Resources Policy 78 (2022) 102876

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

The nexus of carbon emissions, oil price volatility, and human capital efficiency

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ARTICLE INFO

JEL classification:
G30
G32
J24
Q35
Q54

Keywords:
Carbon emissions
Oil price cycles
Human capital efficiency

ABSTRACT

The corporate sector's active engagement is vital for achieving a net-zero future. It entails a sizeable investment in human capital to foster more conscious efforts to limit carbon emissions. Therefore it is critical to evaluate the nexus between carbon emissions and human capital efficiency. This paper analyzes the link between human capital efficiency and carbon emissions using a comprehensive sample of 5740 firms across eight countries spanning over ten years. Our findings show a negative relationship between investment in human capital and carbon emissions. We emphasize that optimal human capital efficiency can help limit emissions by fostering the transitions to renewable energy sources and the development of cognitive appreciation. The results remained robust for periods marked by booming and receding oil prices. These findings have important implications for optimizing firm performance while preserving sustainable development goals.

1. Introduction

Environmental well-being is critical for many reasons, and it impacts not only the social fabric but has economic outcomes. The suboptimal use of natural commodities also triggers ecological degradation, and consistent use of non-renewable natural resources poses a genuine threat (Bansal et al., 2021; Sharma et al., 2021a; Sharma et al., 2021b; Sun et al., 2021). Consequently, we may observe an increase in sovereign risk (Chaudhry et al., 2020; K.-H. Wang et al., 2021), deterioration of credit portfolios (Ji et al., 2021b), regression in investment performance (Ji et al., 2021b), increase in systematic risk (Ji et al., 2021a), and asset transitions (Guo et al., 2022; Yan et al., 2021).

Given these factors, it is reasonable to believe that the development of circular economies and sustainable corporate systems is motivated by fiscal considerations. Many studies have evaluated the viability of green finance to curtail greenhouse emissions and proposed essential steps (Naqvi et al., 2021). highlighted that the development of sustainable finance requires consistent statutory interventions in emerging markets. Such intervention is warranted because sustainable investment is disincentivized in most emerging markets (Bello et al., 2018). indicated that effective management of electricity consumption can help manage the carbon footprint (An et al., 2021). mentioned that the pricing of natural resources can support reducing greenhouse emissions.

Some studies have emphasized larger business practices that can help achieve sustainability goals (Erdoğan et al., 2020). indicated innovation as a leading factor to limit the carbon footprint (X. Zheng et al., 2020). highlighted that industrial restructuring is vital to stop environmental degradation (Li et al., 2021). propagated that investing in research and development can help in achieving the cause. In addition to these factors, investment in human capital can be a plausible driver of sustainable business models. An effective human resource and resulting intellectual capital contributes to a firm's efficiency and capabilities to remain competitive, sustain market share, and create value (Lopez-Cabrales et al., 2006). (Z. Wang et al., 2014) reported that human resources contribute to economic and operational performance (Kor and Leblebici, 2005). suggested that investing in human capital can aid firms in developing new knowledge. One aspect of this could be the cognitive development of human resources to realize the importance of sustainability.

While the role of human capital in corporate performance is mainly recognized, it is surprising that its firm-level relevance in limiting carbon emissions is ignored. At the macro level (Çakar et al., 2021),

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https://doi.org/10.1016/j.resourpol.2022.102876
Received 27 December 2021; Received in revised form 3 June 2022; Accepted 22 June 2022

assessed the link between human capital and environmental degradation and concluded that human capital is essential to reducing carbon emissions. While this study reflects the relationship, it is impossible to generalize this finding at the corporate level because of the firm and sectoral differences.

This constitutes a valid research gap, and we attempt to address this by employing data for 5740 firms across eight countries and five sectors. We use fixed effects regression to investigate the relationship between carbon emissions and human capital efficiency. Our focus is on emissions from a significant natural resource, i.e., oil. Using the data for ten years, we demonstrate a negative relation between human capital efficiency and carbon emissions. Our results also show that while variation in oil prices is essential for explaining the carbon emissions, it does not undermine the relevance of human capital efficiency, which remains a catalyst for carbon emissions. The results have important implications for proactively working on developing human capital as a medium to achieve carbon neutrality.

The rest of the paper is organized as follows. Section 2 highlights our data and methodology, section 3 presents results and discussion, while section 4 concludes.

2. Methodology and data

The mitigation of carbon emissions is a complex issue. It requires a well-coordinated multifacet response (Dong et al., 2020; Khan et al., 2021; Shahbaz et al., 2021; Zhao et al., 2021), including optimizing the use of human capital. We use a multi-step methodology to assess the impact of human capital efficiency on carbon emissions. While there are many pollutants, our study focuses on emissions from oil. We adopt a similar approach to (Umar et al., 2021) to constitute our sample. We select countries where annual oil-related carbon emissions are more than 2% of the global share.[1] Based on this initial criterion, eight countries produce more than 2% of global emissions and are cumulatively responsible for about 47% of oil-specific releases. Table 1 presents statistics for these countries. We can observe that in 2020 the oil-related emissions were about 11 billion tons, with significant contributions from the United States (18.18%), China (9.1%), and India (5.48%).

It is important to note that the sectoral emissions are not uniform, and each industry has a varying contribution. In Fig. 1, we present global oil emissions by sector. It can be observed that 68.13% of oil-related carbon emissions are contributed by five sectors: industry, manufacturing, transport, electricity, and buildings. Therefore, we constitute our sample from companies from these five sectors in the eight selected countries. Only those companies are considered that disseminate emissions data.

The final filter that we apply is to include companies operating throughout the sample period spanning from January 2010 to June 2021 (46 quarters). This results in a total of 5740 companies. The country and sectoral breakdown of our final sample are presented in Table 2.

Table 1
Annual carbon emissions from oil.

Country	CO2 Emissions (Million of Tonnes)	Global Share
World	*11000.07*	
United States	2000.02	18.18%
China	1000.61	9.10%
India	602.67	5.48%
Russia	388.77	3.53%
Japan	377.38	3.43%
Saudi Arabia	342.6	3.11%
Brazil	305.51	2.78%
Germany	250.68	2.28%

Data as of 2020.
Source: https://ourworldindata.org/emissions-by-fuel

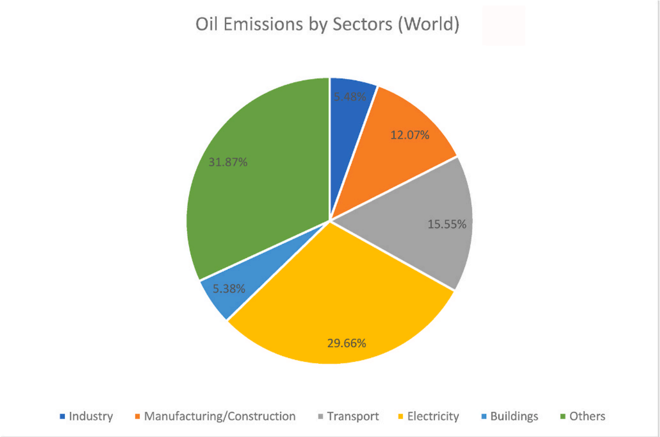

Fig. 1. Oil emissions by sectors (World).

Our dependent variable is the firm-level quarterly oil-related carbon emissions (natural log) which we hypothesize are a function of human capital efficiency (HCE). An increase in human capital efficiency will help limit carbon emissions and vice versa. To gauge this relationship, we use the following panel estimation.

$$InCE_{it} = \alpha_0 + \beta_H HCE_{it} + \beta_X X_{it} + \beta_O OD_t + \beta_C CD_t + u_{it} \quad (1)$$

Human capital efficiency relates economic value added (EVA) to the investment in human capital (HC) (Hasnaoui et al., 2021; Mirza et al., 2020; Yarovaya et al., 2020) and is calculated as follows.

$$HCE_{it} = \frac{EVA_{it}}{HC_{it}} \quad (2)$$

To estimate EVA_{it}, we employ net operating profit after tax (NOPAT) adjusted for employee expenditures (EE), invested capital (IC), and firm-level cost of capital (WACC). This takes the following functional form.

$$EVA_{it} = (NOPAT_{it} + EE_{it}) - (IC_{it} + WACC_{it}) \quad (3)$$

The HC in equation (2) is the firm-specific human capital expenditures, including salaries, wages, commissions, training costs, etc. In equation (1), we introduce a vector of control variables (X). These include firm profitability (ROE), investment in research and development (RD to total Assets), market concentration (HHI), energy intensity (energy consumption to gross domestic product), and population density (PD). The panel estimations are superior to alternate specifications because of their unbiased assessment of the relationship between dependent and independent variables. It is primarily because these estimates can control the interdependencies of the variables (Shan et al., 2022).

In equation (1), there are two dummy variables as well. As the Covid-19 outbroke during our sample period, we control its consequences by proposing a dummy (CD) that takes a value of 1 for the observations between 1Q2020 and 2Q2022 and 0 otherwise. Furthermore, many studies like (Humphrey et al., 2016; Ko et al., 2014; Rappaport, 2000; Reboredo, 2014; Tusiime and Wang, 2020; Y. Zheng et al., 2021) documented that oil price cycles have a spillover impact, including carbon emissions. Therefore, to capture the nexus between oil price volatility, human capital efficiency, and carbon emissions, we include a dummy (OD) that takes a value of 0 during the oil price boom and one otherwise. To identify the boom and bust, we follow the methodology of (Umar et al., 2021) and compare the actual and expected oil prices. Based on this assessment, we recognize 15 quarters as booms and 31 quarters as the bust. To establish the robustness of our results, we also estimate equation (1) separately for boom and bust. Table 3 highlights

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[1] https://ourworldindata.org/emissions-by-fuel.

Table 2
Sample distribution across countries and sectors.

Country	Industry	Manufacturing	Transport	Electricity	Buildings	Total
Brazil	92	67	10	11	7	**187**
China	530	413	132	81	60	**1216**
Germany	413	312	43	18	23	**809**
India	300	211	89	45	29	**674**
Japan	116	103	24	16	8	**267**
Russia	340	311	31	21	18	**721**
Saudi Arabia	114	84	20	15	11	**244**
United States	700	610	152	85	75	**1622**
Total	**2605**	**2111**	**501**	**292**	**231**	**5740**

Table 3
Difference between oil spot and future prices - boom and bust periods.

Quarters	Actual - Expected		t stats
1Q2010	−0.0041	**	−2.2599
2Q2010	−0.0062	**	−1.9995
3Q2010	0.0034	***	2.7566
4Q2010	0.0015	***	2.8911
1Q2011	0.0050	***	3.3870
2Q2011	−0.0076	**	−2.0699
3Q2011	0.0057	**	2.1335
4Q2011	−0.0076	***	−2.7873
1Q2012	−0.0051	***	−2.6932
2Q2012	−0.0062	**	−2.0872
3Q2012	−0.0080	**	−1.9979
4Q2012	−0.0040	**	−2.0352
1Q2013	−0.0046	**	−2.1496
2Q2013	−0.0058	**	−2.1407
3Q2013	0.0071	**	2.2851
4Q2013	−0.0029	***	−3.5881
1Q2014	−0.0016	**	−1.9882
2Q2014	−0.0024	***	−2.9191
3Q2014	−0.0036	***	−3.0905
4Q2014	−0.0045	***	−3.3186
1Q2015	−0.0038	**	−2.0903
2Q2015	−0.0048	**	−2.0545
3Q2015	0.0044	**	1.9973
4Q2015	−0.0029	**	−2.1306
1Q2016	0.0026	**	2.3491
2Q2016	−0.0043	**	−1.9937
3Q2016	−0.0056	***	−2.9853
4Q2016	−0.0077	***	−3.0506
1Q2017	−0.0039	***	−3.0640
2Q2017	−0.0053	***	−2.8379
3Q2017	0.0012	**	2.0390
4Q2017	−0.0027	***	−2.5274
1Q2018	0.0043	**	1.9772
2Q2018	−0.0047	**	−1.9856
3Q2018	−0.0059	**	−2.0238
4Q2018	−0.0090	***	−3.4894
1Q2019	−0.0086	***	−3.0306
2Q2019	−0.0076	**	−2.0748
3Q2019	0.0086	***	3.2910
4Q2019	−0.0040	**	−1.9965
1Q2020	0.0054	***	3.1860
2Q2020	−0.0060	***	−3.6552
3Q2020	0.0041	**	2.0553
4Q2020	0.0079	**	2.1729
1Q2021	0.0031	***	3.5092
2Q2021	0.0065	**	2.0110

*** represent significance at 1%, ** at 5% and * at 10%.
Actual is the real spot prices, while expected are future prices (intraday per Quarter).
If Actual > Expected, this implies a booming quarter and vice versa.

the classification of our sample period as per the price cycles.

3. Results and discussion

The descriptive statistics of selected variables are presented in Table 4. Across our sample countries, we observed maximum HCE in Germany (1.22), followed by Japan (1.17). On the lower side, we have India (0.30), Brazil (0.48), and Saudi Arabia (0.65). As highlighted by (Andreeva et al., 2021; Ouedraogo et al., 2021), one of the critical constraints for the economic growth of developing economies is a sub-optimal investment in human capital. The descriptive statistics do not indicate a significant variation in HCE across the boom and bust periods. In the sectoral sample, the maximum HCE is in transport (1.2), followed by industrial firms (1.1). Similar to the country specification, there is no trend in sectoral HCE during oil price cycles.

The average profitability (ROE) and investment in research and development (RD/TA) highlight some interesting facts. We report the maximum ROE for Japanese firms (0.31) and Brazil (0.30) in our sample firms, while German firms are at the top with the highest investment in R&D (0.38). Transport has the maximum profitability (0.25) among the sectoral presentation, followed by the industrial companies (0.23). Consequently (perhaps), we see the more profitable sectors dominating the investment in research development (Blazenko and Yeung, 2015). Interestingly, there is positive and negative variation in RD/TA during boom and bust cycles, respectively (Chen et al., 2019; Jia et al., 2015; Xing, 2019).

The panel estimations of equation (1) for the entire sample period are presented in Table 5. The Hausman statistics support the fixed effect model by including country and time fixed effects. Our results demonstrate a negative relation between human capital efficiency and carbon emissions. The variable loading is significant at 1%. It implies that increased human capital efficiency limits carbon emissions and helps environmental well-being. This is plausible because as the investment in human capital increases, it leads to innovative managerial practices that assist a transition to sustainable business models. While one aspect of this relationship may stem from renewable vs. non-renewable energy sources (Alvarado et al., 2021; Çakar et al., 2021), a more probable cause is the cognitive recognition of the urgency to limit the carbon footprint (Tolppanen and Kang, 2021). Therefore, investing in human capital can act as a catalyst for sustainable development goals and reduce reliance on replenishing natural resources.

The coefficient of control and dummy variables demonstrate some noteworthy findings. We observe a negative relationship between RD/TA to carbon emissions, implying that research and development can pave the way in reducing oil-related emissions. The energy intensity depicts a positive relationship, which is not surprising because higher consumption will invariably lead to more significant emissions (Y. Y. Wang et al., 2021). The role of energy intensity is of importance for emerging economies that struggle with energy efficiency. The results demonstrate a negative relationship between economic growth (gGDP), suggesting that economic progression provides necessary financial support for energy transitions. The population density is positively related (Gao et al., 2021), while there was no impact of the Covid-19 outbreak on our model.

A compelling coefficient in our sample period is on the oil price dummy, which is significant and positive, and it indicates the impact of oil volatility on carbon emissions. Therefore, it is crucial to understand the mediating role of oil price volatility in explaining the robust

Table 4
Descriptive statistics (Weighted average).

Country Specific									
Country	HCE			ROE			RD/TA		
	Overall	Boom	Bust	Overall	Boom	Bust	Overall	Boom	Bust
Brazil	0.4866	0.0538	0.0455	0.3071	0.2031	0.3501	0.3529	0.4633	0.2909
China	1.0462	1.4019	1.6809	0.2251	0.1489	0.2566	0.3071	0.4033	0.2532
Germany	1.2247	1.3761	1.7407	0.1258	0.0832	0.1435	0.3842	0.5044	0.3167
India	0.3011	0.1062	0.0625	0.1569	0.1038	0.1789	0.2318	0.3044	0.1911
Japan	1.1685	1.8834	1.8351	0.3153	0.2085	0.3594	0.3223	0.4232	0.2657
Russia	1.0086	0.9873	0.2205	0.1931	0.1277	0.2201	0.2230	0.2928	0.1839
Saudi Arabia	0.6516	0.4959	0.3094	0.2232	0.1476	0.2545	0.1106	0.1452	0.0912
United States	0.9952	1.3657	1.2734	0.1529	0.1011	0.1743	0.2359	0.3097	0.1945
Sector Specific									
Industry	1.1001	1.4741	1.7674	0.2367	0.1565	0.2698	0.3229	0.4240	0.2662
Manufacturing	0.9782	1.3107	1.5716	0.2105	0.1392	0.2399	0.2871	0.3770	0.2367
Transport	1.2061	1.6161	1.9378	0.2595	0.1716	0.2958	0.3541	0.4649	0.2919
Electricity	0.9165	1.2281	1.4725	0.1972	0.1304	0.2248	0.2690	0.3533	0.2218
Buildings	0.8206	1.0995	1.3183	0.1765	0.1168	0.2013	0.2409	0.3163	0.1986

Table 5
Panel estimation - complete sample period.

Variables	Coefficients	t stats	Std Error	
Constant	0.9170	1.1094	0.8255	
HCE	−0.5672	−3.1486	0.1801	***
ROE	0.9770	0.8515	1.1474	
RD/TA	−0.0346	−2.1586	0.0171	**
HHI	0.0834	0.9915	0.0842	
EI	0.0545	2.4798	0.0229	**
gGDP	−0.0266	−2.0151	0.0132	**
lnPD	0.3296	1.9665	0.1666	**
OD	0.0486	3.1676	0.0153	***
CD	0.0165	0.2422	0.0682	
Adjsuted R Sq	0.7151			
Hasuman Test FE vs. RE	0.0033			
Country FE	Yes			
Year FE	Yes			
Panel Obs	264040			

*** represent significance at 1%, ** at 5%, and * at 1%.

relationship between HCE and carbon emissions. For this, we present the results of equation (1) for boom and bust periods in Tables 6 and 7, respectively. The coefficient of HCE for both periods is significant and negative. This is in line with our observation for the entire period and depicts that regardless of rising or receding oil prices, the focus on human capital can help limit carbon emissions. It reaffirms that human capital is vital and decisive for achieving a net-zero future. While oil price volatility may influence oil-related emissions, it does not invalidate the stimulus emanating from investment in human capital. The coefficients for control variables are also consistent with the full sample results.

Table 6
Panel estimation - during oil boom.

Variables	Coefficients	t stats	Std Error	
Constant	0.6114	1.0775	0.5573	
HCE	−0.2836	−3.7808	0.0750	***
ROE	0.5601	0.9555	0.5861	
RD/TA	−0.0527	−3.0656	0.0172	***
HHI	0.0760	0.5759	0.1321	
EI	0.0301	2.1313	0.0140	**
gGDP	−0.0133	−1.9941	0.0067	**
lnPD	0.1561	2.1147	0.0738	**
CD	0.0083	0.7855	0.0105	
Adjsuted R Sq	0.6716			
Hasuman Test FE vs. RE	0.0030			
Country FE	Yes			
Year FE	Yes			
Panel Obs	86100			

*** represent significance at 1%, ** at 5%, and * at 1%.

Table 7
Panel estimation - during oil bust.

Variables	Coefficients	t stats	Std Error	
Constant	0.6550	0.8129	0.8061	
HCE	−0.2484	−3.8653	0.0643	***
ROE	0.6449	1.0469	0.6160	
RD/TA	−0.0430	−3.0521	0.0141	***
HHI	0.0467	0.9551	0.0489	
EI	0.0629	3.7136	0.0169	***
gGDP	−0.0233	−2.1496	0.0108	**
lnPD	0.4087	2.0317	0.2012	**
CD	0.0128	0.9833	0.0130	
Adjsuted R Sq	0.7045			
Hasuman Test FE vs. RE	0.0058			
Country FE	Yes			
Year FE	Yes			
Panel Obs	177940			

*** represent significance at 1%, ** at 5%, and * at 1%.

The impact of human capital efficiency on various aspects of firm performance and business verticals is well documented, and in general, our results are aligned with the earlier studies like (Adesina, 2021; J. Guo et al., 2021; Tzeremes, 2014; Wen et al., 2022). The overall findings of this research provide strong evidence that human capital efficiency can support sustainability goals. Since no prior study has assessed this nexus, the results offer a new perspective relevant to human resource development and ecological business models.

4. Conclusion

The consistent use of natural resources for energy generation is a constant source of environmental degradation. Although the world economy will have to rely on oil and gas for energy production in the foreseeable future, efforts are underway to limit the resulting carbon emissions and ecological issues. The onus of these efforts is on various stakeholders, including governments, corporates, investors, legislators, etc. The corporate sector is a significant contributor to greenhouse emissions, and their active involvement is imperative to achieve a net-zero future. At the firm level, some factors like research and development, innovation, etc., have the demonstrated ability to curtail greenhouse emissions. However, the relationship between firm-level human capital and carbon emissions remains unexplored, and in this paper, we attempt to investigate this gap.

We employ a comprehensive dataset of firms across eight countries and multiple sectors to evaluate the relationship between a firm investment in human capital and oil-related carbon emissions. Our results highlight some interesting propositions, and we observe a negative relationship between human capital efficiency and firm-level emissions. It implies that human capital efficiency can help in optimizing ecological well-being by limiting carbon emissions. The findings also suggest that in addition to human capital efficiency, investing in research and development is vital to achieving sustainable business models. In addition, we find that the impact of human capital efficiency is profound despite the oil price cycles. The human capital remained relevant when the oil price was booming and receding. Therefore, while oil price variation may impact firm-level emissions, it does not undermine the relevance of human capital efficiency. We suggest that firms must focus on their human capital efficiency as a catalyst to achieve sustainable development goals.

Data availability

Data will be made available on request.

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