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Research Article

Relationship between Fiscal Subsidies and CO_2 Emissions: Evidence from Cross-Country Empirical Estimates

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Countries disburse subsidies with various motivations, for example, to promote industrial development, facilitate innovation, support national champions, and ensure redistribution. The devolution of subsidies may however also encourage economic activities leading to climate change related concerns, reflected through higher greenhouse gases (GHGs) emissions, if such activities are conducted beyond sustainable point. Through a cross-country empirical analysis involving 131 countries over 1990–2010, the present analysis observes that higher proportional devolution of budgetary subsidies leads to higher CO_2 emissions. The countries with higher CO_2 emissions are also characterized by higher per capita GDP, greater share of manufacturing sector in their GDP, and higher level of urbanization. In addition, the empirical findings underline the importance of the type of government subsidy devolution on CO_2 emission pattern. The analysis underlines the importance of limiting provision of subsidies both in developed and developing countries.

1. Introduction

The practice of supporting local producers through subsidies is a time-tested policy instrument, often applied for countering domestic distortions [1], for granting "infant-industry" protection [2, 3], for facilitating innovation, supporting national champions, ensuring redistribution, and so forth [4]. Subsidies might be offered by countries to their primary, manufacturing, and service sectors in various forms, for example, input subsidies (e.g., per unit fuel subsidy), output subsidies (e.g., per unit price support), and "regulatory reliefs" in terms of weaker environmental standards and tax breaks [5–7].

Subsidies are not necessarily detrimental to environment, and if designed properly, they are capable of ensuring environmental protection (e.g., subsidies for promoting environment-friendly agriculture). However, there exists a rich literature on the adverse environmental implication of subsidies. Heutel and Kelly [6] have observed several environmental implications of input subsidies. First, after provision of subsidies the demand for any subsidized input is expected to rise due to substitution of other nonsubsidized inputs. Second, firms enjoying the benefits of the subsidized inputs tend to produce more, which increases their demand for all inputs. As a result of the overall change in input usage patterns, the sectors receiving subsidies generally grow in size and their expanded scale might cause overproduction. Similarly, as the producers receive higher price per unit of output produced in case of output subsidies, this may lead to overexploitation of natural resources, overproduction, and consequent environmental degradation [8]. It has been noted that subsidies generally encourage overuse of dirty inputs and enable the environmentally inefficient producers to continue in the market [5]. Bajona and Kelly [9] have noted that lowering of subsidies augments environmental sustainability by reducing pollution-causing capital accumulation, shifting of capital and labor to less pollution intensive firms, and enhancing the output of more productive firms (a comprehensive review of definitions of subsidies and their measurement issues has been undertaken in Jones and Steenbilk [10]).

The adverse environmental implication of subsidies, especially energy subsidies, which encourage greater use of fossil fuel, is well recognized in the UN discussion forums. It is estimated that world emissions of CO_2 and greenhouse gases (GHGs) can be reduced by 13 and 10 per cent, respectively, by 2050 with the removal of fossil fuels and electricity subsidies in 20 non-OECD countries [11]. One major objective of the Kyoto Protocol negotiations has been to secure reduction of subsidies, which lead to GHGs emissions [12]. The importance has been restressed in the Rio+20 Conference declaration as well, "We remain focused on achieving progress in addressing a set of important issues, such as, *interalia*, trade-distorting subsidies, and trade in environmental goods and services" [13]. However, the UN initiatives for reduction of fuel subsidies have till date witnessed limited success [14–16].

Subsidies are considered to be detrimental to fair trade as well and the ongoing WTO negotiations under Agreement on Subsidies and Countervailing Measures (ASCM) are trying to ensure better discipline on both direct financial transfers as well as revenue foregone (e.g., interest payment on loan restructuring and tax breaks) [17]. The ASCM classifies the subsidies under two broad categories, namely, actionable (i.e., subsidies which are directly linked with production and hence trade distorting) and nonactionable (i.e., subsidies which are not directly linked with production and hence have lesser impact on trade). Bajona and Kelly [9] observed that elimination of subsidies by China in its bid to enter the WTO has been more successful in reducing emissions as compared to tariff reforms. Presently ASCM and other subsidy related negotiations under WTO (e.g., fisheries subsides and amber box subsidies in agriculture) intend to limit the provision of actionable subsidies by the Member countries, which may also potentially bear harmful environmental consequences and distortions in international trade [18, 19]. However, the extent of subsidy reforms through WTO negotiations has been limited, given the slow progress of the Doha Round negotiations of WTO success so far [20, 21].

Given this background, the current analysis intends to explore the statistical relationship between devolution of budgetary subsidies and transfers and per capita CO_2 emissions for 131 countries over 1990–2010. Nonavailability of long time series data on other GHGs for a large number of countries has restricted us to consider only per capita CO_2 emission as an indicator of climate change. The present analysis intends to contribute to the existing literature in two ways. First, several studies in the theoretical as well as empirical literature have adopted general equilibrium framework or data envelopment analysis (DEA) modelling technique to analyze the impacts of subsidy on environment [6, 9, 22, 23]. However, empirical estimation of the relationship between government budgetary subsidies and per capita CO_2 emissions in a cross-country panel data framework is a relatively less researched area. The current paper bridges this gap by testing the statistical relationship between the two series.

Second, the existing theoretical and empirical literature explains the climate change related repercussions of international trade flows with help of three effects [24–26]. First, through *scale effect* the growing output and exports of the polluting sectors may adversely influence environment, as that may cause additional energy use and exploitation of natural resources [27]. Secondly, trade can lead to change in industry structure and output composition resulting from *composition effect*, which may or may not always be adverse in nature [28]. If output from the polluting manufacturing sectors rises, then the potential for emissions of pollutants also goes up. Finally, with rise in income level, environmental governance is expected to improve in an economy, through adoption of better pollution abatement technologies, formulation and enforcement of stricter regulatory policies, and so forth [29]. In other words, the growing income may create a demand for lower emissions and the associated reforms will be determined by the *technique effect* [27]. Since a considerable proportion of subsidies until the recent period has been provided in the countries with certain underlying trade objectives [4], the empirical analysis intends to capture their influence on these three effects both in developed and developing countries.

The current paper is arranged along the following lines. First, a brief discussion on the existing literature on subsides and their potential implications on climate change concerns is presented. Second, model selection and the data sources for the empirical analysis are explained and macrotrends of the principal variables are illustrated. A cross-country empirical analysis is conducted next for understanding the influence of budgetary subsidies on per capita CO_2 emissions. Finally, based on the empirical results, a few policy conclusions are drawn.

2. Subsidy and Climate Change Concerns: Evidence from Literature

Subsidies often insulate market prices of natural resources from the full social costs of production. The reduction in per unit cost aided by subsidies often influences choice of production techniques and facilitate overexploitation of natural resources, overproduction, and subsequent climate change concerns [8, 30]. Similar subsidy-led adverse environmental impacts are considerable in several resource-intensive sectors, for example, primary sector (e.g., agriculture, fisheries), transport, energy, and water [31–36].

Overproduction in agricultural sector and consequent biodiversity loss is often caused by provision of input subsidies (e.g., fuel, fertilizer, and pesticide subsidy), which incentivizes their overuse by lowering per unit variable costs for the farmers [6]. Evidences on interrelationship between fertilizer usage in OECD countries and their CO_2 emission levels have been reported [37]. Fertilizer subsidies are more helpful for the bigger farmers, given their scale advantage, which may bear further environmental repercussions [38]. Similarly, electricity subsidy reduces per unit cost of irrigation and facilitates cultivation of water-intensive crops, which are by nature also fertilizer and pesticide intensive [39]. Such subsidies lead to groundwater overexploitation on one hand [40] and large scale leaching of nitrates and pesticides into aquifers on the other hand [41, 42]. The fuel subsidies provided in the area of marine fisheries similarly lead to overuse of mineral fuels in fishing trawlers and overfishing [43, 44].

In case of output subsidies, higher than market price provided to domestic farmers through price support measures bears a direct link with the cropping intensity and volume of agricultural production [45]. Intensive cropping leads to environmental concerns like water and soil pollution [46]; conversion of forests, rainforests, and wetlands into cultivable lands [35, 47] and diversion of water [32]. Similarly, the fisheries subsidies in the form of price support results to increased fishing intensity, causing overexploitation of the fish stocks [30]. In other words, both input and output subsidies results into serious environmental as well as climate change related concerns.

Subsidies offered to the manufacturing and energy sector often result in equally harmful environmental consequences [13]. Fuel subsidies contribute particularly to air pollution, emissions of GHGs, and loss of biodiversity, as they reduce the operational cost of recipient industries and leads to higher volume of fossil fuel burning. Such energy-related and other subsidies have emerged as major problems in developed countries [48], emerging economies [4, 49], and leading Asian economies like China [6, 50, 51] and South Korea [52].

As compared to budgetary subsidies discussed above, implicit subsidies are difficult to identify but their magnitude could often surpass the budgetary subsidy by many times [53]. Evidence from the literature reveals that final consumption subsidies (direct and/or indirect) provide perverse incentives to households for overconsumption and results in environmental damage—for example, Eastern Europe and Central Asian countries provide direct subsidies to energy providers to keep the household tariff below the actual cost of production [54]. Kate [55] noted that implicit subsidies provided to Mexican industries in terms of below market price for petroleum fuels resulted in 5.7 per cent increase in energy intensity between 1970 and 1990, as compared to decrease in energy intensity by 35.3 per cent in OECD industry. However, subsidies provided for purchasing environment-friendly goods are also available in some countries [56]. LaFrance et al. [57] show that subsidized crop insurance policies result in expansion of agriculture in marginal quality (economically inferior and environmentally vulnerable) land, which is environmentally detrimental. Fisher-Vanden and Ho [7] noted that as China provides capital subsidy by offering interest on borrowed capital below the market rate, the flat carbon tax system fails in protecting welfare by reducing emissions. A system of progressive carbon tax regime instead is desirable in an economy, which receives subsidies. Moreover, adoption of weaker environmental standards on pollution abatement functions as implicit cost subsidies to producers eventually leading to environmental degradation [5, 58, 59]. Weaker pollution monitoring for Chinese state owned enterprises has been reported in the literature [60]. While estimated values of sector-specific input subsidies (e.g., fisheries) are available for select countries for certain years, one major challenge is however to obtain actual/estimated data on implicit subsidies at country level on a regular basis.

Given the data limitation, the primary objective of the present analysis is to understand the relationship between government budgetary subsidies and climate change concerns as reflected through per capita CO_2 emissions. However, the CO_2 emissions at country level may also be influenced by variables other than budgetary subsidies. A few control variables have been included in the present analysis in line with the existing literature on environmental sustainability, namely, past values of the per capita CO_2 emissions, per capita GDP (PCGDP in PPP, current international \$), share of manufacturing sector in GDP, and level of urbanization in an economy. The income level of a country is generally positively related with its environmental sustainability [61–64], since growing income level leads to a demand for cleaner environment. However, the Environmental Kuznets Curve Hypothesis (EKCH) notes that as an economy moves from primary to secondary sector, with rise in industrial activities higher emissions are observed. However, with further rise in development level, the contribution of the services sector rises in an economy and environmental sustainability improves [65–68]. Hence, in addition to the PCGDP, the square term of it has also been incorporated into the model for understanding the effect of the higher order terms. Next, given the fact that the manufacturing sector is one of the major contributors of GHGs, the share of the manufacturing sector in GDP has been considered as one of the control variables. Finally, level of urbanization (proxied through percentage of urban population in total population) has been included in the model as a control variable as growth divergence may bear climate change repercussions [69, 70].

3. Empirical Model

The following panel data regression model is estimated here for 131 countries over 1990–2010 for analyzing the effect of budgetary subsidies on per capita CO_2 emission:

$$\begin{aligned}\log\left(CO_{2it}\right) = {} & \alpha + \beta_1 \log\left(SUB_{it}\right) + \beta_2 \log\left(SUB_{i(t-1)}\right) \\ & + \beta_3 \log\left(CO_{2i(t-1)}\right) + \beta_4 \log\left(PCGDP_{it}\right) \\ & + \beta_5 \log\left(PCGDP_{it}\right)^2 + \beta_6 \log\left(MFGGDP_{it}\right) \\ & + \beta_7 \log\left(URB_{it}\right) + T_t + C_{it} + GOV_{it} + \varepsilon_{it},\end{aligned} \tag{1}$$

where log represents the natural logarithmic transformation of the variables, α represents the constant term, βs are coefficients, CO_{2it} represents per capita CO_2 emission (in tonne per annum) of country i for year t, SUB_{it} represents budgetary subsidy (as percentage of GDP) provided by country i for year t, $SUB_{i(t-1)}$ represents budgetary subsidy (as percentage of GDP) provided by country i for year $t-1$, $CO_{2i(t-1)}$ represents Per capita CO_2 emission (in tonne per annum) of country i for year $t-1$, $PCGDP_{it}$ represents per capita GDP (PPP, current international \$) of country i for year t, $MFGGDP_{it}$ represents manufacturing value added (expressed as percentage of GDP) of country i for year t, URB_{it} represents the level of urbanization (urban population expressed as percentage of Total population) in country i in year t, T_t represents the time dummies (i.e., $T_1 = 1$ for 1990 and 0 otherwise), C_{it} represents the Cash dummy in country i in year t (takes the value of 1 if the country follows cash accounting method and 0 if the country follows accrual accounting system), GOV_{it} is a government financing dummy in country i in year t (taking the value of 1 if the subsidy corresponds to General Government (GG), and 0 for Budgetary Central Government (BCG) or Central Government (CG)), and ε_{it} represents the disturbance term.

The advantage of using the log-linear model in the current context is that the estimated coefficients can be interpreted as the elasticity between budgetary subsidy and per capita CO_2 emission and other variables.

The independent variables included in the proposed empirical model are in line with the existing empirical literature. First, the literature notes that higher volume of output might be associated with higher emission potential due to factors like additional energy use, exploitation of resources, and so forth. Hence $PCGDP_{it}$ has been considered here as the proxy of the *scale effect*. Second, as per predictions of the EKCH in the early stages of development a country moves from primary to secondary (i.e., manufacturing) sector, leading to increase in emissions level. Given the EKCH empirical evidence and the fact that the manufacturing sector is one of the major contributors to GHGs, $MFGGDP_{it}$ has been considered as the proxy of the *composition effect* in the present context. Thirdly, the EKCH also notes that further development may be associated with greater sustainability with rise in contribution of relatively less polluting services sector, higher citizen demand for cleaner environment, adoption of better environmental governance through stricter enforcement of sustainable practices, and so forth. Therefore, $PCGDP_{it}^2$ and URB_{it} have been included in the present model as the proxies of the *technique effect*.

After running the regression model for all the 131 countries, to check the robustness of the estimated regression models, we have divided the sample countries into two groups (lower income—LIC & LMIC and higher income—UMIC & HIC) on the basis of their per capita Gross National Income (PCGNI) (see next section for details). We have estimated regression Models 4A and 4B and reported the results in Table 3.

4. Data Sources and Macrotrends

The current paper obtains the data on budgetary subsidies from Government Finance Statistics (GFS) (available online at: http://elibrary-data.imf.org/QueryBuilder.aspx?key=19784658&s=322—last accessed on 11 July 2014). It is observed that GFS compiles the government subsidy figures for countries from different government sources as per their reporting practice. Three types of government reporting have been observed in the GFS data for which the required data on subsidy is available. First, the *General Government* (GG) includes all the Central Government (CG) transfers plus budgetary expenses of all the Central Ministries/Departments and the same for the State Governments (SG) (including provincial or regional) and Local Governments. The *Central Government* (CG) transfers on the other hand represent the consolidated transfers of the Central Government (including transfers of Central Ministries/Departments). Finally, subsidies reported under *Budgetary Central Government* (BCG) cover "any central government entity that is fully covered by the central government budget" [72]. In addition, the GFS generally reports the budgetary statistics for countries adopting cash accounting method, but for several countries accrual (noncash) accounting method has been reported. When data is available for a country for different level of government, preference is given to GG over CG and similarly CG over BCG.

IMF provides the data on subsidy under the broad head of "Government and Public Sector Finance" as per the guidelines of *Government Finance Statistics Manual 2001* [72, 73]. Under the specified accounting method (cash and noncash or accrual), for a specified level of government the data on subsidies and transfers to public corporations and private enterprises is available under the heading "Expenses by Economic Type" and subheading "Expense." We have taken the data on subsidies as percentage of GDP of respective countries and the process scale out the size of the economy (as measured by their respective GDP). As per *GFS Manual 2001*, the IMF reported data on subsidies are "…current transfers that government units pay to enterprises either on the basis of the levels of their production activities or on the basis of the quantities or values of the goods or services that they produce, sell, or import. Included are transfers to public corporations and other enterprises that are intended to compensate for operating losses" [72]. In order to understand the differential effects of the data reporting differences in methods of accounting and the level of government, two dummy variables, namely, cash and GG, have been included in the empirical models.

The subsidies considered in the current analysis include only direct budgetary subsidies provided by general government, central government, or budgetary central government of a country. The indirect or implicit subsidies (i.e., income foregone in terms of tax rebate/exemptions, etc.) are not covered due to nonavailability of consistent cross-country data on that front. The effect of subsidies is estimated by considering per capita annual emission of CO_2 (in metric tonne) as an indicator of climate change impact in a country. The per capita CO_2 data is obtained from World Development Indicators database [71].

For the control variables, the data on per capita GDP, share of manufacturing in GDP, and level of urbanization have been taken from World Development Indicators database, while the data on per capita nominal gross national income (PCGNI, US Dollars at current prices and current exchange rates) is taken from UNCTAD database (the data can be accessed from UNCTAD Statistics at http://unctadstat.unctad.org/ReportFolders/reportFolders.aspx—last accessed on March 7, 2014). Moreover, we have classified the countries into four broad groups based on their PCGNI—namely, low income countries (LIC) having PCGNI up to US$ 1,035, lower middle income countries (LMIC) having PCGNI lying between US$ 1,035 and 4,085, upper middle income (UMIC) countries having PCGNI between US$ 4,085 and 12,615, and high income countries (HIC) having

Table 1: Major characteristics of average budgetary subsidies and Per Capita CO_2 emission of selected countries.

Year	Budgetary subsidy (as % of GDP)		Per Capita CO_2 emission	
	LIC & LMIC	UMIC & HIC	LIC & LMIC	UMIC & HIC
1990	2.00 ± 2.93	1.37 ± 1.04	1.65 ± 2.48	9.92 ± 6.41
1991	1.56 ± 1.50	1.42 ± 0.95	1.68 ± 2.63	9.86 ± 7.00
1992	1.71 ± 2.53	1.58 ± 1.03	2.50 ± 3.50	10.3 ± 8.96
1993	1.33 ± 1.42	1.58 ± 1.22	2.47 ± 3.36	10.45 ± 10.28
1994	1.11 ± 1.27	1.43 ± 1.10	2.40 ± 3.26	10.43 ± 10.05
1995	0.82 ± 0.99	1.45 ± 1.20	2.21 ± 3.03	10.47 ± 10.03
1996	1.13 ± 1.43	1.54 ± 1.11	2.02 ± 2.66	10.38 ± 9.69
1997	0.99 ± 1.42	1.40 ± 1.11	1.93 ± 2.46	10.64 ± 10.40
1998	0.94 ± 1.45	1.46 ± 1.69	1.95 ± 2.46	10.3 ± 9.14
1999	1.15 ± 1.53	1.31 ± 0.95	1.92 ± 2.37	10.21 ± 8.61
2000	0.87 ± 1.11	1.48 ± 1.30	1.78 ± 2.15	10.09 ± 8.90
2001	0.96 ± 1.33	1.61 ± 1.62	1.89 ± 2.25	9.82 ± 7.68
2002	1.12 ± 1.51	1.71 ± 1.80	1.98 ± 2.39	9.83 ± 7.43
2003	1.29 ± 1.63	1.61 ± 1.59	2.04 ± 2.54	9.86 ± 8.50
2004	1.36 ± 1.67	1.55 ± 1.62	1.98 ± 2.56	9.67 ± 9.14
2005	1.46 ± 1.83	1.69 ± 1.57	1.71 ± 2.16	9.57 ± 9.04
2006	1.56 ± 1.97	1.72 ± 1.59	1.73 ± 2.30	9.23 ± 8.40
2007	1.45 ± 1.96	1.97 ± 1.95	1.46 ± 1.82	8.96 ± 8.13
2008	1.93 ± 2.69	2.22 ± 2.16	1.16 ± 1.46	8.65 ± 7.57
2009	1.54 ± 2.20	2.12 ± 2.18	1.06 ± 1.35	8.04 ± 7.07
All Year	1.29 ± 1.77	1.69 ± 1.62	1.92 ± 2.59	9.69 ± 8.56

Source: computed by authors based on data provided in IMF Government Finance Statistics Database and World Bank [71].
Note: figure after ± shows the standard deviation from the average estimation.

PCGNI greater than or equal to US$ 12,616—this is in line with World Bank classification of countries based on per capita Gross National Income (GNI) (Source: http://data.worldbank.org/about/country-classifications—last accessed on 24 April 2014). Further LIC and LMIC countries are grouped together whereas UMIC and HIC countries are considered as separate group for robustness check of the model. The dummy variables have been generated from the obtained data series as per the defined specifications.

The overall trends in the two key series considered in the current analysis, namely, budgetary subsidies and per capita CO_2 emissions, are illustrated with the help of Table 1. First, it is observed that the average budgetary subsidies expressed as percent of GDP have fluctuated both for the sample higher income and lower income countries over the study period. However, in the post-2007 period the figure has consistently been higher for the developing countries as compared to their developed counterparts, implying provision of relatively higher budgetary subsidies in these counties in proportional scale. Such development-led divergence becomes all the more obvious from the per capita CO_2 emission trends reported in last two columns, which illustrates that average emissions have been considerably higher in higher income countries as compared to their lower income counterparts. Moreover, Figure 1 shows that for developed countries average Per capita CO_2 emission has fallen down over 2005–2009 (as compared to the 2000–2004 period), which can be explained due to the reduction commitments under Kyoto Protocol (w.e.f. 2005). The decline in average Per capita CO_2 emissions is however more pronounced for developing countries since the 2001-02 period.

Table 2 illustrates the data availability for the present analysis as per the IMF GFS data obtained through the online platform. The first two rows segregate the total observations as per the cash and noncash (accrual) reporting practices. While the first three columns report data availability by the type of government, the last three columns summarize the average subsidy scenario as per the income level of the country groupings. The bottom three rows analyze the data availability scenario with respect to level of government providing subsidy, that is, GG and others (BCG and CG) in terms of income levels of the selected countries. Certain interesting observations emerge from the table. Firstly, it is observed that most of the countries where GFS reports data for either CG or BCG follow cash accounting method. Conversely, the countries where data for GG is available are practicing noncash (accrual) method of accounting. Secondly, majority of lower income (LIC and LMIC) and higher income (UMIC and HIC) countries have adopted cash and noncash accounting method, respectively. Finally, for majority of lower income (LIC and LMIC) countries GFS reports data for either CG or BCG. The wide variation in data reporting practices across the selected countries

TABLE 2: Distribution of budgetary subsidy data availability based on level of development, reporting practices, and accounting standards: 1990–2010.

		Data Reporting Practice			Subsidy	Level of development		
		Govt.—GG	Govt.—others	Total		LIC & LMIC	UMIC & HIC	Total
Accounting standards	Cash	248	1152	1400	1400	820	580	1400
	Noncash	600	128	728	728	151	577	728
	Total	**848**	**1280**	**2128**	**2128**	**971**	**1157**	**2128**
	Subsidy	*848*	*1280*	*2128*		*971*	*1157*	*2128*
Data reporting practice	Govt.—GG					196	652	848
	Govt.—Others					775	505	1280
	Total					**971**	**1157**	**2128**

Source: computed by authors based on IMF GFS database.

justifies the inclusion of the C_{it} and GOV_{it} dummies in the empirical model for capturing the fixed effects corresponding to accounting method and level of government.

5. Empirical Results

The panel data regression analysis has been undertaken with help of the STATA software (version 13.1). To understand the working of the model for the proposed relationship in (1) (in (1), we drop $lsub_{i(t-1)}$ from the list of regressors to carry out diagnostic tests for selection of appropriate specification of the regression model). Hausman specification test is first conducted. It is observed that the Chi-square test statistic of 124.41 (0.0000) is statistically significant. The Hausman test suggests for fixed effect model. For detecting the presence of first order autocorrelation in the model, the Wooldridge test is then performed. The F-test statistic of 34.561 (0.0000) indicates the presence of first order autocorrelation. To check the existence of heteroskedasticity in the estimated model, the Breusch-Pagan/Cook-Weisberg test has been conducted. The Chi-square test statistic of 92.20 (0.0000) indicates the presence of heteroskedasticity. Estimated mean variance inflation factor (VIF) is 19.30, which results from the inclusion of both Log (PCGDP) and its square term in the model. For other variables, the values of VIF are within the tolerance limit of multicollinearity. Based on these diagnostic tests, the present analysis adopts Feasible General Least Square (FGLS) method with time specific fixed effects. The estimated models make correction for the presence of heteroskedasticity and first order panel specific autocorrelation (PSAR(1)) within unbalanced panel data framework.

The estimation results for (1) are summarized in Table 3 and the following conclusions can be drawn. Firstly, the estimation results strongly underline the adverse influence of government subsidies on per capita CO_2 emissions ($lpcco_2$), as reflected from the positive and highly significant coefficients. The results are robust for all the specifications with budgetary subsidies, namely, *lsub*, *lsub(−1)* and the first difference of the series [*lsub-lsub(−1)*]. Translating elasticity terms, the results indicate that, with proportional increase in the budgetary subsidy level in a country, the rate of per capita emission of CO_2 also rises significantly. It is further observed from Model 2 that the coefficient of *lsub(−1)* has been higher as compared to the corresponding coefficient for *lsub*, signifying the importance of the lagged effects of budgetary subsidies on per capita CO_2 emissions. Secondly, among the control variables, the coefficient of $lpcco_2(-1)$ has been found to be positive and significant along the expected lines. The result indicates that a country with historically high level of emissions is expected to continue along the trend line, whereas countries with lower emission records may experience the reverse effect. Thirdly, sign of the coefficients with respect to per capita income indicates that, for one percentage point increase in *lpcgdp*, $lpcco_2$ emission generally increases by a higher proportion, barring the exception in Model 3. Fourthly, the higher order terms of income ($lpcgdp^2$) are mostly associated with a negative sign, which supports the EKCH predictions. Fifthly, the contribution of manufacturing sector in GDP is found to be positively influencing the dependent variable. In other words, growth in manufacturing sector in an economy results in growth of CO_2 emissions. Sixthly, the *lurb* variable is found to be positive in most of the selected model specifications, signifying the negative repercussions of urbanization. Finally, the cash and government dummies are found to be significant, implying the importance of the underlying accounting method and level of government data reporting practices.

To check the robustness of the proposed relationship, we have estimated three additional models by incorporating past values of the per capita CO_2 emission as regressor, by restricting the sample size and by using alternative functional form. It is likely that past emissions of CO_2 will influence present emission (influence of initial condition) and therefore we have included one-year lag of *lpcco2* as a regressor in our Model 3. The estimated result shows that lagged dependent variable holds a positive and significant sign.

In addition, by splicing our sample into two groups LIC & LMIC and UMIC & HIC, we check the robustness of our estimated model (Models 4A and 4B). Several interesting conclusions can be drawn by comparing the two regression models. First, the coefficients of *lsub* for the lower and higher income countries are 0.011 and 0.012, respectively, signifying greater emission growth in the latter group in response to percentage increase in budgetary devolutions. Secondly, the coefficients of *lpcgdp* for the lower and higher income

Table 3: Estimation results on the relationship between budgetary subsidy and CO_2 emissions.

Independent variables	Model 1	Model 2	Test of robustness			
			Model 3	Model 4A: LIC & LMIC	Model 4B: UMIC & HIC	Model 5: First Difference#
lsub	0.012 * * *	0.010 * * *		0.011 * *	0.012 * * *	0.003 * * *
	(0.003)	(0.003)		(0.004)	(0.004)	(0.001)
lsub(−1)		0.019 * * *				
		(0.003)				
lsub–lsub(−1)			0.005 * * *			
			(0.001)			
$lpcco_2(-1)$			0.978 * * *			
			(0.003)			
lpcgdp	2.581 * * *	3.196 * * *	0.148 * * *	1.047 * * *	3.486 * * *	1.482 * * *
	(0.132)	(0.109)	(0.025)	(0.28)	(0.474)	(0.224)
$lpcgdp^2$	−0.093 * * *	−0.127 * * *	−0.007 * * *	0.006	−0.14 * * *	0.054 * * *
	(0.007)	(0.006)	(0.001)	(0.018)	(0.025)	(0.012)
lmfggdp	0.141 * * *	0.175 * * *	0.003	0.108 * * *	0.217 * * *	0.05 * * *
	(0.015)	(0.013)	(0.003)	(0.023)	(0.014)	(0.017)
lurb	0.404 * * *	0.270 * * *	−0.023 * * *	0.663 * * *	−0.142 * * *	0.729 * * *
	(0.036)	(0.028)	(0.005)	(0.039)	(0.04)	(0.174)
cash	0.048 * * *	0.048 * * *	0.012 * * *	0.053 *	0.040 * *	0.010 * * *
	(0.015)	(0.014)	(0.004)	(0.029)	(0.016)	(0.003)
gg	0.009	0.013	0.012 * * *	0.086 * * *	0.020	0.000
	(0.013)	(0.012)	(0.005)	(0.029)	(0.014)	(0.004)
Constant	−16.318 * * *	−18.652 * * *	−0.611 * * *	−12.000 * * *	Omitted	0.005
	(0.541)	(0.453)	(0.114)	(1.024)		(0.009)
Time fixed effect	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	1660	1492	1492	812	843	1472
Number of groups	131	129	129	89	71	129
Wald Chi2	21349	85353	3195786	11155	66742.4	799
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Notes: # first difference of all continuous variables.
Figure in the parenthesis shows the heteroskedasticity [*Panel(hetero)*] and panel specific first order autocorrelation [*PSAR*(1)] corrected standard error of the estimated coefficient.
* * *, * *, and * implies estimated coefficient is significant at 0.01, 0.05, and 0.10 level, respectively.

countries are 1.047 and 3.486, respectively. The observation indicates that per capita income growth in developed countries potentially leads to three times higher CO_2 emissions, vis-à-vis the corresponding figures for the lower income countries. The difference in CO_2 emissions pattern across the two income groups can be explained by existing higher level of output in the richer economies which is in line with the predictions of the *scale effect*, as discussed earlier.

Thirdly, the coefficients of *lmfggdp* for the lower and higher income countries are found to be 0.108 and 0.217, respectively. In other words, the growth in manufacturing sector output in higher income countries potentially leads to two times higher CO_2 emissions, vis-à-vis the corresponding figures for their lower income counterparts. The result underlines the current scenario in several UMIC and HIC countries, including the emerging economies, who are experiencing higher per capita CO_2 emissions in recent period (Figure 1). The positive sign of the coefficient also indicates the presence of a strong *composition effect* in both sets of economies.

Finally, the negative coefficient of $lpcgdp^2$ in the higher income countries indicates the decline in the per capita CO_2 emissions with further rise in income. The estimated results show that, for UMIC & HIC group, the presence of an EKCH type relationship with reference to emission of per capita CO_2 has been confirmed. Conversely, for LIC & LMIC, per capita CO_2 emission is monotonously increasing with rising per capita income. The notion of development difference receives further support from the difference in the sign of the coefficient for the *lurb* variable for the two sets

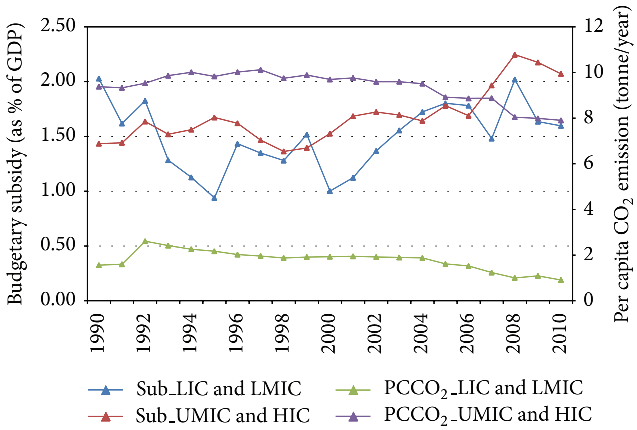

FIGURE 1: Temporal variations of average budgetary subsidy (as percentage of GDP) and average per apita CO_2 emission (in metric tonne per year) across Country Groups. Note: figure is based on average values of the variables across sample countries; source: constructed by the authors.

of countries. While the coefficient is found to be negative in sign for the higher income countries, the same for the lower income countries is found to be positive. In other words, while the growth in urban population and consequent deepening of economic activities leads to per capita CO_2 emissions growth in lower income countries, the reverse scenario prevails in their richer counterparts. The result signifies the positive effects from the rising demand for cleaner environment and better environmental governance in higher income economies in line with the predictions of *technique effect* and EKCH.

The estimated result of a regression model could be specific to functional form. Therefore, to check the robustness of our estimated result, we have estimated Model 5 where first differences of all continuous variables are taken. Except for $lpcgdp^2$, neither the sign nor the significance level of our policy variables changes in this model.

6. Policy Observations

Providing subsidies to the domestic players for achieving both short term and long term objectives is a recognized policy instrument across countries. Nevertheless, the adverse effects of such subsidies are widely acknowledged both in trade and environment literature as well as in different multilateral forums. The ongoing negotiations at the multilateral trade forum, WTO, are presently geared towards containing the subsidies which facilitate overproduction and incentivize input overuse (including fossil fuel subsidy) beyond the actionable level. On the other hand, the major objectives of various multilateral environment-related forums, for example, United Nations Conference on Sustainable Development (UNCSD) and United Nations Framework Convention on Climate Change (UNFCCC), include reduction of the GHGs emissions and protection of biodiversity, with particular focus on reduction of harmful subsidies like fuel subsidies. The modest achievements of the WTO and the UN forum negotiations in securing subsidy reform across countries are presently an area of major concern.

The empirical results of the present study confirming that the per capita CO_2 emission pattern of the countries is adversely affected by provision of budgetary subsidies need to be viewed in this wider context. The broad conclusions are the following. First, the positive and significant relationship between subsidy-GDP ratio and per capita CO_2 emission is in line with the theoretical predictions, as the budgetary support to certain economic activities may lead to overuse of environmentally harmful inputs (e.g., fuels) and cause overproduction, resulting in climate change concerns.

Secondly, the empirical results and the sign on the control variables indicate that the CO_2-subsidy interrelationship is influencing selected countries differently, based upon their position in the development spectrum. The results are in line with the EKCH predictions that as the importance of the manufacturing sector gradually increases in the lower income countries, it worsens their emissions scenario in the short run. A major portion of the subsidy provided in the lower income countries may boost the manufacturing sector activities, with obvious emissions implications. On the other hand, as the higher income countries move towards service-sector driven growth phase, their industrial pollution load gradually declines. In other words, the subsidies influence climate change concerns across different countries differently depending on the relative strengths of the *scale*, *composition*, and the *technique* effects.

Finally, the climate change concern seems imminent for both sets of countries. On one hand for the higher income countries, the presence of a higher *technique effect* might conceal part of the adverse effect of budgetary devolutions. Nevertheless, the regression results from Table 3 underline the concerns resulting from *scale* and *composition effects* for these economies in no uncertain terms. Figure 1 clearly indicates that the budgetary subsidies expressed as percentage of GDP as well as the per capita CO_2 emissions are relatively higher for richer countries as compared to their lower income counterparts. However, the concern is equally serious for the developing countries as revealed from the adverse influence of budgetary subsidies on per capita CO_2 emissions there. In addition, the concern is further compounded by the possible lack of *technique effect* in these economies. The observation underlines the need for an early conclusion of the UN forum negotiations (e.g., Kyoto Protocol, UNFCCC) to secure GHGs reduction commitments from countries across all development spectrum.

The current analysis suffers from two limitations owing to the availability of subsidies data at present. First, the indirect/implicit subsidies provided in a country through revenue foregone (i.e., income foregone in terms of tax rebate/exemptions, etc.) can affect CO_2 emissions significantly. However, the indirect subsidies in the current paper could not be covered due to absence of consistent cross-country data series on that front. The present analysis is therefore based entirely on direct subsidies, which involves budgetary devolutions (i.e., transfer of financial resources). Second, the underreporting of subsidies data is an acknowledged problem in trade literature [4]. In future, development of a comprehensive database by multilateral bodies capturing all forms of subsidies provided by countries would facilitate further policy analysis on this front.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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