assume that in the future, consumption will exhibit characteristics similar to those observed in the past. For a relative risk aversion of 2, we find a risk-free discount rate of 3.1% in real terms for our panel of oil-exporting countries. However, the cross-sectional approach ignores country-specific characteristics and assumes complete homogeneity for the discount rate. Although our sample consists of emerging and developing oil-exporting countries and has some degree of homogeneity, there is still a need to calculate discount rates at the country level, as the consumption characteristics (mean and variance) in each country are likely to present differences, yielding different wealth and precautionary effects.

Table 2. Pooled data of risk-free discount rates (r_f).

α	Wealth effect (%)	Precautionary effect (%)	Discount rate (%)
1	2.17	−0.32	1.85
2	4.35	−1.26	3.09
3	6.52	−2.84	3.68

Figure 4. Risk-free discount rates for oil exporters.



Source: KAPSARC

We now use the values reported in Table 1 to calibrate the risk-free discount rate for each country. The results presented in Figure 4 suggest that a significant disparity exists between the country-specific risk-free discount rates. Note that the mean value of discount rates across countries is 3.14%, which is a value close to that calculated for the combined sample, as reported in Table 2.

Qatar exhibits a significantly elevated discount rate of 13%. Similarly, countries such as Russia, Saudi Arabia and Oman have relatively high discount rates, hovering around 7%. These higher rates are attributable to the rapid and steady growth in per capita consumption, which amplifies the wealth effect and diminishes the precautionary effect in absolute terms. Given that higher discount rates reduce the NPV of future cash flows, in these countries, choosing a risk-free discount rate that is too low (compared to the values depicted in Figure 4) may result in the implementation of safe public investment projects that would otherwise be deemed unvaluable. Conversely, in the case of the United Arab Emirates, we observe an unrealistically low negative discount rate. This result is attributable to the aforementioned financial and real estate crises experienced by the country in 2009 and 2010, which had an impact on both the mean and standard deviation of consumption growth.[20]

5.2. Calculating the Oil-Price Risk Premium

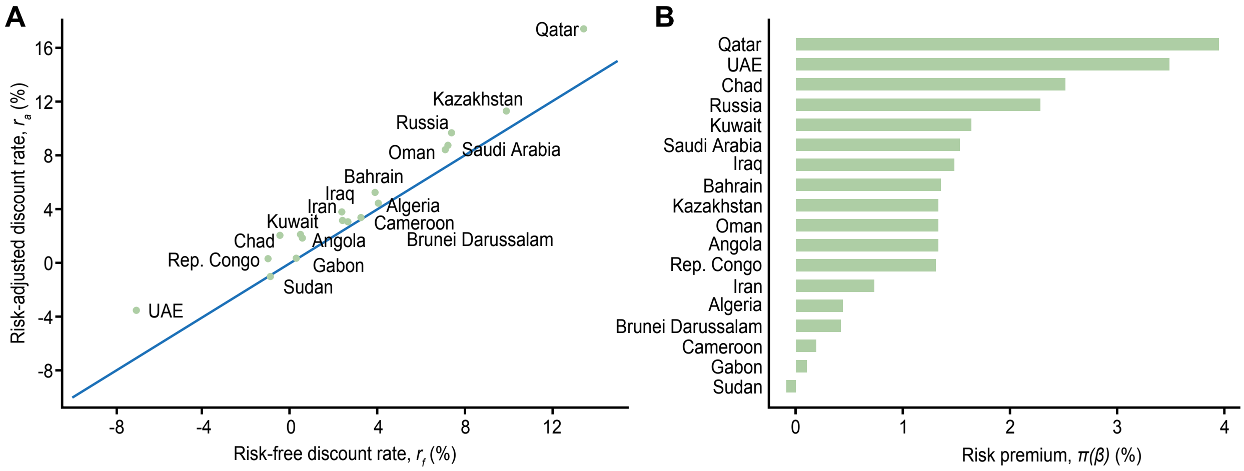
The discount rates calculated in the previous section should be applied to projects whose cash flows are not correlated with consumption. However, as mentioned earlier, this is likely not the case for oil-related projects. The statistics published by the Organization of the Petroleum Exporting Countries (OPEC) for its member nations reveal that in 2021, Saudi Arabia's oil exports accounted for a quarter of its GDP and more than 70% of its total exports. Similarly, approximately 80% of Kuwait's export revenues are derived from oil. For economies that are highly dependent on oil revenues, these figures raise the question of the magnitude of the risk premium associated with the crude oil price. Indeed, as shown in Figure B.1 in Appendix B, oil prices and consumption levels are significantly correlated for most oil-exporting countries. A corollary of this observation is that macroeconomic risks are impacted when projects changing oil exports are undertaken.

Table 3. Calculated country-specific real public discount rates.

Country	Risk-free discount rate (r_f) for cash flows not correlated with aggregate consumption (%)	Risk-adjusted discount rate (r_a) for oil-related cash flows (%)
Algeria	3.99	4.43
Angola	0.51	1.83
Bahrain	3.87	5.22
Brunei Darussalam	2.61	3.03
Cameroon	3.19	3.37
Chad	−0.51	2.02
Gabon	0.23	0.33
Iraq	2.32	3.81
Iran	2.37	3.11
Kazakhstan	9.88	11.21
Kuwait	0.43	2.09
Oman	7.06	8.39
Qatar	13.42	17.37
Rep. Congo	−1.04	0.26
Russia	7.35	9.64
Saudi Arabia	7.19	8.73
Sudan[1]	−0.97	−1.06
United Arab Emirates[2]	−7.07	−3.57

Notes:
[1] Sudan's oil production was divided by four, following the independence of South Sudan in 2011.
[2] Excluding 2009 and 2010, when Dubai was hit by financial and real estate crises, yielding a risk-free discount rate of 0.85% and a risk-adjusted discount rate of 3.93%.

Figure 5. Risk-free versus risk-adjusted discount rates.



Notes: The risk premium is the difference between the risk-adjusted and risk-free discount rates. A relative risk aversion of 2 is assumed.

Source: KAPSARC

Table 4. Comparison of the project's β values.

Country	β	$\beta - \frac{\alpha}{2}$ ($\alpha = 2$)	$\beta - \frac{\alpha}{2}$ ($\alpha = 1$)
Algeria	4.69	3.69	4.19
Angola	2.57	1.57	2.07
Bahrain	2.35	1.35	1.85
Brunei Darussalam	1.63	0.63	1.13
Cameroon	3.63	2.63	3.13
Chad	0.41	**−0.59**	**−0.09**
Gabon	0.48	**−0.52**	**−0.02**
Iraq	1.74	0.74	1.24
Iran	2.19	1.19	1.69
Kazakhstan	3.17	2.17	2.67
Kuwait	1.67	0.67	1.17
Oman	2.99	1.99	2.49
Qatar	0.84	**−0.16**	0.34
Rep. Congo	1.11	0.11	0.61
Russia	4.33	3.33	3.83
Saudi Arabia	3.39	2.39	2.89
Sudan	−0.13	**−1.13**	**−0.63**
United Arab Emirates	1.14	0.14	0.64

Notes:

$\beta - \frac{\alpha}{2} < 0$ *for the countries in boldface.*

Table 3 presents both the risk-free and risk-adjusted discount rates that we calculate for 18 countries (in real terms). We also provide a scatterplot of the risk-free discount rates against the risk-adjusted discount rates in Figure 5(A) and the risk premium (i.e., $\pi(\beta)$) in Figure 5(B). In every country except Sudan, the relationship between the growth rates of per capita gross consumption and oil prices shows a positive covariance, yielding a positive β (see Table 4). This finding indicates a positive risk premium, averaging 1.4% in our panel.[21] As the covariance between gross consumption and oil prices increases, the corresponding risk premium that needs to be taken into account also increases. In this case, the implementation of any oil-related public project would increase the overall risk associated with aggregate consumption, and variations in the cash flows of the project amplify economic fluctuations. Under these circumstances, when evaluating the expected cash flows of oil-related investments, it becomes necessary for decision-makers to utilize a risk-adjusted discount rate that exceeds the risk-free discount rate.

Table 4 presents the β values computed for each country for $\alpha = 1$ and $\alpha = 2$. The average consumption β is found to be 2.12, highlighting that per capita aggregate consumption strongly covaries with oil prices. Furthermore, for all countries except Chad, Gabon, Qatar and Sudan, $\beta - \frac{\alpha}{2}$ is positive, indicating that the precautionary effect, which increases with α, is overshadowed by the risk premium, which increases with β.

5.3. Is There a Link Between Economic Diversification and Discount Rates?

To gain a better understanding of the factors that can explain the abovementioned disparities in public discount rates, let us now consider two key indicators that measure a country's economic stability and resilience.[22] The first is the share of oil (and gas) revenues in national income. Oil revenues provide a major source of income for funding public investments. However, reliance on oil revenues makes countries vulnerable to external shocks and fluctuations in global oil prices. The second indicator that we consider is export diversification, which can help mitigate adverse terms of trade shocks, as it allows countries to spread economic risks across a broader range of products and markets.

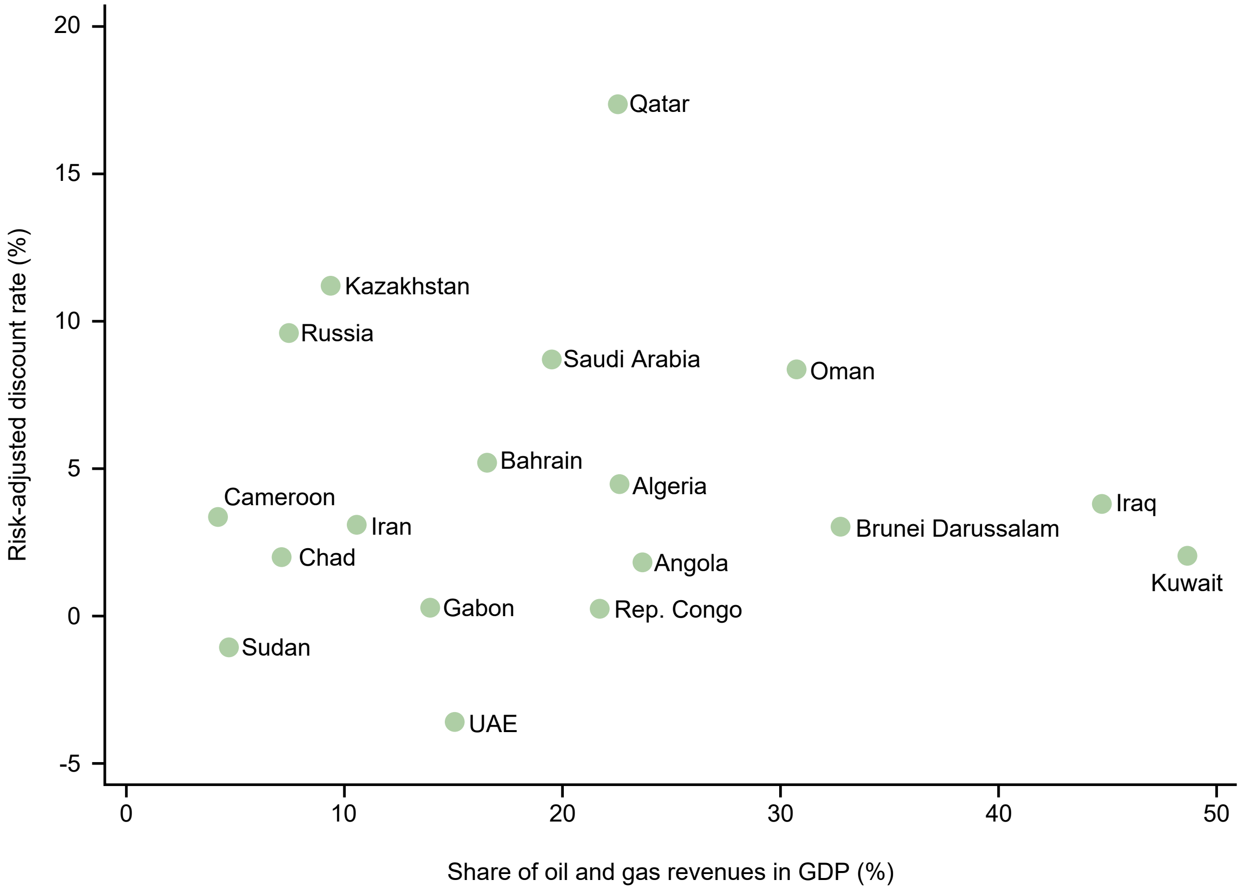
As Equation (19) suggests, two conflicting factors come into play in determining the risk-adjusted discount rate. First, a significant reliance on oil exports and a high share of oil in GDP tend to make the economy more unstable, thereby reducing the risk-free public rate. However, this tendency also results in a stronger connection between macroeconomic indicators and the price of oil, leading to an increase in the risk premium associated with oil prices, which in turn is added to the risk-free discount rate. Ultimately, the critical question is which of these effects takes precedence.

Figure 6 shows a scatterplot of the risk-adjusted discount rates and the average share of oil and gas revenues in GDP over the period considered. It indicates that there is no correlation between the two. This lack of correlation is attributable to the fact that relying on the average values of revenue shares does not provide insight into the volatility of these revenues.

Now, let us consider the relationship between export diversification and the risk-adjusted discount rate. Figure 7 shows that less export diversification (more export concentration) tends to result in lower public discount rates.

Most oil-exporting countries rely on a small number of export products for a large portion of their total exports. In a recent study, Karanfil and Omgba (2023) showed that the impact of the COVID-19 pandemic on oil-exporting countries was less severe for those with a higher level of export diversification. Indeed, poorly

Figure 6. Oil and gas revenues and risk-adjusted discount rates for oil exporters.

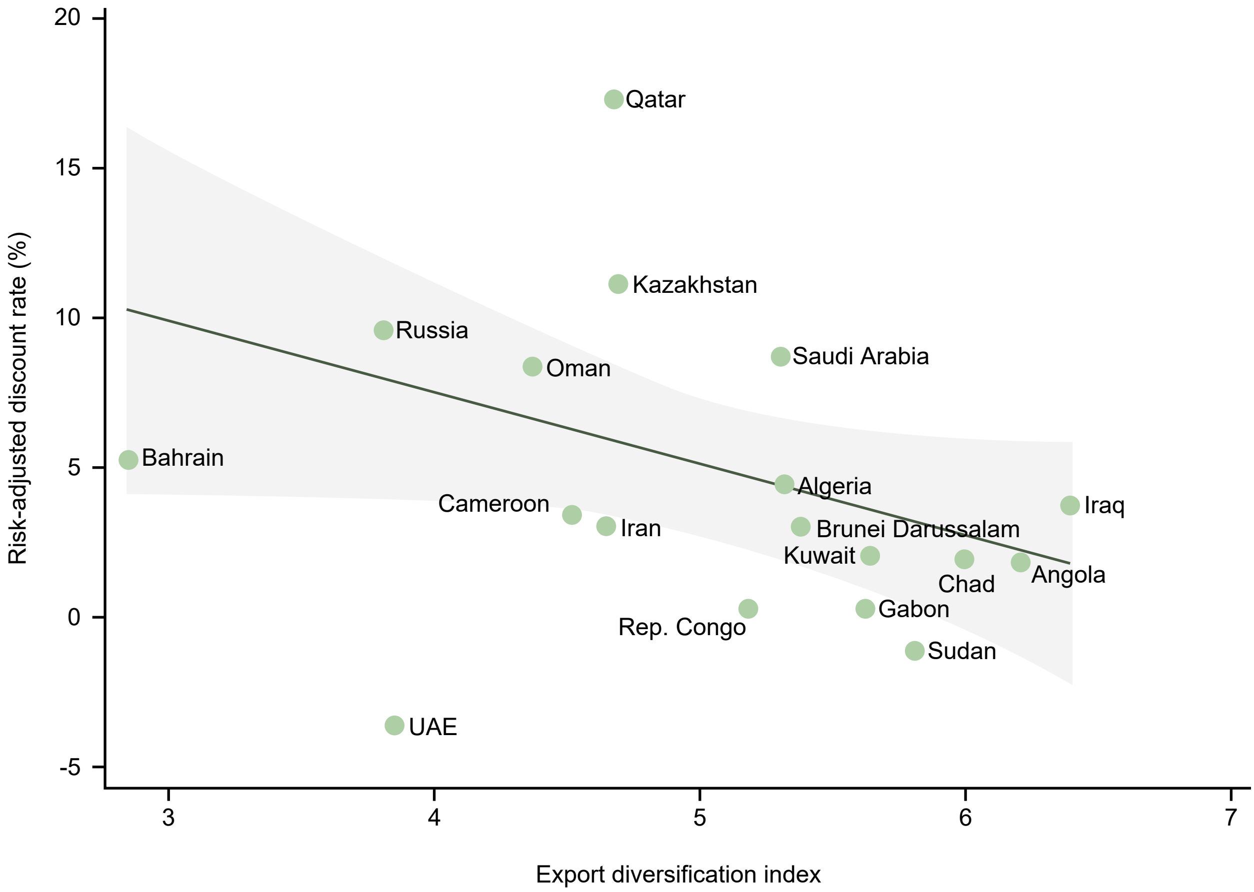


Notes: The fiscal oil and gas revenues of the countries were compiled by Durand-Lasserve and Karanfil (2023) utilizing country reports by the International Monetary Fund (IMF) and national sources.

Source: KAPSARC

diversified economies, regardless of their specific export portfolios, are generally unable to offset a decline in revenue from one product by increasing revenues from other exports. Consequently, a lack of export diversification increases countries' vulnerability and volatility in future aggregate consumption, leading to an elevated precautionary effect that ultimately lowers public discount rates.

Figure 7. Risk-adjusted discount rate and export diversification.



Notes: The export diversification index is from the IMF (2018). The latest available data (year = 2014) are used. Higher diversification index values indicate less diversification (i.e., more export concentration). The dark green line shows the linear regression's fitted values (the slope coefficient is -2.38 and significant at the 5% level with robust standard errors). The shaded area indicates the 95% confidence interval. For the reasons already stated, the United Arab Emirates is considered an outlier and is excluded from the regression.

Source: KAPSARC

5.4. Short- and Long-Term Effects of Combining the Risk Premium and the Opportunity Cost

The observations above beg the following question: How do our results materially impact the public valuation of future oil-related cash flows?

Based on the framework described in Section 4.3, we can define a risk premium coefficient (φ_t) as follows:

$$\varphi_t = 1 - e^{-\pi(\beta)t}. \tag{20}$$

Then, the risk premium in year t amounts to the fraction φ_t of the risky cash flow. In our case, the certainty equivalent of a cash flow from one barrel of oil (q = 1) in year t is given by $(1-\varphi_t)\gamma P_t = e^{-\pi(\beta)t}\gamma P_t$, assuming that the opportunity cost parameter γ remains constant over time. As we already computed $\pi(\beta)$ in Section 5.2, we need to determine γ for each country using Equations (2) and (3). Regarding the price elasticity of global demand (ε_d) and the supply

Table 5. Certainty equivalent of the cash flow generated by exporting a barrel (expressed as a percentage of the oil price).

Country	Market share (ρ) (%)	Risk premium $\pi(\beta)$ (%)	Opportunity cost as a fraction (γ) of the world oil price: Short run	Opportunity cost as a fraction (γ) of the world oil price: Long run	Certainty equivalent as % of the world price: Short run (T = 1)	Certainty equivalent as % of the world price: Long run (T = 20)
Algeria	1.47	0.44	0.92	0.97	92	88.6
Angola	1.19	1.33	0.94	0.97	92.6	74.7
Bahrain	0.2	1.36	0.99	1.00	97.7	75.9
Brunei	0.09	0.42	1.00	1.00	99.1	91.8
Cameroon	0.06	0.19	1.00	1.00	99.5	96.2
Chad	0.09	2.53	1.00	1.00	97.1	60.2
Gabon	0.19	0.1	0.99	1.00	98.9	97.6
Iraq	4.57	1.48	0.76	0.90	75.2	66.8
Iran	3.61	0.74	0.81	0.92	80.8	79.4
Kazakhstan	1.82	1.33	0.91	0.96	89.4	73.5
Kuwait	3.02	1.65	0.84	0.93	83.1	67.1
Oman	1.07	1.33	0.95	0.98	93.2	74.8
Qatar	1.8	3.95	0.91	0.96	87.2	43.6
Rep. Congo	0.02	1.31	1.00	1.00	98.6	77
Russia	11.1	2.29	0.41	0.75	40.5	47.5
Saudi Arabia	12.43	1.54	0.34	0.72	33.7	52.9
Sudan	0.06	−0.09	1.00	1.00	99.8	101.6
United Arab Emirates	4.19	3.49	0.78	0.91	75.6	45.1
Average	2.61	1.41	0.86	0.94	85.2	73

Notes:
The shares of countries in the world oil market pertain to 2022.
The short-term (one-year) risk premium corresponds to the values depicted in Figure 5(B).

elasticity of other producers (ε_s), we employ values consistent with recent research.[23] Specifically, for the short run, we utilize $\varepsilon_d = -0.14$ and $\varepsilon_s = 0.056$, while for the long run, we use $\varepsilon_d = -0.35$ and $\varepsilon_s = 0.11$. On the other hand, we calculate the countries' market shares of global output (ρ) in 2022 using oil supply data from the International Energy Agency (IEA 2023). The results are reported in Table 5.

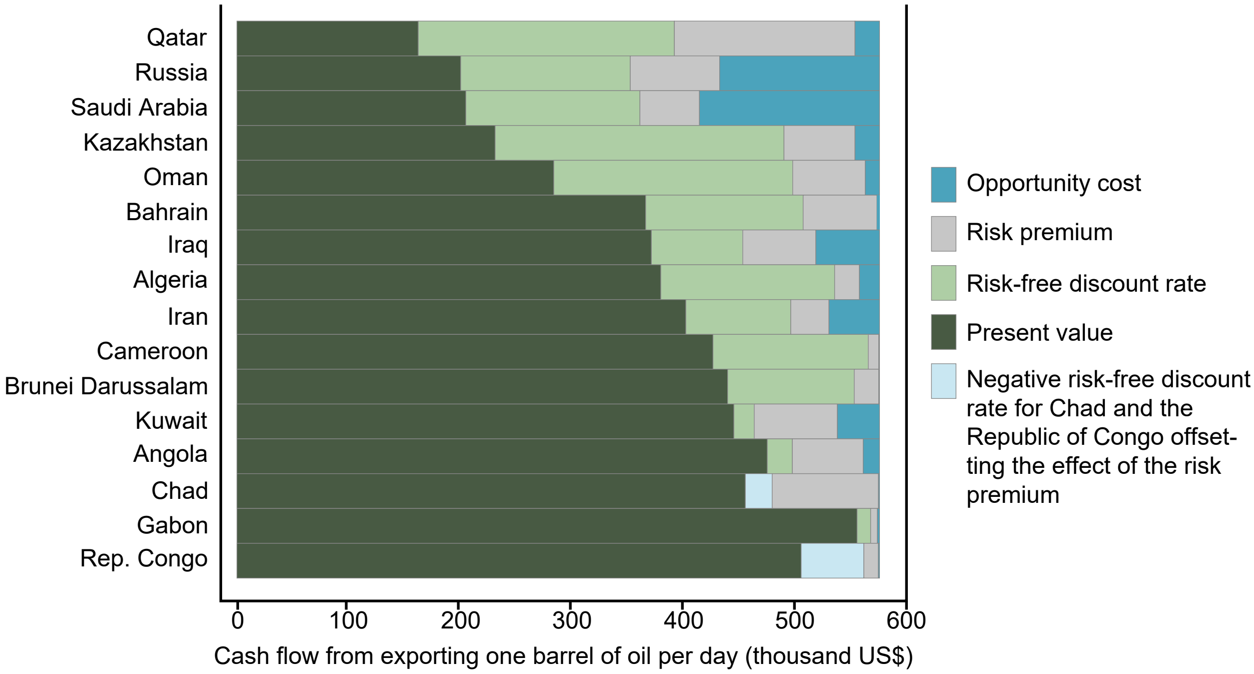
According to Equations (2) and (3), countries with larger market shares experience a lower opportunity cost of oil. For countries with a small market share, the opportunity cost aligns with the international price of oil. For other countries, over the long run, the opportunity cost moves closer to the international price, primarily due to the influence of higher elasticities. The last two columns of Table 5 indicate that, on average, the certainty equivalent of one barrel of oil, valued at its opportunity cost, amounts to 85% of the international price in the short run (one year). However, as the risk premium increases over time, the average certainty equivalent diminishes even further to 73% when evaluating a project with a 20-year lifespan. Based on these findings, accounting for the risk premium and opportunity cost can substantially reduce the profitability of oil-related projects.

5.5. Quantifying the Three Effects Through a Scenario-Based Analysis

Our final analysis in this paper provides a numerical illustration of our framework that involves a public investment project in an oil-exporting country that aims to save a barrel of oil per day from domestic consumption, subsequently sold in the global market. Using the risk-adjusted discount rates (as computed in Section 5.2 and depicted in Figure 5(A)) and the opportunity cost of oil (as presented in Table 5) while considering the 2023-2040 period, we can compute the present value of the cash flows generated by exporting one barrel of oil per day as $\sum_{t=1}^{18} e^{-r_a t} 365 \gamma E[P_t]$. Here, we use the IEA's (2022) Stated Energy Policies Scenario (STEPS) for future oil prices presented in its "World Energy Outlook." STEPS can be characterized as a business-as-usual approach, reflecting the trajectory implied by existing policy settings. According to STEPS, the real oil price falls from its high levels in 2022 and settles at US$82 per barrel by 2030. It then shows a gradual increase, reaching US$84 per barrel by 2035 and ultimately reaching US$88 per barrel by 2040 (in 2021 US$).

For each country in our sample, Figure 8 presents the projected cumulative cash flows over the 2023-2040 period. Considering that oil is sold at the world price projected by STEPS, the undiscounted cumulative cash flows amount to US$577 thousand by 2040 for every country. To decompose the different effects identified in this paper, we successively deduct the reduction in revenues due to the opportunity cost, risk premium and risk-free discount rate. The blue bars show the impact of opportunity costs on cash flows based on the international price ($\sum(1-\gamma)P_t$). Russia and Saudi Arabia, which are the major players in the global oil market, experience a significant impact, with Russia "losing" 25% and Saudi Arabia "losing" 28% of the undiscounted cumulative cash flow. The impact of the risk premium ($\sum \varphi_t \gamma P_t$) is represented by gray bars. The risk premium is very high for Qatar because of the significant comovement of oil prices and gross consumption in the country (see Figure 5(B)). Overall, for the countries depicted in Figure 8, the cumulative cash flows are reduced by more than 16% as a result of the combined effects of the opportunity cost and risk premium. The effect of the risk-free discount rate ($\sum(e^{-\pi(\beta)t} - e^{-r_a t})\gamma P_t$) is illustrated by light green bars. The dark green bars are the resulting[24] present value of the cumulative cash flows ($\sum e^{-r_a t} \gamma P_t$). Despite the positive risk premium observed in all countries, the presence of a negative risk-free discount rate for Chad and the Republic of Congo offsets the effect of the risk premium on cash flows (indicated by the light blue areas) for these two countries. On average, the combination of the three effects leads to a present value that is 35% lower than the undiscounted cumulative cash flows. The GCC countries in Figure 8 are significantly affected, with an average decrease of nearly 50%. The present value of the annual cumulative cash flows derived from exporting one barrel per day varies between US$162 thousand (Qatar) and US$563 thousand (Republic of Congo), with an average of US$375 thousand.

Figure 8. The decomposition of the effects of the opportunity cost, risk premium and risk-free discount rate on the value of exporting a barrel of oil per day from 2023 to 2040.



Notes: The results are obtained for country-specific long-run elasticities (ε_x) and the resulting g coefficients, as presented in Table 5. The real (in 2021 US$) world oil prices ($P_t$) are as projected in the IEA's (2022) STEPS. Due to negative risk-adjusted discount rates, the present value of cumulative cash flows for Sudan and the United Arab Emirates surpasses the undiscounted cash flows. Consequently, these countries are not included in the figure.

Source: KAPSARC

In this paper, we estimate public discount rates for energy transition-related projects that displace oil from domestic consumption. For each country, the present value calculated above can also be used to inform public decision-making regarding the development of new oil production capacity. From a public policy perspective, an oilfield development project will be profitable if, on a barrel-per-day basis, the calculated present value exceeds the sum of the investment cost required to build the corresponding production capacity and the discounted operating expenses incurred when producing over the period considered.

6. Conclusion

In this paper, we study the discounting and valuation of investment projects from the perspective of public policy decision-making in oil-exporting countries. Economic dependence on oil introduces opposite effects on the public discount rate for oil-related cash flows. It both increases overall economic volatility (decreasing the risk-free discount rate) and raises the correlation between aggregate consumption and the oil price (resulting in a greater risk premium). To investigate these opposite effects and their impact on the valuation of oil-related cash flows, our analysis incorporates three key components. These components encompass the consideration of economic uncertainty, quantified by the variance in gross consumption; an oil price-related risk premium, measured by the covariance between the growth rates of consumption and the oil price; and the assessment of the opportunity cost of oil, which is determined as incremental revenue.

For our panel of oil-exporting countries, we find that a risk-free discount rate of 3.1% can be applied to cash flows that exhibit no correlation with gross consumption. Except for Sudan, the growth rates of per capita consumption and oil prices exhibit a positive covariance, resulting in a positive risk premium. On average, this risk premium amounts to 1.4%. These values result in a risk-adjusted real discount rate of 4.5% for the panel.

Significant differences in discount rates are observed among countries. Our analysis reveals that the absence of export diversification amplifies the volatility of aggregate consumption. This increase in volatility results in an increased need for precautionary saving, which in turn reduces the risk-free public discount rate.

The consumption β of investment projects displacing oil from domestic consumption is significantly high for the majority of countries, with an average value of 2.12. For all countries except Chad, Gabon, Qatar and Sudan, the risk premium exceeds the precautionary effect.

For each country in our panel, we determine the present value of exporting a barrel of oil per day from 2023 to 2040, disentangling the various effects at play. We show that, on average, the individual impacts of the opportunity cost, risk premium and riskless discount rate account for 6%, 10.5% and 18.5% of the cumulative undiscounted cash flows, respectively. The cumulative impact of these three effects results in a present value that is 35% lower than the undiscounted sum of cash flows, with a greater impact for GCC countries.

Our estimates are especially useful for policymakers in oil-rich countries considering investment projects or policies that free oil from domestic consumption or that use oil as an input. The estimates enable governments to perform more accurate cost-benefit analyses, ensuring that the decisions made enhance welfare and economic development. This is especially critical for oil-exporting countries pursuing domestic energy transitions and industrial development.

Endnotes

[1] For example, in the third quarter of 2022, oil revenues accounted for 75.9% of Saudi Arabia's total government revenues (SAMA 2022); the International Monetary Fund estimates that in 2022, oil revenues constituted 95.1% and 54.7% of total government revenues in Iraq and the United Arab Emirates, respectively (IMF 2022, 2023).

[2] The risk-free discount rate refers to the public discount rate used for valuing cash flows that are not correlated with per capita consumption. From a public policy perspective, calculating the present value of cash flows correlated with per capita consumption requires adding a risk premium to the risk-free discount rate.

[3] For example, production quotas, logistical constraints, international sanctions, commercial obligations or the need to finance imports through oil export revenues.

[4] Throughout this paper, we employ the terms "social discount rate" and "public discount rate" interchangeably.

[5] We refer to Campos et al. (2015) for a comprehensive review of research on social discount rates.

[6] Final general government consumption expenditures include all current government expenditures for the purchase of goods and services, which includes employee compensation. Expenditures also include spending on national defense and security, with the exclusion of military expenditures classified under government capital formation.

[7] While per capita gross consumption is expressed in 2015 US$, Brent prices are in 2022 US$. The results are not affected by the difference in the base year, as we consider the growth rates of both variables.

[8] In this categorization, the World Bank (2018) uses average export shares from 2012 to 2014. Based on the availability of data from the World Bank, the 26 countries that satisfy this condition and are included in the analysis are Algeria, Angola, Azerbaijan, Bahrain, Bolivia, Brunei Darussalam, Cameroon, Chad, Colombia, Ecuador, Equatorial Guinea, Gabon, Ghana, Iran, Iraq, Kazakhstan, Kuwait, Malaysia, Nigeria, Oman, Qatar, the Republic of Congo, Russia, Saudi Arabia, Sudan and the United Arab Emirates.

[9] We express our gratitude to Christian Gollier for discussing this question and confirming that considering only citizens of GCC countries to calculate per capita consumption is a reasonable fix. This approach, which has been selected because, numerically, it better reflects the actual evolution of these economies, does not assume that policymakers disregard the welfare of expatriate workers.

[10] We use data from national statistical offices as well as international institutions (World Bank and United Nations Global Migration databases) to estimate the number of citizens in each GCC country.

[11] Although there has been a prolonged discussion surrounding the value of δ (which falls beyond the scope of our paper), there is a general tendency in public economics literature to consider $\delta = 0$. In his seminal paper, Ramsey makes the same assumption and claims, "it is assumed that we do not discount later enjoyments in comparison with earlier ones, a practice which is ethically indefensible and arises merely from the weakness of the imagination" (Ramsey 1928). Ramsey's recommendation to treat the utility of different generations equally is widely adopted (e.g., Gollier 2008, 2013a; Solow 1974; Weitzman 2010).

[12] Karanfil and Pierru (2021) determine opportunity cost formulas for different sets of assumptions. We present only the formula derived when domestic oil prices are set by the government, which is a common practice in oil-exporting countries.

[13] In evaluating commodity-based investment projects, it is a common practice to assume that the commodity price follows a geometric Brownian motion (Pindyck 2001).

[14] For this approximation to hold, the growth rate of consumption needs to be normally distributed. See Gollier (2013a) for a proof.

[15] See Gollier (2013a) for a derivation of a similar equation.

[16] β can be obtained by regressing the growth rate of the oil price against the growth rate of aggregate consumption. It measures the inverse of aggregate consumption elasticity with respect to oil cash flows. A parallel can be drawn between the consumption β derived here and the market b derived with the capital asset pricing model (CAPM) to value assets from a market perspective. The risk premium depends on the correlation between asset returns and the (diversified) market portfolio. The CAPM determines a company's equity cost at the market equilibrium, and the company discounts free cash flows at its weighted average cost of capital.

[17] Note that this condition for the project to increase welfare remains the same if all cash flows are expressed in total rather than per capita terms.

[18] Although the question of why the consumption growths of some countries have a normal distribution whereas others do not is interesting from an empirical perspective, it falls beyond the scope of this paper.

[19] We conduct a set of unit root tests, including cross-sectional dependence tests, to verify the statistical properties of the series. All unreported results are available upon request.

[20] Excluding the two years of economic contraction from the analysis, we observe that per capita gross consumption in the United Arab Emirates exhibits a standard deviation of 0.085 and a mean of 0.012. These figures correspond to a positive risk-free discount rate of 0.85%, with a wealth effect of 2.3% and a precautionary effect of –1.45%.

[21] In a study focusing on Saudi Arabia, Pierru and Matar (2014) used real per capita gross consumption data covering the 1987-2010 period and found that for a relative risk aversion coefficient of 2, the risk premium falls within the range of 1.27% to 1.69%. For the same country, our results indicate a risk premium of 1.54%.

[22] In this section, illustrations are provided for the risk-adjusted discount rates. In unreported results, we find that our conclusions hold true if risk-free discount rates are used.

[23] See Almutairi et al. (2023) and Karanfil and Pierru (2021), where the elasticity values considered are from Caldara et al. (2019).

[24] The cumulative undiscounted cash flow is equal to the sum of the opportunity cost effect, risk premium effect, risk-free discount rate effect and present value since we have the following: $\sum P_t = \sum (1-\gamma) P_t + \sum \varphi_t \gamma P_t + \sum (e^{-\pi(\beta)t} - e^{-r_a t}) \gamma P_t + \sum e^{-r_a t} \gamma P_t$.

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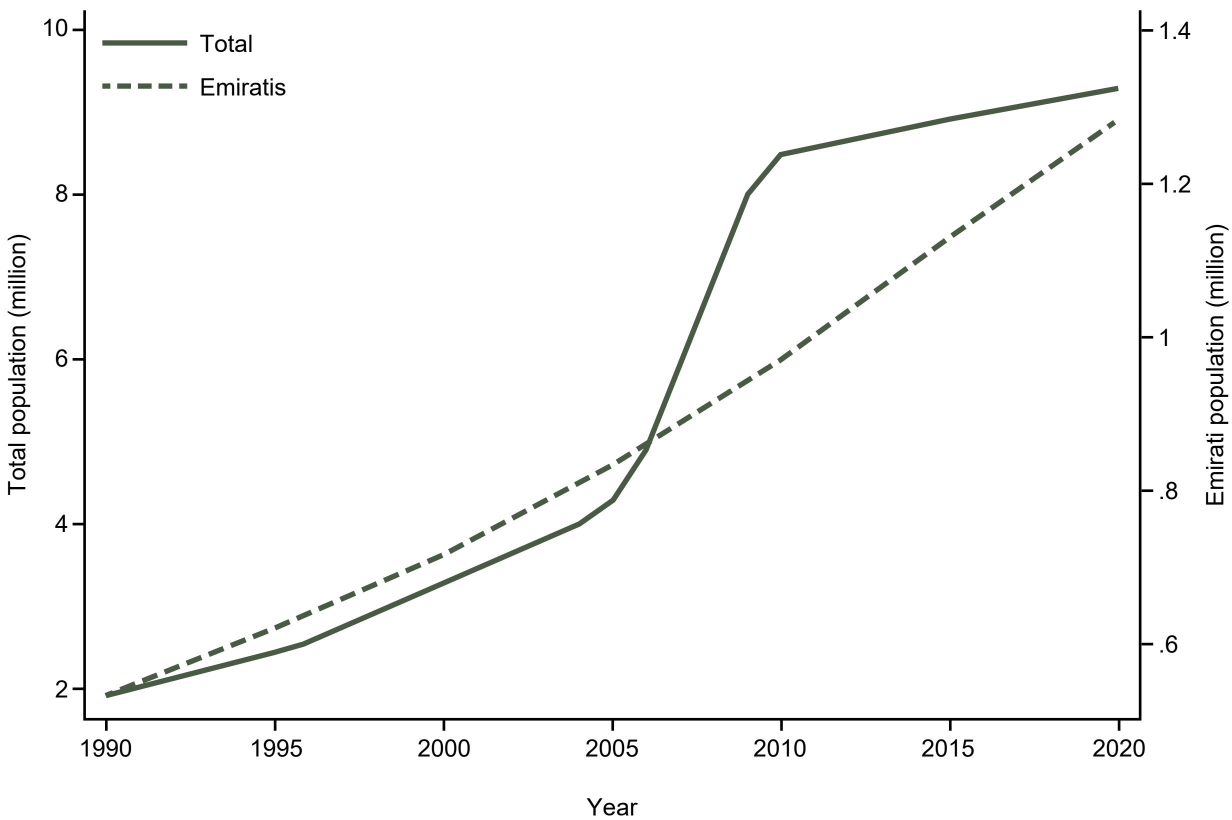
Appendix A: Considering Expatriate Workers in Population

Figure A.1. The evolution of the total population and Emirati citizens in the United Arab Emirates.

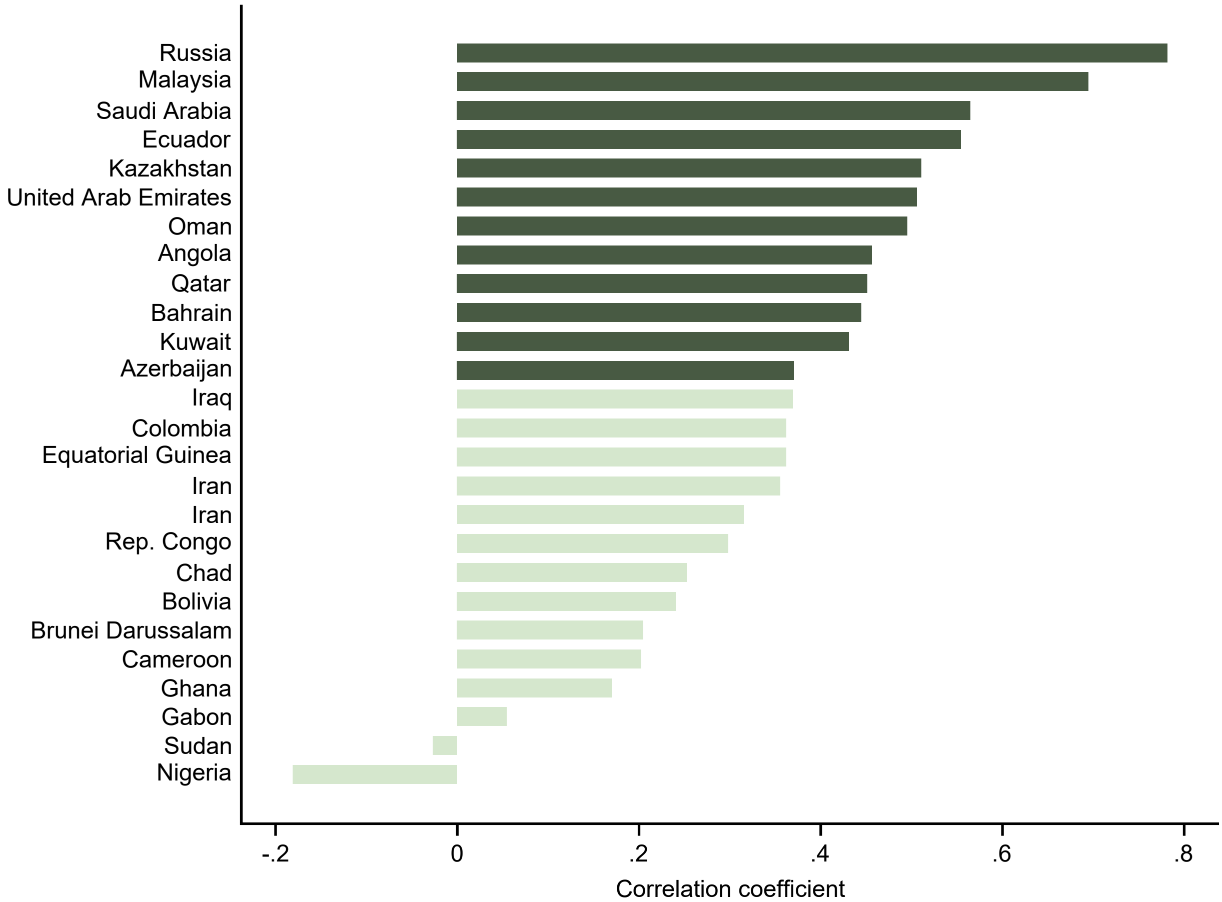


Source: Authors' calculations based on the World Bank and the United Arab Emirates National Bureau of Statistics.

Appendix B: Further Insights Into the Consumption-Oil Price Relationship

Figure B.1 demonstrates that the per capita gross consumption of all GCC countries is correlated with oil prices. Examining the GCC panel in Figure B.2 reveals a stronger correlation when the annual growth rate of oil prices falls within the range of 10% to 30%. However, consumption exhibits more resistance to downward changes. A decline in per capita consumption is evident only in the event of a significant drop in oil prices exceeding 40%. The regression analysis needs to be interpreted with caution, as pooled regression does not capture heterogeneous (country-specific) effects.

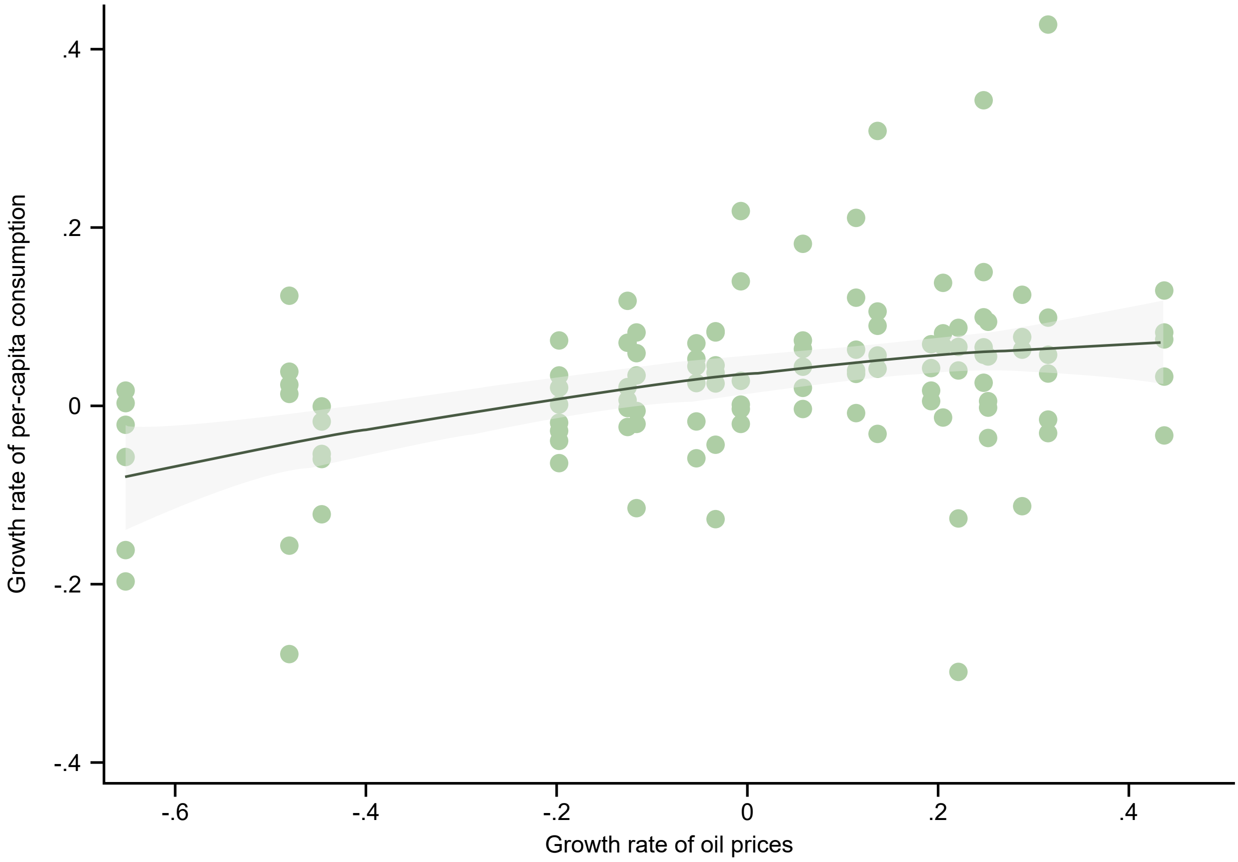
Figure B.1. Correlation coefficients between the growth rates of oil prices and per capita gross consumption.



Notes: Results are reported for the full panel (26 countries). Correlation coefficients significant at the 10% level are shown by darker bars.

Source: KAPSARC.

Figure B.2. Growth rates of oil prices and per capita gross consumption in GCC countries.



Notes: Yearly growth rates are from 1999 to 2020. The green line plots the fitted values of a quadratic regression on pooled data. The 95% confidence interval is shown in gray shading.

Source: KAPSARC

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Notes

Notes

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Fatih's current work mainly focuses on developing economic frameworks to provide insights into energy policymaking in oil-producing countries, particularly Saudi Arabia. His research has been published in general-interest economics journals and leading journals in energy economics.

He received his Ph.D. in Economics from University of Paris 1 Panthéon-Sorbonne in 2008, and prior to that, he completed an M.A. in Economic Analysis and Modeling from the University of Paris 1 Panthéon-Sorbonne and École Centrale Paris in 2005.

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About the Project

This research contributes to the broader project titled "Shadow Pricing of Resources," which aims to investigate how the specific characteristics of oil-dependent economies impact the evaluation of projects from a public perspective.

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