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Abstract: This paper addresses the issue of whether or not social capital explains per capita CO_2 emissions dynamics in Swedish counties in an augmented environmental Kuznets curve framework. By accounting for issues of endogeneity in the presence of dynamic and spatial effects using geo-referenced emissions data, we show that per capita carbon emissions in a county matters for other counties and that net of economic, demographic and environmental factors, social capital has the potential to reduce carbon emissions in Sweden albeit less robustly. We test two different social capital constructs; trust in government and environmental engagement. Specifically, trust in the government inures to the reduction in CO_2 emissions. Membership and engagement in environmental organisations reduces CO_2 emissions only through its interaction with per capita income or trust. The implication of our estimates suggest that investment geared toward increasing the stock of social capital could inure to reductions in CO_2 emissions in addition to climate policy instruments in Sweden

Keywords: Environmental Kuznets curve; Social capital; CO_2 emissions; Spatial panel analysis; Sweden

JEL Classification: C23, Q44, Q53, Q56, Z13

1. Introduction

Economic development is often blamed for creating emissions of carbon dioxides from use of fossil fuel. Many economists might agree on this viewpoint but also point out the negative relation at higher income levels. This is the so-called Environmental Kuznets Curve (EKC) relation, that emissions increase at low income levels as nations need to secure acceptable living standards but then decline at higher income levels because of changes in preferences, technology, and affordability. Grossman and Krueger (1991, 1993) were among the first to introduce the EKC hypothesis, and the literature has since then increased rapidly (see reviews in Dinda 2004; Kijima *et al*. 2010; Goldman *et al*. 2012; Kaika and Zervas 2013). However, many studies fail to establish an EKC relation and are criticized for theoretical flaws, such as neglect of developing countries' fight against environmental damage (e.g. Dinda 2004), repercussions on the economies from environmental degradation (e.g. Arrow *et al*., 1995), and leakage of dirty production from developed to developing countries (e.g. Stern 2002). Another factor generally not accounted for is social capital, the concept of which can be traced to Hanifan (1916). It was later used for explaining cooperative behavior among individuals when they have little economic incentives to do so (e.g. Boix and Posner, 1998). There is ample evidence in the literature that the availability of social capital engenders economic growth (Helliwell and Putnam, 1995; Helliwell, 1996; Knack and Keefer, 1997; Narayan and Pritchett, 1999; Rupasingha *et al*., 2000; Rupasingha *et al*., 2002; Woodhouse, 2006) and environmentally responsible behaviour and action (Pretty, 2003; Pretty and Ward, 2001; Jones *et al*., 2009a,b).

The main purpose of this paper is to investigate the role of social capital for carbon dioxide emissions in Swedish counties over the period 2005-2011. By studying counties with similar institutional set up we avoid some of the criticism raised against the EKC literature (e.g. leakage and differences among countries). However, the operationalization of social capital can be made in several ways. Two central elements are the degree of social trust and number of social contacts in organisations (e.g. Coleman 1988; Putman et al. 1993; Rothstein 2003). We test for different constructs which reflect trust or networking. Another purpose of the study is to estimate the explanatory power of spatial correlation among counties, which can occur from e.g. infrastructure linkages and co-operations. Strategic interaction may also occur where a county could be encouraged to cut its emissions if neighbouring counties are doing same (Donfouet *et al*., 2013).

Sweden is among a small number of countries[1] considered pace-setters in environmental policymaking with significant implementation success (Jänicke, 2005). The country has consistently performed well in rankings on global environmental issues. In the latest report from the climate change performance index for OECD member countries, Sweden ranked tops due essentially to low CO_2 emissions level and good emission trends in especially the housing sector among others (Burck *et al*., 2012). The country was also adjudged the most efficient of all 58 CO_2 emitters in 2013 with a ranking of 5th (Burck *et al*., 2013). With an overall positive score, Sweden however dropped to 7th behind Denmark which ranked tops at 4th position in 2014 (Burck *et al*., 2014). In a related study,

[1] Sweden, Denmark, The Netherlands

Sweden ranked 9th among 86 European countries in the Environmental Performance Index (EPI[2]) for 2014 (Hsu *et al.*, 2014). Despite these stellar performances at the national level, there are still significant differences in performance between municipalities and counties.

Our study is most close to the small literature that explicitly introduces social capital in an EKC framework (Grafton and Knowles, 2004; Paudel and Schafer, 2009; Ibrahim and Law, 2014). Grafton and Knowles (2004) uses a cross-sectional data set at the international scale and tests the impacts of different constructs of social capital on emissions of CO_2, SO_2, or NO_x. Paudel and Schafer (2009) addressed the role of social capital and spatial correlation of the EKC framework by employing both parametric and spatial panel regression models to explain the dynamics of water pollution in 53 Louisiana parishes in the US. Finally, using panel data Ibrahim and Law (2014) analyzed the effect of social capital on the EKC for CO_2 emissions in developed and developing economies. In our view, this study contributes to this literature in two ways. First, the impact of social capital and spatial correlations are tested for regions within a country, which has been made only for water pollution by Paudel and Schafer (2009). The second contribution is a test of the complementarity or substitutability between social capital and income per capita as well as the interaction effect between different elements of social capital on CO_2 emissions to see if there is any significant impact.

The remainder the paper proceeds as follows. We provide a brief literature survey of social capital and its link to the environment and economic growth in Section 2. In section 3, we present a brief analysis of the evolution and distribution of CO_2 emissions data in all Swedish counties. Other data issues and modelling strategy are provided in Section 4, while the fifth part focuses on presentation of the empirical results and discussions. We conclude the paper drawing appropriate policy implications from the results in Section 6.

2. Social capital and economic and environmental performance: a brief literature review

From the foregoing discussion in Section 1, the case for social capital inclusion within the EKC modelling framework is articulated and justified. In this section, we provide a very brief discussion of the literature on the concept of social capital in general and the social capital-economic outcome-environment nexus. We do not attempt to cover all aspects of these concepts in the literature since it falls outside the scope and focus of this paper (for a more detailed literature survey and analysis, see Rudd, 2000; Lehtonen 2004; Ballet *et al.*, 2007; Jones *et al.*, 2009a).

2.1 Social Capital

The concept of social capital has become a widely debated area among sociologists, political scientists and economists over some decades now. It is regarded as some actual or virtual resources

[2] The EPI is developed at Columbia and Yale Universities and used to rank how well countries perform on high priority environmental issues within two broad policy objectives of protection of human welfare from environmental harm and protection of ecosystems. The index is developed from a comprehensive set of 20 indicators.

or assets generated by a people within a locality that could engender a form of collective action toward a common good in a society (Brehm and Rahn, 1997). Many authors have defined social capital differently but they essentially agree on some key components constituting social capital (see Adler and Kwon, 2002 for a review of prospects of social capital). Bourdieu (1985) defined social capital as "the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition". In another breath, Bourdieu (1985) defined it as comprising "…social obligations ('connections'), which is convertible, in certain conditions, into economic capital and may be institutionalized in the form of a title of nobility". Social capital is also deemed as all resources, tangible or intangible, accruing to an individual or group due to their possession of a lasting network of relationships of mutual acquaintance and recognition (Bourdieu and Wacquant, 1992).

Portes (1998) among other sociologists have tried to distinguish social capital from other forms of capital (i.e. economic, human, cultural and political). He defined social capital as "…the ability of actors to secure benefits by virtue of membership in social networks or other social structures". This definition is in the same vein as Fukuyama (1995) "…the ability of people to work together for common purposes in groups and organizations" or "social capital can be defined simply as the existence of a certain set of informal values or norms shared among members of a group that permit cooperation among them" (Fukuyama 1997). Putnam (1995) tried to distill the features of social capital and its impact on those who possess it by stating that "…features of social organizations such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit" and Inglehart (1997) "…a culture of trust and tolerance, in which extensive networks of voluntary associations emerge".

Interestingly, Coleman (1990) highlights the multi-dimensional and often intricate nature of what social capital is. He argued that social capital cannot be bundled into a single entity and that it is defined by what it does. He states as follows "…social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: they all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure". Woolcock (1998) emphasized the importance of information and acts of reciprocity in social capital. Woolcock (1998) defines social capital as "…the information, trust, and norms of reciprocity inherent in one's social networks". Holding all other factors constant, Woolcock (1998) surmised that "…one would expect communities blessed with high stocks of social capital to grow faster, cleaner, wealthier, more literate, better governed, and generally happier than those with low stocks, because their members are able to find and keep good jobs, initiate projects serving the public interests, costlessly monitor one another's behavior, enforce contractual agreements, and respond to citizens' concerns more promptly". One would therefore expect, based on Woolcock' (1998) definition, that *ceteris paribus*, jurisdictions with more abundant social capital would have better environmental quality than those with less stock. Other potential of social capital is its ability to internalize negative externalities such as pollution. According to Rupasingha *et al.*, (2000), "…When social capital is present, externalities are internalized, which has the effect of eliminating or reducing the free rider problem and misuse of public goods while at the same time increasing investments in public goods".

From the above discussion, we can infer from the literature that social capital encapsulates elements of trust (social or individual and institutional), participation in social networks, and compliance with social norms. Trust, whether generalized or institutional, is often considered to be a key component of social capital. It is often used to even proxy for social capital in some cases. Trust is often defined as trust between individuals in general (generalized trust) and trust in social groups such as family, neighbours, friends, etc. and trust in institutions existing in a geographical jurisdiction such as central or local governments, judiciary, police among others (Jones, 2010). Active participation of individuals in social networks, formal or informal, such as Non-Governmental Organizations (NGOs), church, environmental groups and any association constitute the component of social networks (Bourdieu, 1985). The tendency to or not to comply with acceptable social norms is as espoused by Coleman (1990) and Putnam (2000).

2.2 Social Capital-Economic Performance-Environment Interface

There is an emerging strand of literature on either the interconnection between social capital and economic outcomes (Helliwell and Putnam, 1995; Helliwell, 1996; Knack and Keefer, 1997; Narayan and Pritchett, 1999; Rupasingha *et al.*, 2000; Rupasingha *et al.*, 2002; Woodhouse, 2006), social capital and environmental performance (Miller and Laurie 2008; Onyx *et al.*, 2004; Jones *et al.*, 2011; Jones *et al.*, 2009b; Jones *et al.*, 2010; Polyzou *et al.*, 2011; Jones, 2010; Halkos and Jones, 2012) and the link among the three concepts (Grafton and Knowles, 2004; Fredriksson *et al.*, 2005; Paudel and Schafer, 2009; Holstein and Gren, 2013; Ibrahim and Law, 2014, Gren *et al.*, 2014).

It is not uncommon to find in the literature that geographical regions with greater endowments of social capital tend to maintain higher per capita output levels (Helliwell and Putnam, 1995; Woodhouse, 2006). Estimating a spatially explicit model that captures regional differences in Italy, Helliwell and Putnam (1995) established that regions in Italy with greater social capital (i.e. an advanced civic community index comprising sports density, newspaper readership, cultural associations, preference voting incidence, referenda turnaround) experienced higher economic growth rates over the period 1950-1990. This result is corroborated by Rupasingha *et al.*, (2000; 2002) in two related studies in which they established a statistically significant and strong positive causal effect of social capital abundance and differences accounting for differences in economic growth in U.S. counties. Narayan and Pritchett (1996) also established in a study of a sample of 1,376 households located in 87 clusters in Tanzania that a one-standard-deviation increase in social capital (i.e. membership association) in the village increases all households' incomes by approximately 50%. Knack and Keefer (1997) further confirmed that social capital (i.e. trust and civic norms) matters for economic performance in a study of 29 market economies. They find that countries with higher incomes and lower income inequality tend to have more trust and civic norms. Using Putnam's measure of social capital (i.e. membership in formal groups), Knack and Keefer (1997) however found that there is no significant improvement of economic performance. Similar to Helliwell and Putnam (1995), Woodhouse (2006) unequivocally confirmed the hypothesis that a town with high level of social capital (i.e. bonding and bridging social capital) displays high level of economic growth in a study of two regional towns in Australia between 2001 and 2002. In a group of Asian countries however, Helliwell (1996) found limited roles of social capital and institutions in the growth differences among Asian economies. This, according to the author, was due mainly to shortage of comparable data on social capital for the Asian countries considered.

As emphasized by Pretty and Ward (2001), "…*as long as people managed natural resources, they have engaged in collective action*". The belief or prediction that the success or otherwise of an environmental and sustainability policy outcomes can be explained to a significant extent by the levels of social capital in a community or locality has been at the core of policy debate in recent times (Pretty and Ward, 2001; Pretty and Smith, 2003; Miller and Buys, 2008; Pretty, 2003). Social capital (comprising relations of social and institutional trust, common rules, compliance to social norms and sanctions, networking or connectedness in institutions or association memberships, civic participation, etc.) are seen as essential elements which promotes collective action towards a common good, including environmental policy outcomes (Coleman, 1990; Putnam *et al*., 1993; Jones *et al*., 2009a). For instance, social capital with its key elements has been found to be a resource necessary to shape individual and collective action to achieve positive biodiversity outcomes (Pretty and Smith, 2003). It is also an essential tool for framing public and private institutions of resource management with the aim of building resilience to the risk of the climate change scourge (Adger, 2003). Other studies have shown that communities with higher or stronger scores on most components of social capital were more likely to engage in an environmentally friendly activity (Onyx *et al*., 2004; Miller and Buys, 2008). Jones (2010), Jones *et al*., (2009a; 2009b; 2010; 2011), Polyzou *et al*., (2011) and Halkos and Jones (2012) have demonstrated the need to incorporate social capital in environmental policy decision-making processes, especially in the determination of people's willingness-to-pay (WTP) for an environmental policy outcome good.

We further review the relatively scant literature that explicitly incorporates elements of social capital into the EKC framework. Grafton and Knowles (2004) is among pioneer studies to test cross-country differences in national environmental performance against a comprehensive set of social determinants (civic and public social capital, social capacity and social divergence) after controlling for differences in per capita income and population density. Of interest is the categorization of especially civic social capital (trust, civic behaviour, active membership or association in four different types of voluntary organizations) and public social capital (democratic accountability and corruption within the political system). Their findings however did not find any significant impact of social capital on national environmental performance. Thus the presumption that social capital is always good for the environment was discounted. Rather, limiting future rise in population density coupled with lowering input intensities would be the needed impetus for improved national environmental performance. It is also important to note that our understanding of the emissions-social capital nexus would be further enhanced if it is modelled not only across time but also across space. It is possible that environmental performance (e.g. CO_2, SO_2, or NO_x emissions) in one locality could have a spillover effect on a neighbouring jurisdiction. Also, differences in the abundance of social capital in different localities could affect an environmental outcome differently. Are these differences due to space significant or not in modelling this nexus? Paudel and Schafer (2009) addressed these aspects of the EKC framework by employing both parametric and spatial panel regression models to explain the dynamics of water pollution in 53 Louisiana parishes in the US. A social capital index is developed via principal components analysis (PCA) and the effect modelled. They find significant impact of social capital for only nitrogen and phosphorous but not dissolved oxygen. Interestingly, the EKC quadratic curve was found to be U-shaped contrary to the traditional hypothesis of an inverted U-shaped relationship between pollution and income. In a very recent study, Ibrahim and Law (2014) analyzed the effect of social capital on the EKC for CO_2 emissions in 69 developed and developing economies. Using panel data techniques and confirming the existence of the EKC, they find evidence that countries with higher stock of social capital tend to have lower emissions of pollutants due to economic development.

Finally, the literature on the role of social capital in compliance with environmental policy regulation continues to witness significant growth. Among a few of the papers reviewed here, Fredriksson *et al.*, (2005) studied the effect of environmental (lobbying) groups, accounting for political participation and competition and per capita GDP on the stringency of environmental policy (measured by the lead content of gasoline in 1996 and 2000 for 82 and 22 developing and OECD countries, respectively). They find in various model specifications that environmental groups is associated with lower lead content levels in 1996 and even more robust results in 2000. Similarly, Holstein and Gren (2013) studied the effect of the abundance of social capital in Swedish municipalities on enforcement of environmental policy instruments while accounting for environmental attitudes (general environmental interest, engagement in environmental organizations) and economic motives. Using count data model, they provide evidence that environmental attitudes and social capital (trust index and organizational engagement) abundance deter violation of environmental regulations by large firms but have no significant effect on violation by smaller firms. A follow-up study by Gren *et al.*, (2014) considered the effect of social capital on violation of environmental regulations in both municipalities and counties in Sweden using the same data in Holstein and Gren (2013). They developed a simple theoretical dynamic model to analyse this effect as well as empirical evidence from count data regression analysis. The results show that violation reduces in growth of all social capital variables considered (i.e. general trust, trust in local and national governments, and organizational activity).

The studies reviewed so far confirm or suggest the strong explanatory power of social capital on either economic growth or the environment or on the environment within a multivariate EKC framework. In this study, we follow Putnam's definition of social capital to construct our variables. Specifically, elements of social capital relating to trust in the national government and activity level and/or engagement in environmental organizations are considered.

3. Carbon Emissions in Sweden: A Preliminary Analysis

Before estimating the empirical models for this study, we present and analyse the data on CO_2 emissions and per capita CO_2 emissions averaged over a seven-year period (2005-2011) and display them on a map. The top five emitters for the period were Västra Götaland, Skåne, Norrbotten, Stockholm and Södermanland. They accounted for 19.6%, 10.5%, 10.4%, 10.4% and 6.3% respectively of the share of total emissions by all counties in Sweden (see middle map in Figure 1). Clearly, in Figure 1, very high levels of total CO_2 emissions can be seen up north in Norrbotten county, Stockholm county (in the south-east), Västra Götaland (south-west), Skåne (down south) and Gotland (an island east of Kalmar county). What is interesting though is that one can notice some concentration of low emitting counties but same cannot be said of high emitting counties except Södermanland and Stockholm.

In per capita terms at the county level, CO_2 emissions is still very high in Norrbotten county, Södermanland and highest in Gotland. For instance, Gotland county recorded the highest per capita CO_2 emissions of 42.3 tons in 2006, but it reduced to a minimum 33.9 tons in 2009. Following Gotland is Norrbotten with emissions ranging from a high of 13.9 tons per person (recorded in 2007) to a low of 17.2 tons in 2009. Södermanland county also seems to have reduced its emissions per capita from a maximum 13.9 tons (2005) to a minimum 7.3 tons (2009). The remaining counties appear to have relatively low emissions per person given county population.

Data on carbon dioxide emissions trend for the whole of Sweden is starting from the 1990s is shown in Figure 2. The trend captures total and per capita CO_2 emissions the period 1990, 2000 and 2005-2011 for which data is available. What is clear from the Figure 2 is that total CO_2 emissions which peaked in 1990 (55,977 thousand tons) has been decelerating over the period with the trend almost constant over the period 2005-2006. The lowest CO_2 emissions level was recorded in 2009 (45,966 thousand tons), but a jump to historic high levels was evident in 2010 (51,725 thousand tons). The trend has, since 2010, been decreasing. Similarly, CO_2 emission per capita has generally been falling over the entire period except in 2010. Overall, total CO_2 emissions decreased by 13.8% over the period 1990-2011, while CO_2 emissions per capita plummeted by about 22% (6.5 thousand tons in 1990 to 4.8 thousand tons in 2011) over the same period. The impressive outturn in carbon emissions levels can be attributed to the aggressive implementation of the Swedish environmental code over the last twenty years which has placed Sweden among top performers in terms of climate change mitigation policies/practices and environmental performance in general.

Generally, per capita CO_2 emissions have been following a downward trajectory for most counties in Sweden. In terms of percentage changes in carbon emissions, all counties except Gotland have cut down on their CO_2 levels (see Figure 3) over 2005-2011. The highest cut was recorded for Värmland county (29.7%), followed by Uppsala (22%). Other top reducing counties are Halland (19.5%), Kronoberg (19.4%) and Blekinge (18.8%) among others. Eleven other counties cut their total CO_2 emission levels from 10% to 17%, with the least reduction recorded by Skåne county (3.9%). Gotland however increased its share of per capita CO_2 emissions by 3.4%. We implemented further analysis of CO_2 emissions changes for other time periods to aid our understanding of evolving changes in carbon emissions at the regional level. Figure 3 depicts details of this resampling analysis.

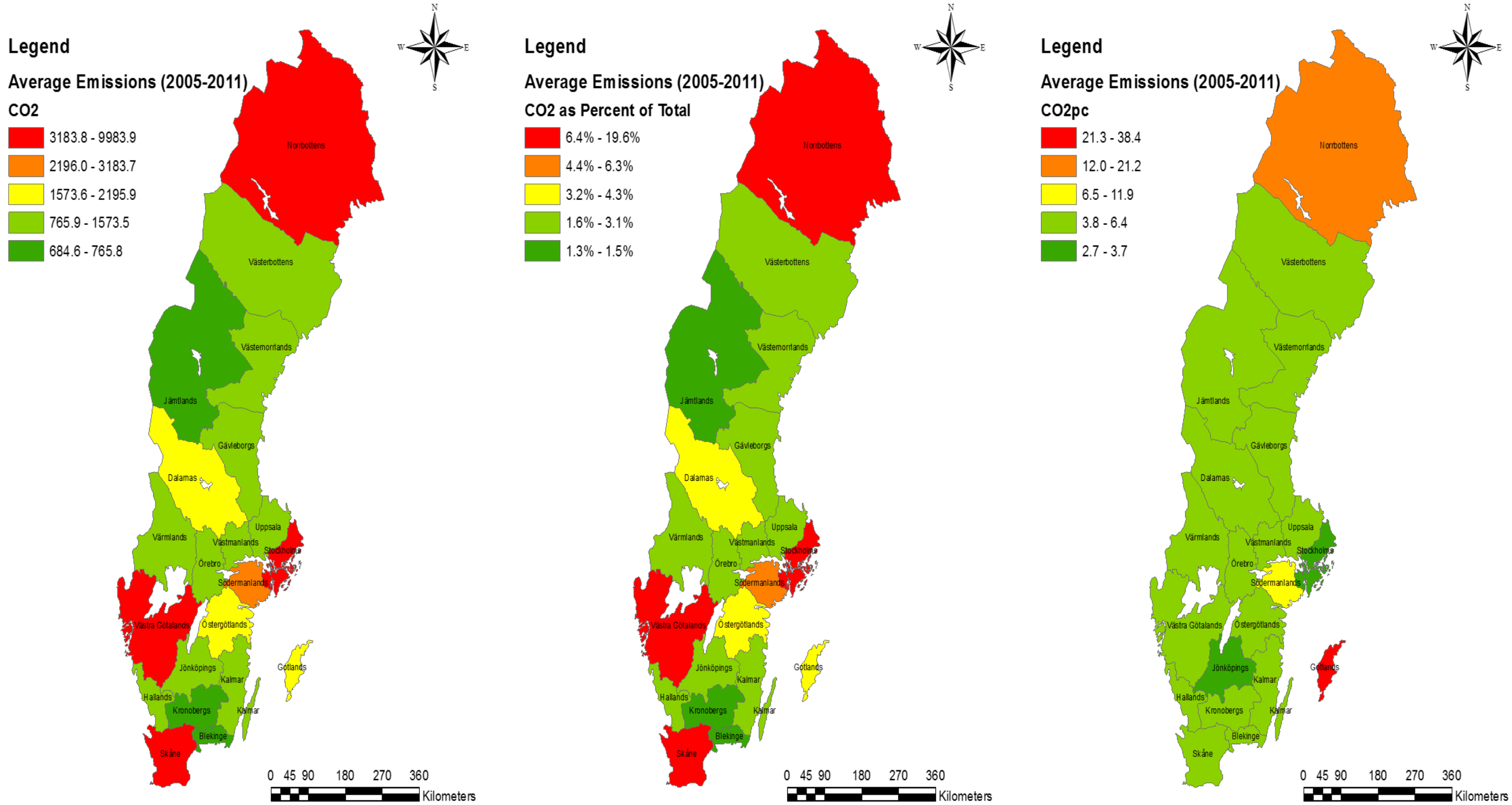

Figure 1: Distribution of CO_2 emissions and CO_2 emissions per capita in Sweden

Source: Authors' construct using carbon emissions data from Swedish National Emissions Database and Statistics Sweden (SCB)

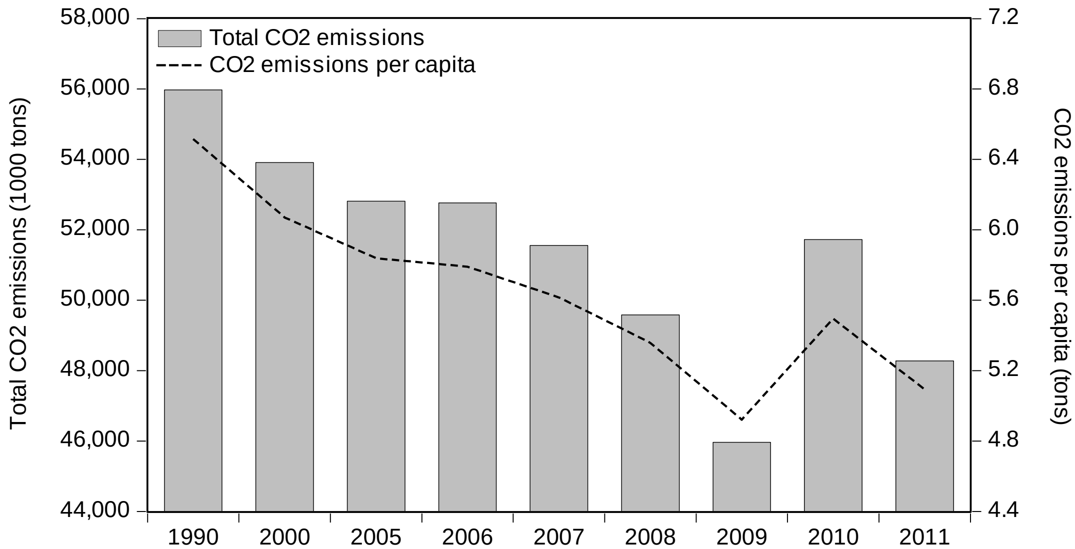

Figure 2: Emissions from CO_2 in Sweden

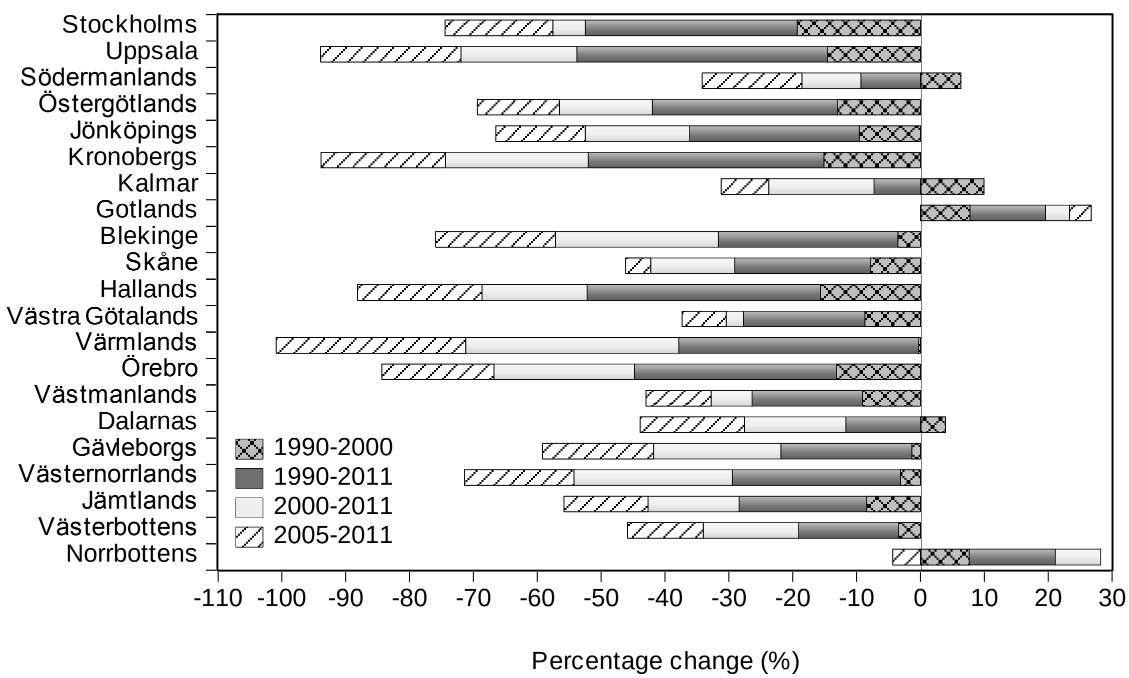

Figure 3: Percentage change in per capita CO_2 emissions in Swedish Counties
Source: Authors' construct using carbon emissions data from Swedish National Emissions Database and Statistics Sweden (SCB)

4. Data and Methodology

4.1 Variable Definitions, Measurement and Sources

We use a balanced panel data across 21 counties in Sweden over a seven-year period, 2005-2011. Specifically, emissions data is denoted by per capita CO_2 emissions. We control for standard EKC covariates such as real gross domestic product per capita and its squared (GDPpc and $GDPpc^2$) to capture for the income turning point in the EKC model. Other control variables include population density and the level of education. Our main variable of interest, social capital, is represented by trust elements and organizational engagement (see Table 1 for data description and sources). Carbon dioxide emissions data is obtained from the Swedish national emissions database[3]. We then calculate per capita CO_2 emissions by finding the ratio between total CO_2 emissions in each county and the corresponding total population. Data on total population, population density (measured as population per square kilometer for each county) and education (i.e. the number of people with post-secondary education of 3 years or more – ISCED97 5A) are retrieved from the Statistics Sweden database[4].

Following the Putnam (1995) definition of social capital, we distinguish between trust (interpersonal/social and institutional trust) and networks/associations. Interpersonal or social trust refers to the situation where one perceives others acting in a similar manner as one's self while trust in institutions refers expectations about institutions' ability to design, implement, monitor and effectively enforce policies to the latter (Jones, 2010; Gren *et al*., 2014). In this study, we use two key indicators of social capital to analyse its impact on carbon emissions. Specifically, we use data on trust in the national government (Trustgov) to represent the trust element of social capital. Organizational engagement and activity level is represented by membership and active participation in environmental organizations (Envorg). We also include a measure of environmental attitude with the variable on general interest in environmental issues (Envint). Social trust and organizational engagement may influence perception of compliance and general societal appreciation of economic actors within each county (Gren *et al*., 2014 with own emphasis). On the other hand, while trust in localized institutions act as perception about their own ability to enforce environmental regulations (including emission targets and standards), trust in the national government gives overall credibility or legitimacy to the environmental policy as such (Gren *et al*., 2014). All data on environmental attitudes and social capital are obtained from an annual survey of Swedish citizens' attitudes (Holmberg *et al*., 2014)[5].

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3 Data can be accessed at http://projektwebbar.lansstyrelsen.se/rus/Sv/statistik-och-data/nationell-emissionsdatabas/Pages/default.aspx

4 Data is available at http://scb.se/en_/Finding-statistics/Statistics-by-subject-area/

5 The SOM Institute (Society, Opinion and Media survey) is part of the University of Gothenburg, Gothenburg, Sweden. Data is accessible upon request from http://www.som.gu.se/som_institute/-surveys/survey-data/

Table 1: Abbreviations, data description and sources

Variables	Description	Source
CO_2pc	Per capita carbon dioxide emissions (tons); Tons/capita	National emission database (RUS) & SCB (2014)
Spatially lagged CO_2pc	Spatially weighted CO_2pc computed using a spatial weight matrix	Authors' construction
GDPpc	Real regional GDP per capita, 100000 SEK/year (2005 constant prices)	SCB (2014)
Popdens	Population per sq. km	SCB (2014)
Educ	Number of people aged 16-74 years with post-secondary education of 3 years or more	SCB (2014)
Trustgov	Trust in the national government (scale '1' very little trust – '5' much trust)	Holmberg *et al.*, (2014)
Envorg	Engagement in environmental organizations (scale 1 – 5, higher index implies higher level of activity)	Holmberg *et al.*, (2014)
Envint	General environmental interest (scale '1' very interested – '4' not interested at all)	Holmberg *et al.*, (2014)

Table 2: Descriptive Statistics of Data

Variable	Mean	Std. Dev.	Min.	Max.
CO2pc	7.63	7.92	2.39	42.32
Spatially lagged CO_2pc	7.63	7.88	2.63	39.11
GDPpc	2.89	0.42	2.34	4.61
Popdens	44.95	63.42	2.50	320.50
Educ	55225.48	78498.26	5239.0	383210.0
Trustgov	3.01	0.28	2.43	4.05
Envorg	1.05	0.09	0.90	1.66
Envint	2.16	0.18	1.70	3.17

The descriptive statistics of the data used for the analysis is summarized in Table 2 (also see Table A2 in the appendix for the correlation matrix). It can be noted that there is much variation in per capita CO_2 emissions in the sample. Average per capita carbon dioxide emissions is approximately 7.6 tons over 2005-2011, with the highest of 42.3 tons recorded in 2006 in the Gotland county (see Figure 1 and 3 for CO_2 emissions distribution). Worthy of note are the variations in the real income per capita and population density data. While real GDP per capita is less variable across counties, population is highly variable indicating the heterogeneous spread of population per land area in Sweden. With regard to indicators of social capital, trust in the national government is quite high (averaged 3). While the highest level of governmental trust was recorded in Norrbotten county (4.05) in 2005, the lowest level was observed in the Stockholm county (average index of 2.43) in 2010. Kronoberg county showed the least level of trust in the government with an index of 5.74 in 2006. Finally, the summary statistics clearly show that there is very little activity in most environment organizations in most Swedish counties. That is, even though on average there may be many people subscribing to membership in environmental organizations, they are not very engaged in the activities of these environmental watchdogs.

4.2 Econometric Methodology and Estimation

The standard pollution-income EKC framework has been modelled either as a quadratic or cubic specification between emissions and income while controlling for other variables such as population density (to control for relative size of each county), education, and urbanization, among others. We adopt a standard quadratic relation between per capita CO_2 emissions and per capita GDP, augmented with two indicators of social capital. We then control for the effect of population density, educational level and a measure of environmental attitude, level of interest in environmental issues.

One of the major issues in the empirical analysis of the EKC is the inclusion of variables other than income. We are motivated to control for the effect of population density, education, environmental attitude and social capital on the basis of the reviewed literature in Section 2 of this paper. The expected sign of population density on per capita CO_2 emissions is an empirical issue. On one hand, and as found in much of the literature, we hypothesize that emissions per capita will increase with increasing population density. This is because counties with high population density, which are usually highly urbanized, are often associated with much economic activities with its concomitant pollution problems (Li *et al*., 2014). The other perspective in the literature intimates a reverse relation. For instance, it has been shown that emissions per capita is a decreasing function of population density (Selden and Song, 1994), while Scruggs (1998) postulated that higher population density can potentially reduce environmental degradation as it highlights its effects and provides the leverage to address pollution problems. The argument by Selden and Song (1994) in their panel of different countries is that sparsely populated countries are more likely to be less concerned about reduction in per capita emissions at all levels of income or development than densely populated ones. They further intimate that emissions from transportation may be lower with people living closer together than the reverse, hence the negative relationship. Carbon dioxide emission was also found to rise monotonically with population density (Cole and Neumayer, 2004).

On education, we expect a negative nexus with per capita CO_2 emissions. The level of education is a measure of the degree and quality of human capital. The higher the level of education, all things being equal, we would expect people to be more informed and concerned about environmental degradation. An informed and environmentally conscious population would engage in economic activities that would emit fewer pollutants into the atmosphere. Furthermore, the more interested people in environmental issues, the less likely they would emit CO_2 since they care about the quality of the environment. Our variable of interest, social capital, is expected to enhance environmental quality through reduced CO_2 emissions per capita. The more abundant the stock of social capital, such as trust and organizational engagement, the more likely it can influence economic activities by inducing a shift in total output from dirty to clean industries, and finally to services which has greater potential in lowering emission levels (Grafton and Knowles, 2004). Further, social capital can reduce emissions per unit of output arising from more effective monitoring and stringent enforcement of environmental regulation, given institutional quality or low levels of corruption (Fredriksson *et al.*, 2004; Grafton and Knowles, 2004). We also posit that social capital may interact to exert some influence on carbon emissions. We hypothesize that the interaction between social capital and per capita GDP will enhance environmental performance. That is, given the stock of social capital in each county, an increase in real per capita income would reduce CO_2 emissions. According to Grafton and Knowles (2004), an improvement in the reservoir of social capital "…complements increases in per capita income to accentuate any beneficial effects in environmental quality…" Thus, we expect a negative relationship between social capital and real GDP per capita interaction on per capita CO_2 emissions.

It is often argued that CO_2 emissions exhibits persistence over time in the sense that past levels of CO_2 emissions usually determines current emission levels (Burnett and Bergstrom 2010; Donfouet *et al.*, 2013; Ibrahim and Law, 2014). Thus in modelling the EKC for per capita CO_2 emissions, Burnett and Bergstrom, 2010; Donfouet *et al.*, 2013; Ibrahim and Law, 2014) include past per capita CO_2 emission levels to account for this temporal dependence, often justified by gradual changes in production structure and technology (Ibrahim and Law, 2014).

We specify a general spatial dynamic model (i.e. a spatial dynamic autoregressive model with spatial autoregressive error (SARAR(1,1)) model as follows the emissions-income-social capital nexus:

$$
\begin{aligned}
lnCO_2pc_{it} &= \eta + \psi lnCO_2pc_{it-1} + \rho W_{ij} lnCO_2pc_{it} + \beta_1 lnGDPpc_{it} + \beta_2 (lnGDPpc_{it})^2 + \beta_3 lnPopdens_{it} \\
&\quad + \beta_4 lnEduc_{it} + \beta_5 Envint_{it} + \beta_6 SC_{it} + \alpha_i + \varepsilon_{it} \\
\varepsilon_{it} &= \lambda M_{ij} v_{it} + \mu_{it}
\end{aligned} \tag{1}
$$

where CO_2pc_{it} is the current level per capita CO_2 emission for county i at time t, respectively. η is the intercept and μ_{it} is the error term assumed to be normally distributed ($N(0,\Omega)$). The dynamic component of the model is captured by the lagged per capita CO2 emissions (CO_2pc_{it-1}), and its coefficient, ψ. SC_{it} is a measure of social capital which includes elements such institutional trust (i.e. trust in the national government) and association and engagement in social networks (i.e. whether or not a person is a member and actively engages in an environmental organization - see Table 1 for variable definition and data sources). α_i is individual county-specific effect, which we assume is approximately fixed over time for each county within the sample (Burnett and Bergstrom, 2010). The fixed effect could include among things political structure, geographical landscape or topography, weather patterns, county infrastructure, etc. (Burnett and Bergstrom, 2010). W_{ij} is a $N \times N$ spatial weight matrix for the autoregressive component and M_{ij} is the spatial weight matrix for the idiosyncratic error term. Spatial dependence models, as pointed out by Anselin and Bera (1998) and Anselin (2000), can either take the form of a substantive or nuisance process. Thus, ρ and λ are the spatial autocorrelation or dependent coefficients in the autoregressive term (i.e. spatial lag) and idiosyncratic error component (i.e. spatial error), respectively. In empirical work, the spatial weights matrices used are often identical ($W = W_{ij} = M_{ij}$).The spatial weights matrix, W, in its simplest form is defined as a first-order contiguity matrix consisting of zeros along the leading diagonal (since a county cannot be its own neighbour) and elements w_{ij} elsewhere, where $w_{ij} = 1$ if i and j are neighbours and $w_{ij} = 0$ otherwise. An alternative specification of the spatial weights matrix is based on the distance between county centroids. In this study, the spatial weight matrix W is defined as the six-nearest neighbours of every county in the sample. In applied spatial econometric work, the weights are standardized such that the sum of the elements in each row equals one (i.e. row standardization). We take the natural logarithmic transformation of all variables used in the estimation except indices of social capital and environmental interest. The EKC hypothesis exists if there is a statistically significant positive and negative relationships between real GDP per capita and its squared, and per capita CO_2 emissions, respectively (i.e. $\beta_1 > 0$ and $\beta_2 < 0$).

Applying the following restrictions to the parameters $(\lambda = 0)$ and $(\rho = 0)$, we obtain the dynamic spatial lag model (SAR) and the dynamic spatial error model (SEM), respectively. Since the spatial lag model directly accounts for relationship between carbon emissions (i.e. dependent variables) which we believe to be spatially related, we prefer to estimate a spatial dynamic model that allows us to capture the impact of per capita CO_2 emissions from neighbourhood locations (i.e. spatial lag parameter). Our preference is further supported by Donfouet (2013) who asserts that since the SEM accounts for omitted variables, modelling the EKC by allowing for spatial interdependence in the error process does not seem to make much economic sense in accounting for such spillover effects. Thus, we estimate the following "time-space simultaneous" model (Anselin, 1988):

$$\begin{aligned} lnCO_2pc_{it} &= \eta + \psi lnCO_2pc_{it-1} + \rho W_{ij} lnCO_2pc_{it} + \beta_1 lnGDPpc_{it} + \beta_2 (lnGDPpc_{it})^2 + \beta_3 lnPopdens_{it} \\ &\quad + \beta_4 lnEduc_{it} + \beta_5 Envint_{it} + \beta_6 SC_{it} + \alpha_i + \mu_{it} \end{aligned} \tag{2}$$

Estimation of equations (2) with pooled ordinary least squares (OLS) regression presents some challenges. Specifically, the estimation presents a problem of endogeneity in the variables and therefore application of OLS estimator is likely to yield biased and inconsistent estimates. There is potential endogeneity between per capita CO_2 emissions and per capita income, other explanatory variables as well as the presence of the lagged per capita CO_2 on the right-hand side (RHS) of equation (2). The lagged dependent variable could also be correlated with the error term. Further, the spatial lag term $(W_{ij} lnCO_2pc_{it})$ is correlated with the disturbance term, it must be treated as endogenous. To avert these endogeneity challenges, we therefore estimate variants of equations (2) with the system generalized method of moments (system GMM) by Blundell and Bond (1998) with a spatially lagged CO_2 variable on the RHS to account for spatial effects in the data. The system GMM estimator has been found to outperform the first-difference GMM of Arellano and Bond (1991; 1995) in the presence of an autoregressive term such as the lagged per capita CO_2 emissions. In the case of the system GMM, the basic idea is to estimate equation (2) as a system of two equations (first differences and levels). The lagged difference of the first order and the lagged level variables are then used as instruments for the equations in first differences and levels, respectively. The use of the instrumental variables in this estimation allows for consistent and unbiased of the parameters given measure error and endogenous RHS variables. To ascertain the consistency of the GMM estimator, we use the Sargan over-identification restrictions and a set of serial correlation tests in the first-differenced error term (usually an AR(1) and AR(2)). We check the validity of the instruments using the Sargan test

(χ^2) such that failure to reject the test imply valid instruments and hence no misspecification of the estimated model. On the other hand, the first order serial correlation, AR(1), should be rejected while failure to reject the second order AR(2) serial correlation test would imply absence of serial correlation of that order.

After estimating the models, we calculate the income turning point[6] for each EKC equation to determine the maximum level of income at which emission levels begin to fall with increased economic growth. Results with interaction between social capital and income per capita in the EKC model are also illustrated.

5. Results and Discussion

In this section, we present results estimated from the specified spatial dynamic panel model. Prior to estimating the models, we test for spatial interdependence in the carbon emissions data using the global Moran's I and Geary's C statistics. Both results indicate the existence of spatial dependence in carbon emissions across counties (see appendix A1 for detailed results and discussion of global and local measures of spatial dependence). We then proceed to estimate the spatial models incorporating the two key social capital indicators – *Trustgov* (trust in the government) and *Envorg* (engagement and membership in environmental organizations).

The spatial dynamic model results based on the system GMM is shown in Table 5. The co-efficient of the spatially lagged dependent variable is positive and significant, confirming spatial spillover effect. We first assess the appropriateness of the system GMM estimator based on the Sargan and serial correlation tests in Table 5. We fail to reject the Sargan over-identification restrictions for validity of instruments used in all eleven specifications. Similarly, the absence of second order serial correlation in the residuals further validates the appropriateness of the system GMM estimator except in columns 1, 8 and 11 where we fail to reject the hypothesis of no serial correlation of the first order.

Consistent with our expectation, per capita CO_2 emissions is significantly persistent in all the models. That is, previous per capita CO_2 emissions level significantly and positively determine current emissions trend. This result confirms that of Burnett and Bergstrom (2010), Donfouet *et al.*, 2013 and Ibrahim and Law (2014) who found significant persistence in CO_2 emissions in their studies. The results regarding the existence of an EKC for CO_2 emissions is confirmed in all but two (columns 1

The turning point in eqs. (1-3) (i.e. maximum income at which change in per capita CO_2 emissions with respect to income equal zero) is calculated as follows:

6 $$\Rightarrow \frac{1}{CO_2 pc_{it}} \frac{\partial CO_2 pc_{it}}{\partial GDPpc_{it}} = \beta_1 (\frac{1}{GDPpc_{it}}) + \frac{2\beta_2}{GDPpc_{it}} (lnGDPpc_{it}) = 0$$

$$lnGDPpc_{it} = -\frac{\beta_1}{2\beta_2}$$

$\Rightarrow$ Income turning point, $GDPpc_{it}^{\max} = e^{(-\frac{\beta_1}{2\beta_2})}$

In the interaction case (i.e. $GDPpc_{it} \times SC_i$) in eq. 4, the income turning point is given by the formula:

$$GDPpc_{it}^{\max} = e^{\left[-\frac{(\beta_1 + \beta_7 \times SC_i)}{2\beta_2}\right]}$$

and 11) of the estimated models given the insignificant coefficients of per capita income squared in the model without social capital (i.e. column 1) and both level and squared income terms in model (11) or any of the interaction effect between per capita income with elements of social capital. The calculated annual income threshold or turning point ranges between SEK335600 and SEK558300 per capita, both of which are higher than the average income of 289000.

Shedding light on the presence of spatial effects in the emissions-income-social capital nexus, we find confirmation for the existence of spatial dependence, congruent with the univariate test findings on the carbon emissions data based on the Moran's I and Geary's C test statistics. Specifically, the spatially lagged per capita CO_2 emissions is highly significant (at the 1% significance level) in all variant models and positive as well. That is, by controlling for endogeneity challenges inherent in dynamic settings by utilizing the spatial dynamic system GMM estimator, we have been able to show that carbon emissions in a given county in Sweden positively affect emission levels in surrounding counties. The spatial autoregressive emissions parameter falls within the -1 and +1 assumed in spatial lag models. From a policy perspective, this indicates that CO_2 emissions in one county should not be at the risk or expense of its neighbouring county(ies). Another perspective to understanding the results is that CO_2 emissions is not only affected by within county-specific characteristics, but significantly influenced by per capita carbon emission levels in counties within its neighbourhood. Our results thus reiterates the importance of augmenting the EKC framework for emissions to include spatially weighted emissions variables since it matters for our understanding of carbon emissions dynamics.

Without accounting for social capital in the model, we find limited evidence for an EKC in specification (1) given the insignificant squared income per capita term, albeit with the hypothesized inverted U-shape. Similarly, after controlling all elements of social capital, including interaction effects, column (11) also fails to fails to confirm an EKC for per capita CO_2 emissions since all terms fail the statistical significance test.

We assess the importance of social capital elements in the model by sequentially including each indicator at a time and then including each element of governmental trust and environmental group engagement and their interaction effects as shown in Table 4. By including only trust in the government in the model (i.e. column 2), we find that more trust in government and for that matter its ability to implement environmental policies to the letter, the lower the carbon emissions that would be observed. The same negative impact is observable if we include both trust in the government and people's membership and engagement in environmental organizations. Even though being a member of an environmental organization is negative, it is not statistically significant (column 3). What is striking though is that in quantitative terms, the magnitude of this effect of social capital as measured by government trust is almost indistinguishable when we control for only trust in the government in the model (see columns 2 and 3). With the exception of the additional significant beneficial effect of trust on carbon emissions observed in model (9), the remaining coefficients turned out positive albeit insignificant in all cases. These results imply some limited robustness of the role of social capital in explaining CO_2 emissions dynamics in Sweden. However, in cases where we observe significant negative relationship, the results suggest trust in government policy seems to significantly impact on emissions reduction in Sweden. This goes to affirm that the national government may have succeeded in creating the needed credibility around Sweden's environmental policy (i.e. environmental quality objectives), including its generational goal. This result is not surprising because in addition to having a

Table 5: Spatial dynamic system-GMM estimates

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
$lnCO_2pc_{t-1}$	0.131***	0.201***	0.154***	0.183***	0.186***	0.127***	0.154***	0.154**	0.157*	0.162*	0.128
	(0.0483)	(0.0410)	(0.0334)	(0.0513)	(0.0528)	(0.0484)	(0.0578)	(0.0772)	(0.0943)	(0.0952)	(0.0991)
Spatially lagged $lnCO_2pc$	0.625***	0.606***	0.659***	0.630***	0.594***	0.698***	0.602***	0.605***	0.614***	0.587***	0.530***
	(0.110)	(0.110)	(0.115)	(0.0999)	(0.107)	(0.111)	(0.104)	(0.0970)	(0.122)	(0.117)	(0.127)
lnGDPpc	4.641**	6.394***	4.627**	7.892***	8.264***	7.103***	7.059***	7.369***	11.37***	11.69***	5.954
	(2.285)	(1.996)	(1.965)	(2.539)	(2.631)	(2.342)	(2.698)	(2.524)	(2.753)	(3.107)	(5.981)
$(lnGDPpc)^2$	-1.723	-2.567***	-1.765*	-3.259***	-2.994***	-1.499*	-2.832**	-2.480**	-2.804***	-2.710**	-1.502
	(1.061)	(0.949)	(0.933)	(1.165)	(0.972)	(0.859)	(1.247)	(0.997)	(1.088)	(1.252)	(1.650)
lnPopdens	-0.236***	-0.211***	-0.215***	-0.218***	-0.257***	-0.222***	-0.202***	-0.217***	-0.228***	-0.254***	-0.234***
	(0.0444)	(0.0534)	(0.0463)	(0.0679)	(0.0581)	(0.0495)	(0.0696)	(0.0718)	(0.0563)	(0.0721)	(0.0746)
lnEduc	-0.418***	-0.481***	-0.379***	-0.514***	-0.495***	-0.432***	-0.548***	-0.540***	-0.507***	-0.510***	-0.607***
	(0.0929)	(0.0876)	(0.0756)	(0.100)	(0.0986)	(0.107)	(0.109)	(0.108)	(0.104)	(0.114)	(0.142)
Envint	-0.0404*	-0.0405**	-0.0454*	-0.0369*	-0.0292	-0.0556**	-0.0194	-0.0211	-0.0405	-0.0339	-0.00767
	(0.0236)	(0.0174)	(0.0246)	(0.0210)	(0.0305)	(0.0265)	(0.0270)	(0.0265)	(0.0342)	(0.0377)	(0.0439)
Trustgov		-0.0540***		-0.0517**	0.268		0.383	0.357	-0.0681***	0.219	1.166
		(0.0167)		(0.0201)	(0.242)		(0.248)	(0.239)	(0.0162)	(0.286)	(0.903)
Envorg			-0.00881	0.0123		2.885*	1.173*	0.00576	4.277***	3.964**	2.599
			(0.0374)	(0.0452)		(1.500)	(0.654)	(0.0460)	(1.266)	(1.577)	(1.928)
$lnGDPpc \times Trustgov$					-0.315			-0.383*		-0.279	-0.405
					(0.236)			(0.228)		(0.279)	(0.298)
$lnGDPpc \times Envorg$						-2.913*			-4.267***	-3.953**	-0.383
						(1.499)			(1.255)	(1.566)	(3.535)
$Trustgov \times Envorg$							-0.404*				-0.753
							(0.228)				(0.681)
Constant	2.663	2.342*	2.162	1.872	1.227	-0.0126	1.378	1.845	-1.946	-2.246	0.862
	(1.773)	(1.376)	(1.743)	(1.158)	(1.503)	(2.668)	(1.191)	(1.456)	(2.100)	(2.107)	(3.405)
Turning point (100 SEK)	3,845	3,474	3,709	3,356	3,772	4,046	3,477	4,090	3,549	3,959	5,583
AR(1): p-value	0.1092	0.0785	0.0969	0.0595	0.0773	0.0786	0.0871	0.1126	0.0282	0.0339	0.1208
AR(2): p-value	0.2639	0.6277	0.3255	0.5441	0.4644	0.2462	0.4634	0.3263	0.4451	0.3236	0.2841
Sargan: p-value	0.3721	0.4241	0.3772	0.4970	0.4284	0.4406	0.5637	0.5205	0.4981	0.4657	0.5558
Observations	126	126	126	126	126	126	126	126	126	126	126
No. of cross-sections	21	21	21	21	21	21	21	21	21	21	21

Note: Standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1. Income turning points are in 2005 constant prices. All variables are logged except indicators of social capital and environmental interest. W denotes a spatial weight matrix based on 6 nearest neighbours. $\rho = W \times lnCO_2pc = Spatially\ lagged\ lnCO_2pc$; Dep. var.=$lnCO_2pc$.

total of 25 governmental agencies working independently and in some cases jointly to realize milestone targets, a cross-party committee (in Parliament) working within the spirit of broad political consensus is also in place.

On the other hand, a rather puzzling effect of engagement and membership in environmental organizations on emissions can be observed. The coefficient is positive and statistically significant (columns 6, 7, 9, and 10), implying that the higher the level of activity in the organization, the higher the level of per capita CO_2 emissions. Even though this result is somehow counter-intuitive, it is not so surprising given the data on the distribution of the level of engagement in environmental organizations in Sweden. Generally, activity level in these organizations by its members is very low. On average, activity level is around 1.1 across all counties. Note that environmental organization is indexed such that a higher index, ranging from 1-5, implies higher level of activity. Thus the result obtained could be explained by this rather low base of activity level in these organizations. That is, even though we may have many people joining environmental organizations in Sweden, not a significant proportion are actually engaged in their activities. The result is that people may not necessarily be much influenced behaviourally in a way to induce environmentally responsible practices that would contribute to lowering GHGs. Grafton and Knowles (2004) established that active membership in associations did not improve environmental quality but rather impacted adversely on the environment. They conclude on the note that the presumptive view that more social capital necessarily improves environmental performance cannot always be true. Also, Paudel and Schafer (2009), contrary to the hypothesized EKC, found a U-shaped relationship between water pollution (i.e. nitrogen pollution) and social capital, indicating higher nitrogen pollution is associated with both low and high levels of social capital in Louisiana parishes in the U.S. Even though they could not explain this unexpected dynamics with their data, they inferred, similar to Grafton and Knowles (2004) that since social capital incorporate various elements, some may improve environmental quality while others may serve to weaken the quality of the environment.

Further, we hypothesize that higher levels of social capital are associated with lower CO_2 emissions per capita which is accentuated at higher levels of per capita income (Grafton and Knowles, 2004 also considered a similar hypothesis for civic social capital and income on overall national environmental performance indicators, while Ibrahim and Law (2014) considered similar interaction in the case of CO_2 emissions). When we consider only the interaction effect between trust in the government and real income per capita, the hypothesis of no significant effect is rejected in only one of four specifications (see column 8). That is, the association between trust in the government and income is beneficial to the environment, since emissions level significantly decreases through this interaction. Grafton and Knowles (2004) found the same significant effect on an air quality index in their cross-section study but with no significant impact on SO_2 emissions. Our result is also confirmed by Ibrahim and Law (2014) for CO_2 emissions. Similarly, the interaction terms between environmental organization and income per capita significantly reduces carbon emissions (columns 6, 9 and 10). Lastly, the interaction between the two social capital elements significantly (at the 10% level) induces a reduction in emissions in the absence of their interaction with income indicating complementarity effect between the two variables on CO_2. This interaction effect, though negative, loses its significant impact on CO_2 emissions reduction in the model where we included all elements of social capital and their interaction terms with real per capita income (see column 11).

Furthermore, we find that the more interested people are in environmental issues, *ceteris paribus*, the lower their inclination to emit more carbon dioxide into the atmosphere. The coefficient of environmental interest is inversely related to per capita CO_2 emissions albeit statistically significant at either the 5% or 10% levels in almost half of the estimated models (i.e. columns 1-4 and 6). Other control variables including population density and education significantly influence carbon emissions in the same direction. High population density is associated with lower levels of CO_2 emissions per capita. Our results are consistent with Selden and Song (1994) who showed that per capita emissions decreases with population density even though the reverse may be observed with regard to total emissions. Our results show that the coefficient of population density is robustly negative and statistically significant at the 1% level. Many other evidences in the literature however show the reverse (e.g. Grafton and Knowles, 2004). They argue that since emissions are very much an economic activity induced phenomena, more people within a geographical region are collectively likely to emit more than less people per land area (Grafton and Knowles, 2004). The sign of the population coefficient is not inconsistent with the data given the evidence presented in Figure 1. It is evidently clear from the map that even though total CO_2 emissions on average is quite high in some countries, the picture in per capita terms a much promising case of a generally falling emissions over the period considered. Also, education came out as a robust driver of carbon emissions in all cases considered. The number of people with at least post-secondary school education significantly inures to the benefit of the environment as indicated by its negative sign. In terms of its magnitude, the effect is consistently much stronger than population density albeit both appear to be stable across alternative specifications. As more people become highly educated, they are expected to be well informed about the debilitating impact of CO_2 emissions on their environment in terms of climate change and other harsh effects. That is, the higher the number of educated citizens, *ceteris paribus*, the lower the level of emissions the country is likely to observe. Thus an empowered and environmentally knowledgeable population would be a critical conduit to realizing environmental policy outcomes/objectives such as clean air and reduced GHG emissions. The results suggest that an increase in the number of people with at least 3-year post-secondary education by 1% would, *ceteris paribus*, reduce per capita CO_2 emissions by roughly 0.379-0.607 percentage points.

Finally, we carried out a number of sensitivity analysis on our models based on different neighbourhood definitions. The results based on both simple contiguity and distance spatial weights matrices did not in any significant way alter the evidence presented here. We do not report those results but are available upon request.

5. Concluding Remarks

In this paper, we have estimated spatial dynamic panel models to examine the role of social capital in explaining the pollution-income relationship often modelled in an EKC framework for all 21 counties in Sweden. Specifically, we assess whether an increase in the abundance of social capital significantly reduces the environmental costs of economic growth. The results provide evidence of the existence of an inverted U-shaped EKC for per capita CO_2 emissions in most of the models estimated. Further, formal tests showed the presence of significant spatial dependence in the emissions data across counties. The results imply that per capita CO_2 emissions in one county matters for its neighours, a phenomenon we modelled in a spatial dynamic system GMM with a spatially lagged per capita CO_2 emissions incorporated as an additional explanatory variable to explore this potential spillover. Importantly, we have established that social capital plays a significant role in explaining per capita CO_2 emissions differences across Swedish counties. Particularly important is the fact that trust in the national government helps in reducing CO_2 emission levels in Sweden. This is significant in the sense that the government may have succeeded in getting the needed credibility for Sweden's environmental policy given that citizens believe government through responsible agencies and other stakeholders can implement the environmental regulation to the letter for desired results. However, social capital in terms of environmental engagement rather showed a positive effect on emissions. Interestingly, the interaction between social capital elements and real income per capita seem to bode well for the environment. However, the interaction between the two social capital indicators, though negative, is marginally significant in only one of the estimated models.

We concede that the analysis in this study could have been much more revealing if data were available for a longer period than the seven-year length used. Further, future analysis could explore other spatial econometric models such as the spatial Durbin model (SDM) with elements of both spatial error and spatial lag models nested in the SDM. The SDM could then be tested to check if it is reducible to either the SEM or SAR via likelihood ratio test. This model (SDM) is quite appealing since it can explicitly capture dynamic effects of the dependent variable, the spatial dependence parameter and other spatially explicit explanatory variables to check for example the effect of income or land use dynamics in neighboring counties on surrounding counties and their impact on carbon emissions.

Nonetheless, it suffices from the evidence to say that building or investing in the stock of social capital in addition to Sweden's stride made in a shift toward less emissions of CO_2 , could complement other policy instruments being used (such as CO_2 tax and subsidies for renewable energy.) Another equally important aspect is that the allocation of social capital may improve effectiveness of policies through improved targeting. For example, subsidies for renewable energy may have large impacts on fossil fuel replacement in counties with relatively much abundance of social capital. Similarly, social capital as a target device for enforcement of compliance with climate policies may reduce overall transaction cost.

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Appendix

A1. Distribution of per capita CO_2 emissions: a spatial autocorrelation analysis

We use the classical global Moran's I statistic (Moran, 1948) to assess the level of spatial dependence in the emissions data and its evolution over time. The global Moran's I statistic (only one value calculated) is a spatial dependence measure that describes the overall spatial relationship across all the geographic units for the whole study area (Moran, 1948; Li *et al.*, 2014). The values of global Moran's I ranges between -1 and 1, where I tends toward zero in the absence of spatial autocorrelation. In the case of positive spatial autocorrelation, the value of I corresponds to a value greater than zero while the reverse holds true for negative spatial autocorrelation. We complement the analysis with another global spatial autocorrelation measure (Geary's C (Geary, 1954), which is inversely related to the Moran I. The null hypothesis (H_0), similar to Moran's I is the absence of spatial autocorrelation. The expected value for the C index is 1 in the absence of no spatial autocorrelation. The lower bound value is zero (0) with a value close to 0 but less than 1 implying positive spatial autocorrelation (i.e. positive if $[0,1[$) and negative spatial autocorrelation if $]1,\infty[$.

The two global measures of spatial dependence of a series are strongly linked, but the detection test based on Moran's I statistic is suggested to be more robust and powerful than the one based on the Geary's C (Dubé and Legros, 2014). Anselin (1995) among other researchers have also shown that Moran's I statistic is even more robust against the form of the spatial weights matrix utilized (see the appendix a summary of Moran's I and Geary's C test statistics and the link between them).

In the context of our regional CO_2 emissions data, we also make use of exploratory spatial data analysis (ESDA) to detect spatial regimes in the emissions data. Localized version of Moran's I of spatial autocorrelation, which measure the extent to which high and low values are clustered together is used here. Unlike global Moran's I which is a global index representing the entire geographic area under study, the local indicator of spatial association (LISA) or local Moran's I_i considers spatial variations in the study areas locally. It describes the heterogeneity of spatial association across different geographic units within the area under study (Li *et al.*, 2014). We implement this exercise using the Moran scatterplot (Anselin, 1995; 1996) to facilitate the detection of spatial clusters of high values of per capita CO_2 emissions and spatial clusters of low values of per capita CO_2 emissions data in Sweden over the sample duration. The Moran scatter diagram plots the spatial lag of standardized per capita CO_2 emissions against the original values. The values are then distributed into four quadrants to depict spatial clustering. The four different quadrants of the scatterplot correspond to the four types of local spatial association between a region and its neighbours: HH denotes a county with a high value surrounded by other counties with high values and LH indicates a low value county surrounded by counties with high values. LL indicates low values are surrounded by low values while HL depicts high values surrounded by low values. Quadrants HH and LL refer to positive spatial autocorrelation indicating local spatial clustering of similar values. On the other hand, quadrants LH and HL depict negative spatial autocorrelation indicating local spatial clustering of dissimilar values.

Thus, as a precursor to the empirical spatial econometric modelling, we explore both global and local spatial dependence in our dependent variable (i.e. per capita CO_2 emissions) using the aforementioned methods. The result of both global Moran's I and Geary's C applied on the natural logarithm of per capita CO_2 emissions are shown in Table 3. The results reveal highly significant and positive spatial dependence of the emissions variable. The Moran's I value is close to 1, indicating a very strong spatial dependence in the cross-sections or counties as far as per capita CO_2 emissions are concerned. To reinforce or corroborate this finding, the Geary's C statistic is close to 0, an unambiguous confirmation of significant positive spatial dependence. This means that emissions in one county matters for emissions in another county(ies) due to the potential spatial spillover effect. In other words, positive spatial correlation indicates that counties with similar levels of per capita CO_2 emissions are more likely to be spatially clustered than could have occurred by pure chance (Lundberg, 2002). This reinforces the need to incorporate this spatial dependence in the empirical analysis.

Table A1: Tests for Spatial Dependence for log CO_2 emissions per capita

	Moran's I	Geary's C
Test statistic	0.977	0.022
Mean	-0.007	1.000
Std. dev.	0.046	0.046
Z-score	21.355	-21.355
P-value*	0.000	0.000

Note: * Two-tailed test. Results are based on the randomization assumption as opposed to the normal approximation

We go a step to explore potential spatial clustering of per capita CO_2 emissions values for each county using the local Moran's I_i. The results are displayed in the Moran scatterplot (Figure A1). As evident below, the trend of the fitted values of the spatially lagged per capita CO_2 emissions against the original values indicate positive spatial autocorrelation. The computation of the local Moran's I_i for each county revealed significant local spatial effects for five counties – Stockholm, Södermanland, Jonkoping, Gotland and Norrbotten. Another interesting feature of the Moran scatterplot is that much of the CO_2 emissions concentration are in the third quadrant (i.e. low per capita CO_2 emissions in a county are surrounded by low emission values from neighbouring county(ies) – LL). On the opposite side, a few number of counties - Södermanland, Gotland and Norrbotten – form a spatial cluster in the first quadrant (i.e. HH). Thus, high per capita CO_2 emissions values in a geographic unit is surrounded by a high emitting county(ies). Incidentally, these three counties are the top average per capita CO_2 emitters over the period 2005-2011.

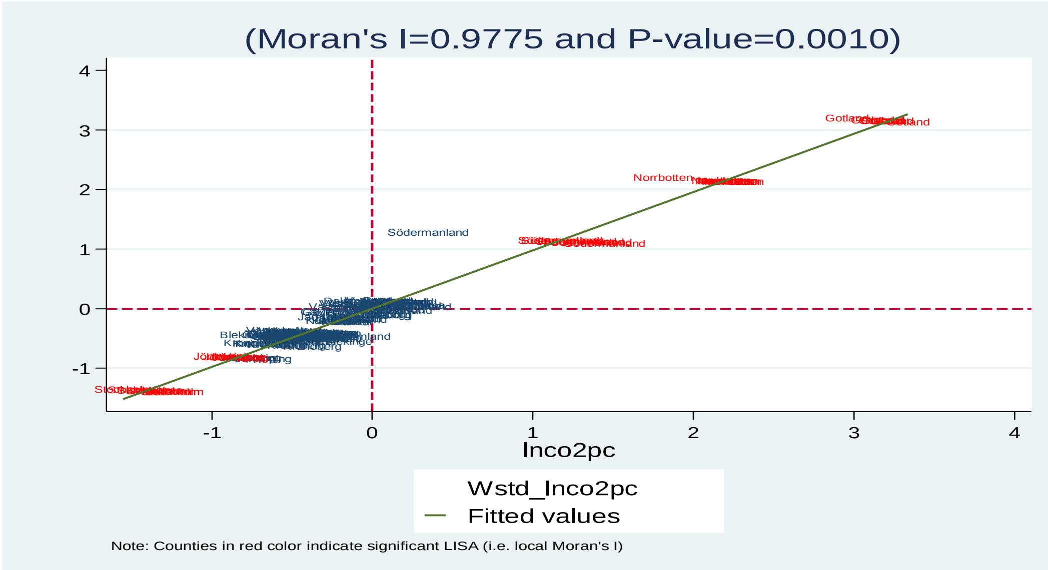

Figure A1: Moran scatterplot for log of CO_2 emissions per capita

A2. Table A2: Correlation Matrix

	CO2pc	Spatial CO2pc	GDPpc	Popdens	Educ	Trustgov	Envorg	Envint
CO2pc	1							
Spatial CO2pc	0.992***	1						
GDPpc	-0.173**	-0.180**	1					
Popdens	-0.218***	-0.219***	0.770***	1				
Educ	-0.226***	-0.226***	0.783***	0.911***	1			
Trustgov	0.136	0.109	-0.139*	-0.198**	-0.207**	1		
Envorg	-0.030	-0.034	0.060	0.085	0.075	-0.114	1	
Envint	0.024	0.014	-0.049	-0.046	-0.056	0.202**	-0.058	1

Note: *** p<0.01, ** p<0.05, * p<0.1

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