Essays on the Economics of Multifunctional Forests, Migration and Climate Change

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Abstract

This thesis compiles five papers that independently cover issues on multifunctional forest, migration and climate change. Paper I addresses these questions: What is the effect of site quality on forest growth rate and variability in forest growth? How does site quality impact on ecosystem services, that is, timber production and carbon sequestration? Site quality indicator was found to positively affect forest growth and growth rate, and decreases uncertainty in the productivity. Using dynamic optimization model, Paper II estimates the economic value of site quality taking into account its interaction with timber value and carbon sequestration in Swedish forest. Analytical results showed that net present value when considering ecosystem services provided by the forest and its interaction with site quality is higher than in the case without site quality interaction. Paper III links educational attainment to internal migration decisions with much on rural-urban perspective using Ghana as a case study. The effect of educational attainment on migration decisions in 2005/2006 for urban in-migrant was found to be higher than the effect for rural in-migrant, with its significance varying for the different stages of educational attainment. In absolute terms, whereas the effect of secondary educational attainment on migration decisions for urban in-migrant is higher than for rural in-migrant, the reverse holds for higher educational attainment during the period 2012/2013. Paper IV examines the effect of climate element on internal migration decisions using similar methods and data as for Paper III. Whereas temperature positively affects the probability to migrate, aridity index negatively affects migration decisions. Individuals tend to move to the rural areas relative to urban areas with an increase in precipitation and or a decrease in aridity. Paper V explores the effect of climate variability and socio-economic factors on the number of infectious disease patients in Sweden. Temperature showed a linear negative effect on the number of patients, but a non-linear relationship when winter temperature is used. Conversely, a positive effect of precipitation on the number of patients is found, with modest heterogeneity in the effect of climate variables on the number of patients across disease classifications observed. Socio-economic factors were found to correlate with number of patients. We found significant persistence in the number of infectious disease patients but found only temperature and income as dominant drivers in a dynamic model.

Keywords: Multifunctional forest; Forest growth; Site quality; Ecological conditions, Migration; Education; Climate change; Infectious diseases; Ghana; Sweden

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Dedication

To the memory of my mom, Ms. Charlotte Duah, and my dear wife, Salome.

Contents

List of publications

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

I Amuakwa-Mensah, F.* and Gren, I-M. (2017). Impacts of site quality on mean and variability in forest growth and value of ecosystem services in Sweden. (Submitted to *International Journal of Biodiversity Science, Ecosystem Services & Management*).

II Amuakwa-Mensah, F.* and Gren, I-M. (2017). Multifunctional forestry and interaction of site quality mechanism (Manuscript)

III Amuakwa-Mensah, F.*, Boakye-Yiadom, L. and Baah-Boateng, W. (2016). Effect of education on migration decisions in Ghana: a rural-urban perspective. *Journal of economic studies*, Vol. 43 Iss: 2, pp.336 – 356

IV Amuakwa-Mensah, F.* (2017). Climate element of migration decisions in Ghana: Micro Evidence. (Manuscript)

V Amuakwa-Mensah, F.*, Marbuah, G and Mubanga, M. (2017). Climate variability and infectious diseases nexus: evidence from Sweden. *Infectious Disease Modelling*, Vol. 2, Iss: 2, pp. 203-217

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1 Introduction

This thesis comprises five papers that cover different aspects of multifunctional forests, migration and climate change. Specifically, the first two papers are on multifunctional forests, where paper I calculates the effects of site-specific ecological conditions on forest growth and provision of ecosystem services in terms of timber and carbon sequestration in Sweden. Based on the estimates from paper I, we analyze the economic value of the interaction of site quality with the ecosystem services provided by the forest in the form of timber production and carbon sequestration within a dynamic optimization model in paper II. The third paper is independent of the previous two and it links educational attainment to internal migration decisions with a focus on rural-urban drift using Ghana as a case study. With recent interest in how environmental or climatic factors affect migration decisions, the fourth paper examines the effect of climate elements on migration decisions using similar methods and data for paper III. The final paper explores the effect of climate variability and socio-economic variables on the number of infectious disease patients in Sweden. In the following subsections, key concepts and themes in this thesis are discussed.

1.1 Forest growth, Site quality and Multifunctional forestry

The forest is generally known to provide multiple services and goods such as timber, bioenergy, biodiversity, recreation values, and carbon sequestration. This brings to light the concept of multifunctional forestry, which in simple terms can be seen as the ability of the forest to provide multiple and interconnected outputs or services that may either be positive or negative, intended or unintended, complementary or substitute, marketable or non-marketable (Maier et al., 2001). Optimal management of these services, which can be complements or substitutes in forest production, require tools for assessing forest growth and productivity. For example, high productivity can promote timber production and carbon sequestration in growing biomass, but may be detrimental for biodiversity. In principle, current and future forest productivity depends on management practices and quality at the site as given by environmental, biophysical and climate conditions (see review in Noormets et al., 2015).

Several of these factors are subject to stochastic fluctuation because of weather conditions, for example. Forest productivity and associated ecosystem services can then be predicted only under conditions of uncertainty. Since society is usually concerned about stability in the provision of any goods and services, both mean and variability in production of the forest ecosystem services need to be assessed (e.g. Brock & Xepapadeas, 2002; Gren et al., 2014; Vardas & Xepapadeas, 2010). Despite a large body of literature on the estimation of impacts of management practices and site conditions on forest growth (e.g. Bontemps and Bouriaud, 2014; Skovsgaard and Vanclay, 2008) there is, to the best of our knowledge, no study on the effects on both mean and variability in forest growth. Consequently, Paper I calculates the effect of environmental factors on the growth of Swedish forests by considering management practices and computes the associated effects on the value of timber and carbon sequestration. Paper I is most similar to the literature on the estimation of stand level forest production and growth function in economics.

A common assumption is that the growth follows a sigmoid form which starts at the origin, a point of inflection occurring early in the adolescent stage, and either approaching a maximum value, an asymptote, or peaking and falling in the senescent stage (e.g. (Fekedulegn et al., 1999). Growth functions which portray these features include theoretical models like the logistic, Gompertz, Chapman-Richards, von Bertalanffy and Schnute functions. However, the parameters from the non-linear estimation are mostly correlated since a change in one parameter may cause the other parameters to change in order to maintain its functional form. Due to this, an introduction of other explanatory variables additively in the function may give a misleading conclusion about the effect of these variables on the growth rate. Therefore, a linearized version of the logistic function is used in Paper I to examine the effect of management practices and site quality on the mean and variability in forest growth.

Analysis of environmental conditions at the site has a long tradition in forestry, where it usually has been measured by a site quality index (see Bontemps and Bouriaud (2014) for a review). The site quality index shows the potential of tree growth under ideal conditions, and is usually measured as the biomass potential at a certain age of a tree species (e.g. Skovsgaard & Vanclay, 2008). In Sweden, the calculation of the index is based on statistical assessment of multiple effects of different environmental factors at a site (Hägglund and

Lundmark, 1977). The index can indicate the constraints of the ecological niche and distribution of tree species (Bontemps and Bouriaud, 2014). It has also been shown that the composition of fungal communities in soil can be related to soil fertility, a component of the site quality index, in boreal forests in Sweden (Sterkenburg et al., 2015). If so, the use of the soil quality index can also reflect the impacts of fungi diversity of forest growth. There is a large body of literature on the role of biodiversity in forest productivity, which mainly shows a positive effect (see meta-analyses in Gamfeldt et al., 2013; Piotto, 2008; Zhang, Chen, & Reich, 2012). The findings of Paper I are summarized in section 2 of this thesis.

Site-specific ecological conditions which mostly drive the productivity of the forest and the ability of the forest to provide essential ecosystem services, have the tendency of interacting with other ecosystem services provided by the forest to enhance its economic value (Duncker et al., 2012). In spite of the potential benefits of site-specific ecological conditions in enhancing forest growth, there have not been studies to compute the economic value of site quality via its interaction with timber and carbon value of the forest. Thus, Paper II calculates the economic value of site quality in forest management and also analyzes how site quality can inform management practices such as harvest in Swedish forests. This objective is achieved by considering a dynamic optimization problem where the forest manager maximizes his/her net present values of both timber and non-timber benefits subject to the development in the standing biomass volume which is dependent on site quality. In addition, site quality is assumed to be affected by harvest. Following Amuakwa-Mensah and Gren (2016) and earlier studies (see Skovsgaard and Vanclay (2008) and Bontemps & Bouriaud (2014) for review) we used site index as a proxy for site productivity or quality. In terms of sensitivity analysis, we vary the discount rate, intrinsic growth rate, the marginal impact of soil quality on standing biomass growth and timber and carbon prices. The summary of the findings of Paper II are presented in section 2 of the thesis.

1.2 Migration, education and environmental change

This section focuses on the linkages between migration and education, on one hand, and the relationship between environmental change (especially climate change) and migration decisions on the other hand. Generally, it is often assumed that migrants are usually people of the lowest economic status. It may be true that unskilled workers comprise the bulk of perpetual wanderers. However, among people having relatively large amount of training, the percentage of those persons who leave home communities to try their fortunes elsewhere is relatively high. According to Eggert et al. (2010), the propensity to migrate is higher for high-skilled individuals than low-skilled persons. The impact of education on development is profound since education plays a transformative role in the lives of poor people by providing them with skills, independence and confidence. On the other hand, economic motivation is the underlying premise of most theories of migration (Lucas, 1997; Sjaastad, 1962; Todaro, 1969).

The well informed is more likely to migrate than the less informed, and through education, an individual has the potential of obtaining and analyzing employment information and also using more sophisticated modes of information to analyze the net present value of migrating (Greenwood, 1975). This suggests that the highly educated may have better access to information about job prospects and living conditions in other regions than the less educated. Therefore, education serves as a means of reducing the income risks which are linked to migration. Further, the psychic costs which are associated with the torture one goes through as a result of leaving family and friends are likely to be less as education increases (Schwartz, 1973). This is because higher educational groups are more homogeneous over space in terms of their culture and manners, making them more receptive to new environments. Education, in one way or the other, may reduce the importance of social ties and tradition, thus increasing the individual’s awareness of other localities and cultures. In spite of the importance of education in migration decisions, the literature on the rural-urban dimension is scanty. To the best of our knowledge there is no literature on the Ghanaian context which examines the rural and urban perspective of the impact of education on migration with relatively recent data. Thus, Paper III examines the effect of education on migration decisions focusing on migrants with rural and urban destinations.

Regarding the debate on the relationship between environmental or climatic factors and migration decisions, there has been a lot of interest in recent times, however empirical studies about the subject are limited and fragmented. Migration in one way is seen as an adaptive strategy as it helps reduce the risk associated with the adverse effect of environmental and climate change. Accordingly, migration reduces the reliance on the environment for livelihood as income is diversified through remittances, decrease in the risk to life, livelihood and ecosystem, and enhancement in the capacity of households and communities in the presence of negative effect of environmental and climate change (IOM, n.d.). Paper IV examines how climate variables such as temperature, precipitation and aridity, together with socioeconomic factors explain internal migration decisions in Ghana.

Concluding from the proponents of the ‘new economics of migration’ theory (Lauby and Stark, 1988; Stark, 1991; Stark and Bloom, 1985), an individual decides to migrate by considering the benefits that he/she stands to gain from migration and other factors, such as how to minimize the risk associated with climate-related events. This suggests that minimizing such risks is possible in the form of insurance and government programs. However, such markets and programs are few or scarcely exist in developing countries (Abu et al., 2014). Most developing countries, including Ghana, rely heavily on agriculture, but very few of these countries have access to crop insurance (Linnerooth-Bayer and Mechler, 2006) in order to cope with crop losses due to extreme weather events, a common phenomenon in agriculture.

According to Abu et al. (2014), risk diversification in the event of climate-related shock mostly among poor farmers is very devastating, and migration is usually one of the numerous strategies that individuals or households use to minimize such risk. Seasonal migration flows from the semi-arid northern regions to cocoa farming areas and other destinations in the south are well-established patterns in some West African countries such as Ghana, Togo, Mali and Burkina Faso (Sharp et. al 2003). Abu et al. (2014) also state that differences in the ecological zones account for seasonal migration in Ghana. Paper IV therefore employs an econometric technique within a migration model framework to explore how the climate element explains migration decisions. Accordingly, the study investigates whether climate element is one of the many drivers of internal migration in Ghana. Although climate per se is rarely the direct root of migration, except in extreme cases like floods or droughts, it can nevertheless aggravate difficult living conditions at the margin of subsistence hence necessitating migration. A summary of the results from Paper IV is also presented in Section 2.

1.3 Climate change and health outcome nexus

The impacts of climate change on human health include intensity of transmission of vector-borne, tick-borne and rodent-borne diseases, food- and water-borne diseases, and changes in the prevalence of diseases associated with air pollutants and aeroallergen. Climate change could alter or disrupt natural systems, making it possible for diseases to spread or emerge in areas where they had been limited or had not existed, or for diseases to disappear by making areas less hospitable to the vector or the pathogen (National Research Council, 2001). Thus, climate change, including climate variability, has multiple influences on human health and these are expected to be either direct or indirect (Costello et al., 2009; IPCC, 2014, 2007). People are affected directly through changing weather patterns and indirectly through food and water quality and quantity, agriculture, among others. Exposure to any of these conditions can cause morbidity and even death.

Until recently, the climate-health nexus did not feature prominently in the climate change discourse. In the past, discussions on climate change focused on the effects of the phenomenon on the global economic outlook and eco-systems sustainability (McMichael et al., 2009). Increasingly, scientists have become interested in the potential effects of global climate change on health (Campbell-Lendrum et al., 2003; Carson et al., 2006; Costello et al., 2009; IPCC, 2014; McMichael et al., 2006; Nerlander, 2009; Woodward et al., 2011; Wu et al., 2016). According to McMichael et al. (2006), climate change already has and will continue to have a negative impact on the health of human populations.

Evidence already exists that climate change affects the rates of malnutrition, diarrhoeal diseases, malaria and deaths as a result of changing precipitation and high temperatures (McMichael & Woodruff, 2005). This is because there is ample evidence that links most of the world's emerging and re-emerging infectious diseases to climatic variations. Not all of the effects of climate change will be harmful to human health but the damages are projected to outweigh the benefits (Confalonieri *et al*., 2007). A warmer climate is expected to bring benefits to some populations, including reduced mortality and morbidity in winter and increase local food production, particularly in northern high latitudes. Against this background, the negative effects of climate change on health are likely to be greater and are more strongly supported by evidence than are the possible benefits.

Developed countries are not immune to the health impact of climate change. According to Panic & Ford (2013), climate-dependent infectious diseases are likely to impact on most developed countries. For example, water-borne and food-borne diseases which are caused by environmental or climatic factors are likely to affect almost all developed countries (Panic and Ford, 2013). Also, Northern European countries, particularly Sweden, are expected to be affected by tick-borne diseases which are predominantly caused by increased daily precipitation, humidity, changing patterns of seasonal precipitation, increased average temperatures and extreme heat. Although the impact of climate change on health is anticipated, few studies have really used data to empirically estimate the effect on health outcomes, specifically infectious diseases. Most of the few studies which exist are based on biophysical experiments and do not control for socioeconomic covariates.

There is ample evidence of the effect of socioeconomic factors such as migration, population density, transportation, poverty level, household design and architecture etc., on infectious disease spread (Guillet et al., 1998; Knapp et al., 1997; Moore & Mitchell, 1997; National Research Council, 2001). For instance, migration is one of the means by which diseases spread, either because migrants bring new pathogens with them to their destinations or because the migrants themselves constitute susceptible populations and lack immunity to endemic diseases in their areas of settlement (Geller, 2001). Also, population density is another important factor in spreading diseases since population concentration may facilitate the spread of infectious diseases if there are persons in the population who are infected. In most cases, population density has often been linked to increasing ease with which airborne infections, waterborne diseases, and sexually transmitted infections are spread among the populace (Geller, 2001). Paper V, therefore attempts to explain the effect of climate variability and socioeconomic factors on the number of infectious diseases patients in Sweden. A detailed description of the study and a summary of results are stated in section 2.

1.4 Contribution to literature

The contribution of this thesis is in the areas of forestry economics, development economics, climatic change and health economics. In the area of forestry economics, Paper I estimates forest growth functions at a national scale for Sweden and this provides parameter values for a bioeconomic model at the national level. In addition, the paper examines the impact of management practices and site conditions on both mean and variability in forest growth. Furthermore, we calculate the effect of site-specific ecological conditions on provision of ecosystem services in terms of timber and carbon sequestration in Sweden. Unlike other studies, Paper II considers the interactive effect of site-specific ecological conditions with a multifunction of the forest, that is, timber and carbon sequestration, within a discrete dynamic optimization model. The paper quantifies the economic value of site quality and its interaction with timber and carbon sequestration. The novelty of this study is that, unlike previous studies which focused on tree species diversity (Erskine et al., 2006), birds (Nghiem, 2014) and scenic value (Caparrós et al., 2009) as proxy for biodiversity, we attempt to compute the contribution of site productivity to forest value and also trace how site productivity can affect the management decision of the forester. Duncker et al. (2012) in an attempt to examine how forest management affects ecosystem services (such as timber production, carbon sequestration, water quantity and quality, and preservation of biodiversity) considered the abundance of deadwood; density of large-diameter trees; number of tree species; and area of woodland key habitats as proxies for biodiversity. However, the site quality indicator used in Papers I and II is a composite index that captures both above and below ground diversity.

In the field of development economics, Paper III differs from earlier studies on internal migration (Ackah and Medvedev, 2012; Beals et al., 1967; Boakye-Yiadom, 2008; Caldwell, 1968) on two main grounds. First, we considered how the determinants of migration differ for rural and urban destinations with emphasis on education. Second, we examined how these determinants of migration have changed over time by considering the Ghana Living Standards Survey datasets of 2005/06 and 2012/2013. Unlike earlier studies in Ghana (Abu et al., 2014; Van der Geest et al., 2010; Warner and Afifi, 2014), Paper IV carries out a nationwide analysis of how the climate elements explain migration decisions using Heckman's two steps procedure to address the problem of self-selection. Previous studies on environmental or climate change and migration relationship do not control for selection bias that is mostly associated with unobserved individual and household attributes of the migrants and non-migrants. Moreover, studies on environmental or climate change and migration in Ghana do not consider weather elements such as temperature and precipitation. Paper IV uses a nationwide geo-referenced survey data and global climate data to examine the effect of temperature and precipitation on internal migration decisions. Furthermore, the study calculates an aridity index that measures the degree of drought, and analyzed its effect on migration decisions. Lastly, the study investigates the role of climate variables in explaining the decision to move to rural or urban areas, given the fact that most rural areas are predominantly agricultural based economies.

Likewise, Paper V relates environmental economics to health economics by exploring how socioeconomic factors together with climate variability affect the number of infectious diseases patients. Earlier studies mostly are based on biophysical experiments and do not control for socioeconomic covariates and do not focus on developed countries. In Sweden, Lindgren (1998), Lindgren et al., (2000) and Lindgren and Gustafson (2001) examined the link between climate change and infectious diseases. However, these studies ignored socioeconomic factors in their analysis and focused only on one infectious disease (i.e. tick-borne encephalitis). Paper V therefore contributes to the literature by analysing the effect of climate variability and socioeconomic factors on infectious disease patients in Sweden. To the best of our knowledge, our study is the first to estimate the effect of climate variability and socioeconomic factors on the number of infectious diseases patients in Sweden using such unique data. We used different temperature values (i.e. summer, winter and average) to examine the seasonal effect of temperature on the number of infectious disease patients.

2 Summary of Appended Papers

2.1 Paper I: Impacts of site quality on mean and variability in forest growth and value of ecosystem services in Sweden

This paper calculates the effects of site specific ecological conditions on forest growth and provision of ecosystem services in terms of timber and carbon sequestration in Sweden. We estimate forest growth functions and uncertainty in forest productivity that consider management practices and forest site quality. We include harvest of trees, fertilization, thinning and scarification as management practices, and a site quality index as a measurement of given environmental conditions at the forest site. Site quality is measured by a site quality index, which, in Sweden, is based on calculation of impacts of a number of different site properties such as soil quality, local climate, and plant species composition on the potential growth of trees. We make use of time series data for a period of approximately 50 years, and estimate forest growth functions at the aggregate level and for different regions in Sweden. Fully modified ordinary least squares is used to account for serial correlation and non-stationarity in the variables. The estimated forest growth function was used to estimate the effect of changes in site quality on the current and future values of timber and carbon sequestration from forests.

The regression results show that the site quality indicator adds positively to forest growth and growth rate, and decreases uncertainty in the productivity of the forest. The positive effect of site quality on forest growth and growth rate supports a positive effect of an indicator of diversity and tree species on forest productivity (Piotto, 2008; Zhang et al., 2012). The estimated intrinsic growth rate for the whole of Sweden is 0.13, that is close to the level of 0.12 used for boreal forest in integrated assessment model of climate change (Eriksson and Vesterberg, 2016). Further, if the site quality index reflects diversity in soil as indicated by Sterkenburg et al. (2015), then the result supports the expectation of a stabilizing impact on growth rate of biodiversity (eg. Campbell, Murphy, & Romanuk, 2011; Ives & Carpenter, 2007). Calculations show that a marginal increase in site quality can raise the expected benefits from timber and carbon sequestration by 20% and reduce the cost of risk by the same percentage.

2.2 Paper II: Multifunctional forestry and interaction of site quality mechanism

The productivity of the forest and the ability of the forest to provide essential ecosystem services is mostly driven by management practices and prevailing site quality which in most cases are determined by environmental, biophysical and climatic conditions (Noormets et al., 2015). These site specific ecological conditions have the tendency of interacting with other ecosystem services provided by the forest to enhance the economic value of the forest (Duncker et al., 2012). In spite of the potential benefits of site-specific ecological conditions in enhancing forest growth, there has not been studies to compute the economic value of site quality via its interaction with timber and the carbon value of the forest. Thus, this study calculates the economic value of site quality in forest management and analyzes how site quality can inform management practices such as harvest in Swedish forests. This objective is achieved by solving a dynamic optimization problem where the forest manager maximizes his/her net present values of both timber and non-timber benefits subject to development in the standing biomass volume that is dependent on site quality. In addition, site quality is assumed to be affected by harvest.

Analytical results show that the inclusion of site quality in the model induces forest growth which in turn increases the volume of harvest per year compared to the case where maximization is done without site quality interaction. In addition, net present value when considering timber values plus carbon sequestration and site quality interaction is higher than the case where only timber and carbon sequestration were considered. The calculated monetary value of site quality via its impact on biomass growth over a 100 year period is about SEK2196 per hectare and SEK6213 per hectare for interactions with timber and with both timber and carbon, respectively. Given that the productive forest area in Sweden is about 22.7million hectares, the value of site-specific ecological conditions in Swedish forest is about SEK498million-SEK1.41billion, corresponding to about 0.001-0.002% of GDP. Given the positive contribution of site-specific ecological conditions on forest value, policies which promotes silvicultural management practices with the view to enhancing site quality are recommended. However, our results are sensitive to changes in the intrinsic growth rate of the forest, timber and carbon prices.

2.3 Paper III: Effect of education on migration decisions in Ghana: a rural-urban perspective

In spite of the importance of education in migration decisions, literature on the rural-urban dimension is scanty. Thus, this paper examines the effect of education on migration decision focusing on rural and urban in-migrants by comparing the 2005/2006 and 2012/2013 rounds of the Ghana Living Standards Survey (GLSS5 and GLSS6). The study adapts Sjaastad’s human capital framework as a basis for examining the effect of education on migration. The migration decision equation is estimated using the Heckman two-stage procedure to account for selectivity bias. The findings suggest that anticipated welfare gain and socio-economic variables such as sector of employment, sex, experience, age, educational level and marital status significantly affect an individual’s migration decision. While educational attainment is observed to have a positive effect on migration decision in the period 2005/2006, the study finds a negative effect of educational attainment on migration decision in the period 2012/2013.

The effect of educational attainment on migration decision in 2005/2006 for urban in-migrant is higher than the effect for rural in-migrant, with its significance varying for the different stages of educational attainment. In absolute terms, whereas the effect of secondary educational attainment on migration decisions for urban in-migrant is higher than for rural in-migrant, the reverse holds for higher educational attainment during the period 2012/2013. Based on the mixed effect of education on migration decision as evident from the study, policies to enhance the educational system in Ghana should be complemented with job creation in the entire country. Moreover, special attention should be given to the rural sector so that the jobs to be created in the sector do not require skilled workers as much as in the urban sector. With high quality education and job creation, the welfare of individuals living in urban and rural areas will be enhanced.

2.4 Paper IV: Climate element of migration decisions in Ghana: Micro Evidence

Following the work of Lewin et al., (2012) and Sjaastad's (1962) human capital framework, this study examines how climate variables such as temperature, precipitation and aridity, together with socioeconomic factors explain internal migration decisions in Ghana. In addition, based on the conditions prevailing in the various ecological zones in Ghana, the study explores the probability of migration into the ecological zones. The paper made use of the 2005/06 and 2012/13 rounds of Ghana Living Standards Survey

(GLSS5 and GLSS6), and Heckman two-stage method to account for selectivity bias. Since migrants and non-migrants self-select themselves based on their individual and household attributes, some of which are unobservable, the error term of the welfare function of the migrant and non-migrant may be correlated. Using geo-referenced data together with global climate data, temperature and precipitation values were extracted to construct an aridity index. The results show that socio-economic factors such as anticipated welfare gains, household size, education, the sector of employment and others, together with the climatic element do significantly affect an individual's migration decisions. The coastal savannah and forest ecological zones have a greater probability of accommodating more in-migrants relative to the northern savannah ecological zone. Whereas temperature positively explains the probability to migrate, aridity index negatively affects migration decisions. That notwithstanding, there exists a non-linear relationship between temperature, precipitation, aridity and migration decisions. The findings also show that although the probability to migrate to an urban area is higher relative to its rural counterpart, individuals tend to move to the rural areas relative to urban areas with an increase in precipitation and or a decrease in aridity.

2.5 Paper V: Climate variability and infectious diseases nexus: evidence from Sweden

This paper analyzes the effect of climate variability and socioeconomic factors on infectious disease patients in Sweden. The theoretical framework for this study follows the work of Graff Zivin & Neidell (2013) where we relate climate variability to health. Based on Grossman's (1972) postulation which characterizes health as an investment good, Graff Zivin and Neidell (2013) extended how health can influence productivity through the extensive margin (that is, a process where illness reduces labour supply hence affecting productivity) to an intensive margin. The intensive margin is when productivity is affected assuming a fixed labour supply. Through the intensive margin the theoretical model is able to capture more precise health effects. Graff Zivin & Neidell (2013) modelled the representative individual's health production function as a function of ambient pollution levels, mitigation activities to pollution exposure in the form of avoidance behaviour and medical care that reduces the negative health consequences from pollution exposure. Based on this, we redefine the health production function to examine the role of climate variability on health.

Our study utilizes panel data from in-patient care diagnoses records on infectious and parasitic diseases, climate indicators (e.g. temperature and precipitation) and socio-economic variables for all twenty-one (21) counties in Sweden from 1998-2013. Temperature and precipitation values used are deviations from the normal, that is, mean of 1961-1990. The study employed both static and dynamic analyses, and also accounts for county and year fixed effects. Although we recognized that infectious and parasitic diseases are dynamic in nature, we also considered a static model in the analysis because the dataset for this study is based on annual records and as such we assume that the spread of the diseases would reach its steady-state within a year. We considered a pooled estimation where all the infectious and parasitic diseases are lumped together, and a disaggregated estimation where dominant infectious and parasitic diseases (such as intestinal infectious diseases and other bacterial diseases) are separated from less dominant ones. Different temperature values (i.e. summer, winter and average) are used to examine the seasonal effect of temperature on the number of infectious disease patients.

We observed that temperature has a linear negative effect on the number of patients. The relationship between winter temperature and the number of patients is non-linear and "U" shaped in the static model. Conversely, a positive effect of precipitation on the number of patients is found, with modest heterogeneity in the effect of climate variables on the number of patients across disease classifications observed. The effect of education and number of health personnel explain the number of patients in a negative similar direction, while population density and immigration drive up reported cases. Income explains this phenomenon non-linearly. In the dynamic setting, we found significant persistence in the number of infectious and parasitic-diseased patients, but found only temperature and income as dominant drivers.

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