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The Energy Transition and Export Diversification in Oil-Dependent Countries: The Role of Structural Factors

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Key Points

The energy transition toward decarbonization is expected to impact producers of fossil fuels. However, oil-exporting countries are currently key players in the modern economy. Thus, the energy transition will not be successful if state revenues in these countries are not stably maintained. These countries can protect themselves against revenue volatility and mitigate carbon risk by diversifying their economies. However, export diversification appears to be particularly challenging for many oil-producing countries. It is natural to ask why some oil-exporting countries have managed to diversify their economies whereas others have not. We hypothesize that the differences in oil producers' diversification patterns may be associated with differences in their structural characteristics. Such differences may cause countries' diversification trends to diverge. To investigate this hypothesis, we examine whether all countries converge toward the same diversification level. We also check whether their diversification efforts diverge overall but create separate convergence clubs. The results show that structural and institutional factors play a central role in the diversification process. In particular, countries with higher quality infrastructure, human capital and research and development efforts are more likely to converge toward high diversification. Thus, these factors provide greater resilience in turbulent times and promote a successful energy transition.

1. Introduction

Carbon-emitting exhaustible resources (including oil and gas) contribute substantially to the economic prosperity of oil-exporting countries. For example, carbon assets represent 40% of total wealth in Middle Eastern and North African countries (Lange, Wodon and Carey 2012). World Bank World Development Indicators (WB WDI) from 2019 indicate that natural gas and oil rents comprise 18% of these countries' gross domestic product (GDP). However, critical evaluations suggest that, on average, economies that depend on oil revenues have not benefited greatly from exploiting their natural endowments.

Oil producers face various challenges in managing their wealth. For example, the 'Dutch disease' describes the phenomenon in which a resource boom leads to negative economic consequences. These consequences can include increased demand and prices for non-traded goods, real exchange rate appreciation and reduced competitiveness in non-resource and tradable sectors. Oil producers must also cope with the volatility of resource revenues, weak institutions and governance and limited transferability of skills, among other issues. These specific challenges of resource-rich countries are collectively viewed through the analytical framework of the resource curse (Auty 2007).

Atkinson and Hamilton (2003), Alexeev and Conrad (2009), Frankel (2010), Van der Ploeg (2011) and Ross (2015) provide surveys of studies on the resource curse. Although this literature has not reached a consensus, oil-producing countries are expected to face new challenges related to climate change and the global energy transition. Indeed, the global roadmap to reduce the use of hydrocarbons calls for a structural shift and transition to low-carbon and resilient models of economic development. This impending shift is enshrined in countries' nationally determined contributions under the 2015 Paris Climate Change Agreement.[1] Additionally, more than 70 countries, which are responsible for about 76% of global emissions, have pledged to achieve net-zero carbon emissions (United Nations 2020). This emerging scenario may impact global oil market fundamentals and, thus, will affect oil-producing countries' long-term investment and development plans (Jackson and Jackson 2021; Rioux et al. 2022). The recent coronavirus pandemic offered a preview of the economic consequences that oil producers may face if hydrocarbon revenues fall.

Oil producers can mitigate this new set of challenges by diversifying their economies. For these countries, diversification can transform hydrocarbon revenues into other forms of assets and protect their economies from commodity price volatility. According to the IEA (2018), the diversification of oil economies can also ensure the security of the global economy during the energy transition. However, export diversification appears particularly challenging for many oil producers. For some of these economies (e.g., Algeria, Angola and Kuwait), oil and gas comprise over 75% of total exports. Nevertheless, some countries have made progress toward export diversification. For example, oil and gas revenues were less than 20% of total exports for the United Arab Emirates (UAE) in 2019[2] (IEA 2021a). These results raise the question of why some oil-exporting countries have been able to diversify their economies and others have not.

In this study, we hypothesize that differences in structural characteristics can generate differences in oil producers' diversification paths. These structural factors may include infrastructure, human development, macroeconomic stability and financial conditions. Differences in these factors may explain why economies that exploit the same natural resource, oil, may have significantly different export baskets. Moreover, some countries with similar initial characteristics may converge toward the same level of diversification, whereas other countries' diversification paths may diverge. To test this hypothesis, we first investigate whether oil-exporting countries' diversification efforts are converging over time. Then, we examine whether the diversification paths of individual countries create convergence clubs with different steady-state levels of diversification.

We also investigate the factors driving the formation of convergence clubs and discuss how they can help improve oil-exporting countries' resilience in the future. We find that improvements in the commercial and financial fields are associated with greater odds of inclusion in a high diversification club. Good institutional quality and infrastructure are also correlated with greater economic diversification. Countries with higher human capital stocks and levels of research and development (R&D) tend to fall into a higher diversification club as well. However, economies with adverse macroeconomic conditions, such as high inflationary economic environments, are more likely to fall into a low diversification club.

By focusing on oil producers' export diversification patterns, this study contributes to the literature on diversification in resource-rich countries. Such analyses are rare but can provide valuable insights into the dynamics of the relationships among resource abundance, diversification and economic development. Many prior studies recognize the importance of diversification in early stages of development (Imbs and Wacziarg 2003; Cadot, Carrère and Strauss-Kahn 2010; Gylfason and Wijkman 2015). However, most studies of the relationship between natural resource endowment and development focus on the resource curse.

Export diversification is thought to be important for reducing the impact of the resource curse (Ghoddusi and Wirl 2021). However, as Hausmann, Klinger, and Lopez-Calix (2010) note, factors related to the resource curse do not always explain differences in oil producers' export concentration levels. Along similar lines, Cherif and Hasanov (2016) find that recommended diversification policies may not produce the expected effects in oil producers. This result arises because the diversification of these economies mainly depends on the initial technological gap and the importance of oil revenues. Furthermore, Djimeu and Omgba (2019) argue that oil producers' diversification trajectories are determined by factors that governed their economies before an oil price or volume boom. Thus, an oil boom can harm export diversification in countries with low initial levels of diversification. However, it may not affect export diversification for countries with high initial diversification levels.

This study builds on these previous studies by investigating export diversification patterns in oil-producing countries. We highlight the existence of convergence clubs at different diversification levels among oil-producing countries. We also emphasize the role of export diversification in oil producers during this era of energy transition.

The rest of this paper is organized as follows. Section 2 discusses the benefits of export diversification for oil producers by illustrating the role of diversification in resilience to the coronavirus pandemic's economic consequences. Section 3 presents the analysis and our results. We first investigate the heterogeneity in diversification levels among oil producers. Then, we test whether oil producers converge to the same level of diversification. We also check whether diversification patterns vary across different convergence clubs. Finally, we examine the underlying factors that affect the likelihood that a given oil producer will move from a low-level to a high-level diversification club. Section 4 concludes.

2. Benefits of Export Diversification for Oil Producers: The Coronavirus Pandemic

The coronavirus pandemic has illuminated economies' vulnerability to external shocks. Although every economy has faced risks due to the pandemic, they have not all suffered equally. The unanticipated economic consequences of the pandemic have allowed economies that depend on oil revenues to assess their resilience. They have been able to observe firsthand the enhancing role of diversification during a major and abrupt change in the economic environment.

The economic shocks generated by the coronavirus pandemic exposed oil producers to price volatility, which is a fundamental element of these economies' vulnerability. Traditionally, when these economies benefit from favorable prices, they perform well. Most of these countries' governments set procyclical policies, increasing government expenditures and investments when prices are high to boost economic growth (Kaminsky, Reinhart, and Vegh 2004). However, collapsing oil prices often result in economic slumps in these countries (Van der Ploeg and Poelheke 2010). During the pandemic, a global economic downturn, which was accompanied by a sudden drop in global oil demand, led to an oil price collapse. This collapse increased pressure on public finance in oil-producing countries, as these governments' budgets and spending largely depend on revenues from oil exports (World Bank 2020a).

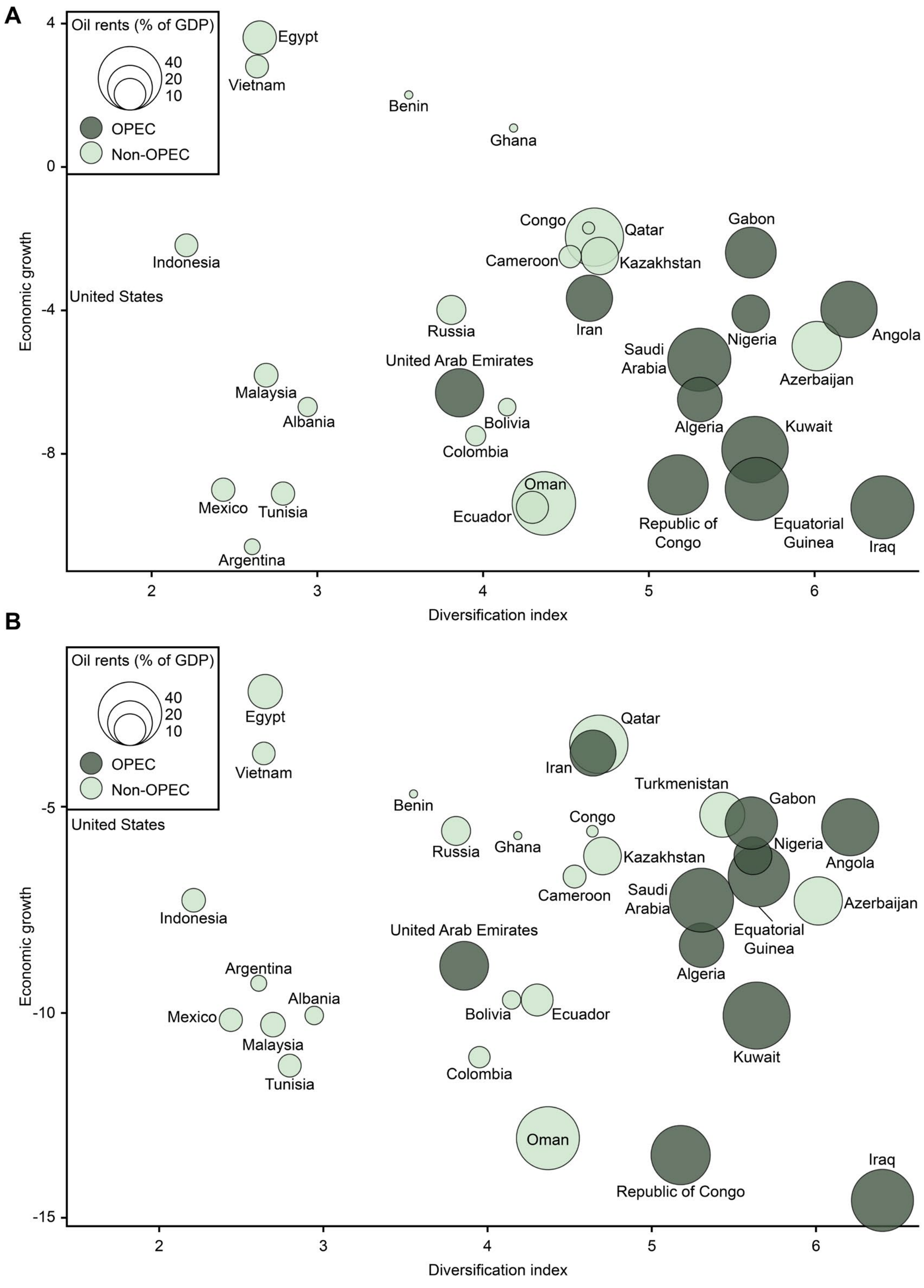
Oil prices have declined sharply in the past. For example, oil prices dropped about 72% from $112 per barrel in June 2014 to $31 per barrel in January 2016.[3] Ideally, a volatile oil price environment should create significant incentives for oil producers to increase their share of non-oil exports in total exports. In other words, policymakers in these countries should have already been prioritizing export diversification. However, recent empirical studies suggest that oil producers nevertheless exhibit higher export concentration levels than their non-oil counterparts do on average (Djimeu and Omgba 2019; Ross 2019).

In this context, an empirical assessment of export diversification's role in economic growth and development, especially in the face of global disturbances, is important. Such an analysis can help oil-exporting countries better understand the relevance of adopting diversification policies. The unanticipated economic consequences resulting from the ongoing coronavirus pandemic allow us to assess the effectiveness of diversification strategies. Specifically, we investigate whether diversification has improved the resilience of oil-exporting countries to the global economic downturn caused by the pandemic. We use projections of economic growth for 2020 before and after the pandemic hit to measure countries' resilience.

Figure 1 illustrates the relationship between the export diversification index and economic growth in 2020. Our main sample includes 31 countries with positive net oil exports for most of the period from 1981 to 2014. For illustrative purposes, we also include some oil-exporting countries (e.g., former Soviet states, the United States) that do not fully satisfy these conditions. We return to this idea when we discuss the empirical results. However, using alternative samples does not meaningfully affect the conclusions of this analysis.

The diversification index used for Figure 1 and throughout this study is taken from the International

Figure 1. Economic growth and export diversification among oil producers in 2020.



Source: Authors' calculations based on data from World Bank and IMF.
Notes: Economic growth (Figure 1(a) reflects the World Bank's GDP growth estimates for 2020 (World Bank 2021). Growth adjustments (Figure 1(b)) are the difference between the World Bank's 2020 growth forecasts released in January 2020 (World Bank 2020b) and the growth estimates released in January 2021 (World Bank 2021). Diversification index values are based on 2014 data (IMF 2018). Bubble sizes indicate the share of oil rents in GDP. Average shares of oil rents over the period from 1981 to 2018 are calculated using data from the WB WDI. The World Bank (2020b, 2021) provides no GDP forecasts for Norway and the United Kingdom, which had diversification indexes of 3.8 and 1.95, respectively, in 2014.

Monetary Fund (IMF) (2018). We use the Theil diversification index, which is one of the most commonly used measures of export diversification (Cadot, Carrère, and Strauss-Kahn 2010). The index is constructed such that higher values indicate higher export concentrations (i.e., less export diversification). The index accounts for variations in exports at both the extensive and intensive margins. Diversification at the extensive margin occurs when the number of new products exported or the number of new markets increases. Diversification at the intensive margin occurs when export revenues across existing export products become more evenly distributed.

The compositions of export portfolios (i.e., the types of products in the export basket) also affect the vulnerability of countries' economies. The diversification index that we use in this study does not fully capture changes in export portfolio composition. However, it is adequate for assessing countries' exposures to commodity trade shocks. Economies that rely on the exports of only a few commodities are undoubtedly more vulnerable than other economies. These economies are vulnerable to changes in both demand and supply. If a country exports only a few products, fluctuations in the demand for its products can bring high volatility to its export earnings. An increase in competition or a drop in its market share because of new entrants can greatly affect revenues. On the supply side, disruptions in supply chains or exogenous shocks affecting the country's production capacity can also create instability in export revenues. Countries with only a few export products cannot compensate for a drop in revenues from one product with an increase in other export revenues. In general, this principle holds for all poorly diversified economies, regardless of their export portfolios.

In Figure 1, we use GDP growth rate forecasts for 2020 obtained from the World Bank's Global Economic Prospects to measure economic growth (World Bank 2021). The pandemic's impact on economic growth can also be measured using 2020 growth adjustments rather than 2020 growth forecasts. Growth adjustments may capture the effects of the pandemic more accurately. Hence, we use earlier GDP growth rate forecasts for 2020 from the World Bank (2020b) to reflect growth expectations just before the pandemic's onset. We then calculate growth adjustments by subtracting growth expectations just before the pandemic from the later growth estimates from the World Bank (2021). Figures 1(a) and 1(b) provide scatterplots of these growth forecasts and adjustments relative to export diversification levels.

We can draw several important conclusions from Figure 1. First, it provides evidence that countries with less export diversification (i.e., higher diversification indexes) suffered more from the global economic crisis caused by the pandemic. Second, as expected, the figure shows that countries with higher oil rents as a percentage of GDP have lower diversification levels. All OPEC members[4] tend to have lower diversification levels. Only the United Arab Emirates seems to have been somewhat more successful in diversifying its export base, as we discuss later in the paper.

Additionally, the figure indicates that some countries, such as Argentina, Mexico and Tunisia, appear to fall outside of the standard diversification–economic resilience relationship. They have high diversification levels but are among the countries that were hit hardest by the pandemic. A possible explanation for this observation is that these countries also had some of the highest mortality rates from the COVID-19 pandemic. Thus, the health crisis seems to have had a more profound effect on these countries' economies during the pandemic. Figure A.1 in Appendix A provides the pandemic mortality rates of the countries depicted in Figure 1.[5]

To complement these results, we study the differential impact of diversification on employment. Resilience is a polysemous notion used in several disciplines, such as ecology, economics and physics (Martin 2012; Martin and Gardiner 2019; De Siano, Sciabolazza, and Sapio 2020). Here, we adopt the approach of Martin (2012), who investigates the disparities in economic prosperity following a recessionary disturbance, with a focus on employment. However, unlike Martin (2012), who focuses on the regional level, we consider resilience from a macroeconomic perspective.

For the analysis, we use cross-country data on employment from the International Labour Organization (ILO). We estimate an ordinary least squares (OLS) regression with lost working hours owing to the coronavirus pandemic as the dependent variable and export diversification as the independent variable. Table 1 shows that when the export concentration increases (i.e., the diversification index is higher), lost working hours increase. Thus, countries with greater diversification were more resilient with respect to employment during the coronavirus pandemic.[6]

Further, Table 1 confirms the above argument that the economies of countries that were hit hardest by the health crisis suffered more severely. Specifically, we find that the mortality rate is positively associated with lost working hours during the pandemic.

Overall, the data from Figure 1 and Table 1 suggest that oil-exporting countries can benefit from export diversification in uncertain and challenging times. Figure 1 clearly illustrates the benefit of export diversification for countries that rely predominantly on oil for their incomes. This result corroborates Gelb's (2010) finding that Malaysia and Indonesia have succeeded in avoiding the resource curse by diversifying their exports. Additionally, carbon accumulation is likely to decelerate further after the pandemic through increased investments in and consumption of clean energy (IEA 2020, 2021b). This trend will impact energy markets and has implications for economic policymaking in oil-rich countries. Thus, the current pandemic, the clean energy transition and the prospects for the future of oil resources necessitate urgent responses. However, as Figure 1 shows, oil-exporting economies have made limited progress in diversifying their exports. The key question is why some oil-exporting countries have somewhat succeeded in diversifying their economies, whereas others have experienced slow and insufficient progress. The next section investigates this question empirically.

Table 1. Diversification and employment during the coronavirus pandemic.

Variable	Coefficient
Diversification index	0.847** (0.409)
Mortality rate	0.009*** (0.002)
Constant	3.881* (1.988)
No. of obs.	31
R^2	0.47

Source: Authors.
Notes: The dependent variable is working hours lost in 2020 owing to the COVID-19 crisis. This indicator is estimated by the ILO and represents the percentage of hours lost relative to the baseline, adjusting for the population aged 15–64. The baseline is the latest pre-crisis quarter, that is, the fourth quarter of 2019, seasonally adjusted. Higher values of the diversification index imply lower levels of diversification. Robust standard errors are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively. Obs = observations.

3. Empirical Analysis

We hypothesize that the observed differences in diversification patterns among oil producers may be associated with differences in their structural characteristics. Such differences may cause countries' diversification trends to diverge. Some countries with similar initial characteristics may converge toward the same steady state, whereas others may diverge toward different equilibria. Countries with different initial characteristics are also likely to diverge. To investigate these possibilities, we examine whether all countries converge toward the same diversification level. We also check whether their diversification efforts diverge as a whole but create separate convergence clubs.

We consider the period from 1981 to 2014, as our diversification data are available for these years. We select countries to analyze based on their net oil export positions. In our main sample, countries are classified as oil exporters if they are net oil exporters during the majority of the study period. We exclude oil-exporting countries that do not fully satisfy this condition. We also exclude countries for which diversification data are not available (e.g., former Soviet states). Based on this definition and classification, we include 31 countries in our sample. Table C.2 in Appendix C provides the list of countries in the sample and descriptive statistics of their net oil exports.

3.1. Testing for Global Convergence and Identifying Convergence Clubs

We start by testing for global convergence using the convergence club test developed by Phillips and Sul (2007, 2009). This test allows us to account for heterogeneous transitional dynamics over time. It uses a stepwise clustering algorithm to identify convergence clusters within a panel dataset and examines the transition paths between clusters. This approach to convergence, which is also called the $\log(t)$ test, has become popular and is widely used. It offers several advantages over more traditional tests, such as beta and sigma convergence tests and unit root and cointegration tests.[7] For example, it does not require any particular assumption about the order of integration of the panel data. As this test has been used in previous convergence studies, we describe its features only briefly. We refer the reader to Phillips and Sul (2007, 2009) for more details.

We consider the diversification index series for country i and year t, denoted DI_{it}. A model of this series based on a single factor can be written as follows:

$$DI_{it} = \delta_{it}\mu_t. \tag{1}$$

Here, δ_{it} measures the idiosyncratic distance between the single common trend component μ_t and the systematic part of DI_{it}. To allow for the heterogeneous evolution of cross-sections, we model the idiosyncratic distance in Equation (1) as evolving over time. Thus, it can capture each cross section's deviation from the common component. We model δ_{it} as follows:

$$\delta_{it} = \delta_i + \frac{\sigma_i \xi_{it}}{L(t)t^{\alpha}}. \tag{2}$$

Here, δ_i is fixed, $\xi_{it} \sim iid(0,1)$ across cross-sections but is weakly time-dependent[8] and stationary over t, and α is the speed of convergence. The function $L(t)$ is slowly-varying such that $L(t) \to \infty$ as $t \to \infty$. In line with the literature, we define $L(t) = \log(t)$. The null hypothesis of convergence can be written as $\mathcal{H}_0 : \delta_i = \delta$ with $\alpha \geq 0$. Hence, the alternative hypothesis is $\mathcal{H}_A : \delta_i \neq \delta$ with $\alpha < 0$ for all cross sections.

Following Phillips and Sul (2007), we estimate δ_i using the following equation:

$$h_{it} = \frac{DI_{it}}{\frac{1}{N}\sum_{i=1}^{N} DI_{it}} = \frac{\delta_{it}}{\frac{1}{N}\sum_{i=1}^{N}\delta_{it}}. \qquad (3)$$

Here, h_{it} is a series of relative transition parameters measuring δ_{it} with respect to the average of a panel with *N* cross sections. This average must differ from zero. Note that from Equation (3), the cross-sectional mean of h_{it} is unity by definition. Then, using Equation (3), the cross-sectional variance ratio is constructed as follows:

$$H_t = \frac{1}{N}\sum_{i=1}^{N}\left(h_{it} - 1\right)^2. \qquad (4)$$

If δ_{it} converges to δ, then the relative transition parameters converge to unity. Thus, from Equation (4), the cross-sectional variance converges to zero. Phillips and Sul (2007) use this property to test the convergence hypothesis and group the cross-sections into convergence clusters. Finally, we estimate an OLS regression on the dispersion of the relative transition parameters defined in Equation (4).

$$\log\left(\frac{H_1}{H_t}\right) - 2\log L(t) = \hat{a} + \hat{b}\log(t) + \hat{u}_t, \qquad (5)$$

where $\hat{u}_t$ is the error term. The fitted coefficient of $\log(t)$ is $\hat{b} = 2\hat{\alpha}$, where $\hat{\alpha}$ is the estimate of α in Equation (2). Using the $\log(t)$ test, if the t-statistic associated with $\hat{b}$ is below –1.65, the null hypothesis of convergence is rejected at the 5% significance level.

In the case of global divergence, local convergence to multiple equilibria may still occur. In other words, we may observe clustering behavior such that countries' diversification patterns converge within certain subgroups. Phillips and Sul (2007, 2009) suggest a step-by-step procedure for identifying such convergence clubs in a panel. The proposed algorithm consists of estimating repeated $\log(t)$ regressions (see Equation [5]) with cross sections added or removed to create convergence clubs. The algorithm stops when the only cross sections that remain do not belong to any of the identified convergence clubs. These cross sections are then classified as divergent. As this procedure may overestimate the number of clubs, we also perform a club merging exercise. This process consists of iteratively running joint $\log(t)$ tests on neighboring clubs and merging them if the test statistic is greater than –1.65 (Schnurbus, Haupt, and Meier 2017).

Based on this method, we first examine whether oil-exporting countries' diversification efforts as a whole have been converging over time.[9] Table 2 provides the results. The *t*-statistic for this analysis, –37.25, is well below –1.65, suggesting that the null hypothesis of convergence can be rejected.[10]

Next, we employ Phillips and Sul's (2007, 2009) clustering algorithm to investigate whether groups of countries converge within different clubs. Table 3 reports the results of running this algorithm. The *t*-statistics suggest that three different convergence clubs exist. We then test whether any sets of the three clubs can be merged to form a bigger convergence club. The results of this analysis, shown in Table 4, indicate that the clubs in Table 3 are robust and should not be merged.

Table 2. Global convergence test results.

Variable	Coefficient ($\hat{b}$)	*t*-statistic
$log(t)$	–0.79	–37.25

Source: Authors.

Table 3. Tests for convergence clubs.

Convergence club	Average *DI*	Coefficient ($\hat{b}$)	*t*-statistic	Members
Club 1	5.12	–0.08	–0.95	Algeria, Angola, Bolivia, Cameroon, Republic of Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Norway, Qatar, Saudi Arabia, Venezuela
Club 2	3.92	0.13	1.63	Argentina, Colombia, Congo, Ecuador, Oman
Club 3	3.00	0.32	3.28	Benin, Canada, Egypt, Indonesia, Malaysia, Mexico, Tunisia, United Arab Emirates, United Kingdom, Vietnam

Source: Authors.

Table 4. Results of the club merging test.

Merging test	Coefficient ($\hat{b}$)	*t*-statistic
Club 1 + Club 2	–0.37	–8.25
Club 2 + Club 3	–0.21	–3.48

Source: Authors.

To check that the results are not driven by our choice of sample, we perform the same analysis for several different samples. First, we drop countries that are marginally oil exporters based on Table C.2 in Appendix C from our initial panel. The excluded countries are Benin, Vietnam, Congo, Bolivia, Tunisia, Cameroon and Argentina. Second, we exclude countries that are not always net oil exporters throughout the sample period. This sample excludes Argentina, Benin, Bolivia, Canada, Colombia, Egypt, Equatorial Guinea, Indonesia, the United Kingdom and Vietnam. Third, we add 19 oil-importing countries to our initial panel, resulting in a panel of 50 countries. Finally, we include only countries whose oil rents accounted for at least 5% of their GDPs on average from 1981 to 2014 (World Bank 2014). Appendix D shows that our results are robust to all these alternative sample selection rules.

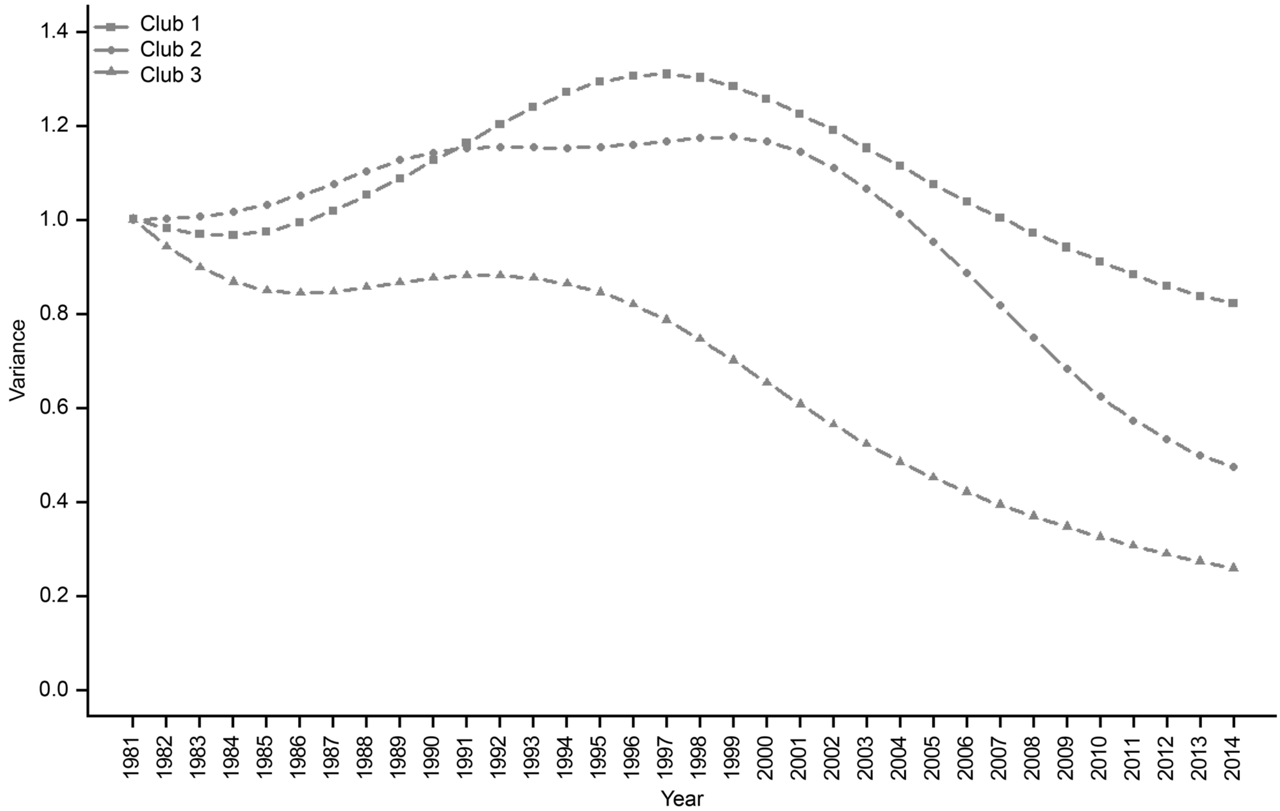
As the second column of Table 3 shows, Club 1 includes countries whose export diversification performance has been poor for more than three decades. Although the *t*-statistic (–0.95) for this club is greater than –1.65, it is still negative. According to Phillips and Sul's (2007, 2009) interpretation, this club can be considered to have its own convergence pattern with weak transitional divergence. In other words, the transitions of countries in this club follow different paths. For instance, as Figure B.1(a) in Appendix B shows, some countries, such as Bolivia and Nigeria, initially diverge but then catch up and converge. Other countries, such as Iraq and Venezuela, end up diverging from the common trend. As Figure 2 indicates, this club has the highest variance in transition parameters. The dispersion in the diversification index increased significantly until 1997 (i.e., divergence). However, it has decreased over the last 15 years (i.e., catch up and convergence).

Notably, all OPEC countries except for the United Arab Emirates belong to Club 1. This finding corroborates the conclusions derived from Figure 1 regarding OPEC members and the United Arab Emirates. An interesting example country in this cluster is Norway. As mentioned above, its diversification efforts have not been successful, as its economy has remained largely undiversified. In 1981, Norway's Theil diversification index was 2.9. In 2014, this index reached 3.8, showing that the concentration of its export baskets has increased over time. Venezuela's diversification has exhibited a similar trend, having increased from 5.2 in 1981 to 5.9 in 2014. Figure B.1(a) shows the countries' transition curves.

Club 2 includes countries with more volatile patterns and relatively low speeds of convergence (i.e., $\hat{\alpha} = \frac{\hat{b}}{2} = 0.07$). Until the early 2000s, the dispersion among the countries in this club increased (i.e., they diverged). Figure 2 shows that since then, however, their dispersion has fallen rapidly (i.e., they are quickly catching up and converging). The countries in this cluster have been converging to a common diversification path since the early 2000s, as Figure B.1(b) illustrates. Within this club, Oman and Congo have improved their export diversification over this period, whereas Colombia has performed more poorly. Colombia's initial diversification index in 1981 was 3.8, and it improved in the early 2000s, achieving an index value of 2.7 in 2005. However, this trend reversed after 2010, and its diversification index was 3.9 in 2014.

Club 3 includes countries with substantial downward trends in the diversification index over the sample period. In other words, these countries have improved their export diversification. Their speed of convergence is also higher (i.e., $\hat{\alpha} = 0.16$). As Figures 2 and A.1(c) show, Club 3's within-club dispersion has been falling since the early 1990s, indicating steady convergence. The variance of the transition parameters decreased by about 75% during the sample period. The United Arab Emirates is a representative example of this club. Its diversification index progressed from 5.7 in 1981 to 3.8 in 2014, reflecting great achievements in diversification.

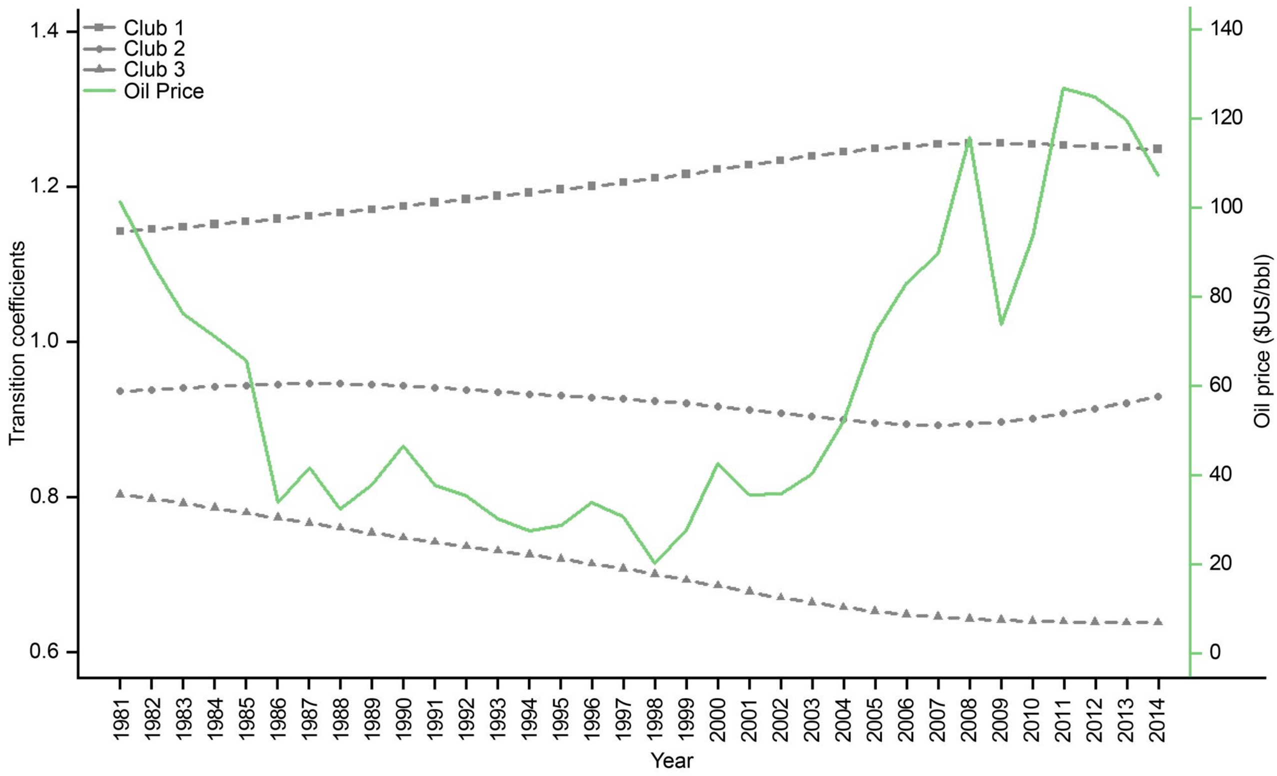
Figure 2. Variances of the transition parameters.



Source: Authors.
Note: The variances for each club are normalized by their 1981 values.

We further illustrate these findings by computing the relative transition coefficients using the average diversification indexes for each club. The results are shown in Figure 3. Following Phillips and Sul (2007, 2009), if a club's relative transition coefficient is greater than one, we conclude that its diversification index is above the steady-state level. The converse holds for relative transition coefficients below one. As the transition curves do not narrow toward unity, we conclude that the three clubs do not converge toward a unique diversification path. Throughout most of the sample period, the transition path of Club 1 diverges away from those of other clubs. It begins slightly converging at the end of the period as its members improve their diversification. Conversely, Club 3 has experienced a continuous downward (and diverging) trend over the sample period, suggesting that its members have steadily improved their export diversification. Finally, diversification efforts in Club 2 appear to fluctuate throughout the period. Its transition path slightly converges to that of Club 1 in recent years, following the spikes in oil prices, indicating reduced diversification.

Figure 3. Oil prices and transition curves among clubs.



Source: Authors' estimates of transition coefficients (left axis) and BP (2020) for oil prices (right axis).
Note: Brent crude oil prices from BP (2020) are given in 2019 U.S. dollars per barrel.

Belonging to a high diversification club is important for economic resilience. As discussed above (see Table 1), highly diversified economies tend to be more resilient in turbulent times. We again investigate the relationship between resilience and diversification, this time using club membership as a proxy for diversification. Specifically, we regress lost working hours due to the COVID-19 crisis on a dummy variable that equals one for countries in Club 3. This club has the highest diversification level. The results are shown in Table E.1 in Appendix E. As expected, we observe a negative and significant correlation between lost working hours and membership in Club 3. Thus, Club 3 members lost fewer working hours on average owing to the pandemic.

3.2. Determinants of Diversification Convergence Clubs

The results obtained in the previous section show that different oil-exporting countries follow different diversification paths. We now seek to identify the determinants of these differences and the extent to which they lead to the formation of the three convergence clubs. To answer these questions, we investigate the interactions between countries' structural characteristics and convergence club membership. In this analysis, the dependent variable is the club to which an oil-exporting country belongs. We define it as an ordinal variable because the clubs can be ranked according to their steady-state diversification levels. Club 1 has the lowest diversification level, and Club 3 includes the countries with the most diversification. Given that we use an ordinal dependent variable, we estimate an ordered logit regression model. This model can determine the extent to which an oil exporter's characteristics are associated with the likelihood that it belongs to one of the three clubs.

We denote club membership as y_i, which takes the values zero, one and two. We assume that it is related to a latent continuous variable y_i^*. In the ordered logit regression model, the variable y_i^* is linearly related to a vector of covariates. Thus, we write:

$$y_i^* = X_i\beta + \varepsilon_i, \tag{6}$$

where X_i is a vector of variables determining each country's club membership and β is a column vector of regression coefficients. ε_i is the error term, which is assumed to follow a standardized logistic distribution. As the dependent variable y_i^* is unobserved, we estimate the model using maximum likelihood techniques. After estimating the model, we can obtain odds ratios as the exponentials of the estimated coefficients in β. A positive (negative) coefficient yields an odds ratio greater (less) than one.

Next, we identify factors that may explain the differences in oil producers' diversification paths and the resulting club memberships. We consider many variables that are frequently used in the literature as factors that may be associated with export diversification patterns. These variables include oil wealth, macroeconomic stability, human capital, research and development (R&D), institutions and infrastructure. We also consider trade openness, population, initial constraints on the economy and economic development (IMF 2017; Djimeu and Omgba 2019; Lashitew, Ross, and Werker 2020). Descriptive statistics and the data sources for all the explanatory variables used in the regressions are provided in Table C.1 in Appendix C. We describe them in more detail as follows.

We use oil reserves and oil production in per capita terms to measure the oil wealth of each country in our panel. As discussed above, oil wealth is usually associated with the 'Dutch disease,' and a booming oil sector generally leads to an increase in export concentration. Furthermore, Ross (2019) indicates that in oil-rich countries, oil sector development offers few spillovers into other sectors. This outcome arises because few other products require the same skills and knowledge as the oil industry.

We use inflation, given by the GDP deflator series from the World Bank, to capture macroeconomic stability. Inflation is an indicator of the quality of macroeconomic policymaking and a government's overall ability to manage its economy (Ndikumana 2000). We expect to observe a negative relationship between export diversification and inflation rates. It can be difficult to invest in new industries in a volatile economic environment, and inflation can act as an implicit tax on investments, impeding a country's diversification (Combes and Ebeke 2011).

We use the primary school enrollment rate as a proxy for human capital, which is expected to increase diversification. Human capital accumulation generally enhances productivity and attracts investment (Gylfason and Nganou 2014). Daniele (2011) shows that dependence on natural resources is associated with lower human development and higher illiteracy. Similarly, R&D expenditures are an important contributor to economic growth. Many studies show that an increase in R&D leads to growth through its positive effects on innovation and total factor productivity (TFP) (Romer 1990).

Export diversification can benefit from these effects. For example, Cirera, Marin, and Markwald (2015) show that R&D expenditures positively affect export diversification for a set of Brazilian firms. Similarly, we expect TFP to be positively correlated with diversification.

We use the rule of law index drawn from the World Bank's Worldwide Governance Indicators (WGI) to capture institutional quality. Inclusive institutions should be conducive to business development and especially private sector investment. As Metcalf and Wolfram (2015) show, better governance is associated with a lower volatility of arbitrary actions toward business. Hence, poor institutional quality may reduce investment in all sectors (Torres, Afonso, and Soares 2012). However, good institutions provide the necessary conditions to encourage diversification (Ebeke, Omgba, and Laajaj 2015). Solid institutions can improve productivity and support new technologies that drive growth (Nelson 2008).

We use access to electricity as a proxy for infrastructure development. Infrastructure provides the basic economic conditions for private sector development outside of the natural resource sector. Thus, it should reduce export concentration and drive industrial growth and diversification (Krane 2015; IMF 2017). We measure trade openness as the share of international trade (i.e., exports plus imports) in GDP. The new trade theory highlights trade as a vector for advanced technology transfers, investment and growth through increasing returns to scale and network effects (Coulibaly, Gnimassoun, and Mignon 2018). Trade openness should therefore have a positive effect on export diversification.

As mentioned above, structural factors may determine export diversification in oil-producing countries. Efforts to ensure effective export diversification may fail if the structure of the economy is not fully understood. Djimeu and Omgba (2019) argue that diversification trends in oil-rich countries are determined by factors that govern or constrain their economies. More specifically, countries with low initial levels of diversification are more likely to remain less diversified. Hence, following Djimeu and Omgba (2019), we control for initial constraints using countries' initial diversification levels.

We also control for countries' economic and financial development levels. We use GDP per capita to reflect the level of development and the domestic credit provided by the financial sector to reflect financial development. Financial development should facilitate credit access for entrepreneurs and, thus, is expected to positively affect the process of economic diversification (IMF 2017). Mahadeva (2014) shows that limited financial development causes governments in resource-rich countries to extract resources more impatiently. Thus, it is more difficult for them to diversify away from natural resource revenues.

Table 5 reports the results of estimating the ordered logit regression model for the determinants of club convergence. As some of the abovementioned variables are correlated, we estimate different model specifications. The estimated coefficients are expressed as odds ratios, which indicate the probability that a country falls into a high rather than a low diversification club. Whereas probabilities range from zero to unity, odds ratios range from zero to infinity. For any explanatory variable, an odds ratio above one means that a one-unit increase in that variable increases the odds of belonging to a high diversification club.

Table 5. Determinants of diversification clubs.

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Initial diversification	0.365*** (0.022)	0.241*** (0.031)	0.367*** (0.04)	0.526*** (0.052)	0.489* (0.062)	0.461*** (0.081)	0.564*** (0.126)	0.242*** (0.032)
GDP per capita		1*** (8.10^{-6})	1*** (8.10^{-6})	1*** (1.10^{-5})	1*** (5.10^{-5})	1*** (2.10^{-5})	1*** (2.10^{-5})	1*** (1.10^{-5})
Electricity		1.091*** (0.026)	1.025*** (0.004)					
Trade		1.05*** (0.007)	1.026*** (0.004)		1.022*** (0.009)	1.024*** (0.008)		
Oil reserves per capita		0.946*** (0.016)			0.861*** (0.031)			
Oil production per capita			1*** 2.10^{-5}	1*** 2.10^{-5}		1*** 2.10^{-5}		
Rule of law				14.27*** (3.97)	9.49*** (7.25)	40.44*** (20.97)		
School					1.19** (0.087)	1.018 (0.017)	1.121* (0.069)	1.005 (0.012)
Finance					1.143*** (0.034)	1.026*** (0.009)	1.044*** (0.009)	1.035*** (0.008)
Inflation							0.947*** (0.018)	0.986** (0.006)
R&D							5.61** (4.11)	
TFP								9.341*** (7.881)
LR χ^2	373**	341***	304***	343***	328***	307***	193***	343***
Pseudo R^2	0.18	0.39	0.26	0.34	0.67	0.49	0.44	0.41

Source: Authors.
Notes: LR represents the likelihood ratio test for goodness of fit. The estimated coefficients of the variables are given as odds ratios. Robust standard errors are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

The odds ratio of initial diversification is less than one. Thus, a higher initial export diversification index (i.e. lower initial diversification) is associated with significantly lower odds of belonging to a high diversification club. The estimated reduction in the odds of belonging to a high diversification club is between 44% and 62%. This result is consistent with Djimeu and Omgba (2019) and confirms the importance of path dependency for export diversification.

Per capita GDP has an estimated odds ratio of unity. This means that a country is equally likely to fall into each convergence club regardless of its per capita GDP. In other words, per capita GDP has no link to the likelihood of belonging to any of the three diversification clubs. This finding implies that per capita GDP is a narrow measure. It does not fully capture the impacts of differences in countries' development levels on their diversification paths. We can further elucidate this finding by considering the average per capita GDP levels of each club. The average per capita GDP in Club 1 is $14,040, compared to $15,750 for Club 3. Club 2 has the lowest per capita GDP of less than $6,900 on average. Clearly, the likelihood of belonging to a high or low diversification club is not explained by per capita GDP alone.

In all the models, the coefficients of the other explanatory variables have the expected signs and statistically significant effects. Commercial and financial development, captured by trade openness and domestic credit, are associated with greater odds of belonging to a high diversification club. Strong institutions and infrastructure similarly improve diversification. Greater oil wealth (measured by per capita oil reserves) is associated with belonging to a lower diversification club. This finding is in line with those obtained by Ross (2019).

Conversely, per capita oil production has an odds ratio of unity, indicating that oil production is not associated with the diversification clubs. In other words, during the period under consideration, oil production alone cannot explain diversification patterns and the resulting convergence clubs. In oil-exporting countries, oil production is subject to many constraints. For example, OPEC's production cuts or logistical constraints may cap oil supply, whereas international sanctions may limit exports. Countries' domestic oil consumption, commercial obligations or the need to finance imports with oil exports can also impact oil production and exports (Karanfil and Pierru 2021). As a result, we can reasonably conclude that the link between oil production and economic structure (including export diversification) is weak.[11]

Countries with a greater human capital stock as measured by either TFP or R&D tend to belong to higher diversification clubs. This result is consistent with Muysken and Nour (2006). They find that the deficient educational system, along with dependence on foreign technologies and low R&D efforts, constrain economic diversification and growth in the Gulf countries. Table 5 also suggests that countries with poor macroeconomic conditions (proxied by the inflation rate) have lower odds of belonging to a high diversification club. Overall, our findings are in line with the results of previous studies.

Before we conclude, we provide several caveats to this analysis. First, some of the structural factors associated with club membership may be endogenous to diversification, meaning that our results should be interpreted with caution. Second, the clubs in the ordered logit regression should be treated as ordinal rather than cardinal. In other words, moving from Club 1 to Club 2 is not necessarily equivalent to moving from Club 2 to Club 3. As Table 3 shows, the average diversification index values for Clubs 1, 2 and 3 are 5.12, 3.92 and 3, respectively. Moving from Club 1 to Club 2 reflects a larger shift than moving from Club 2 to Club 3 does based on these interclub differentials. Thus, the export portfolios of countries in Club 1 are relatively riskier than those of Clubs 2 and 3, on average.

To address the cardinal differences in the diversification levels of the three clubs, we test the relationship between the club means and structural factors. This analysis is based on the assumption that the countries in each club are converging to the club's average diversification level. For this purpose, we assign the average diversification level of each club for each year to the individual countries in that club. Thus, each country takes its clubs' average diversification value instead of an ordered club membership number. The results from OLS regressions using this specification are reported in Appendix F. Overall, they confirm the findings of the ordered logit regressions.

4. Conclusions

In this study, we first examined whether export diversification improves oil-exporting countries' resilience in the face of economic downturns. Our analysis utilized recent data on the coronavirus-induced recession. The results show that economies with greater export diversification were the least affected by the economic crisis. This finding illustrates oil producers' vulnerability during a period of low oil prices. Furthermore, after the pandemic, the decarbonization of the world economy is expected to accelerate through increased investments in and consumption of clean energy. This phenomenon may place additional pressure on the revenues of oil states and energy markets. This vulnerability increases the urgency for oil producers to adopt resilient economic development models, particularly through economic diversification.

Despite the relationship between economic resilience and diversification, countries' export diversification paths have shown little progress over the study period. Diversification has even declined for some oil producers. Our convergence analysis suggests that oil-exporting countries' diversification efforts have diverged overall but form three convergence clubs with different paths and levels of diversification. Motivated by this finding, we investigated why some oil-exporting countries have been more able to diversify their exports away from oil than others.

For this analysis, we used ordered logit models to identify the determinants of convergence club membership. We found that an oil producer must have solid political and macroeconomic stability to diversify successfully. It must reduce risk to allow easy access to credit and attract private investment. Furthermore, it must build human capital effectively. We can therefore reasonably argue that many oil-exporting countries' failures to diversify reflect domestic structural weaknesses. Our results also suggest that export diversification is path-dependent, as the initial level of diversification significantly determines club membership. It is therefore crucial for countries to provide specific incentives to establish a class of domestic entrepreneurs who can catalyze the dynamics of diversification. They must be able to absorb additional investments from oil revenues to prevent the adverse consequences of the energy transition for oil economies. This transition will affect the stability of energy markets.

Traditional oil-exporting countries, such as Gulf Cooperation Council countries, have been increasing efforts to diversify their economies away from exhaustible resources. To do so, they have been implementing structural reforms. Many of them have launched strategic plans or visions toward this aim. For instance, Saudi Arabia's Vision 2030 aims to enhance local content, support national products and expand the country's industrial base to promote new industries. Additionally, the Vision's Financial Sector Development Program is meant to strengthen financial institutions to support private sector growth and stimulate investment. Moreover, the National Transformation Program aims to improve economic enablers, such as the government's operational efficiency and infrastructure. As this study shows, all these policy measures and reforms can help increase the likelihood that Saudi Arabia's economy will become more diversified and resilient.

Endnotes

[1] Nationally determined contributions are submitted to the United Nations Framework Convention on Climate Change secretariat every five years.

[2] Its other exports were mainly pearls, precious metals and stones, machinery and transport vehicles. Additionally, according to the UAE Ministry of Economy, the travel and tourism sector contributed almost 12% of the country's GDP in 2019.

[3] These oil prices are nominal Brent crude oil prices. Monthly data are taken from Federal Reserve Economic Data provided by the Federal Reserve Bank of St. Louis.

[4] The current OPEC members are Algeria, Angola, Congo, Equatorial Guinea, Gabon, Iran, Iraq, Kuwait, Libya, Nigeria, Saudi Arabia, United Arab Emirates and Venezuela. Qatar terminated its membership in 2019.

[5] Figure A.1 shows that the severity of the pandemic has remained relatively low in Sub-Saharan African countries. Nguimkeu and Tadadjeu (2021) find that these countries have younger populations, lower population densities and lower rates of urbanization, reducing the effects of COVID-19.

[6] Several *a priori* mechanisms may explain this finding. Countries with low diversification levels may also have larger non-tradeable sectors (e.g., services), which suffered more from lockdown measures during the pandemic. Moreover, the governments of traditional oil-exporting countries, which are less diversified, may have relatively greater financial capacities. Thus, they can more easily compensate people who lost their jobs or whose work was suspended. Further research is necessary to assess the principal mechanisms driving the estimated impact of diversification on employment.

[7] According to the convergence hypothesis, a unique steady state exists, and deviations from this steady state are temporary. Thus, in a panel data setting, if the variable of interest is stationary, then the convergence hypothesis can be accepted (Evans and Karras 1996). Similarly, if two countries series' converge, those series are expected to be cointegrated.

[8] The series ξ_{it} is weakly time dependent if ξ_{it} and ξ_{it+k} are almost independent as k increases. Thus, the observations ξ_{it} and ξ_{it+k} are asymptotically uncorrelated.

[9] Phillips and Sul (2007) recommend discarding some small fraction (r) of the time series data. Hence, we estimate Equation (5) using data starting at $t = rT$, where T is the total number of years in the sample. Further, based on Monte Carlo simulations, Phillips and Sul (2007) show that $r = 0.3$ is satisfactory in terms of both sample size and test power. This approach draws attention to the results as the sample size gets larger. Additionally, we use the Hodrick and Prescott (1997) filter to remove the cyclical component and extract long-run trends in export diversification. This approach is in line with Phillips and Sul (2007) and subsequent studies.

[10] All reported *t*-statistics are derived from robust variance estimators with the Newey-West correction for autocorrelation (Newey and West 1987; White 1980). The estimates are therefore consistent in the presence of autocorrelation or heteroskedasticity.

[11] In our sample, the correlation between per capita oil reserves and per capita oil production is very high (0.79). The literature (e.g., Pickering 2008) shows that extraction (independent variable) and reserves (dependent variable) have a robust relationship. Because extraction is endogenous to reserves, we do not introduce both variables into the model simultaneously to avoid collinearity.

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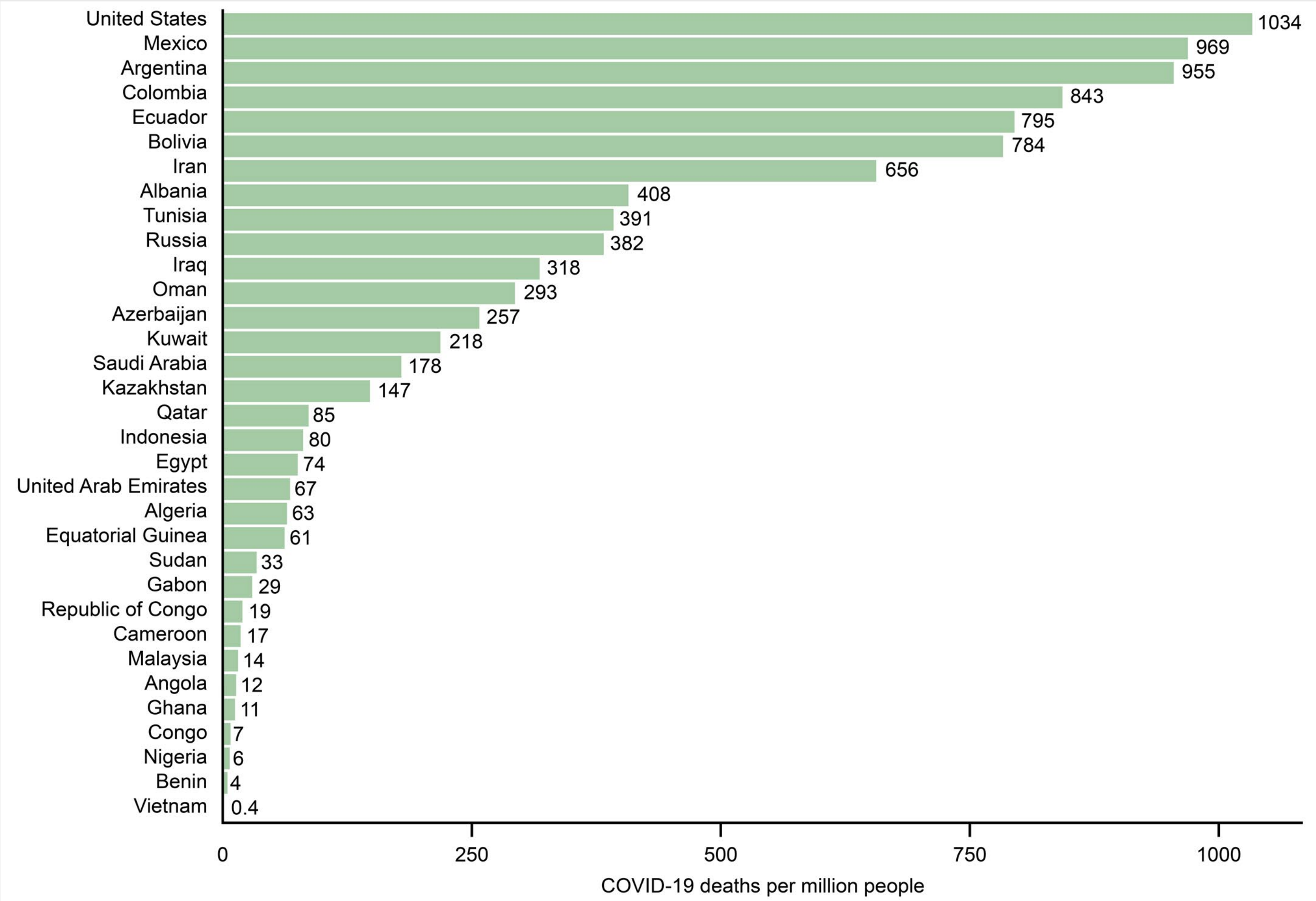
Appendix A

Appendix A.1. COVID-19 Mortality Rates

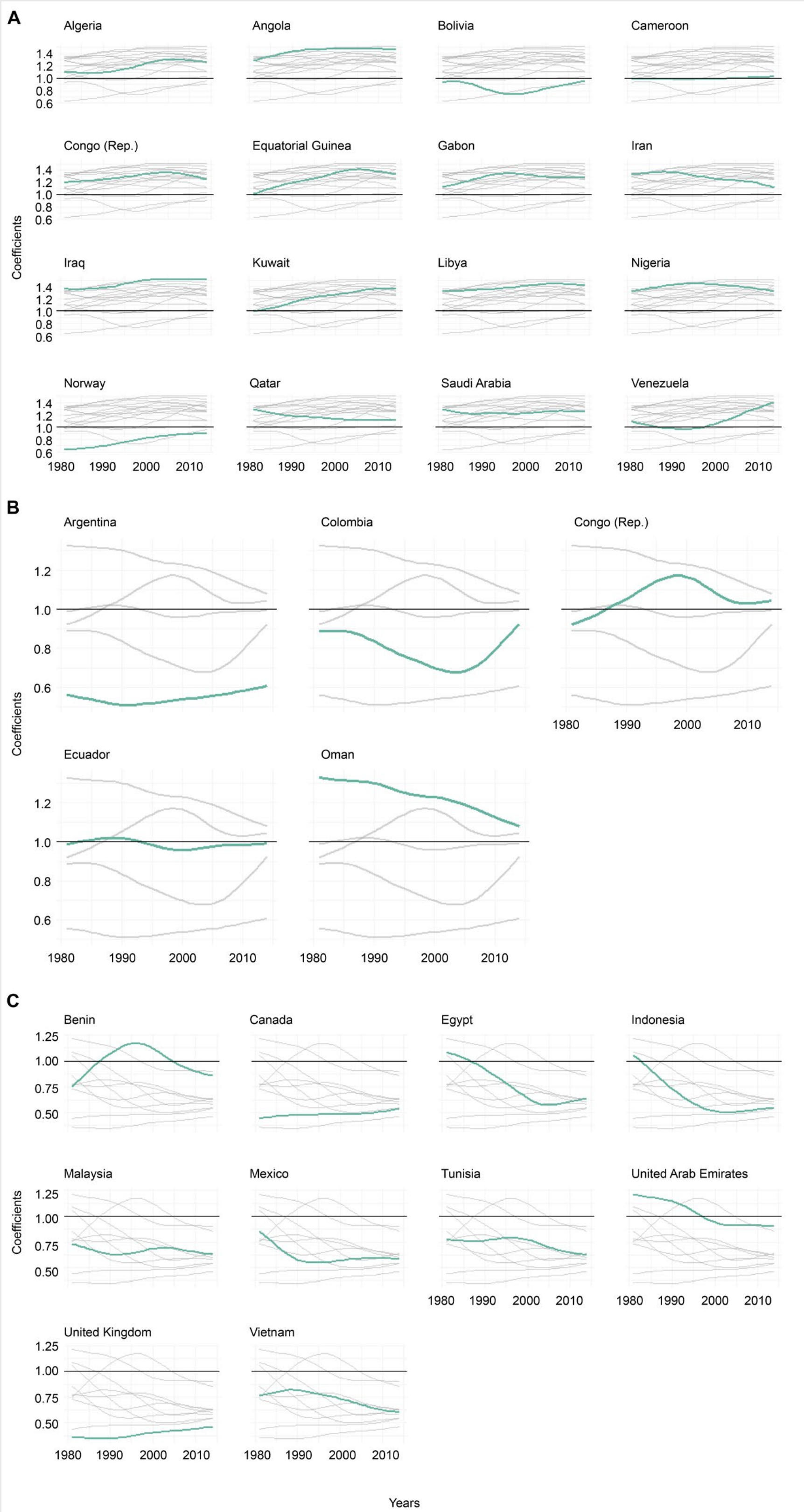
Figure A.1. Mortality rates from COVID-19 among oil producers.



Source: Data are from Our World in Data (https://ourworldindata.org/coronavirus).
Note: Total deaths are as of December 30, 2020. No data are available for Turkmenistan.

Appendix B: Transition Curves

Figure B.1. Transition curves for oil-producing countries.



Source: Authors.

Appendix C: Descriptive Statistics

Table C.1. Descriptive statistics of the variables and data sources.

Variables	Mean	Std. dev.	N	Description	Source
Diversification	4.2	1.3	1,054	Export diversification Theil index	IMF
Initial diversification	4.6	1.3	1,054	Export diversification Theil index in 1981	IMF
GDP per capita	13,402	19,615	1,000	GDP per capita (constant 2010 US dollars)	WB WDI
Oil reserves per capita	5.5	11.8	769	Oil reserves per capita (thousand million barrels per million people)	BP Statistical Review (reserves); WB WDI (population)
Oil production per capita	8,499	14,083	1,051	Oil production per capita (kilotonnes of oil equivalent per million people)	IEA (production); WB WDI (population)
Electricity	84.4	25.3	589	Access to electricity (% of population)	WB WDI
Trade	69.7	35.9	950	Sum of exports and imports of goods and services (% of GDP)	WB WDI
Rule of law	-0.36	0.97	496	Confidence in and abidance by the rules of society	WB WGI
School	88.9	12.6	583	School enrollment, primary (% net)	WB WDI
Finance	42.9	39.6	971	Domestic credit provided by the financial sector (% of GDP)	WB WDI
Inflation	85.9	972.6	998	Annual growth rate of the GDP deflator	WB WDI
R&D	0.63	0.59	258	R&D expenditures (% of GDP)	WB WDI
TFP	0.69	0.27	782	TFP level at current purchasing power parity (United States=1)	Penn World Table

Source: Authors' calculations based on the above-cited sources.

Appendix C: Descriptive Statistics

Table C.2. Descriptive statistics of net oil exports.

Country	Net exports				Period with net exports
	Mean	Std. dev.	Min	Max	
Algeria	38,604	10,122	26,145	61,626	All
Angola	41,661	28,829	5,076	94,410	All
Argentina	5,536	5,752	-1,288	16,110	1985–2014
Benin	91	115	0	371	1981–1998
Bolivia	90	124	0	454	1983–1984; 1986–1987; 1991–1994; 2000–2008; 2012–2014
Cameroon	4,123	1,883	846	7,460	All
Canada	34,600	26,829	-12,535	106,675	1983–2014
Colombia	14,273	11,320	-1,972	41,549	1986–2014
Congo	1,125	163	634	1,440	All
Republic of Congo	10,054	3,341	4,204	15,661	All
Ecuador	12,833	4,297	4,843	21,717	All
Egypt	12,402	8,077	-948	25,130	1981–2004; 2008–2014
Equatorial Guinea	6,814	7,360	0	18,430	1994–2014
Gabon	11,817	3,529	6,309	18,382	All
Indonesia	21,971	20,754	-10,060	63,286	1981–2005; 2007–2008
Iran	106,485	27,429	39,877	139,882	All
Iraq	67,949	40,162	1,960	126,869	All
Kuwait	58,477	26,379	6,383	104,633	All
Libya	53,372	14,254	15,970	77,759	All
Malaysia	12,317	5,906	1,654	21,965	All
Mexico	82,116	13,009	61,388	111,632	All
Nigeria	93,727	22,615	54,028	125,791	All
Norway	88,781	43,440	15,680	151,983	All
Oman	34,793	8,613	16,905	48,581	All
Qatar	29,714	14,181	13,023	53,553	All
Saudi Arabia	300,183	77,610	117,847	465,614	All
Tunisia	2,614	886	1,136	3,936	All
United Arab Emirates	90,889	25,728	41,231	136,919	All
United Kingdom	14,798	25,381	-30,518	49,558	1981–1990; 1993–2004
Venezuela	94,776	27,585	46,636	135,512	All
Vietnam	8,533	6,538	0	19,852	1988–2014

Source: Authors' calculations based on data from the IEA.

Appendix D: Robustness Checks

Appendix D.1. Excluding Small Net Oil Exporters

As per Table C.2, the excluded countries are Argentina, Benin, Bolivia, Cameroon, Congo and Tunisia.

Table D.1. Global convergence test results (excluding small net oil exporters).

Variable	Coefficient ($\hat{b}$)	*t*-statistic
$\log(t)$	–0.8	–35.51

Source: Authors.

Table D.2. Tests for convergence clubs (excluding small net oil exporters).

Convergence clubs	Coefficient ($\hat{b}$)	*t*-statistic	Members
Club 1	0.09	3.2	Algeria[1], Angola[1], Republic of Congo [1], Equatorial Guinea[1], Gabon[1], Iran[1], Iraq[1], Kuwait[1], Libya[1], Nigeria[1], Norway[1], Saudi Arabia[1], Venezuela[1]
Club 2	0.44	1.47	Colombia[2], Ecuador[2], Oman[2], Qatar[1]
Club 3	0.31	19.7	Canada[3], Egypt[3], Indonesia[3], Malaysia[3], Mexico[3], United Arab Emirates[3], United Kingdom[3], Vietnam[3]

Source: Authors.
Note: [1], [2], and [3], denote each country's club membership based on the convergence analysis with all oil exporters (31 countries).

Table D.3. Club merging test results (excluding small net oil exporters).

Merging test	Coefficient ($\hat{b}$)	*t*-statistic
Club 1 + Club 2	-0.38	-8.73
Club 2 + Club 3	-0.4	-18.9

Source: Authors.

Appendix D.2. Excluding Countries That Are Not Always Net Oil Exporters

As per Table C.2, the excluded countries are Argentina, Benin, Bolivia, Canada, Colombia, Egypt, Equatorial Guinea, Indonesia, United Kingdom and Vietnam.

Table D.4. Global convergence test results (excluding countries that are not always net oil exporters).

Variable	Coefficient ($\hat{b}$)	*t*-statistic
$log(t)$	-0.74	-157.3

Source: Authors.

Table D.5. Tests for convergence clubs. (excluding countries that are not always net oil exporters).

Convergence clubs	Coefficient ($\hat{b}$)	*t*-statistic	Members
Club 1	0.09	3.55	Algeria[1], Angola[1], Republic of Congo [1], Gabon[1], Iran[1], Iraq[1], Kuwait[1], Libya[1], Nigeria[1], Norway[1], Saudi Arabia[1], Venezuela[1]
Club 2	1.09	8.39	Cameroon[1], Congo [2], Ecuador[2], Oman[2], Qatar[1]
Club 3	0.29	4.82	Malaysia[3], Mexico[3], Tunisia[3], United Arab Emirates[3]

Source: Authors.
Note: [1], [2], and [3], denote each country's club membership based on the convergence analysis with all oil exporters (31 countries).

Table D.6. Club merging test results (excluding countries that are not always net oil exporters).

Merging test	Coefficient ($\hat{b}$)	*t*-statistic
Club 1 + Club 2	-0.42	-34.8
Club 2 + Club 3	-0.45	-20.9

Source: Authors.

Appendix D.3. Including Net Oil Importers

Table D.7. Global convergence test results (including net oil importers).

Variable	Coefficient ($\hat{b}$)	*t*-statistic
$log(t)$	-0.66	-41.52

Source: Authors.

Table D.8. Tests for convergence clubs (including net oil importers).

Convergence clubs	Coefficient ($\hat{b}$)	*t*-statistic	Members
Club 1	-0.08	-0.95	Algeria[1], Angola[1], Bolivia[1], Cameroon[1], Republic of Congo [1], Equatorial Guinea[1], Gabon[1], Iran[1], Iraq[1], Kuwait[1], Libya[1], Nigeria[1], Norway[1], Qatar[1], Saudi Arabia[1], Venezuela[1]
Club 2	0.34	4.55	Argentina[2], Brazil, Chile, Colombia[2], Congo [2], Ecuador[2], Ghana, Greece, South Korea, Mali, Oman[2], Philippines
Club 3	0.21	3.63	Benin[3], Canada[3], China, Egypt[3], France, Germany, India, Indonesia[3], Israel, Japan, Kenya, Malaysia[3], Mexico[3], Morocco, Spain, Thailand, Tunisia[3], Turkey, United Arab Emirates[3], United Kingdom[3], United States, Vietnam[3]

Source: Authors.
Note: [1], [2], and [3], denote each country's club membership based on the convergence analysis with only oil exporters (31 countries).

Table D.9. Club merging test results (including net oil importers).

Merging test	Coefficient ($\hat{b}$)	*t*-statistic
Club 1 + Club 2	-0.33	-8.87
Club 2 + Club 3	-0.15	-3.51

Source: Authors.

Appendix D.4. Countries with Oil Rents At Least 5% of GDP

Table D.10. Global convergence test results (including countries with oil rents at least 5% of GDP).

Variable	Coefficient ($\hat{b}$)	*t*-statistic
$log(t)$	-1.01	-36.61

Source: Authors.

Table D.11. Tests for convergence clubs (including countries with oil rents at least 5% of GDP).

Convergence clubs	Coefficient ($\hat{b}$)	*t*-statistic	Members
Club 1	0.20	3.31	Algeria[1], Angola[1], Chad, Republic of Congo[1], Equatorial Guinea[1], Gabon[1], Iran[1], Iraq[1], Kuwait[1], Libya[1], Nigeria[1], Norway[1], Oman[2], Qatar[1], Saudi Arabia[1], Sudan, Trinidad and Tobago, Venezuela[1], Yemen
Club 2	0.96	8.52	Bahrain, Ecuador[2], United Arab Emirates[3]
Club 3	-0.26	-1.44	Egypt[3], Indonesia[3], Malaysia[3], Papua New Guinea, Syria, Tunisia[3]

Source: Authors.
Notes: [1], [2], and [3], denote each country's club membership based on the convergence analysis with only oil exporters (31 countries).

Table D.12. Club merging test results (including countries with oil rents at least 5% of GDP).

Merging test	Coefficient ($\hat{b}$)	*t*-statistic
Club 1 + Club 2	-0.27	-3.96
Club 2 + Club 3	-0.75	-11.7

Source: Authors.

Appendix E: Diversification and Employment

Table E.1. Diversification and employment during the coronavirus pandemic for Club 3.

Variable	Coefficient
Club 3	-2.402** (1.144)
Mortality	0.008*** (0.002)
Constant	8.57*** (0.727)
No. of obs.	31
R^2	0.48

Source: Authors.
Notes: The dependent variable is working hours lost in 2020 owing to the COVID-19 crisis (see notes in Table 1). Club 3 is a dummy that equals one for countries in Club 3 (i.e., the countries with the highest diversification levels). Robust standard errors are in parentheses. ** and *** indicate significance at the 5% and 1% levels, respectively. Obs = observations.

Appendix F: Determinants of Diversification

Table F.1. Analysis using club means instead of ordinal rankings as the dependent variable.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Initial diversification	0.413*** (0.016)	0.432*** (0.025)	0.447*** (0.033)	0.258*** (0.037)	0.154*** (0.043)	0.223*** (0.045)	0.295*** (0.061)
GDP per capita		2.10−6*** (1.10−6)	1.10−6*** (3.10−6)	3.10−6*** (4.10−6)	4.10−6*** (3.10−6)	5.10−6*** (3.10−6)	3.10−6*** (2.10−6)
Electricity		−0.017*** (0.002)	−0.01*** (0.002)				
Trade		−0.007*** (0.001)	−0.007*** (0.001)		−0.002 (0.001)	−0.002 (0.001)	
Oil reserves per capita		0.009*** (0.003)			0.009*** (0.003)		
Oil production per capita			1.10−6*** (4.10−6)	6.10−6 (4.10−6)		1.10−6 (4.10−6)	
Rule of law				−0.846*** (0.55)	−0.375*** (0.09)	−0.813*** (0.07)	
School					−0.018*** (0.004)	−0.008** (0.003)	−0.024** (0.012)
Finance					−0.007*** (0.002)	−0.003** (0.001)	−0.008*** (0.001)
Inflation							0.018*** (0.005)
R&D							−0.256* (0.145)
Observations	1,054	412	563	492	227	300	203
R^2	0.29	0.55	0.41	0.49	0.69	0.59	0.63

Source: Authors.
Notes: Robust standard errors are in parentheses. *, ** and *** indicate significance at the 10%, 5% and 1% levels, respectively.

Alternatives to pooled OLS estimates include fixed effects models and dynamic panel data approaches. Fixed-effects models cannot be fully applied here, as initial diversification is a country-specific time-invariant variable. Dynamic panel data techniques (i.e., panel unit root tests, cointegration tests, etc.) require datasets with larger time dimensions than our dataset has. Furthermore, they require the panels to be strongly balanced or to have no gaps in each individual time series. Most of our variables are far from satisfying those conditions. Further analyses of diversification determinants using panel data techniques are beyond this study's scope.

Notes

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About the Project

This study is part of an ongoing KAPSARC project Revisiting Fiscal Breakeven Oil Prices. The project aims to provide a detailed macroeconomic/fiscal policy analysis of the resilience of oil producers to changes in oil prices. It contributes to a better understanding of how oil-exporting countries adjust their fiscal policies in response to variations in oil prices, and what the short-term and possible long-term consequences are for economic growth.

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