Spatial Economic Aspects of Climate Change

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by

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Abstract

Our objective in this special issue is twofold. First, we emphasize the importance of comprehending that the global impacts of climate change notwithstanding, there are salient region-specific impacts that vary across space. Second, given this observation, we show how rigorous modeling of the connections between climate change and (i) land use changes, (ii) forestry, (iii) infrastructure, and (iv) local labor markets sheds light on a variety of climate change induced spatial economic effects. Following this introductory paper, there are seven additional papers in this special issue. Each of these papers discusses a particular research question at the interface of what we call "climate change and space."

Keywords: Forestry, Infrastructure, Land Use, Local Labor Market, Space

JEL Codes: Q54, R11

1. The Problem Stated

A variety of gases such as carbon dioxide, methane, nitrous oxide, and water vapor are now frequently referred to as greenhouse gases because much like the glass in a greenhouse, they trap infrared radiation that would ordinarily escape into the earth's atmosphere. This entrapment tends to have a warming effect on the globe and the resulting "global warming" can ultimately lead to climate change.[4] As noted by Batabyal and Nijkamp (2019), there is little or no debate on the proposition that the greater the level of greenhouse gases, the greater is the equilibrium temperature of the earth. They also note that the expected functional relationship between greenhouse gases and the earth's temperature is expected to be non-linear with the potential existence of one or more tipping points. In addition, there is virtually no debate on whether anthropogenic emissions of greenhouse gases cause a noteworthy rise in global temperature in comparison with present temperature levels and in comparison with natural fluctuations in the temperature levels. As noted by Kahn (1998, p. 167), the "debate centers around the magnitude and timing of the change, and its significance to human welfare."

Even though the presence of fundamental uncertainty about many aspects of climate change---see Nordhaus (2013) and Wagner and Weitzman (2015)---affects how researchers think about the underlying issues, it is fair to say that, in general, there are two broad ways of looking at and analyzing the problem of climate change. First, one can look at climate change as an example of what economists call a global public bad---see Hanley *et al.* (1997, p. 43)---and then proceed to study the properties of and the difficulties faced in designing and implementing international environmental agreements (IEAs) between nations for the purpose of reducing greenhouse gas

[4] In the remainder of this editorial, we use the terms "climate change" and "global warming" interchangeably.

emissions. In fact, there is now a substantial literature on this topic[5] and economists in particular and social scientists in general have devoted a great deal of time studying why it is so difficult to secure agreement among nations to reduce the *global* emissions of greenhouse gases.

In the second way of conceptualizing and studying the climate change problem, researchers acknowledge the global dimension of the problem but then point out that the *regional* impacts of climate change vary across *space* and are very likely to be *dissimilar*. This point has been made in the case of agriculture by Van Kooten and Folmer (1996) and others. Therefore, this dissimilarity calls for an explicit recognition of the fact that the region-specific effects of climate change pose region-specific problems that, in turn, require region-specific solutions. Although this fact has now been recognized in the work of Ruth (2006), Ruth *et al.* (2006), Smith and Mendelsohn (2006), Calzadilla *et al.* (2007), and Karetnikov and Ruth (2014), it is fair to say that relative to the number of studies that have concentrated on the global dimensions of climate change, there are far *fewer* studies of this same phenomenon's regional or spatial dimensions.

2. Objectives of the Special Issue

Given this lacuna in the existing literature and the paucity of published research on climate change in this and other regional science journals,[6] the objective of the seven papers that together comprise this special issue of *Spatial Economic Analysis* is to provide systematic analyses of some of the key spatial economic impacts of climate change. In determining which of myriad such

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For additional details, see Folmer *et al.* (1993), Folmer and van Mouche (1994), Batabyal (1996, 2000), Folmer and de Zeeuw (2000), Batabyal and Beladi (2002), Barrett (2003), Nordhaus (2015), Hsiang and Kopp (2018), Chander (2018), and the many references cited in these sources.

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To the best of our knowledge, there are only two published papers in this journal that have something to do with climate change. The first, by Temurshoev and Oosterhaven (2014) looks at CO_2 emissions in passing but the main purpose of this paper is to study the nature of sectoral linkages in an economy. The second, by Dall'erba and Dominguez (2016) is about how climate change affects farmland values across the southwestern United States. As such, this paper complements the analysis conducted in the three papers in this special issue that analyze the nexuses between climate change and changes in land use.

impacts to focus on, we have been guided by some of the significant findings in the current literature.

For instance, Dale (1997, p. 753) and other researchers[7] have pointed out that "humans will change land use, and especially land management, to adjust to climate change and these adaptations will have some ecological effects." Therefore, the first three of seven papers---by Nicita *et al.* (2020), Engstrom *et al.* (2020), and Estrada *et al.* (2020)---analyze land use changes, broadly construed, from alternate vantage points. Specifically, the paper by Nicita *et al.* (2020) studies the relationship between climate, land values, and landscape diversity in a Mediterranean region. The paper by Engstrom *et al.* (2020) utilizes a bioeconomic lens to examine pollination by bees and the optimal provision of "semi-natural habitats" in the Stockholm region. The paper by Estrada *et al.* (2020) studies how the risks associated with climate change impact both crop yields and agricultural land.

Kirilenko and Sedjo (2007, p. 19697) have argued that "[c]hanging temperature and precipitation pattern and increasing concentrations of atmospheric CO_2 are likely to drive significant modifications in natural and modified forests." As such, the fourth and the fifth papers---by Albers *et al.* (2020) and Siebel-McKenna *et al.* (2020)---look at how forests might be protected and managed in the face of climate change. In particular, the paper by Albers *et al.* (2020) studies how policies that protect certain areas can attenuate some of the deleterious impacts of climate change stemming from forest loss and increased carbon dioxide emissions. The paper by Siebel-McKenna *et al.* (2020) analyzes how the notion of a carbon price can be used to get forest

7 For additional details, see https://www.usgs.gov/faqs/how-do-changes-climate-and-land-use-relate-one-another-1?qt-news_science_products=0#qt-news_science_products. Accessed on 21 February 2020.

managers to adopt longer rotation periods which, in turn, lead to higher levels of carbon sequestration in the pertinent ecosystem.

According to Schweikert *et al.* (2014, p. 306), "[c]limate change poses a critical threat to future development, particularly in areas where poverty is widespread and key assets such as infrastructure are underdeveloped for even current needs." Consistent with this viewpoint, the sixth paper---by Wang *et al.* (2020)---studies how seaports adapt to climate change induced natural disasters. Finally, the seventh paper---by Fouzia *et al.* (2020)---examines how climate change induced natural disasters influence the labor market in a variety of counties in the United States. The rationale for this study is provided by the work of Jessoe *et al.* (2018, p. 230) who use Mexican data and point out that extreme heat "increases migration domestically from rural to urban areas and internationally to the US. A medium emissions scenario implies that increases in extreme heat may decrease local employment by up to 1.4% and climate change may increase migration by 1.4%."

With this discussion of our objectives out of the way, we now proceed to succinctly comment on the intellectual contributions of the seven papers that comprise this special issue. To this end, we first concentrate on the three papers that analyze the connections between global warming and changes in land use.

3. Land Use Changes

3.1. The Ricardian approach

Nicita *et al.* (2020) begin their analysis of the connections between land values, climate change, and landscape diversity in Sicily by first pointing out that farmers in the Mediterranean region in general are likely to be adversely affected by the higher mean temperatures that one can expect from the onset of global warming. That said, how exactly might Mediterranean farmers respond to the expected temperature changes? In addition, might we see changes in "agrobiodiversity" and land returns?

To answer these sorts of questions, the authors conduct their analysis with the so called "Ricardian approach" made famous by the earlier work of Mendelsohn *et al.* (1994). This approach uses economic data on the value of land to study how climate in different places influences the net rent or value of farmland. By directly measuring farm prices or revenues, this framework is able to account for the direct impacts of climate on the yields of different crops as well as the indirect substitution of different inputs, the introduction of different activities, and other possible adaptations to different climates.

Using data for individual farms in Sicily provided by the Italian Farm Accountancy Data Network, the authors first identify a variety of explanatory variables such as farmland value, the elevation levels of the individual farms, the land share that is rented, and the so called Shannon-Wiener index of agrobiodiversity. They then estimate a series of econometric models that yield useful insights into the functioning of Sicilian farms.

Specifically, we learn that there is spatial correlation in the data and that adaptation to climate change by farmers is endogenous. We also learn that the maintenance of agrobiodiversity is important because it positively affects farmland value, provides adaptation and mitigation benefits, and enhances the provision of ecosystem services. Therefore, from a policy perspective, the findings in this paper clearly call for action to preserve and even increase agrobiodiversity because of its numerous salutary impacts on, *inter alia*, the value of farmland.

3.2. Pollination and rapeseed oil production

It is well known that healthy ecosystems are resilient in the sense of Holling (1973). In addition, as Perrings (1995) has pointed out, a key value of biodiversity stems from the fact that it promotes an ecosystem's Holling resilience. Even though these two points are now well understood, Engstrom *et al.* (2020) contend that there is a pressing need to better comprehend the complex interactions between climate, crops, and biodiversity.

As such, the authors of this paper use a bioeconomic model to analyze the key role played by diverse and wild pollinator bees in enhancing the production of rapeseed oil in the Stockholm region. The diverse bees studied include solitary bees and bumble bees. In addition, the authors are keen to assess how changes in the habitats of these wild pollinator bees---what they call semi-natural habitats---along with climate change affect the well-being of the two types of bees. Climate change is important in this setting because it is expected to have *dissimilar* impacts on the ability of the solitary and the bumble bees to pollinate rapeseed.

To shed light on these sorts of issues, the authors analyze an infinite-horizon, discrete-time, dynamic, stochastic general equilibrium bioeconomic model with three state variables. They are temperature and the two different types of bees. The key task confronting a farmer is to determine the optimal amount of *land* or semi-natural habitat to set aside and not cultivate.[8] In terms of the model of this paper, this means that the farmer first observes the stock of the two types of bees and then ascertains how much land to set aside or leave uncultivated. Put differently, each year's decision to leave land wild is based on the known stocks of the two types of bees. What is stochastic

[8] Some land is set aside and not cultivated because this land provides the habitat for the two types of bees being studied.

in the model is the impact that a year's set aside decision has on the regeneration of the two bee stocks.

The bioeconomic model yields some interesting conclusions. We learn that except when the number of solitary bees is very low, the optimal amount of semi-natural habitat is negatively related to the current stock of bees. Second, even though bumble bees are the major pollinators relative to solitary bees, solitary bees have a "resilience value"---meaning that they contribute to the overall pollination service capacity---that depends on the two bee stocks and is an increasing function of both the mean temperature and the variation in this temperature. Given that very little is now known about the nexuses between temperature and bee population dynamics, from a policy standpoint, this paper is useful because it shows how one might *quantify* the economic value of biodiversity.

3.3. Assessing impacts on agriculture

Even though many studies have now examined the impacts of climate change on agriculture, most of these studies focus on state, country, or even broader regions. Hence, they ignore the *spatial* variability in the effects of climate change even though these effects can be large. Given this state of affairs, Estrada *et al.* (2020) build on the work of Blanc (2017) and include "crop emulators" into an integrated assessment model (IAM). The construction of this IAM is complex because it combines elements of statistical and econometric methods, process-based crop models, statistical simulation, and an integrated assessment framework. The use of this IAM permits the authors to generate individual and multivariate probabilistic projections and risk metrics that can be used to support the activities of both decision makers and stakeholders. In addition, the authors also provide a specific application of the so called "Assessment of Impacts and Risks of Climate Change on Agriculture (AIRCCA)" simulation model with which they create stochastic impact scenarios and risk metrics at a very fine spatial resolution for rain fed maize, wheat, and rice, which are, arguably, three of the most important global crops.

The detailed empirical analysis conducted by the authors leads to a number of noteworthy findings. Here are three examples. First, we learn that unabated climate change will significantly affect the present distribution of areas that are suitable for the rain fed production of the three crops under study. Second, many parts of the world such as northern Africa, the Middle East, and the eastern parts of the United States will experience non-trivial declines in crop yields. Finally, although some parts of Europe will see increases in crops yields as a result of climate change, the same cannot be said about other parts such as Portugal and Spain which are likely to experience declining yields for all crops during the present century.

The AIRCCA model that the authors work with has two key advantages. First, it can readily be used by policy makers to gauge the impact of climate change on agriculture and on agricultural land in a policy maker's chosen region of interest. Second, alternate settings in the model can easily be adjusted by a policy maker to compare and contrast the implications of alternate climate change scenarios.

4. Forestry

4.1. Protecting forest areas

The degradation of forests contributes not only to forest area loss but the resulting carbon emissions exacerbate the climate change problem. Therefore, policies that protect forest areas ought to mitigate the climate change problem. Based on this intuition, Albers *et al.* (2020) conduct fieldwork and then analyze the properties of what they call "protected area policies" (PA). Their analysis is guided by the belief that managers can best use their limited enforcement budgets by first comprehending the ways in which villagers make their extraction choices.

The model utilized by the authors has two types of agents in it. Both types of agents are able to influence the stock of a specific resource. There is a landscape manager and there are individual villagers who harvest the resource that is subsequently sold at a particular price. The manager can affect the extraction decisions of the villagers by selecting PAs and also by choosing the extent to which these PA designations are enforced. The manager has full information about the villagers, particularly their response to the creation of PAs. An individual villager knows the location of the PAs, the likelihood of getting caught if he illegally extracts from a PA, and the fact that other villagers will be making similar *spatially* explicit extraction choices. In each time period, an individual villager chooses how to allocate his time to resource extraction across a spatial landscape and to wage labor in his village. After an extraction period, the resource grows via an exogenously given density dependent growth process. The equilibrium of interest in this strategic interaction or game between the manager and the individual villagers is a spatial Nash equilibrium.

Application of the model shows that how much additional carbon storage a network of PAs gives rise to depends greatly on the extent to which this network is able to change the spatial decisions of the individual extractors. Second, the optimal configurations and the enforcement of created PAs differs between managers who concentrate on PAs specifically versus managers who concentrate on the *entire* landscape. Finally, with many nations and communities now formulating REDD[9] policies based on the enforcement of PAs, the analysis in this paper shows that by paying

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[9] The acronym REDD refers to reducing emissions from forest degradation and deforestation.

attention to the spatial decisions of extractors, one can gain insights into how a policy maker might *increase* the avoided carbon emissions produced by REDD funding.

4.2. Managing forests differently

Forests are standardly considered to be carbon sinks. Hence, forest managers can take actions to increase the capability of storing carbon by practicing enhanced reforestation and afforestation and also by either avoiding or delaying deforestation. Also, if the goal of forest management is to reduce atmospheric CO_2 concentrations then it is essential for managers to pay attention to random timber and carbon prices and the carbon fluxes arising from natural disturbances such as wildfires.

With this background, Siebel-McKenna *et al.* (2020) use a stochastic dynamic programming approach to determine the optimal decisions of a forest manager who faces probabilistic tree growth and alternate specifications of wildfire risk over a range of carbon prices. Specifically, this manager maximizes the expected net present value of an even-aged stand by waiting to harvest until the optimal rotation age is reached. This maximization problem is stochastic because, following the work of van Kooten *et al.* (1992), the growth of a forest stand is represented by Markovian transition probability matrices. The region studied is the Quesnel Timber Supply Area (QTSA) in British Columbia, Canada.

Application of the model demonstrates that when one accounts for carbon prices in the forest management problem, the optimal rotation periods become *longer*. In contrast, accounting for natural disturbances such as wildfires reduces the same optimal rotation period and this reduction can be interpreted as a safeguard against the increased risk. We also learn that as carbon prices rise, the amount of carbon sequestered in living and dead biomass first increases but then plateaus and that the amount of carbon stored in harvested wood products decreases. Finally, if, as a result of climate change, natural disturbances increase over time then this feature will make it more difficult for national governments to use forest management to be in compliance with international environmental agreements such as the 2015 Paris agreement.

5. Infrastructure

It is now well known---see Min *et al.* (2011)---that the number and the strength of climate change induced natural disasters are likely to increase over time. Seaports are very vulnerable to certain kinds of natural disasters such as hurricanes, strong winds, and heavy rainfall. Therefore, if seaports are to be resilient in the sense that they are able to function under a wide range of potential natural disasters then they will need to adapt[10] efficaciously to such disasters.

Wang *et al.* (2020) note that even though the above point has been recognized, there is very little analytical research on the adaptive behavior of seaports. In addition, the few existing studies on this topic have paid *no* attention to how the market structure of the terminal operator companies (TOC) and the kind of competition or cooperation they engage in affects the incentives to adapt to the greater likelihood of natural disasters. To fill this lacuna in the literature, the authors of this paper analyze a model of a region with two seaports that interact---compete or cooperate---with each other. Each seaport consists of an upstream port authority (PA or landlord) and several downstream TOCs (the tenants) that operate in an oligopolistic market structure. The two seaports are spatially distinct and they are subject to climate change induced natural disasters. The authors seek to answer the following two questions: First, how does competition or cooperation by the TOCs in the same port (intra-port) and competition or cooperation by them across the two ports

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[10] See Kahn (2016) for a general discussion of the importance of adaptation in the context of climate change.

(inter-port) affect the adaptation investments that are undertaken? Second, does the market structure within which the TOCs operate have any effect on the disaster preparedness of the two seaports?

Given a particular seaport, the authors find that climate change induced adaptation is an increasing (decreasing) function of the number of TOCs in this (the other) seaport. Second, common ownership of the various TOCs across the two seaports decreases adaptation to climate change. Finally, if the likelihood of disasters affecting the two seaports under study is asymmetric then there is greater adaptation by the seaport that expects to be hit by a disaster with a higher probability. The generality of these findings can be ascertained by examining the case where adaptation is undertaken not just by the PAs but *also* by the individual TOCs.

6. Local Labor Market Effects

As our discussion of the various papers comprising this special issue shows, the climate change phenomenon has had and is likely to continue to have powerful economic impacts over space. That said, Fouzia *et al.* (2020) make three useful points in their paper. First, they contend that we still know relatively little about the many ways in which climate change induced natural disasters affect *local* labor markets. Second, they point out that even though some existing studies provide information about the "employment effects" of natural disasters, this is not enough. In addition to the employment effects, we also need to learn about the pertinent "wage effects." Third, they remind us that it is important to comprehend the *mechanisms* that give rise to the varied employment effects of natural disasters.

To this end, the authors use U.S. county level data about climate change induced disasters that comes from the "Spatial Hazard Events and Losses Database for the U.S." and investigate the impacts of eight different kinds of disasters on local labor markets. Because, for most disasters, the temporal persistence and the related spatial spillover effects are largely unknown, these authors conduct their econometric analysis with a Spatial Durbin Error Model (SDEM). This modeling strategy allows them to account for the fact that the economies of counties that are adversely impacted by a natural disaster are *also* impacted by what happens in neighboring counties.

The findings obtained by these authors provides ample food for thought. Here are four examples. First, some disasters such as heat and hurricanes lead to positive total impacts on both employment and wages but other disasters such as tornados and severe storms have the opposite effects on employment and wages. Second, depending on the disaster being considered, the past effects can either strengthen or weaken the direct or immediate effects. Third, the impacts of the different types of disasters that are studied are typically transmitted over both time and space and hence it would be manifestly unwise to *ignore* either of these two categories of spillovers. Finally, even though it is difficult in practice to disentangle the underlying demand and/or supply shifts that cause the observed changes in employment and wages, it is sometimes possible to use socio-economic indicators to identify the correlation between the disaster generated impacts that we see and demand and/or supply shifts.

7. Conclusions

We have now set the stage for this special issue of seven papers in this editorial by first pointing to the lacunae that exist in the current literature on the spatial economic impacts of climate change and then by briefly discussing the contributions of the individual papers. We believe that each of these seven contributions expands the current frontier of knowledge about the connections between climate change and (i) land use changes, (ii) forestry, (iii) infrastructure, and (iv) local labor markets. As such, this special issue ought to be of great interest to all readers of this journal who are interested in learning more about the myriad ways in which the phenomenon of climate change and spatial impacts are linked. In addition, the research described here should stimulate research into the connections between climate change and related spatial topics such as migration (e.g. Gray and Wise, 2016), the relocation of firms (e.g. Linnenluecke *et al.*, 2011), and the spread of diseases (e.g. Jaya *et al.*, 2017 and Jaya and Folmer 2020a, 2020b).

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