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The relationship between CO_2 and Foreign Direct Investment in the agriculture and fishing sector of OECD countries: Evidence and policy considerations

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Abstract

This work focuses on the relationship between Foreign Direct Investment (FDI) and the environment. More specifically, it investigates the impact FDI inflowing the "agriculture and fishing" sector of OECD countries exerts on Carbon dioxide (CO_2) emissions level deriving from sectoral fuel combustion. To this end, a purpose-built dataset containing statistics for 30 OECD countries over 25 years (from 1981 to 2005) is analyzed through the econometric technique of panel data. Apart from other evidence, the result of the analysis shows the existence of negative relationships characterizing the technique (–0.0848), scale (−0.0036) and cumulative (–0.0044) effects of FDI on CO_2. From an environmental-economic point of view, this outcome would mean that an increase of the considered type of FDI reduces the CO_2 level. It might be concluded, therefore, that FDI plays a beneficial role in the environment. However, a more in-depth look at the quantitative aspect of the coefficients achieved and just mentioned would help us to highlight more appropriately the neutral role FDI has on the considered environmental feature. In terms of policy considerations, this evidence does not allow us to argue against those strategies aimed at enforcing the flow of FDI into the sector under our consideration.

JEL classification: F18; F64; O13; O44; P48; Q17; Q56; R11

Keywords: Foreign direct investment (FDI); Agriculture and fishing sector; Environmental impact of FDI; Globalization; FDI and CO_2.

1. Introduction

According to what has already been reported in Pazienza (2014, 2015), the literature investigating the FDI-environment relationship can be grouped into three main veins of discussion: 1) the environmental effects of FDI flows; 2) the competition for FDI and its effects on environmental standards; 3) the cross-border environmental per-

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formance. These have not yet reached a clear and conclusive understanding of their associated phenomena and more research is required (McAusland, 2008; OECD, 2002a). This is even truer for the first theme where the majority of research carried out so far has largely focused on the macro-aspects of the link between FDI and some considered pollutants by investigating data aggregated at the country level (i.e. Shahbaz, Nasreen, & Afza, 2011; Liang, 2006). Minor attention, instead, has been paid to investigate the issue while considering the specific features of each single sector of economic activity with the risk of producing misleading results and policy considerations (Pazienza, 2015; 2014). Moving on from this consideration and following a similar approach of analysis used by Pazienza (2015), the aim of this paper is to contribute to the understanding of the FDI–environment relationship by taking into account the flow of FDI arriving into the "agriculture and fishing" sector of OECD countries and Carbon dioxide (CO_2) from sectoral fuel combustion, this being one of the pollutants more specifically linked to the practice of activities of our considered sector. The main aim is to verify whether and how the first impacts the latter.

As generally referred in those works related to the issue of environmental effects of FDI, it is possible to observe how FDI does not affect the environment as an isolated phenomenon. On the consideration that it also interacts with various other factors, analysts have often developed their works by decomposing the environmental effects of FDI into technique, scale and composition (or structural) effects (i.e. He, 2008, 2006; Liang, 2006; Cole & Elliott, 2003; Grossman & Krueger, 1995, 1993a, 1993b, 1991)[1]. The technique effect is associated with the transfer and diffusion of technology and/or the introduction of regulation. It refers to the change in the production method resulting from an economy's growth process which, among other things, can be induced by FDI inflow. The technique effect is almost always associated with the fact that, in a given country, the quantity of emissions per unit of considered goods produced or consumed depends on their production or consumption "techniques". Due to a mechanism of allocative efficiency among countries, which implicitly exists in the free movement of investment, liberalization can very likely change these techniques especially through policy and technological channels. In other words, the technique effect generally refers to the development, introduction and diffusion of new and more stringent environmental regulations and/or more efficient technologies, which are expected to exert a beneficial role on the environment.

The scale effect refers to the increase in the size of the economy[2]. It is generally expected to be detrimental for the environment since an increase in the size of an economy – which can also be the result of an economy liberalization process – implies more production and, in turn, more pollution. It must be pointed out, however, that the scientific discussion on the scale effect contains the Environmental Kuznets Curve (EKC) argument in itself. Although this is the subject of different views, the EKC highlights how the detrimental impact of an economy growth process can be verified up to a certain point. Afterwards, an improvement of the environmental condition can be observed as a result of the increased capacity of countries to adopt new and more efficient technologies as a result of their higher level of richness (e.g. Stern, 2004a, 2004b).

Lastly, the composition (or structural) effect is associated with the change in the industrial structure of an economic system occurring as a shift in the pattern of economic activity. The environmental implication of this considered effect is generally expected to be beneficial to the environment on the assumption that the already mentioned free movement of investment encourages allocative efficiency among countries (OECD, 2001). As a result, for example, in a considered country a more polluting production sector might shrink and a less polluting expand. The outcome is that its total emissions will likely fall with a beneficial result for the environment. Other works, however, highlight how in a free trade and investment context, the expected sign of the impact resulting from the composition effect can be positive or negative depending on the productive specialization of a country. This, of course, depends on the country's competitive advantages, which can be characterized by opposite sources (Cole & Elliott, 2003).

Having said this, we now move onto entering the details of our empirical task and presenting the results we have achieved in relation to the issue subject of our attention. To this end, this work is structured as follows. The next section is devoted to the presentation of the materials and methods we have used. A further section focuses on the

[1] These terms were first used by Grossman and Krueger (1991) in their investigation on the environmental impact of trade liberalization within the context of the NAFTA agreement. The same terms can also be used for the case of FDI studies on the consideration that trade and FDI are strongly correlated as proven by various studies (e.g. Ghosh, 2007; OECD, 2002b).

[2] Although theoretically different, "technique" and "scale" effects appear very similar. They are quite difficult to separate especially in empirical analysis. As will be clarified later in the next section, the "technique" effect is identified by the only variable of GDP taken in isolation. The "scale" effect is identified by two variables contemporarily considered, namely the GDP per-capita and its squared computation. The same is done for the FDI variable.

presentation of the achieved results. A concluding section remarks and discusses the most relevant results with the aim of highlighting some policy prescriptions.

2. The materials and methods of the analysis

For the reasons already highlighted in Pazienza (2014, 2015), the innovative contribution of this work to the understanding of the FDI–environment relationship is represented by the fact that it proposes an investigation approach based on the observation of single sectors of economic activity. More specifically, it looks at the "agriculture and fishing" sector to verify whether and how the sectoral FDI inflow impacts the level of Carbon dioxide (CO_2) from the sectoral fuel combustion. To this end, we have built a dataset with the aim of investigating it econometrically. It contains 24 different variables resulting from the observation of 30 OECD countries for 25 years (namely the period between 1981 and 2005)[3]. The statistical gaps in the source databases deeply characterize our panel dataset which – according to Greene (2012) – is as a result strongly unbalanced. Due to the country and time units characterizing the dataset, we have analyzed it through the econometric technique of panel data. It is suitable for unbalanced data technique and shows the advantage of checking for unobserved heterogeneity (as a form of omitted variable bias), and investigating dynamically over time. The panel data technique also shows the advantage of reducing the problem related to the existence of collinearity among variables. This allows the achievement of more precise estimates generated by the efficiency gain resulting from the higher quantity of data which can be considered with respect to other techniques such as cross-section and historical time series analysis (Greene, 2012; Wooldridge, 2000; Gujarati, 1995).

The model subject of our analysis is represented by the equation below. It expresses a log-log functional relationship with the aim of achieving coefficients representing the elasticities of the relationships subject of investigation[4]:

$$\begin{aligned} \mathrm{CO_2sctr}_{it} = {} & \alpha + \beta_1 \mathrm{GDPsctr}_{it} + \beta_2 \mathrm{GDPsctr}^2_{it} + \beta_3 \mathrm{FDIsctr}_{it} + \beta_4 \mathrm{FDIsctr}^2_{it} \\ & + \beta_5 \mathrm{SCTRrel}_{it} + \beta_6 \mathrm{MKTopn}_{it} + \beta_7 \mathrm{EDU} + \beta_8 \mathrm{PROTarea}_{it} + \beta_9 \mathrm{CRpr}_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

where ***i*** an ***t*** respectively represent the 30 cross-sectional and the time units (1981–2005) we have already mentioned; $\boldsymbol{\varepsilon}$ is the error term. For the explanation of the other considered variables, we refer to the following table (Table 1) where a more schematic presentation is reported.

To explain the reason behind the choice of CO_2 as the dependent variable of our analysis, we first highlight its straight link with the sector in analysis due to the fact that it is considered in terms of emissions deriving from those sectoral activities whose operations are based on fuel combustion such as the use of agricultural and fishing machinery[5].

With regard to the explanation of how the induced-GDP and the induced-FDI technique, scale, cumulative and composition effects are identified in the above equation model, we proceed similarly to what has been done in other works (Pazienza, 2015). According to Cole and Elliot (2003), the induced-GDP technique effect is identified through the estimated coefficient of the GDP variable taken in isolation, since it happens as a result of a change in the income level and tells us how the dependent variable changes (in percentage terms) when GDP changes by 1%. The induced-GDP scale effect is, instead, represented by the GDP squared variable since it represents the size of a country's economy and its enlargement. More specifically, the scale effect is achieved by computing the partial derivative of the above equation with respect to GDP so that what appears in the generic equation as β_1 GDPsctr + β_2 GDPsctr^2 turns into $\beta_1 + 2\beta_2$ GDPsctr. The elasticity of the scale effect is then observed only through $2\beta_2$ and, from an environmental-economic view, it tells us how the dependent variable changes (always in percentage terms) in response to the 1% GDP change

[3] The countries we are considering are: 1) Australia; 2) Austria; 3) Belgium; 4) Canada; 5) Czech Republic; 6) Denmark; 7) Finland; 8) France; 9) Germany; 10) Greece; 11) Hungary; 12) Iceland; 13) Ireland; 14) Italy; 15) Japan; 16) Korea Republic; 17) Luxembourg; 18) Mexico; 19) The Netherlands; 20) New Zealand; 21) Norway; 22) Poland; 23) Portugal; 24) Slovak Republic; 25) Spain; 26) Sweden; 27) Switzerland; 28) Turkey; 29) The United Kingdom; 30) The United States of America.

[4] We recur to the use of a log–log form due to the presence of exponential series in our model and also because – as will be seen later – the regressors in our models are expressed in different units of measurement. The elasticity then becomes a more objective measure since it allows us to quantify the relationship between the dependent variables and the independent variables in percentage terms.

[5] Apart from fuel combustion, other relevant links between CO_2, agriculture and fishing can be observed. Deforestation - which is often caused by the expansion of agriculture - and biomass burning are among the major responsible of CO_2 increase (Fernandes & Thapa, 2009; World Bank, 2009). With regard to fishing, instead, various studies highlight how a heavy marine resources exploitation and a thoughtless removal of marine biota (basically du to uncontrolled fishing) would also increase the almost unknown atmospheric Carbon dioxide (pCO_2), which implies an increase of CO_2 (e.g. Fasham, 1993; Shaffer, 1993).

Table 1
Variable specification[a].

No.	Variable	Description	Source
1	CO_2 sctr Dependent variable	Natural log. of the ratio between the amount of Carbon dioxide (in million tons) from fuel combustion in the sector and the amount of population.	Our computation on IEA estimation and UN data
2	GDPsctr	Natural log. of the ratio between the sectoral GDP (in real US$) and the amount of workers in the sector.	Our computation on UN/OECD data
3	$GDPsctr^2$	(1lag_ln GDPsctr ∗ 1lag_ln GDPsctr) square of the natural log of the sectoral GDP per worker in the sector (in real US$).	Our computation on UN/OECD data
4	FDIsctr	One year lag of the natural log. of the ratio between the sectoral FDI inflow[b] (in real mln. of US$) and the GDP (in real US$)[b].	Our computation on UN/OECD data
5	$FDIsctr^2$	(ln FDIsctr ∗ ln FDIsctr); square of the natural log of the sectoral FDI inflow (in real mln. of US$) per GDP (in real US$).	Our computation on UN/OECD data
6	SCTRrel	Natural log. of a sectoral relevance indicator given by the ratio between the sectoral GDP (in real US$) and the total GDP (in real US$).	Our computation on UN data
7	MKTopn	Natural log. of a market openness indicator given by the ratio between the amount of export f.o.b. (in real US$) and the total GDP (in real US$).	Our computation on IMF/UN data
8	EDU	Natural log. of the average year of school indicator.	Our computation on CID Harvard data
9	PROTarea	Natural log. of the surface of protected area (in squared Km.).	Our computation on UN data
10	CRpr	Cross-product derived from the product between the natural log. of the sectoral GDP per worker in the sector (in real US$) and the natural log. of the total FDI inflow per GDP (in real mln. US$).	Our computation on UN/OECD data

[a] All the financial data in our database is in US$ and transformed from current to real terms by using the USA Gross National expenditure Deflator (base year = 2000) gathered from the World Bank (World Bank database at http://databank.worldbank.org).
[b] We focus our attention on the FDI inward flow, and not on the inward stock, because the FDI stock represents the direct investment position on a historical-cost basis, namely the investment amount already in the host country as opposed to the flow of capital into the host country at a considered year. In agreement with Cantwell and Bellack (1998), the use of the book value (which is the historical cost) does not take into account the distribution of the stock age and makes international comparison of FDI stocks almost impossible.

(e.g. He, 2008, 2006; Liang, 2006; Cole & Elliott, 2003; Antweiler, Copeland, & Taylor, 2001)[6]. The contemporary consideration of the technique and scale effects allows us to compute the cumulative (or total) effect which is, indeed, achieved through the algebraic sum of the terms resulting from the partial derivative of the model equation with respect to GDP. In other words, the coefficient is represented by the betas in $\beta_1 + 2\beta_2$ GDP and its environmental-economic meaning indicates the change (in percentage terms) of the dependent variable as GDP varies by 1%. Its actual impact can be computed while considering, for example, the sample mean income of OECD countries as *GDP* (e.g. Managi, Hibiki, & Tsurumi, 2008).

Similarly, the induced-FDI effects on the considered environmental dependent variable can be observed as follows. The technique effect is associated with the variable of the FDI sectoral inflow taken in isolation. As a consequence, it can be observed through β_3 in the above equation model that is the estimated coefficient of the FDI variable. The induced-FDI scale effect is determined through $2\beta_4$ resulting from $\beta_3 + 2\beta_4\ FDIsctr$ that is the partial derivative with respect to FDI of $\beta_3\ FDIsctr + \beta_4\ FDIsctr^2$ in the above equation. The cumulative effect is finally represented by the contemporary consideration of the coefficients of the technique and scale effects, namely $\beta_3 + 2\beta_4\ FDIsctr$, and can be computed while substituting *FDIsctr* with the sample mean of the sectoral FDI inflow in OECD countries. The environmental-economic meanings of the results of the induced-FDI effects are identified in the same way as done for

[6] In some works (i.e. Antweiler et al., 2001), scale and technique effects are separately measured by employing two different identities. While the earlier is measured in terms of GDP per squared km, the per-capita GDP is used for the latter. Similarly to Cole and Elliot (2003) – who use per-capita GDP to capture both the effects – we employ the sectoral GDP per-worker. The GDP per squared km., also tried in our analyses, came out insignificant. It must be noted that transformations of the above-mentioned GDP variables in cubic terms resulted insignificant and reduced or invalidated the significance of other variables in the estimated models.

Table 2
Summary statistics of the variables considered in the model.

Variable	Obs	Mean	Std. Dev.	Min	Max
Id	750	–	–	1	30
Year	750	–	–	1981	2005
EDU	750	2.12257	.2730594	1.029619	2.505526
CO_2sctr **(dependent var.)**	744	−15.55893	.8372048	−18.57597	−12.6687
MKTopn	662	−2.459594	3.221396	−15.70503	3.740827
SCTRrel	650	−3.354633	.7404608	−5.598056	.3206728
GDPsctr	600	17.83365	2.826254	14.23709	31.6578
$GDPsctr^2$	599	326.0136	122.0182	202.6947	1002.216
CRpr	514	−321.9877	174.7688	−920.6189	432.9947
PROTarea	480	−6.205169	1.807776	−9.219663	−1.6507
$FDIsctr^2$	331	517.8182	80.28949	311.1336	777.9856
FDIsctr	330	−11.43911	19.69514	−27.89239	27.45324

the induced-GDP ones[7]. The composition effect is captured in our model by considering a variable representing the relevance of our investigated sector. In our modelling, this is given by the ratio between the sectoral GDP and the total.

Having noted these methodological aspects, we now move onto presenting the results of the analysis which will be the content of the next section.

3. The results of the analysis

Our analysis results are achieved by using the tool Stata/IC 12.1 for Windows. The summary statistics of the variables considered in our model are reported in the table below (Table 2).

Before presenting the estimation procedures and results, we point out that our model specification is made the subject of a few tests with the aim of checking it for heteroskedasticity, autocorrelation, stationarity and cointegration. The LR test is employed to perform a likelihood-ratio test for the null hypothesis of panel homoskedasticity (Greene, 2012), shows a p-value $= 0.0000$ which implies the existence of heteroskedasticity problems in our model. Autocorrelation is checked through a specific test for panel data models (Drukker, 2003; Wooldridge, 2002) which shows a p-value $=$ 0.0000. This induces us to accept the alternative hypothesis of the test saying that our model specification is affected by autocorrelation. Through the employment of the Fisher test, as developed by Maddala and Wu (1999), we then check the stationarity condition of the variables considered in our model specification. The test – up to three lags – makes us observe that the majority of our variables are non-stationary since they show a p-value ≥ 0.05. As a consequence, we proceed to analyze our panel while considering the variables in first-differences to deal with the non-stationarity problem and control for serial correlation[8]. We estimate robust OLS, FE and RE models due to the existence of heteroskedasticity and autocorrelation problems in our panel[9]. Their results are shown in the table below (Table 3).

The implementation of the Brush–Pagan (LM) test for the choice between the OLS model over FE/RE performs a p-value equal to 1.0000 which makes us choose the OLS model and on which we focus from now on[10].

To comment on the actual estimate result, we first observe how – as it would be expected – the two variables associated to GDP (namely, the sectoral GDP per worker and its squared version) do not generate any useful statistical

[7] Similarly to what has been said in the previous footnote, in our analyses we consider the FDI variable in per-GDP terms. Even in this case, the transformation of the FDI variables in exponential terms beyond the squared form was not statistically significant.

[8] We transform our variables in first-differences to adopt a dynamic specification of our model (Engle & Granger, 1987). This decision also comes as a result of the Engle–Granger test for cointegration we ran on the OLS model while considering our variables in levels. The test makes us accept the null hypothesis of no-cointegration. This means that the residuals of the regression are non-stationary and its variables are not cointegrated.

[9] To correct our model for heteroskedasticity and autocorrelation, especially in OLS and FE, we recur to the use of Driscoll–Kraay standard errors. These generate estimates which are robust to various forms of spatial (cross-sectional) and temporal dependences (Hoechle, 2007: 282).

[10] The F-test for the joint significance of the variables in the OLS model is highly statistically significant with $F(8, 19) = 60.29$ and a p-value $=$ 0.0000. In addition, the F-test is also run to check for the joint significance of the two considered FDI variables which shows a p-value $= 0.0003$. Therefore, we reject the null hypothesis of the test and can say that our model including these variables is correctly specified.

Table 3
Panel data estimation results.

CO_2sctr dep. var.	OLS	FE	RE
GDPsctr	−0.0032 (0.0062017)	0.0101 (0.0050995)*	−0.0032 (0.0054187)
$GDPsctr^2$	0.0019 (0.0016746)	0.0014 (0.0020731)	0.0019 (0.0017079)
FDIsctr	−0.0848 (0.045561)***	−0.1318 (0.0292269)***	−0.0848 (0.026198)***
$FDIsctr^2$	−0.0018 (0.0008641)***	−0.0027 (0.000599)***	−0.0018 (0.000565)***
SCTRrel	−0.1358 (0.1266087)	−0.0675 (0.1371938)	−0.1358 (0.1373609)
MKTopn	0.0517 (0.0679675)	0.0162 (0.0801983)	0.0517 (0.066728)
EDU	0.1320 (0.4898129)	0.1819 (0.344598)	0.1320 (0.3589489)
PROTarea	−0.0462 (0.1111729)	−0.0961 (0.1563837)	−0.0462 (0.114618)
CRpr	0.0004 (0.000052)***	0.0004 (0.0000554)***	0.0004 (0.0000448)***
Constant	−0.0062 (0.0130101)	−0.0008 (0.0104774)	−0.0062 (0.0120121)
N. obs.	**94**	**94**	**94**
N. groups	**20**	**20**	**20**
R-squared	**0.1614**	**n.a. with robust estimates**	**Rho = 0**
Adj. R-squared	**n.a. with robust estimates**		

Robust standard errors in parenthesis; ** p-value $\leq 5\%$.
*** p-value $\leq 1\%$.
* p-value $\leq 10\%$.

evidence[11]. As a result, we are unable to make any comment on the relationship between CO_2 and GDP and on the induced-GDP technique, scale and cumulative effects on the dependent variable.

The two variables linked to the FDI flow (the one-year lag FDI and the FDI squared), instead, show evidence of statistical relevance. More specifically, we observe a statistical significant (p-value = 0.001) and negative relationship (–0.0848) when FDI is taken as it is[12]. Another significant (p-value = 0.000) and negative relationship (–0.0018) between CO_2 and the sectoral inflow of FDI is achieved when FDI is considered in its squared form. Referring back to what has already been said in section two, the elasticities of the induced-FDI technique and scale effects are respectively observed through β_3 (the estimated coefficient of the FDI variable taken in isolation) and $2\beta_4$ derived from the partial derivative of our considered equation with respect to FDI. In this specific case, the elasticities are –0.0848 for the technique effect and –0.0036 for the scale effect. The elasticity of the induced-FDI cumulative effect is represented, as a consequence, by the estimated betas in $\beta_3 + 2\beta_4$ *FDIsct*, namely *–0.0848–0.0036(LnFDIsctr)*. By bringing to solution this algebraic relation while considering, as an example, for *FDIsctr* the mean value of the FDI inflow (as shown in the table of the summary of the statistics) the cumulative effect can actually be computed and results equal to –0.0436[13].

The practical explanation of the environmental-economic meaning of these results would make us say that, with regard to the technique effect, a 1% increase of the sectoral FDI inflow generates a decrease of about 0.0848% of CO_2. The result associated with the identification of the induced-FDI scale effect would make us say that a 1% increase of the sectoral inflow of FDI determines a decrease of the sectoral CO_2 emission by about 0.0036%. Finally, the cumulative effect, which is the actual response (always in percentage terms) of the dependent variable to changes of the FDI level, would indicate a decrease of −0.0848 – *0.0036 FDIsctr* when the FDI level increases by 1%. As already said, it is equal to –0.0044 if computed while considering the mean value of FDI in our sample and its negative sign is the result of the algebraic sum between the technique and scale effects, which are both negative.

Our analysis does not find any evidence of statistical significance for the variable associated with the sectoral relevance (SCTRrel). Therefore, we are unable to comment on the composition effect. The variables representing

[11] The reason for this expectation is due to the fact that, although here we are working on IEA estimates of CO_2 from fuel combustion in the "agriculture and fishing" sector, it must be highlighted that this pollutant is not really associated with the exercise of agricultural activities. In fact, according to estimates of the World Resources Institute (WRI) – which will be better presented in the concluding section – the quota of "other fuel combustion" associated with "agricultural energy use" is just 1.4% of the total CO_2 generated by anthropogenic activities (Herzog, 2009; Baumert et al., 2005).

[12] As described in Table 1, this variable is considered with a one-year lag to mean that it exerts its statistically significant effects – that is technique effects – on CO_2 with a lag of one year.

[13] We recall that the sample mean of the OECD countries' sectoral inflow of FDI is equal to –11.43911.

the market openness (MKTopn), education (EDU) and protected areas (PROTarea) are also found to be statistically irrelevant.

The last noteworthy finding of our analysis is the statistically significant (p-value = 0.0000) and positive relationship (0.0004) between the cross-product accounting for the interactive effect of GDP and the total inflow of FDI on CO_2. This would suggest that an increase of 1% of the sectoral GDP generates an increased impact – although quantitatively insignificant – of about 0.0004% of the total inflow of FDI on CO_2.

4. Concluding remarks and policy considerations

In this work we have mainly analysed the relationship between the inflow of FDI in the "agricultural and fishing sector" of OECD countries and the emission level of CO_2 from fuel combustion in the sector to primarily assess whether FDI plays a role in contributing to determine the level of the considered pollutant or, in more general terms, to observe if FDI can be considered beneficial or detrimental to the environment.

To this purpose, we have constructed a dataset containing data for 30 OECD countries and 25 years (the period between 1981 and 2005). The dataset, strongly unbalanced due to gaps in the statistical information on the source databases of the various international organizations, has been the subject of investigation through an equation model organized in such a way as to take into account technique, scale and composition effects according to the mainstream literature. Due to the country and time units characterizing the database, the empirical analysis has been developed through the use of the econometric technique of panel data. For easier and more systemic reading of the results of our analysis, we report the concluding discussions and policy considerations in the next sub-sections.

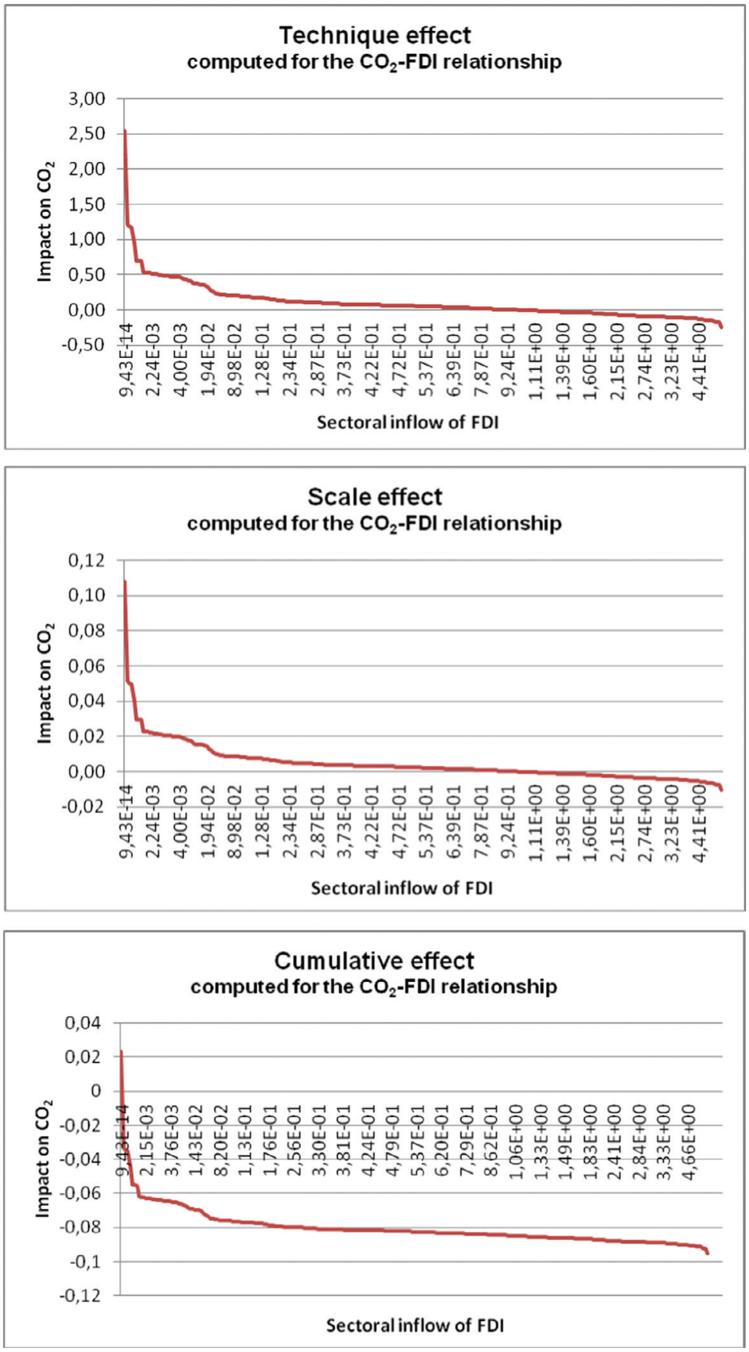
4.1. The induced-FDI technique, scale and cumulative effects

Our model estimation gives us evidence of the existence of a statistically significant relationship between the dependent variable (CO_2 emissions from sectoral fuel combustion) and the sectoral inflow of FDI considered in its linear and quadratic terms. The contemporary observation of this result and that achieved for the CO_2–GDP relationship (which does not show any evidence of statistical significance as will be reported in more detail in the next sub-section) would induce us to think that the generation of CO_2 emissions in the "agriculture and fishing" sector is more linked to the activities run with the concourse of foreign investment – probably due to their production modes – rather than those exerted in the sector considered as a whole. It is not the case, in fact, that the contribution of the agricultural sector to the generation of the considered type of polluting emission is very small, as will be seen later. This may be the reason why our model statistically explains the relationships subject of our interest with respect to FDI and not to GDP.

Having said this and entering the details of our considerations on the technique, scale and cumulative effects of the CO_2-FDI relationship, our analysis makes us observe a technique effect equal to –0.0848, showing a beneficial role of the considered investment flow for the environment since it highlights a decrease of CO_2 in response to an increase of FDI. The same could be observed when considering the scale effect that is when considering the FDI variable in its quadratic form, for which a coefficient equal to –0.0036 is achieved. This beneficial role of the sectoral inflow of FDI on our dependent variable is confirmed by the cumulative effect characterizing our investigated relationship which is equal –0.0044 (computed as an average) as a result of the algebraic sum between the technique and the scale effects. The graph here below (Graph 1) gives a better idea of the trends associated with the above-mentioned effects.

As we can more clearly observe, at a first stage the CO_2–FDI relationship is characterized by a decreasing trend due to the negative elasticity associated with the technique effect. As a result of this, CO_2 decreases as FDI increases. At a later stage, in correspondence with a turning point we compute at the level FDI per-GDP equal to 5.92E-11[14], the elasticity of the scale effect is still negative but flattens the trend with the result that CO_2 still decreases as FDI increase but at a slower rate. The overall impact of FDI on CO_2, highlighted by the cumulative effect, keeps showing

[14] As for a methodological note, the turning point is now computed by considering the partial derivative with respect to FDI of our estimated function ($LnCO_2 = -0.0848\ LnFDI - 0.0018\ LnFDI^2$) and then making it equal to zero. The result is LnFDI = –(0.0848/0.0036) = –23.55 which converted into real numbers through exp(–23.5) gives 5.92E-11.



Graph 1. Trends of the technique, scale and cumulative effects observed.

the beneficial role of FDI on the environmental feature under consideration since an increase of the investment level cumulatively generates a decrease of the emission level of our considered pollutant.

Our result agrees with those studies which have found evidence of the beneficial role of FDI on CO_2 through the observation of a negative relationship between them, while specifically focusing their attention of analysis on the agricultural sector (e.g. Yanchun, 2010). However, a different view unavoidably exists and is expressed in those analyses where opposing evidence has been produced. Jorgenson (2007), for example, finds a positive relationship between the inflow of FDI in the primary sector and CO_2 emissions, although his case study was a focus on less developed countries and the amount of CO_2 emissions level was considered in different terms from those we have used[15].

Once again, apart from the debate still open in the literature and going beyond the observation of the algebraic signs of the coefficients we have achieved from our analysis, the consideration of their quantitative aspect should induce us to speak in terms of an almost neutral role of FDI on the considered pollutant.

Considering the result we have achieved, the policy suggestion could convincingly go along with the indication of enforcing the sectoral inflow of FDI (and trade liberalization with it). It is very likely, in fact, that FDI is characterized by levels of technological innovation which make possible the beneficial – and almost neutral – role it exerts on the CO_2 emission level from the sectoral fuel combustion.

4.2. The induced-GDP technique, scale and cumulative effects

The analysed model fails to give us significant results with regard to the two considered relationships (linear and quadratic) between the CO_2 emissions from the sectoral fuel combustion and the sectoral GDP. Therefore, we are unable to comment either on the technique effect and the scale effect or on the cumulative effect induced by GDP on our considered type of CO_2.

As anticipated in the previous section, this could be explained by the fact that the contribution of the agricultural sector to the generation of this type of CO_2 is very small. This misleading aspect of our analysis can be easily observed in a couple of graphs. The two charts below (Graph 2 and Graph 3), produced by the WRI for 2000 and 2005, show that the world contribution of agriculture to the generation of CO_2 from energy use is about 1.4% of the total emission[16]. Seen from this perspective, CO_2 cannot be considered as a pollutant particularly associated with agricultural activities and its consideration surely represents the misleading aspect of our analysis.

4.3. The impact of FDI on CO_2 through GDP

As our considered model fails to produce statistically significant results in relation to the impact GDP generates on our considered variable, we are unable to comment on the impact of FDI on CO_2 through GDP. In fact, the CO_2–GDP and the CO_2–GDP^2 relationships were both found to be statistically insignificant. As already said in the previous section, the fact that GDP is unable to statistically explain a relationship with the sectoral CO_2 from fuel combustion may be due to the very small role it plays in its generation. As a result, we only rely on the direct relationship between CO_2 and FDI to have an idea of the impact the latter generates on the earlier.

4.4. The composition effect

The composition effect, which we have considered in terms of relevance of the "agriculture and fishing sector" cannot be the subject of any comment because, once again, the various estimation attempts of our considered model did not produce any statistically useful evidence.

4.5. Other evidence

We have already said in presenting the results achieved by analyzing our model that the variables represented by market openness, education levels and the size of protected areas were not found to be statistically significant.

The only noteworthy result of our estimation work can be seen in the negative relationship between CO_2 emissions and the cross-product we have used, which makes us observe how an increase of the sectoral GDP causes a decreasing impact of the total inflow of FDI on our considered dependent variable. As done in the previous section, we can comment

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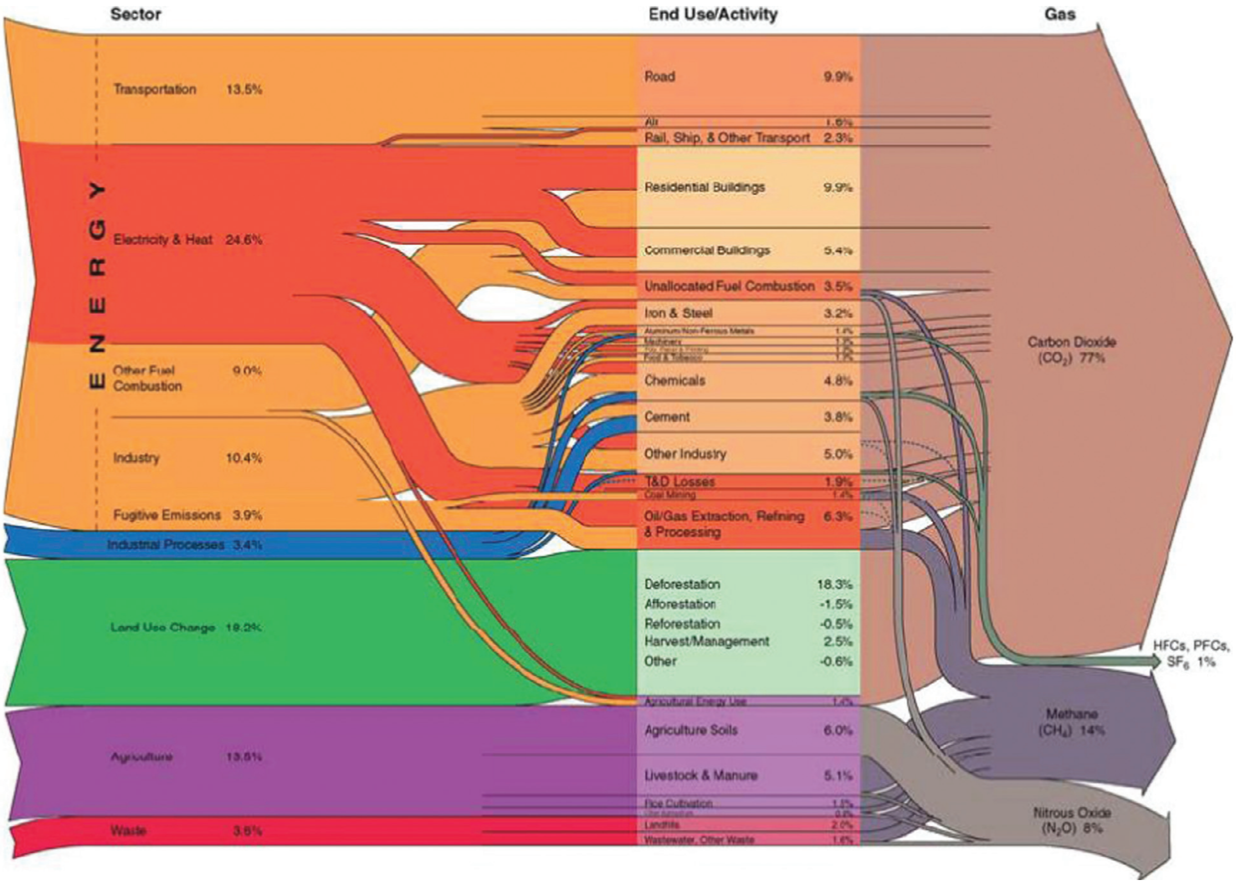
[15] In Jorgenson's work CO_2 was considered as the amount of emissions from agricultural production as a whole. We have used, instead, data associated with the amount of CO_2 generated in the "agriculture and fishing" sector as a result of fuel combustion activity.

[16] We do not have similar detailed computations for the OECD countries. The only OECD country for which computations of this kind were made in 2005 is the U.S.A., thanks to the activity run by the WRI. The U.S.A. data also shows the irrelevance of agriculture in contributing to the generation of CO_2 emission from energy use and fuel combustion (www.wri.org/chart/us-greenhouse-gas-emissions-flow-chart). Nevertheless, it is interesting to investigate CO_2 since it is considered as the most significant GHG contributing to global warming (IPCC, 2007).



Graph 2. World Greenhouse Gases at 2000.
Source: Baumert, Herzog, and Pershing (2005), p. 14.

on it while referring to two different aspects. On the one hand, we can refer to it in terms of a very broad substitute of what we have missed to observe in relation to the examination of the effect of FDI on CO_2 through the sectoral GDP. In this sense, the algebraic sign of the relationship remains negative and indicates an inverse relationship between FDI and CO_2. On the other hand, it might be intended as a general indication of a composition effect, since it gives an idea of how the emission level associated with our considered polluting agent changes in response to modifications of the relevance of the sector subject of investigation. Once again, the policy indication arising from these considerations would suggest the adoption of an approach oriented to the increase of the sectoral FDI inflow and/or of the relevance of the considered sector because they are beneficial to the environment, this intended in terms of reduction of CO_2 emissions from sectoral fuel combustion.

Electronic sources

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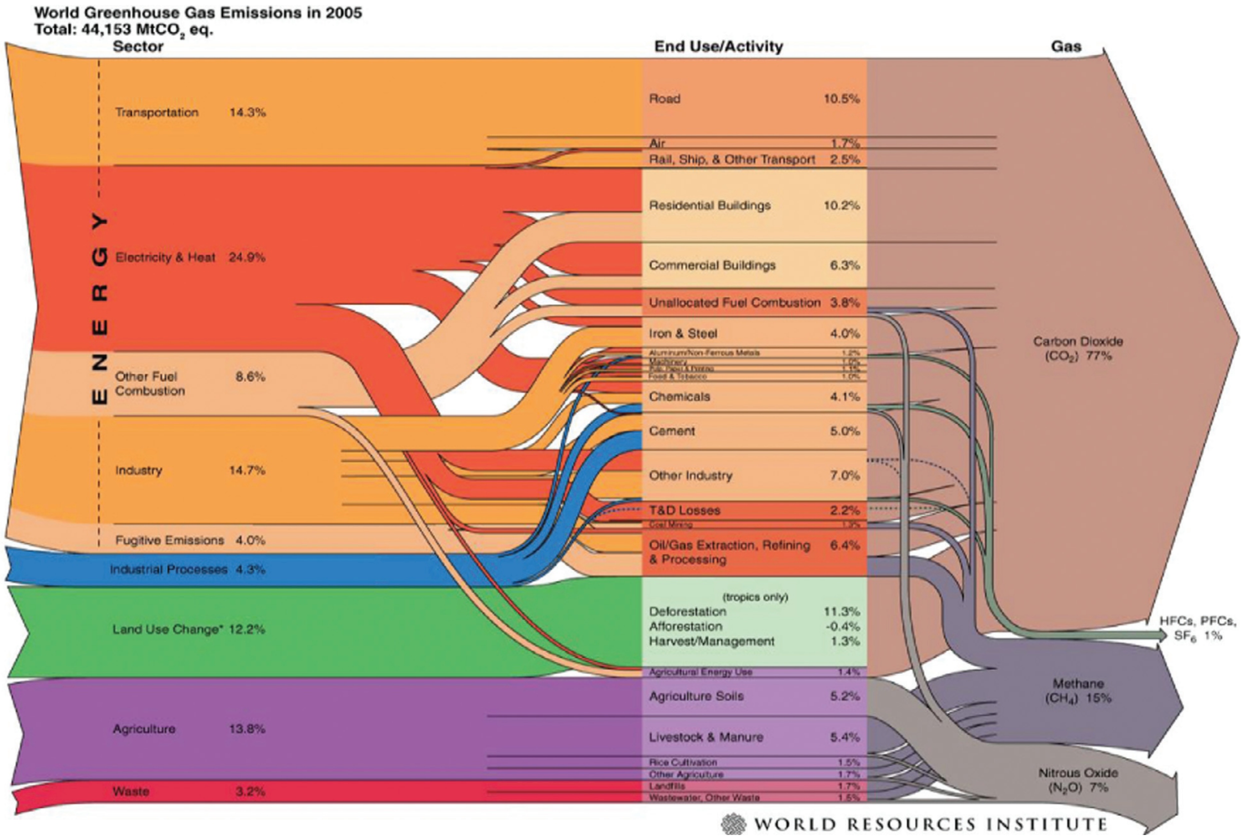
http://stats.oecd.org/glossary
http://www.cid.harvard.edu/ciddata/ciddata.html
http://www.esds.ac.uk/
http://www.iea.org
http://www.stata.com/help.cgi?contents
http://www.stata.com/statalist/
http://www.un.org
http://www.wri.org



Graph 3. World Greenhouse Gases at 2005.
Source: Herzog (2009), p. 2.

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