Journal of Environmental Management 294 (2021) 112946



Contents lists available at ScienceDirect

Journal of Environmental Management

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





# Vertical financial disparity, energy prices and emission reduction: Empirical insights from Pakistan

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ARTICLE INFO

*Keywords:*
Vertical financial disparity
Energy prices
Carbon emissions
Environmental regulation
Industrial structure

ABSTRACT

The economic and environmental aspects of energy production have become important due to the increasing complexity energy sector and envoirnmental pollution, warranting to test the connection between financial imbalances, energy prices and carbon emission. The study aims to test the impact of vertical fiscal imbalances (VFI) on energy prices and carbon emission trends by considering the dual-perspectives of environmental regulation and industrial structure. The empirical outcomes indicated that vertical fiscal imbalances limited the environmental quality of Pakistan. Furthermore, VFI also caused environmental degradation by affecting industrial structure. VFI inhibits the intensity of environmental regulation, promotes the upgrade of industrial structures, both of which cause additional carbon emissions. The study suggest to energy ministries and energy regulation offices to revisit the machinism of energy prices determination and revised machanisim should provide a user-friendly assessment to understand the actual costs associated with the rising concern of environmental pollution. By this, envoirnmental protection maximization and optimal energy conservation is expacted to increase. Based on empirical findings, the study extends the suggestion that vertical fiscal imbalances should be considered an active indicator by the key policy makers and other stakeholders for energy prices determination and environmental quality upgradation.

## 1. Introduction

The intertemporal nexus between vertical financial disparity often termed as fiscal imbalance and environmental condition have become extensive subject of debate and research (Tiep et al., 2021). Pakistan's fiscal imbalances have risen to the highest level over the last three decades, while the deficit has risen to 8.9% of GDP at the end 2018 as compared to 6.6% annually (see Fig. 1). Equally, Pakistan's environmental equality remains a serious concern for local and international authorities in the recent period. (Nieto et al., 2018). According to the Pakistan Ecological Environment Bulletin (2018), only 35.8% of 6 cities, with air quality close to population quality benchmarks, account for 55.4% of the country's land area. Heat waves, droughts, floods, acid rain, haze and water pollution are considered to be the major contributors to the increase in pollution. Unfortunately, Pakistan's forest area accounts for only 5.2% of the total land, far from the global (20%) benchmark. More than 40% of the country's population is suffering from food shortages, with food wastage as high as 30% (Depa et al., 2018). Pakistan has experienced severe floods almost every year in the last decade. The 2010 Flood directly affected 20 million people, killed 1,781, injured 2,966, and destroyed more than 1.89 million houses. During the 2011 flood, 5.3 million people were affected and 1.7 million acres of arable land was inundated (Hashim Nisar Hashmi, 2012). Collective measures have been taken by the central & local government for

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https://doi.org/10.1016/j.jenvman.2021.112946
Received 19 February 2021; Received in revised form 23 March 2021; Accepted 5 May 2021
Available online 18 June 2021
0301-4797/© 2021 Published by Elsevier Ltd.

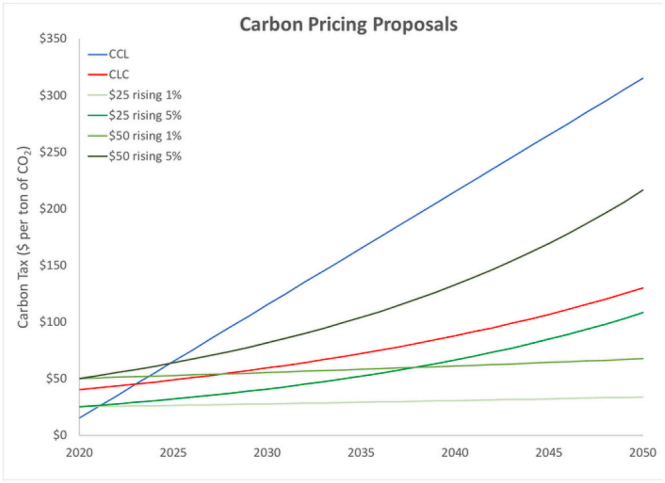


**Fig. 1.** Carbon pricing proposal.

environmental protection to reduce the consumption of fossil fuel-based energy (Yoshino et al., 2019).

In this regard, contemporary research has been attempted to discuss environmental issues with the economic perspective. The relationships among environment, industrial structure, foreign direct investment, trade, corporate ownership, economic agglomeration and market segmentation are emerging topics to be discussed recently (Zhou et al., 2013) (Ren et al., 2014) and (Witt, 2014), while these studies explored the behavior of the fiscal system and the government with changes in the environment quality, in particular the impact of fiscal decentralization on the environment (Rodriguez-Gonzalez et al., 2018) & (Lepitzki and Axsen, 2018). It has been noted that fiscal decentralization and vertical fiscal imbalances (VFIs) contribute to improving the quality of the environment through better public expenditure structure (Alemzero et al., 2020b) and (Alemzero et al., 2020a).

So, what is the environmental effect of vertical fiscal imbalance? Compared with the uncertain environmental impact of fiscal decentralization, will the VFI cause environmental quality to deteriorate (Atilgan and Azapagic, 2016) & (Zhang et al., 2016)? If the answer is yes, what could be the mechanism? And how this mechanism would work? Is there regional heterogeneity? If the answer is uncertain, what could be the reason? In view of the above consideration, unlike the existing research, this study attempts to weigh VFI impression on environmental pollution from another impartial result of the fiscal system, that is, VFI to supplement the existing research (Iqbal et al., 2021). According to the aforementioned literature, following suggestions are required to be discussed further. Firstly, the vertical fiscal imbalance is still persisting as a consequence of decentralization of powers and expenditures from the central government due to finance and tax reforms (Li et al., 2021). This is a realistic perspective for a better understanding of the environmental effects in on developing economies like Pakistan (Iqbal et al., 2021). Next, the indirect effects of VFI on environmental pollution from two paths that are needed to be addressed at global and regional (heterogeneous) levels, and the possible mediating and transmission mechanisms need to be assessed (Winner, 2012). To some extent, the proposed contribution would further complement the fiscal system's environmental impact mechanism, and provide a broader spectrum on the relationship between fiscal reform and environmental pollution (Alemzero et al., 2021). Also, the regional differences and mechanisms of the impact of VFI on environmental pollution need to be explained in detail (Anh Tu et al., 2021), whether vertical fiscal imbalances are common to affect the environmental quality on the basis of empirical support for the implementation of differentiated fiscal system reforms in different regions (Lee, 2016).

Based on the above analysis, this study considers carbon emissions as a pollution variable to examine the impact of VFI on environmental pollution. Global warming, as one of the major factors of environmental pollution, and other problems caused by carbon emissions have been a major concern of many scholars. Unlike other scholars, the relationship among fiscal imbalance, energy prices and environmental pollution form emerging economies like Pakistan has been measured. Various econometric models have been used to justify the findings. Firstly, the model for vertical fiscal imbalance has been proposed, and the pooled and fixed effects have been quantified in terms of energy prices and environmental pollution. Our contribution also includes the development of a comprehensive policy section based on the findings.

## 2. Theoretical framework and research hypothesis

The cross-regional environmental coordination and protection mechanisms is not effectively established or operated, thereby weakening the incentives to pollution control and the effectiveness of government environmental regulations. Under such circumstance, the vertical fiscal imbalance would inevitably have a negative effect on regional environmental quality (Yoshino et al., 2020b). Furthermore, the population is quite a young one with the average age being 17, and children under 15 are made up of 42% of the Population (Africa energy outlook, 2019). (GDP/POP) is the income per capita steadily growing since the 2000s. Africa has experienced a 3.1% low GDP in about a decade from now, relative to the World's growth rate of 3.5%. The GDP per capita in Africa is about a third of the World's cumulative GDP. SSA has even a worse average GDP per capita ratio of about filth of World. Two countries dominate Africa's economy; South Africa (17%) and Nigeria (12%). The rest are commodity-dependent countries exposing them to global price volatility and complicated recovery pathways when exogenous shocks hit them. However, Kenya, Ethiopia, and Rwanda have grown their economies through investment and the services sector's uptake in their various economies (Africa energy outlook, 2019). Therefore, the following assumption is proposed:

**Hypothesis 1**. Vertical fiscal disparity increases envoirnmental pollution significantly

### 2.1. Vertical fiscal imbabalnces and envoirnmental pollution

It is theoretically found that vertical fiscal imbalances can also have an indirect impact on environmental pollution through the transmission mechanism of the mediated variables (environmental regulation & industrial structure). Overall, it could be seen that the vertical fiscal imbalance and the resulting short-sighted behavior of policy-makers would not only deteriorate the eagerness of the local government's ecological governance, but also harmfully affect the positive environmental regulation effects. This may cause significant obstacles to the improvement of regional environmental quality. Based on the above explanation, the following assumption proposed:

**Hypothesis 2a**. The vertical fiscal disparity significantly exacerbate environmental pollution by reducing the intensity of environmental regulations.

**Hypothesis 2b**. The vertical fiscal imbalance affect the industrial structure significantly and thus have an effect on the environmental pollution level, but with an uncertain direction.

### 2.2. Regional heterogeneity effects and mechanisms

Despite the vertical fiscal imbalance, the amount of pollution control and an environmental protection costs of fiscal expenditure is comparatively greater due to the regionally dependent nature of VFI, which has certain promotional effects on industrial innovation, industrial upgradation, environmental regulation and to compensate for its negative effects on environmental pollution (Harijan et al., 2011),

(Peña-Martel et al., 2018) (Sun et al., 2016). Furthermore, this could result in a lack of infrastructure, investment and human capital to support scientific and technological innovations (Taghizadeh-Hesary et al., 2021) and (Taghizadeh-Hesary et al., 2020). Hence, the economic growth quality and environmental pollution does not perform well. At the same time, the development of production in these areas has weakened an environmental regulation that is not beneficial to the environment. Based on the above analysis, the following hypotheses have been developed.

**Hypothesis 3a**. the impact of vertical fiscal imbalances on environmental pollution is regionally dependent, with differences in the eastern, central and western regions. Similarly, as regards the heterogeneity in mechanisms, the following hypothesis can be presented.

**Hypothesis 3b**. the mechanisms of vertical fiscal imbalance on environmental pollution are differentiated across regions.

Furthermore, the correlation is a positive one, meaning as electrification rate increases, renewables consumption of total energy consumption increases (Sun et al., 2020) and (Li et al., 2020).

## 3. Methodology and model specification

### 3.1. Model specification

The proposed research has modeled the original regression equation as shown below in the logarithm to reduce the heteroskedasticity of the underlying variables.

$$lnPC_{i,t} = C + \alpha\ ln\ VFI_{i,t} + \beta\ ln\ CONTROL_{i,t} + \mu_{i,t} + \theta_{i,t} + \in_{i,t}, \quad (1)$$

where $PC_{i,t}$ represents $CO_2$ per capita for city for the year t, $VFI_{i,t}$ is the magnitude of VFI, $CONTROL_{i,t}$ signifies the control variables strictly impacting $CO_2$, while $\alpha$, $\beta$ are coefficients to be estimated. $\mu_{i,t}$ Characterizes the specific impact, $\theta_{i,t}$ represents the time varying effect and $\in_{i,t}$ is the random error.

#### 3.1.1. Mechanism test model

In order to evaluate the mechanism, the relationship has been selected as below:

$$I_P = T(S,Q)^{-\phi}E^{\theta} \quad (2)$$

According to the profit (π) function (i.e., income produced through output (Y) minus the cost of these kinds of inputs), the profit maximization function is also measured, which is affected by externally determents energy prices, capital and labor, given as

$$\max_{K,L,M} \pi = PF(K,L,E) - R\cdot k - W\cdot L - P_E\cdot E \quad (3)$$

Here, P is the level of commodity price, R is the interest rate of nominal capital (capital price), W represents the labor price in terms of wage rate and PE is the price of energy. Process of maximization produces pollution functions over manufacturing channels through a comprehensive assumption procedure.

$$I_p = T^{-\phi}E^{\theta} = T^{-\phi}\left[\frac{\gamma W}{P_{E\beta}}\right]^{\theta} L^{\theta} \quad (4)$$

Specifically, equation (2) measures the impact of mediator variables on $CO_2$, equation (3) measures the impact of VFI on the mediator variables, while equation (4) verifies the aggregate impact of VFI, mediator variables, and other control variables. Environmental regulation and industrial structure are considered as mediators. In the above-mentioned equations, if the VFI has an effect on $CO_2$ by affecting environmental regulation and industrial structural up-gradation, the coefficients must be statistically significant. There is a mediating effect when the symbol is consistent., However, there is a suppressing effect if the symbol is opposite. Further, as per equation (4), if both (independent & mediating) variables are significant, it indicates that the VFI has both direct and indirect effects on $CO_2$.

### 3.2. Variables and data

This study utilizes four variables: the independent variables: the dependent variables; the mediator variables; and the control variables, as explained below.

#### 3.2.1. Vertical fiscal imbalance

This study refers pollution instigated through manufacturing production undertakings and domestic energy usage. Thus, its domestic energy usage has been defined as a common commodity, it has been assumed that per unit domestic rate of energy consumption relies on customer income and commodity prices (i.e., energy prices PE), as shown in the following formula

$$ec = \frac{\eta y}{P_E} \quad (5)$$

Here, y stands for income per capita and mention to the minimal tendency of power consumption. Therefore, the level of residential energy usage is equivalent to the product of the rate of per unit energy usage and population size (POP), which has been outlined as follows,

$$E_c = POP\cdot ec = \eta\frac{POP\cdot y}{P_E} = \eta\frac{Y}{P_E} \quad (6)$$

Through the replacement of Y from equation (4) into equation (6), the relation for pollution associated to domestic energy usage can be obtained as follows,

$$I_c = T^{-\phi}\left[\eta\frac{y}{P_E}\right]^{\theta} = \frac{n^{\theta}A^{\theta}\alpha^{\theta}\gamma^{\theta\gamma}}{\beta^{\theta(\alpha+\gamma)}}T^{-\theta}\frac{W^{\theta(\alpha+\gamma)}}{R^{\theta\alpha}P_E^{\theta(1-\gamma)}}L^{\theta} \quad (7)$$

Accumulation manufacturing pollution sketched in equation (4) and domestic pollution can be represented by equation (7), which causes the subsequent environmental pollution function,

$$I = I_p + I_c = \left[\frac{n^{\theta}A^{\theta}\alpha^{\theta}\gamma^{\theta\gamma}}{\beta^{\theta(\alpha+\gamma)}}\frac{W^{\theta(\alpha+\gamma)}}{R^{\theta\alpha}P_E^{\theta(1-\gamma)}} + \frac{\gamma^{\theta}}{\beta^{\theta}}\frac{W^{\theta}}{P_E^{\theta}}\right]T^{-\theta}L^{\theta} \quad (8)$$

According to equation (8), with ceteris-paribus, environmental pollution (I) rises through growth in workforce size (L) and minimal wage (W). Increased labor supply will therefore reduce marginal labor output if wages are sluggish labor that will become more expensive than energy and labor costs (Lin and Xu, 2018) & (Demircioglu and Audretsch, 2017), while more energy will be consumed to replace labor. Increased energy consumption will intensify emissions of pollutants, thereby increasing environmental pollution (Mohsin et al., 2018b) and (Mohsin et al., 2021b).

Based on the aforementioned equations, the vertical fiscal imbalance of four provinces has been calculated in the period 2000–18. Overall, the average vertical fiscal imbalance indicates an increasing trend with an increase from 0.598 in 2000 to 0.681 in 2018. The kernel density estimation of the years 2000, 2018, 2016 have been presented in Fig. 1. It also indicates an increase in vertical fiscal imbalance, with the density curve peaking in the year 2018. Overall, these results indicate that after 2007, there was an increase in the number of provinces with serious vertical fiscal imbalances, and the vertical fiscal imbalance presented a large dispersion in Pakistan during the study period (Ward, 2012).

#### 3.2.2. Carbon emission ($CO_2$)

$CO_2$ has been used as the proxy variable for pollution. $CO_2$ data has been obtained via the equation shown below (Xing and Fuest, 2018). Thus, it is used to specify the amount of energy price distortion associated with the price of energy (PE). The real energy price of is donated by PE. Consequently, the profit maximization function defined in Eq. (3) becomes:

$$\max_{K,L,E}\pi = P\cdot F(K,L,E) - R\cdot K - W\cdot L - (1-\tau)P_E\cdot E \tag{9}$$

### 3.2.3. Envoirnmental regulation

Environmental regulation (ER) has been added as a mediator in this study, which affects ecological environment. In this paper, we follow one of the prevailing ideas for to obtaining an assessed ER index, (i.e., to measure the ER level by using the ratio of pollution abatement and control expenditures (PACE) to production cost or output value) (Shahbaz et al., 2019). As stated in equation (10), the distortion of energy prices (τ) leads to an increase in energy consumption compared to other factors of production, because energy prices are low compared to the other input variables. Consequently, companies tend to substitute labor and capital with energy production. Replacing these factors, in order to determine the objective function, by considering both manufacturing and domestic pollution,

$$\frac{K}{E} = \frac{\alpha(1-\tau)P_E}{\gamma R},\ \frac{K}{E} = \frac{\gamma W}{\beta R},\ \frac{E}{L} = \frac{\alpha W}{\beta(1-\tau)P_E} \tag{10}$$

Further, evaluating the industrial structure (INS) is another work to be done. Although approaches for measuring INS differ across situations, it is considered from the study by Dupor and Guerrero (2017), given as follows:

$$I' = I_p' + I_c' = \left[\frac{n^\theta A^\theta \alpha^{\theta\alpha}\gamma^{\theta\gamma}}{(1-\tau)^{\theta(1+\gamma)}\beta^{\theta(\alpha+\gamma)}}\frac{W^{\theta(\alpha+\gamma)}}{R^{\theta\alpha}P_E^{\theta(1+\gamma)}} + \frac{\gamma^\theta}{\beta^\theta(1-\tau)^\theta}\frac{W^\theta}{P_E^\theta}\right]T^{-\theta}L^\theta \tag{11}$$

Equation (11) shows with ceteris-paribus that the downward distortion of energy prices resolves exacerbating environmental pollution in two ways. First, compared to other factors of production, energy prices are relatively cheap, which leads to a decline in marginal energy costs, leading to an increase in energy input by companies.

### 3.2.4. Control variables

The following control variables have been considered in this study: (1) population density (POP) is evaluated through the ratio of the province population under administrated area; (2) foreign direct investment (FDI). The effect of foreign direct investment on carbon emissions has been proven; (3) technology progress (TECH). Innovative technology in product typically endorses the energy efficiency and alleviate $CO_2$ more effectively (Ko, 2019) & (Doljak and Stanojević, 2017). However, assessing progress in technology is a difficult task. Therefore, it is usually replaced by the R&D investment in most cases. In this paper, the TFP (total factor productivity) is first evaluated, which is then decomposed into two characteristics (i.e., efficient technology and technological progress in specific economic development). One of the post-decomposed value will thus be treated as the technology progress. (4) energy structure (EN).

## 4. Empirical results

Pakistan is shifting towards improving factor productivity and expanding production scale. Therefore, contributions derived from growth effect are more important than the intensive effect of technological progress. This does not obviously reduce carbon emissions, which indicates a need for more in the long run. The significantly positive coefficient of foreign direct investment supports that it increases the level of carbon emissions and environmental pollution, which also verifies the “pollution shelter” Hypothesis Supporting research done by (US EIA, 2018) Egypt is the topmost consumer of natural gas and oil products in Africa, making up 22% of petroleum products and 37% of dry natural gas consumption in 2016. The issue of cleaner production has become so central to Egypt as this narrative shows the country is not producing and consuming clean fuels.

### 4.1. Priliminary findings

Now, move to the mechanism analysis according to equation (2) -(4) with regression results also shown in Table 1. First, analyze the regression results when the environmental regulation was used as a mediator in equation (2) -(4). The increase of vertical fiscal imbalance will reduce the government environmental regulation as per expectation of H2a. Column 3 shows that the environmental regulation is significantly correlated with $CO_2$ (negatively), which implies that a 1% increase in environmental regulation will induce a 0.206% reduction in $CO_2$. Further, column 4 denotes the significance of correlation coefficient of mediator. A 1% increase in VFI induces 0.86% increase in $CO_2$ emission (i.e., verification in $H_2$a). According to the above outcomes, VFI can be a direct source of $CO_2$. The environmental regulation and government’s role in regional environmental protection can be helpful to improve environmental equality. An increase in VFI not only led to a direct increase in carbon emissions, but also resulted in an additional 0.14% of $CO_2$ by affecting environmental regulation while the structure of green finance is significant, and positive, which indicates that it contributes an industrial structure upgrading as per expectation of H2b. Industrial structure in column 6 is significantly positively correlated with pollution emissions, where a 1% increase would induce an 11.14% increase in carbon emissions. One possible explanation for this mechanism is consistent with the study of (Karatas et al., 2018).

Based on the above analysis, VFI can promote industrial structure, while industrial structure will also significantly improve carbon emissions. Therefore, the indirect effect value of vertical fiscal imbalance to carbon emissions is 0.6205%. An additional 0.6205% of carbon emissions by affecting industrial structure. Moreover, the indirect impact is larger than the direct impact, which would further exacerbate the environmental pollution.

### 4.2. Main empirical findings

#### 4.2.1. Analysis of environmental regulation

Table 1 presents the descriptive statistics for the underlying variables. Environmental pollution has been considered with a major contribution from $CO_2$ emissions (i.e., 54% of the total GHG emissions). Pakistan’s Average Monthly Wages have been reported at 118.6$ per month, while the industrial sector contributes 64% of the country’s GDP. Column 2 illustrates that the impact of vertical fiscal imbalance on environmental regulation is negative, while column 3 shows that the environmental regulation has a significant negative impact on carbon emissions, which implies that an increase in the environmental regulation intensity would decrease the carbon emissions and hence improve the environmental equality. In column 4, the coefficients of vertical fiscal imbalance and environmental regulation are still significant, after the environmental regulation is controlled, and the pollution effect caused by vertical fiscal imbalance decreased from 0.819 to 0.677. Thus, according to these empirical results, the vertical fiscal imbalance has led to an increase in carbon emissions directly, which, at the same time, has enhanced the pollution effect by worsening the effects of environmental regulation.

Secondly, Table 2 shows the estimated results of the samples in the central province. According to the results, the ratio of vertical fiscal imbalance to carbon emissions is positive at 1% level of significance, which indicates that vertical fiscal imbalance can trigger an increase in carbon emissions. Overall, we believe that in the central region, the vertical fiscal imbalance has led to an increase in carbon emissions (Yousaf et al., 2020), (Tehreem et al., 2020), (Wasif Rasheed and Anser, 2017) and (Xu et al., 2020).

Meantime, the vertical fiscal imbalance has also, to some extent, exacerbated carbon pollution by reducing the pollution abating effect of environmental regulation, which eventually is not conducive to the improvement of environmental equality.

**Table 1**
Descriptive statistics.

| Descriptive Statistics | | Mean | Median | Std.dv | Min | Max |
|---|---|---|---|---|---|---|
| lnI | Environmental pollution | 0.54 | 0.523 | 0.116 | 0.006 | 0.4320 |
| lnPOP | Population size | 216.56 | 216.632 | 0.320 | 200.56 | 216.292 |
| URB | Urbanization ratio | 0.368 | 0.351 | 0.111 | 0.323 | 0.3660 |
| PST65 | Aging population ratio | 0.08 | 0.066 | 0.013 | 0.053 | 0.0800 |
| lnENP | Energy price | 0.055 | 0.544 | 0.348 | 0.042 | 0.0550 |
| DIS | Energy price distortion | 2.368 | 2.345 | 0.843 | 0.770 | 5.6310 |
| lnSAL | Nominal wages | 118.6 | 110.321 | 0.211 | 108.831 | 11.621 |
| lnRENT | Return on capital | 9.431 | 8.532 | 0.324 | 6.4511 | 9.431 |
| INS | Industrial structure | 0.642 | 0.620 | 0.030 | 0.541 | 0.650 |
| ENS | Energy Consumption | 496.65 | 432.232 | 0.233 | 423.03 | 496.65 |
| TRO | Trade openness | 0.284 | 22.131 | 0.396 | 0.238 | 0.284 |
| ENC | Environmental Consciousness | 7.898 | 7.829 | 1.048 | 5.121 | 11.644 |

**Table 2**
Estimation results based on the full sample (Random effects).

| Variables | Pooled-OLS | Fixed effects | Random effects |
|---|---|---|---|
| L/D | 0.191** | 0.312*** | 0.296*** |
| | −0.089 | −0.096 | −0.107 |
| lnPOP | 0.226*** | 0.259*** | 0.194*** |
| | −0.011 | −0.061 | −0.021 |
| PST65 | 0.135 | −0.006 | −0.071 |
| | −0.273 | −0.196 | −0.229 |
| lnENP | −0.225*** | −0.139*** | −0.155*** |
| | −0.017 | −0.019 | −0.022 |
| DIS | 0.014* | 0.019*** | 0.021*** |
| | −0.007 | −0.008 | −0.009 |
| lnSAL | 0.059*** | 0.062*** | 0.071*** |
| | −0.013 | −0.019 | −0.013 |
| lnRENT | −0.019 | −0.019** | −0.018** |
| | −0.013 | −0.008 | −0.008 |
| FDI | 0.298*** | 0.081 | 0.07 |
| | −0.068 | −0.061 | −0.052 |
| ENS | 0.04 | 0.479*** | 0.423*** |
| | −0.041 | −0.056 | −0.047 |
| TRO | −0.019 | 0.047** | 0.039* |
| | −0.022 | −0.019 | −0.022 |
| ENC | 0.027*** | −0.010 | −0.005 |
| | −0.01 | −0.011 | −0.01 |
| Constant | −2.436*** | −2.704*** | −2.337*** |
| | −0.122 | −0.439 | −0.209 |
| F test | | 43.52*** | |
| LM test | 1499.88*** | | |
| Hausman test | | 259.66 (p = 0.000) | |
| Wooldridge test | | 3.71 (p = 0.002) | |

**Table 3**
Estimation results based on the full sample (Fixed effects).

| Variable | Pooled Effects | Fixed Effects | Pooled Effects | Fixed Effects |
|---|---|---|---|---|
| L/D | 0.009 | 0.691*** | −0.029 | 0.013 |
| | −0.105 | −0.137 | −0.115 | −0.15 |
| lnPOP | 0.311*** | 0.059 | 0.199*** | 0.527*** |
| | −0.011 | −0.079 | −0.014 | −0.104 |
| PST65 | 1.528*** | 0.728*** | 0.439 | −1.202*** |
| | −0.29 | −0.249 | −0.394 | −0.424 |
| lnENP | −0.149*** | 0.046 | −0.190*** | −0.203*** |
| | −0.029 | −0.038 | −0.022 | −0.033 |
| DIS | −0.025** | 0.004 | 0.005 | 0.031*** |
| | −0.011 | −0.011 | −0.01 | −0.009 |
| lnSAL | 0.005 | −0.059*** | 0.081*** | 0.141*** |
| | −0.021 | −0.019 | −0.014 | −0.027 |
| lnRENT | −0.103*** | −0.037*** | −0.004 | −0.007 |
| | −0.023 | −0.014 | −0.013 | −0.01 |
| FDI | 0.258*** | 0.337** | 0.177** | −0.004 |
| | −0.095 | −0.133 | −0.084 | −0.067 |
| ENS | −0.217*** | 0.027 | 0.291*** | 0.492*** |
| | −0.059 | −0.064 | −0.049 | −0.086 |
| TRO | −0.073*** | 0.047** | −0.240*** | −0.076 |
| | −0.02 | −0.02 | −0.085 | −0.075 |
| ENC | 0.029** | −0.014 | 0.066*** | −0.015 |
| | −0.011 | −0.012 | −0.01 | −0.013 |
| Constant | −1.692*** | −0.049 | −2.778*** | −5.344*** |
| | −0.136 | −0.592 | −0.148 | −0.728 |
| F test | | 36.21*** | | 25.31*** |

Note: The standard deviation is in parentheses.

*4.2.2. Estimating role of industrial structure*

Next, we move on our analysis to another mediator variable industrial structure, and depict the regression results in Table 2. Firstly, results in Tables 1 and .2 review the estimated results of the samples in the eastern region. The regression coefficients of vertical fiscal imbalance and industrial structure are still significant and the coefficient caused by vertical fiscal imbalance decreased from 0.819% to 0.485%. Overall, in the eastern region, the vertical fiscal imbalance has led to an increase in carbon emissions, which has also triggered the pollution effect by promoting the industrial structure. This makes environmental pollution worse than ever before. Secondly, Tables 1 and .2 and Table 3 report the estimated results of the samples in the central region. According to column (3), the ratio of VFI to carbon emissions is significantly positive at a level of 1% (i.e., the VFI has significantly enhanced the carbon emissions level in the central region). Further investigation concerning the impact of vertical fiscal imbalance on industrial structure upgrade found that its regression coefficient is significantly positive at a level of 1% (i.e., vertical fiscal imbalance has promoted the industrial structure). Results in Tables 1 and 2 show that industrial structure has a significant positive impact on carbon emissions, which has boosted environmental pollution. Further, it can be seen that both the regression coefficients of vertical fiscal imbalance and industrial structure are still significant, and the vertical fiscal imbalance coefficient decreased from 2.524% to 0.928%. According to the above-mentioned results, we know that the vertical fiscal imbalance has led to an increase in carbon emissions, which further triggers pollution effects through indirect effects by improving the industrial structure.

According to the results, this study proposes carbon pricing of different rates for different slats. Fig. 1. Shows the comparative analysis of CCL and CLC results for different carbon tax rates. It is expected that it will not only help to improve the fiscal imbalance but also improve environmental conditions with harming economic progress. Our findings are consistent with (Taghizadeh-Hesary et al., 2019) and (Taghizadeh-Hesary and Yoshino, 2019). To address this issue, we employed the dynamic OLS method to recheck the model, where a one period lagged indicator of vertical fiscal imbalance is considered as the instrumental variable. The results are listed in column (2). Comparing the results for VFI, the findings are consistent after the endogeneity problem is taken into consideration, although the coefficients of some control variables show sensitivity in terms of magnitude, sign and level of significance (Anser et al., 2018), (Anser, 2019) and (Anser et al., 2020).

### 4.3. Discussion on findings

If the pandemic persisted to December, the economy would reduce by 0.8%, meaning Egypt will be the only country attaining a positive growth pattern in North Africa African Development Bank (2019). The increase in the Pandemic spendings will further exacerbate the country's fiscal deficit to 8.5% in 2020 in the face of lower revenues, culminating in public debt reaching 85% (Bank African Development, 2019). Egypt's government took measures to alleviate the pandemic's adverse effects on the economy and people by putting together a stimulus package worth 6.34 billion dollars, which is 1.6% of Egypt's GDP. The country reduced gas prices for industry and a stimulus package of 63 million dollars (Bank African Development, 2019). Most South Asian countries access to these clean cooking technologies is very abysmal, having harmful effects on the population. Hence the need to measure it with renewables consumption. A direct relationship is expected between them. It is coded as CleanT&FC. Of course, the big elephant in the room is Electrification; all these variables can't be measured without people having access to electricity. Access to clean electricity, especially renewables, is very key to ensuring energy security on the continent.

More so, Energy imports have security implications for a country. The more a country depends on external sources to meet its energy needs, the more vulnerable the country is to negative exogenous shocks such as oil price volatility and other market shocks. The correlation is anticipated to be a positive one. It is coded as Eneimprt. Another important variable is that of the Quality of the regulatory environment operating in the country. It shows how the government can formulate and implement sound regulations and policies for effective private sector participation and development. It is encoded as regquality, And finally, effective compliance talks about the Quality of government policies, free interference from political actors in state institutions, and government credibility to see such policies come to fruition. As the literature has revealed and given the theoretical basis for the analysis, a pooled model at the firm level is used as done in (García-Álvarez et al., 2017). The GDP growth is expected to be reduced by 6.2 and 8.1 points, giving rise to a budget and current account widening deficit coupled with inflation doubling against what was initially projected (AfDB, 2020). The real GDP growth rate is forecasted to contract by 2.3% in 2020, as the pandemic continues to the first half of 2020 and will worsen by 4.2% by the worst-case scenario if the pandemic continues to December (AfDB, 2020). The country's economy lacks diversity and relies mostly on the primary sector, dominated by mining. The Gini coefficient for DRC is 42.1%, which is very high for the country. This explains the uneven distribution of income in the country. The wealth in the country is not equally distributed among the population. That is almost half of the people of varying income distribution in the country. The higher the Gini coefficient, the inconsistent the income distribution.

Oil and gas make up 90% of Nigerian's foreign exchange earnings and more than 50% of the government's fiscal revenue (Hepburn et al., 2020) (AfDB, 2020). The government's revenue is forecasted to fall by 90% in 2020 due to lower oil demand coupled with increased spending increasing the budget deficit to about 6.7% and 7.8% in a worst-case scenario (AfDB, 2020). All this will increase the current account deficit to 5% in the country's worst-case scenarios, provided the pandemic goes beyond 2020. (AfDB, 2020) (Hepburn et al., 2020). In the light of these economic woes, the country has come out with a stimulus package to lessen the pandemic's burden. It has set up a naira 500 billion credit facilities ($1.4 billion) to aid the health sector, give tax relief to the populace, and encourage companies to continue to employ even amid the pandemic. (AfDB, 2020). The government has increased the number of conditional cash transfers to the households to 3.6 million and reduced the interest rate from 9% to 5% (AfDB, 2020). All these aimed at cushioning the impact of the pandemic. South Africa is Sub Saharan Africa's second-largest economy, with a population growth of 1.2% and nearly 60 million people. Its GDP per capita is $7525 and GDP of789billion dollars. South Africa's average annual GDP growth since 2010 is 1.9%, showing the country has been on a slower growth pathway. Its Gini coefficient is the highest among the countries in the study. This shows the stark reality of the uneven distribution of wealth in South Africa. Despite its GDP per capita, the income distribution is highly irregular. This does not promote social inclusion. Furthermore, Table 1 shows that South Africa's economic performance has been very sluggish due to inefficient structural reforms in the energy sector and labor rigidity. This has had dire consequences on the economy. The economy has been growing on average of 1.1% for the last five years (AfDB, 2020). The country is faced with hydra-headed problems of a high unemployment rate of 30% coupled with economic contraction in the second half of 2019 as well as the COVID-19 and its resultant effects, electricity supply bottlenecks, and financially distressed state-owned companies, making the growth in 2020 almost nonexistent (AfDB, 2020).

## 5. Conclusions and policy implications

This study explores the impacts and mechanisms of VFI on carbon emissions in Pakistan during the period 2000–2018. The causal effects and transmission mechanisms across different scenarios were comparatively analyzed. According to the empirical findings, the rise in vertical fiscal imbalances will significantly increase carbon emissions, which has been verified through various robustness tests. Secondly, vertical fiscal imbalances have a significant direct impact on carbon emissions. Also, it is evidenced that an indirect source of increase in carbon emissions by influencing environmental regulation and the upgrading of industrial structure. The ecological environment is therefore deteriorating, but the two mechanisms are distinct. It restricts the intensity of environmental regulations and increases the carbon emissions in the context of environmental regulations. On the other hand, it promotes the upgrading of industrial structure and thus increases the carbon emissions in context of industrial structure.

Further, the mechanism has significant heterogeneity between the constructs. Regardless of the environmental regulation or industrial structure, the central region's transmission path is more significant and larger than the eastern and western regions. In the central and eastern regions, carbon emissions can be indirectly affected by vertical fiscal imbalances. This phenomenon can have an impact on environmental regulations and industrial structure. Whereas, this insignificant effect hinders the transmission path in the western region, which has the effect of vertical fiscal imbalances on environmental regulations and the upgrading of industrial structure, thereby undermining the promotional effect of carbon emissions indirectly caused by vertical fiscal imbalances. Finally, the results show that fiscal imbalances increase environmental costs in terms of energy prices. Unfortunately, the setting of appropriate energy consumption charges causes the imposition of designated taxes to be censored. Energy prices do not reflect the level of environmental damages, air pollution and significant changes in the environment and the multiple hazards of fuel-based transportation. Through proper valuation of the actual costs of environmental damages and increasing environmental pollution concerns, energy prices should ensure a green and safe environment for consumers.

### 5.1. Policy implications

Studies pointed out that revenue must be matched by responsibility, so that local governments have both financial resources and the corresponding environmental management powers and responsibilities to improve the quality of the environment. Another matter that needs to be done to simulate the local government's enthusiasm and efficiency in the protection of the environment. Next, policymakers should pay close attention to the distorting effects of vertical fiscal imbalances on local government behavior and be optimistic that close surveillance will be maintained to improve the efficiency of environmental governance. Studies have shown that vertical fiscal imbalances do not contribute to

improving environmental quality by weakening environmental regulations. It is therefore necessary to reduce the pollution promoting the effect of vertical fiscal imbalances by implementing co-existence and flexible government expenditure on environmental protection and monitoring of environmental protection. As illustrated in existing literature, the increase in environmental protection expenditure is conductive to a conduction in pollution. This will help prevent government expenditures on production from crowding out financial expenditures related to technological innovation. This is also conducive to a change in the phenomenon that the upgrade of the industrial structure leads to an increase in pollution emissions, thus weakening the second stage of the transmission path (i.e., as implicated in mediated effects) and reducing the negative environmental effects of vertical fiscal imbalances.

Although, this research proposed a quantitative investigation of the relationship between vertical fiscal imbalances and carbon emissions for the first time, there are still limitations left for the future research. As this study is based on data from a single developing country (Pakistan), this may be a limitation of this work. However, a generalization of this idea is left for future research, where a number of developing economies can be considered with the broader picture of the role of vertical fiscal imbalances in energy pricing and environmental pollution.

## Credit author statement

Conceptualization, methodology, Sajid Iqbal; review, visualization: Ahmad Raza Bilal; data curation, supervision: Weiqing Li; visualization, editing, writing of draft: Fengsheng Chien; writing and software: Quang-Thanh Ngo; writing, visualization and editing: Tien-Dung Nguyen.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgment

This research is partly funded by University of Economics Ho Chi Minh City, Vietnam.

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