Essays on Environmental Management

Species Invasion, Social Capital and Energy Demand

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Abstract

This thesis contributes to the economic literature on invasive species, social capital connection to climate change and environmental good provision as well as energy demand management. It contains five independent papers connected by the broader theme of environmental management. Two papers (I and II) deal with invasive species while the third and fourth probes the effect of social capital on carbon dioxide emissions (CO_2) and individuals' decision to contribute toward environmental protection. The first paper attempts a comprehensive theoretical and empirical review of findings in economics with respect to the challenging question of how to manage invasive species. We find a relatively large body of literature on the assessment of damage costs of invasive species; single species and groups of species at different geographical scales. Estimated damage costs show large variation, from less than 1 million USD to costs corresponding to 12% of gross domestic product (GDP), depending on the methods employed, geographical scale, and scope with respect to inclusion of different species. In the second paper, a simple bioeconomic model is developed and applied to the management of the aquatic invasive species *Elodea canadensis* (Michx) in Lake Lötsjön in Sweden. A weed harvesting programme is proposed and numerically investigated based on the model. Results suggest that it is economically optimal to engage in the weed cutting programme since it yields positive net economic benefits and that early action is the best strategy. Social capital is the main connecting factor between Paper III and IV. In both papers, different constructs of social capital were computed through principal component analysis and modelled empirically to explain different environmental outcomes. Paper III investigates whether or not social capital explain Swedish county-level aggregate and sectoral per capita CO_2 emissions in an environmental Kuznets curve (EKC) framework. The results showed significant dampening effects of trust and overall social capital indices on total emissions, but impact heterogeneity was evident among sectors. Estimated effects were negative on emissions from industry but positive on transport emissions. In Paper IV, we assess the influence of social capital on individuals' willingness to contribute toward environmental protection in Sweden. Findings show significant impact of social capital. The fifth paper provides an empirical analysis of energy demand in Ghana. Elasticities of seven key disaggregated energy types were estimated using time series analysis. The results suggest energy prices, income, urbanization and economic structure are significant demand drivers of the different energy types with varying elasticities. Further evidence show high degree of inter-fuel substitution in energy demand in Ghana, particularly from gasoline, diesel and kerosene toward LPG consumption.

Keywords: Social capital, Carbon emissions, Spatial econometrics, Invasive species, Bioeconomic modelling, Willingness to contribute, Energy demand, Sweden, Ghana

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Dedication

To Dinah and Alisa.
Also dedicated to the memory of my father (Kennedy Marbuah) and sister (Dinah Apraku).

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List of Publications

This thesis is based on the work contained in the following papers, referred to by Roman numerals in the text:

I Marbuah, G., Gren, I-M. and McKie, B. (2014). Economics of harmful invasive species: A review. *Diversity*, 6, 500-523.

II Marbuah, G., McKie, B. and Tattersdill, K. (2016). Optimal management of aquatic invasive species in Sweden: Case of *Elodea canadensis* (Manuscript).

III Marbuah, G. and Gren, I-M. (2016). Social capital and carbon emissions in Sweden (Submitted to *Environment and Development Economics*).

IV Marbuah, G. (2016). Is willingness to contribute for environmental protection in Sweden influenced by social capital? (Manuscript).

V Mensah, J.T., Marbuah, G. and Amoah, A. (2016). Energy demand in Ghana: A disaggregated analysis. *Renewable and Sustainable Energy Reviews*, 53, 924–935

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1 Introduction

This thesis is a composition of five independent papers under the broad theme of environmental management. A number of research questions are addressed in the thesis. (i) What is the damage cost of harmful invasive species? Which is the best management strategy? Which policy instruments should be used in order to affect peoples' behaviour? (ii) Is it optimal from an economic perspective to control aquatic invasive species in lakes? If so, when should control effort be applied in order to maximize benefits to society and the invaded ecosystem? (iii) Are there regional heterogeneity in per capita carbon dioxide (CO_2) emissions across Swedish counties? Are emission dynamics in a local county influenced by trajectories in neighbouring regions? Does social capital play any role in explaining CO_2 emissions within and across counties? How do different sources of CO_2 emissions respond to different constructs of social capital abundance in a given county? (iv) Are individuals in Sweden inclined to contribute to prevent environmental damage due to the level of trust, civic engagement or other forms of social capital embedded in the society? (v) What are the key drivers of gasoline, diesel, liquefied petroleum gas (LPG), kerosene, biomass, residual fuel oil and electricity consumption in Ghana? To what extent does substitution/complementarity between different energy types exist and the implication on energy policy in Ghana? How fast or slow do consumers adjust to long-run equilibrium following a short-run shock to energy consumption? What do estimated elasticities hold for energy demand and supply policies in Ghana?

Studies on the economics of biological invasive species and their associated problems were scarce in the mainstream economic literature, until the last few decades. But intentional and unintentional introduction of invasive species into new environments have had, and continue to have substantial ecological, human, social and economic impacts at national, regional and global scales (Pimentel *et al.*, 2001; Gren *et al.*, 2009; Zehnsdorf *et al.*, 2015). Natural habitats of indigenous species have been disturbed, ecosystem functioning degraded, and aesthetics of natural environments impaired due to biological invasions. This worrying phenomenon has received recognition from ecologists, economists and public authorities with environmental protection and management oversight. Paper I addresses the first set of questions through a comprehensive and an updated review of the literature on the economics of invasive species management. In particular, we provide an overview of recent developments in economics, and which challenges remain. We review both theoretical and empirical studies addressing various management strategies and using different

methodological approaches. Our findings revealed a relatively large body of literature on the assessment of damage costs of invasive species; single species and groups of species at different geographical scales. Estimated damage costs show large variation, from less than 1 million USD to costs corresponding to 12% of GDP, depending on the methods employed, geographical scale, and scope with respect to inclusion of different species. Decisions regarding optimal management strategies, when to act in the invasion chain and which policy to choose, have received much less attention in earlier years, but have been subject to increasing research during the last decade. More difficult, but also more relevant policy issues have been raised, which concern the targeting in time and space of strategies under conditions of uncertainty. In particular, the weighting of costs and benefits from early detection and mitigation against the uncertain avoidance of damage with later control, when the precision in targeting species is typically greater is identified as a key challenge. The role of improved monitoring for detecting species and their spread and damage has been emphasized, but questions remain on how to achieve this in practice. This is in contrast to the relatively large body of literature on policies for mitigating dispersal by trade, which is regarded as one of the most important vectors for the spread of invasive species. On the other hand, the literature on how to mitigate established species, by control or adaptation, is much more scant. Studies evaluating causes for success or failure of policies against invasive species in practice are in principal non-existing.

Results in Paper I provided important information on what obtains in the economics literature on invasive species management in general. We narrow the focus into a case study on a specific but common invasive species *Elodea canadensis* (Michx) found in many freshwater systems in Sweden in Paper II where an attempt is made to answer the second set of questions raised above (see Josefsson and Andersson, 2001; Strand and Weisner, 2001; Zehnsdorf *et al*., 2015) . The invasive aquatic *E. canadensis* might provide benefits for nature and society when present with low abundances, by contributing to nutrient regulation in lakes, but can cause damages when it forms extensive monocultures which choke lake littoral zones with most disruption to swimming, fishing and boat traffic. No study has considered both potential benefits and damage costs of this taxa of invasive species in decision analysis. Using a simple bioeconomic model developed to describe the population dynamics of the weed in Lake Lötsjön in Sweden, we conducted an analysis of the optimal management of the species providing both good and bad effects on society. Results show the economic viability of a mechanical weed cutting programme simulated over a 50-year

horizon. More important, it is optimal to expend resources in the first few years of control in order to achieve near eradication of the invasive species.

The concept of social capital (with elements such as trust, civic engagement and social norms) has continued to generate debate since its introduction into the mainstream economic literature. It has been used to explain cooperative behaviour among individuals when they have little economic incentives to do so (e.g. Boix and Posner, 1998). Ostrom (2009) suggested that social capital may influence collective action and policy making and implementation in different jurisdictions, especially in dealing with the commons in environmental and resource management. Recent evidences seem to suggest social capital abundance engenders economic growth (Helliwell and Putnam, 1995; Knack and Keefer, 1997; Rupasingha *et al*., 2002; Woodhouse, 2006) as well as environmentally responsible behaviour and action (Pretty, 2003; Pretty and Ward, 2001). Furthermore, there is an emerging convergence in evidence in the environmental valuation literature that show robust indication social capital strongly induces willingness to contribute (WTC) for environmental goods and services (see Gelissen, 2007; Jones *et al*., 2009; Polyzou *et al*., 2011; Yogo, 2015). Yet another strand of literature has found limited or no role for social capital in explaining environmental performance (e.g. Grafton and Knowles, 2004). To address this seeming conflict in the literature as well as questions (iii-iv) raised in the introductory part of this section, we show new evidence that supports the former strand of literature highlighting the importance of social capital in relation to the environment. Specifically, Papers III and IV address distinct yet related issues in which social capital is the central focus. Social capital's role in explaining carbon emissions is explored in the Swedish context with county-level data on per capita CO_2 emissions at the aggregate and sectoral scale in Paper III. Modelled within an environmental Kuznets curve (EKC) framework, the results showed, after accounting for spatial spillover effects, significant dampening impacts of trust and composite social capital indices on total emissions, but the direction of impacts differed among sectors. The estimated effects were negative on emissions from industry but positive on transport emissions. The EKC relation could be established only for total and transport emissions.

In relation to Paper IV however, we investigate the extent to which different constructs of social capital influence individuals' willingness to contribute (WTC) toward environmental protection in Sweden. We constructed four indices of social capital: social trust, institutional trust, civic participation and a composite index comprising all considered elements of social capital and their influence on WTC analyzed. Using data from the 2010 wave of the International

Social Survey Programme (ISSP) on Sweden, we empirically show that all four social capital parameters are significant and robust drivers of Swedish public's willingness to contribute when the payment vehicles are increased higher prices or taxes or through lifestyle changes in order to protect the environment. We find statistically significant impact for social trust and civic participation on WTC. Institutional trust is not significant when the payment vehicle is a reduction in the standard of living. Overall, the composite index of social capital came out as a robust predictor of individuals' likelihood to contribute irrespective of the payment vehicle.

Finally, the role of energy resources in meeting different needs of households, industries, etc. in any economy cannot be overemphasized. Different types of energy sources are required to meet demand for lighting, cooking, electricity generation among many other uses. Demand for energy in Ghana similar to most developing countries exceeds the available supply. A key challenge to Ghana's energy sector is inadequate access to modern energy services such as liquefied petroleum gas (LPG) and electricity, although some improvements over the past decade is evident. This has created a relatively high dependence on traditional energy sources including biomass (mainly charcoal and wood fuel) to meet the energy needs of households. It is estimated that about 76% of Ghanaian households depend on biomass for cooking and heating water (Mensah and Adu, 2015). Paper V provides a detailed analysis of the drivers of disaggregated energy demand in Ghana. We consider the following disaggregated energy types – gasoline, diesel, LPG, kerosene, solid biomass, residual fuel oil and electricity and model their relative responsiveness to carefully selected set of covariates. Time series econometric methods, autoregressive distributed lag and partial adjustment models, were utilized to estimate short and long run disaggregated energy demand determinants. Results show that energy prices, income, urbanization and economic structure are significant demand drivers of different energy types in Ghana with varying elasticities. There is evidence of high degree of inter-fuel substitution in energy demand in Ghana, particularly from gasoline, diesel and kerosene toward LPG consumption.

2 Summaries of Appended Papers

2.1 Paper I: Economics of harmful invasive species: A review

Intentional and unintentional introduction of invasive species into new environments have had, and continue to have profound ecological, human, social and economic effects at national, regional and global scales. Natural habitats of indigenous species have been disturbed, ecosystem functioning degraded, and aesthetics of natural environments impaired due to biological invasions. This worrying phenomenon has received recognition from ecologists, economists and public entities with environmental protection and management oversight. For example, OTA (1993) estimates damage costs of 79 harmful invasive species (HIS) to be some $185 billion at the maximum, which corresponds to 1.4% of GDP (gross domestic product) of the US in 1993. Later studies also indicate large damage costs as related to GDP, up to 12% (see review in Gren *et al*., 2009 and Table 1 in Section 3 of the paper). The damages and their causes are much explained by economic activities; as vectors of HIS through international trade and as drivers increasing ecosystem vulnerability through changes in land uses and environmental pollution. This, in turn, implies that strategies for managing HIS can be found in economic solutions to these causes and their effects. Non-economic factors that influence HIS introduction include among others activities undertaken for the purposes of deriving non-material benefits from species' introduction for aesthetics, educational (e.g. ornamental plants for horticultural studies; invasive fish for aquaculture experiments, etc.) and cultural heritage (e.g. religious values).

However studies on the economics of biological invasive species and their associated problems were scarce in the mainstream economic literature, until recently. In the last few decades, the economic field has been witnessing a relative explosion of both theoretical and empirical expositions aimed at shedding light on the economic problem of invasive species. In principle, we can identify three main questions addressed in this literature: (*i*) what is the damage cost of HIS? (*ii*) which is the best management strategy? and (*iii*) which policy instruments should be used in order to affect peoples' behavior? The literature on the first question arose relatively early, some studies are found in 1980s, and have been subject to reviews in mid 2000s (Born *et al*., 2005; Lovell and Stone 2005). These reviews showed large differences in estimated damage costs of single species, which is explained by differences in methods applied, and the spatial and dynamic scale of the studies. The two other questions started to be addressed and analyzed in the economic literature approximately 20 years later.

Some of this literature is reviewed in Gren (2008), who concluded that much of the literature so far was theoretical and in its infancy. Nevertheless, Gren (2008) pointed out important lessons that were already apparent, such as the need to use tariffs on trade or inspections of cargos with care, given they can be counter-productive and even increase the risk of HIS, as well as the trade-off between early detection and response and risk of spending large resource on invasive species that would not cause any harm.

In this paper, we provide an updated review of the literature on the economics of invasive species management. In particular we provide an overview of recent developments in economics, and which challenges remain. We review both theoretical and empirical studies addressing various management strategies and using different methodological approaches. The biological invasion chain, commonly applied on the ecological literature, serves as a point of departure for the review, which is discussed in Section 2 of the paper.

The review revealed a relatively large body of literature on the assessment of damage costs of invasive species; single species and groups of species at different geographical scales. However, the estimated damage costs show large variation, from less than 1 million USD to costs corresponding to 12% of gross domestic product, depending on the methods employed, geographical scale, and scope with respect to inclusion of different species. Decisions regarding optimal management strategies, when to act in the invasion chain and which policy to choose, have received much less attention in earlier years, but have been subject to increasing research during the last decade. More difficult, but also more relevant policy issues have been raised, which concern the targeting in time and space of strategies under conditions of uncertainty. In particular, the weighting of costs and benefits from early detection and mitigation against the uncertain avoidance of damage with later control, when the precision in targeting species is typically greater is identified as a key challenge. The role of improved monitoring for detecting species and their spread and damage has been emphasized, but questions remain on how to achieve this in practice. This is in contrast to the relatively large body of literature on policies for mitigating dispersal by trade, which is regarded as one of the most important vectors for the spread of invasive species. On the other hand, the literature on how to mitigate established species, by control or adaptation, is much more scant. Studies evaluating causes for success or failure of policies against invasive species in practice are in principal non-existing.

2.2 Optimal management of aquatic invasive species in Sweden: Case of *Elodea canadensis*

The invasive species phenomenon is widespread globally, with multiple impacts on the biodiversity and functioning of invaded ecosystems (Rørslett *et al*., 1986; Mjelde *et al*., 2012; Zehnsdorf *et al*., 2015). The incidence of invasive species imposes substantial ecological/environmental damage and economic costs. For example, it is estimated that economic damages from harmful invasive species amounts to more than $US335 billion in the US, UK, Australia, South Africa, India and Brazil (Pimentel *et al*., 2001). By the final stage in the invasion process where adaptation is probably the last resort, annual damages estimated for the invasive *Emerald Ash Borer* (Agrilus planipennis) is about $US70 million per annum in the US state of Ohio (McDermott *et al*., 2013a). The situation is no different for Sweden where the costs of 13 nonnative invasive species were estimated to be on average $US3.3 billion (Gren *et al*., 2009).

Aquatic invasive species are regarded as one of the most destructive species in the invasion taxa imposing severe damages on most of its invaded habitats and native living organisms with consequent environmental and economic costs. Production losses from agriculture, fishery, recreation, real estate (i.e. property value reduction) are some of the economic impacts of invasive species in aquatic ecosystems (see Marbuah *et al*., 2014). Notable among these adverse impacts include but not limited to estimated damage costs of about $US6billion per year due to production loss from fishery in 13 Florida lakes in the US arising from aquatic plant invasion (Adams *et al*., 2007). Similarly, Zebra mussel in the US and Canada imposed around $US 0.1-5 billion per year destruction cost to power plant facilities not excluding aquaculture, sport fishery, boat damage and aesthetic impairment of same species in the Great lakes region of US and Canada ($US3.5 billion per annum; see Lovell and Stone, 2005). The introduced signal crayfish in Sweden has successfully outcompeted and reduced production of native noble crayfish in Lake Halmsjon costing approximately $US8/person. In the same vein, Yellow Floating Heart in Lake Väringen resulted in significant recreational losses thus imposing control cost of about $US90/person (Kataria, 2007; Carlsson and Kataria, 2008; Gren, 2008; Marbuah *et al*., 2014 for reviews on the economics of invasive species).

Elodea Canadensis (Michx), native to North America, is a submerged aquatic plant which is now invasive in many regions of the world. It is dioecious and flowers between June and August every year and vegetatively reproduces fragmentation dominating in both native and introduced populations (Bowmer *et al*., 1984). It was first introduced into Europe in 1859 as an ornamental plant (aquarium and pond plant in botanical gardens) and rapidly spread throughout

Europe (Cook and Urmi-König, 1985; Josefsson and Andersson, 2001). In Sweden, *E. canadensis* was first introduced into lake Mälaren in 1871 but year of introduction in other lakes in Sweden is unknown (Josefsson and Andersson, 2001). Since its first introduction, *E. canadensis* is now common and established in nutrient-rich lakes and slow moving rivers in the whole of southern and central Sweden (Josefsson and Andersson, 2001; Larson, 2007). Its impact has been well documented and includes the following. It competes with other native species in its environment and sometimes displaces indigenous vegetation, thus reducing biodiversity (Rørslett *et al*., 1986; Mjelde *et al*., 2012). Additionally, it can grow densely given favourable environmental conditions, spreads fast and affect an entire lake ecosystem (Josefsson and Andersson, 2001). In Sweden, it has caused major changes in habitat modification in infested lakes (Josefsson and Andersson, 2001). It also causes problems for boat traffic, fishing (especially crayfish), swimming, and other recreational value of lakes where present in dense mass (Josefsson and Andersson, 2001; Zehnsdorf *et al*., 2015). Furthermore, *Elodea* impairs aesthetic beauty of lakes with consequent negative impact on real estate property values.

E. canadensis is a plant commonly used in constructed wetlands – that is wetlands which are built/maintained to absorb chemical contaminants (e.g. heavy metals, excess nutrients) adjacent to sewage outflows and mines. At moderate abundances, *E. canadensis* has positive effect by reducing eutrophication. Eutrophication (nutrient pollution) occurs when excess nutrients stimulate planktonic algal blooms, which dominate the surface of the water, sucking all oxygen out of the water (especially as the algal biomass decays) and blocking light. This basically kills the rest of the lake ecosystem. As eutrophication is mostly a summer phenomenon, *E. canadensis* could be beneficial by absorbing a lot of the excess nutrients into macrophyte biomass, so that the algae never bloom and the water remains clear. By the late winter when *E. canadensis* starts to die back, the risk period for summer eutrophication is over. Conversely, at very high abundances *E. canadensis*potentially pose a risk of decaying biomass being disruptive by favouring eutrophication, but there are other negative outcomes (such as fishing, bathing, boating) which face the greatest risks at those high densities (see for e.g. Strand and Weisner, 2001; Josefsson and Andersson, 2001 for details on *E. canadensis* dynamics and impacts).

Mechanical treatment (i.e. harvesting through cutting) is the only weed control programme at the moment where biocontrol (using agents such as the herbivorous fish Asian grass carp) and herbicide use are inapplicable either because it is prohibited or has been unsuccessful (Zehnsdorf *et al*., 2015).

Mechanical cutting of the invasive weed *Yellow Floating Heart* (Nymphoides peltata) was successfully applied to Lake Väringen in Sweden (Carlsson and Kataria, 2008).

The purpose of this paper is to model optimal management (i.e. weed cutting and removal) of *E. canadensis* that generates benefits in small quantities from reduced eutrophication which turn into damages at higher densities because of contribution to eutrophication as well as impairment of ecosystem services such as swimming, fishing and boat traffic where the greatest risks are likely to be felt. Using a simple bioeconomic model developed to describe the population dynamics of the weed in Lake Lötsjön in Sweden, we conducted an analysis of the optimal management of the species providing both good and bad effects on society. To the best of our knowledge, there are currently no studies assessing optimal management of an invasive species with both potential positive and negative ecological and social outcomes. In general there are relatively few studies on the optimal management of invasive species compared to the large body of literature on the calculation of costs of invasive species (see Marbuah *et al*. 2014 for a review). Much of the existing literature has been focused on optimal timing and choice of control measures for invasive species (Finnoff *et al*., 2005; Settle and Shogren 2002); role of the invader's life history for optimal management (Buhle *et al*., 2005; Hastings *et al*., 2006; Elofsson and Gren, 2015) or identification of best management strategy from risk analysis (Leung *et al*., 2002; Hyytiäinen *et al*., 2013).

Results from simulating our parametrized model over a 50-year period indicates that it is optimal to engage in the proposed weed cutting and removal control programme since it yielded positive net economic benefits. The results further revealed that total net present value of benefits is quite sensitive to choice of discount rate, changes in intrinsic growth rate of the invader, environmental carrying capacity of the lake but most responsive to the damage cost parameter.

2.3 Social capital and carbon emissions in Sweden

The concept of social capital can be traced to Hanifan (1916). It was later used for explaining cooperative behaviour 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; Knack and Keefer, 1997; 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). However, despite these empirical findings

there are few studies on the impact of social capital on carbon emissions at the regional or national scales. Instead, there is a large body of literature examining the relation between economic growth and pollution in the so-called Environmental Kuznets Curve (EKC) framework where it is hypothesized 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 (see reviews in Dinda 2004; 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 important criticism is biased and inconsistent estimates arising from model misspecification due to omission of spatio-temporal effects in emissions data if significant present (Burnett *et al*., 2013; Aklin, 2016).

The main purpose of this paper is to investigate the role of social capital for carbon dioxide (CO_2) emissions in Swedish counties over the period 2005-2011. By studying counties with similar institutional set up we avoid some of the criticisms raised against the EKC literature (e.g. leakage and differences among countries). However, the operationalization of social capital can be made in several ways, and a distinction is usually made between cognitive and structural components (Putman, 2000). The cognitive aspect refers to the predisposition of individuals to act in a way which is beneficial for society, and the structural aspect the interaction among individuals (e.g. Kaasa and Parts, 2008). Different constructs of trust are often used to measure the cognitive part, and networks and civic engagement are applied to measure the structural part. We test for both constructs. Specifically, in this paper, we test the effect of composite indices of trust and membership and engagement in different forms of organizations on CO_2 emissions in Sweden.

It has been argued that these two social capital variables interact since networking can reinforce trust, and vice versa (Kaasa and Parts, 2008). Similar interaction may appear for income and social capital, where a higher income level is associated with more abundance of social capital (Kaasa and Parts, 2008). By incorporating social capital in our model individually and interactively with real income, we shed light on our understanding of this interaction effect which influences the shape of the EKC by shifting it downward if the interaction turns out negative and statistically significant. The implication of such a result is that there is a lower CO_2 emissions cost of economic

development (Ibrahim and Law, 2014). In this vein, we test the explanatory power of both types of interaction terms for carbon emissions. 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. That is, counties may set emission targets for CO_2 based on emission levels chosen by their neighbours (Donfouet *et al*., 2013).

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; Keene and Deller, 2013; Ibrahim and Law, 2014; Carratini *et al*., 2015). The evidence from these studies have been mixed. Whereas Grafton and Knowles (2004) did not find significant evidence of impacts of any social capital construct on emissions of CO_2, SO_2, and NO_x, Paudel and Schafer (2009) established a significant role played by social capital (measured by a composite index of different measurements of organizational activities) in explaining water pollution from phosphorus in 53 Louisiana parishes in the US. Keene and Deller (2013) examined the impact of social capital in an EKC framework on emissions of fine particulates in US counties, and accounted for spatial autocorrelation. They constructed a composite index of different organizational activities, and found that this social capital construct reduces emission of fine particulates. Ibrahim and Law (2014) analyzed the interaction effect between social capital and GDP/capita on CO_2 emissions in developed and developing economies and found significant complementarity in their effects. Carratini *et al*., (2015) examined the impact of general trust on green-house gas (GHG) emissions in 29 European countries. They find that abundance of social capital has a significant reduction on GHG emissions.

In our view, this study contributes to this literature in two ways. First, the impact of social capital and spatial correlations are tested for small 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 as argued in the preceding paragraph.

Using the system generalized method of moments (GMM) to account for endogeneity in the presence of dynamic and spatial effects using geo-referenced emissions data, the results showed significant negative impacts of trust and the overall social capital indices on total emissions, but the direction of impacts differed among sectors. The estimated effects were negative on emissions from

industry but positive on transport emissions. Common results to most type of emissions were significant dynamic and spatial carbon emissions effects, but EKC relations could be established only for total and transport emissions.

2.4 Is willingness to contribute for environmental protection in Sweden influenced by social capital?

The extant environmental and resource economics literature has identified and highlighted several factors that drive people to make financial contributions toward the provision of a public good such as the environment (see Mitchell and Carson, 1989; Meyer and Lieber, 2010). The decision by individuals willing to pay for the environment can be explained by a combination of socio-economic and demographic variables such as income, age, education, marital status, etc. Yet an emerging strand of literature in environmental management has emphasized the critical role played by social capital in influencing pro-environmental attitudes and by extension individuals' tendency to contribute toward environmental quality improvements. Despite this recognition, studies in this area of research are limited but have been growing in the last few years. For example, recent evidence in the literature show robust indication social capital is positively linked to willingness to contribute (WTC) for environmental goods, environmental regulation/policy and management success (see Gelissen 2007; Jones *et al*., 2009; Polyzou *et al*., 2011; Yogo, 2015; Pretty and Ward 2001; Pretty and Smith, 2003). Pretty and Ward (2001) emphasize that "…as long as people managed natural resources, they have engaged in collective action" and that the presence of high stocks of social capital elements promote collective action towards a common good, including environmental sustainability.

The main aim of this paper is to empirically investigate the extent to which social capital influences individual decision regarding WTC for environmental protection in Sweden. The main hypothesis we test is that *all things equal*, social capital is positively related to individuals' WTC for environmental quality in Sweden. We apply the ordered logistic model to environmental and social capital data obtained from the 2010 International Social Survey Programme (ISSP) on Sweden to achieve this aim. The Swedish ISSP survey reflects a nationally representative selected sample covering individuals aged 18-79 years residing in Sweden. It covered the period 2010-02-16 to 2010-05-05 using fixed form self-administered paper questionnaire. The purpose for the survey in Sweden was to examine the attitude of residents in Sweden on environmental issues and to compare it with the attitude of people in some forty countries as well as how the attitudes of Swedish residents have changed since 2000.

We contribute to the social capital-environment literature in two ways. In the absence of studies with explicit focus on modelling social capital and its link to the environment in Sweden, this study fills the gap by utilizing several social capital elements in the context of individuals' tendency to contribute toward environmental preservation. Secondly, by considering three different measures of WTC (i.e. higher taxes, prices and accept standard of living cuts), we provide evidence on the sensitivity of each of these measures to the different social capital constructs as well as the aggregate index. The motivation for this approach is based on the argument that even though social capital in its aggregate form may predict willingness to contribute to the environment (e.g. Jones *et al*., 2009; Jones *et al*., 2010), individuals may react differently to sub-elements in forming their decision to contribute to prevent environmental damage. The need to isolate and analyze each sub-component is therefore a plausible justification.

We find statistically significant impact for social trust and civic participation on WTC. Institutional trust is not significant when the payment vehicle is a reduction in the standard of living. Overall, the composite index of social capital is a robust predictor of individuals' likelihood to contribute irrespective of the payment vehicle.

2.5 Energy demand in Ghana: A disaggregated analysis

The role of energy resources in meeting the needs of households, industries, etc. among others in any economy cannot be overemphasized. Different types of energy sources are required to meet demand for lighting, cooking, electricity generation among many other uses. Demand for energy in Ghana similar to most developing countries exceeds the available supply.

A key challenge to Ghana's energy sector is inadequate access to modern energy services such as liquefied petroleum gas (LPG) and electricity, albeit some marked improvement over the past decade is evident. This has created a relatively high dependence on traditional energy sources such as biomass (mainly charcoal and wood fuel) to meet the energy needs of households. It is estimated that about 76% of Ghanaian households depend on biomass for cooking and heating water (Mensah and Adu, 2015).

The impact of continual exploitation of forest lands and burning of wood fuel by households and industries on environmental degradation continues to engage decision-makers at the local, national, regional and international levels. Experts argue that the overreliance on biomass as a key energy source by Ghanaian households is among the main drivers of the rapid depletion of Ghana's forest cover which stands at about 2% loss per annum. Thus the incessant depletion of

the forest to meet primary energy consumption if not curtailed is likely to derail efforts at ensuring environmental sustainability and inhibit Ghana's attainment of the sustainable development goals.

It is in recognition of the debilitating impact of continued use of primary energy sources such as biomass on climate change that the United Nations has been advocating intensification of programs/ policy initiatives that encourages a switch from traditional energy sources to an enhanced access and utilization of modern and efficient sources like LPG (Mensah and Adu, 2013). The Government of Ghana therefore launched a National LPG Programme in 1990 to promote LPG use as an alternate energy source to charcoal and firewood. Urban households, public institutions and the informal commercial sector requiring mass catering facilities were targeted through extensive promotional and educational campaigns [3]. The results of these promotional efforts bore some significant fruits with LPG consumption doubling in 1992 and by 2004; total LPG consumption was over 50,000 t per annum which is about ten times more than pre-promotional consumption levels (UNDP, 2004). Promotion of LPG use among rural households was also initiated through the Unified Petroleum Price Fund (UPPF). The idea of this policy was to compensate oil marketing companies that transport petroleum products like LPG to rural and distant locations outside a radius of 200km from the Tema Oil Refinery (TOR) to cover transportation cost (UNDP, 2004). Despite these efforts, LPG consumption levels remained low in even urban areas with high demand for wood fuel. Another complementary effort was the completion of the West African Gas Pipeline (WAGP) project in 2006 to enhance gas supply for electricity generation in Ghana.

Despite these developments, frequent power crises and shortages in LPG supply have almost rolled back most of the gains made in terms of supply for domestic and industrial uses. The high dependence of Ghana on natural gas supply from Nigeria through the WAGP which is erratic, coupled with inadequate gas storage infrastructure (due to low investment) and a crippling refinery are among the reasons for the rampant frequent power outages and LPG shortages respectively in the country. Nonetheless, industry experts are optimistic that the fledgling oil and gas industry will offer sustainable supply of natural gas to boost electricity generation, especially following the completion of the "Ghana gas infrastructure project", to end the looming power crises.

A major concern however is that solving the energy crises in the country requires not just short term measures but an integrated energy policy design that seeks to tackle both demand and supply side management issues. This is because in an environment where population and urban growth is on the ascendency,

meeting the energy needs of the populace will require both increased generation capacity and efficiency in demand. These can be realized only when driving forces behind energy demand are known, critically analyzed and thoroughly understood. Knowledge of such demand drivers will then help in predicting the future demand needs and implementing measures to engender efficiency in the demand.

The goal of this study is to provide a comprehensive analysis of the drivers of disaggregated energy demand in Ghana to offer guidance on energy policy prescriptions towards achieving the overarching aim of becoming an "energy sufficient economy" to propel the engines of economic growth and development. To realize this goal, we consider a comprehensive set of disaggregated energy demand sources – gasoline, diesel, LPG, kerosene, solid biomass, residual fuel oil and electricity. We use the autoregressive distributed lag and partial adjustment models respectively to estimate short and long run disaggregated energy demand determinants. This is important for purposes of policy planning and implementation since the estimated coefficients could inform energy demand management as well as the supply side. Critical policy and sensitive issues such as petroleum price subsidization, urban planning as well as the need for further investment in energy infrastructure could benefit from this paper's results.

Our results show that energy prices, income, urbanization and economic structure are significant demand drivers of the different energy types in Ghana with varying estimated elasticities. Further, there is evidence of high degree of inter-fuel substitution in energy demand in Ghana, particularly from gasoline, diesel and kerosene towards LPG consumption. We recommend, among different policy options, a customization of energy price subsidization policies, especially on LPG, to reduce the unintended beneficiary dilemma or spillover effect of current government policy. Other policies such as intensification of energy conservation programs and market entry of independent power trading companies to enhance energy service delivery through competition are also worthy of note.

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