POLICY ANALYTICS FOR ENVIRONMENTAL SUSTAINABILITY

Research Statement

Kustini LIM-WAVDE

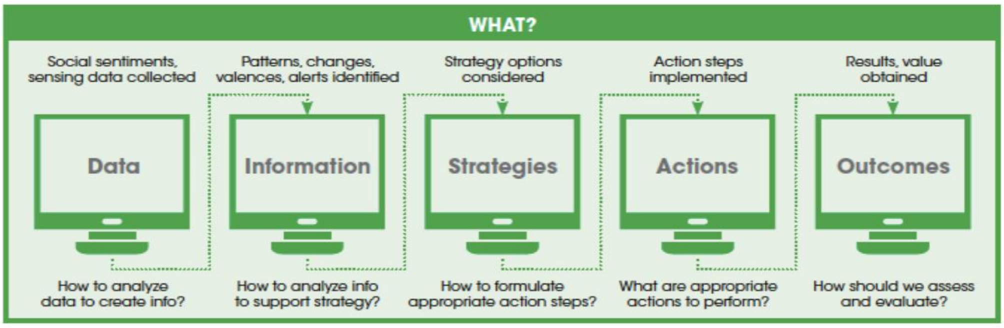
Last revised: October 7, 2017

Motivation

Human activities have caused environmental problems, such as climate change, pollution, endangered species, and resource depletion. To address these issues, policy-makers have an important role in providing effective public policies to achieve environmental sustainability. These have motivated me to conduct research on policy analytics to provide policy-makers with valuable insights for making informed decisions in planning their next policies and strategies. My research contributes to the growing body of research in *computational social science fusion analytics* that employs a combination of machine methods and explanatory empiricism. This involves data analytics, math programming, engineering optimization, geospatial and spatiotemporal analysis, advanced econometrics, and assessment of empirical causality with inventive research designs.

Background and Theory Development

Today, new technologies are enabling us to collect, store, and analyze data from various sources, including public data, firms and organizations, and also sensor data. The data can be analyzed and transformed into meaningful information that is useful for policy-makers to formulate strategies and policies, as shown in the process below.



Informedness is an essential construct in my research work. I developed a new construct, *household informedness*, defined as “the degree to which households have the necessary information to make utility-maximizing decisions in their daily activities, such as managing their household waste” [1]. This research explores the role of household informedness in influencing household decisions about the amount of *household hazardous waste* (HHW) that they enable to be collected and recycled. HHW is generated from leftover products that contain toxic, flammable, and corrosive materials, for example, used batteries, motor oil, insecticides, and electronic devices. I proposed two variables that influence household informedness: provision of public education about HHW and environmental quality information from government agencies.

Policy Analytics for Household Informedness

Household decisions about waste management can be analyzed using consumer utility maximization theory. Households maximize their utility based on the costs related to waste disposal and the information they acquire or is provided to them. In my empirical study on the impact of household informedness [1], I assess the impact on HHW collection and recycling under this theory.

I employed fixed-effects regression and a system of equations model to estimate the impact of household informedness on HHW collection and recycling activities using county-level panel data. For waste collection data in California, my analysis results show that public education on HHW had a positive effect on the amount of HHW collected and recycled. It may have had a negative effect on the amount of HHW material collected that comes from products with non-hazardous substitutes though. For example, HHW public education may help to decrease the amount of Reclaimable Waste collected (used motor oil, oil filters, etc.). Why? Because some educational campaigns encourage households to reduce the consumption of motor oil by using synthetic oil instead of traditional motor oil, and by changing their motor oil less frequently than before. Additionally, when environmental quality information is sent directly via mail to households, an increase in the number of maximum contaminant level violations in the drinking water is associated with the amount of HHW collected in a way that goes beyond straightforward correlation.

This study contributes new ideas and methods about the quantification of *household informedness elasticity* of HHW collection and recycling outputs. This measure is useful for waste managers to gauge the responsiveness of households in terms of the quantity of HHW collected and recycled, as more educational programs and environmental quality information become available to households. The article was published in 2017 in *Resources, Conservation and Recycling*, a research journal on sustainability management and conservation of resources. A story of this research was featured in SMU's Research Bulletin in August 2017 [6].

Geospatial Policy Analytics over Time for HHW Collection

Spatial analysis yields useful insights for different localities. The spatial patterns that are observed may change over time due to the changes in various influential factors. So I have been conducting geospatial policy analytics with a spatio-temporal county-level dataset [2] from the State of California. This study reveals interesting insights that provide useful input for policy-makers to evaluate the management of HHW programs across multiple counties and regions over time.

I performed exploratory analysis to find spatial patterns of HHW collection, and how such patterns have changed over time. I employed spatial autocorrelation analysis to identify clusters of HHW collection of different densities. In particular, I used a *geographically-weighted regression* model to capture spatially-varying relationships between HHW collection density and related influential factors: HHW policy, policy enforcement, and demographics. The analysis results show that some clusters of counties in Northern California have exhibited higher HHW collection density. My results indicate differences between the counties in Northern and Southern California in terms of program effectiveness, county population density, and household behavior.

Considering the spatial patterns, I investigated whether *pro-environmental spatial effects* are present [3]. Such "spillovers" represent the influence of HHW-related practices in close-by regions. At the same time, I also assessed the effects of government grants for projects on HHW collection output levels. These grants provide the necessary funding for projects that establish or expand HHW collection and recycling drop-off facilities, curb-side and take-back programs, and collection events.

I also modeled the causal relationships of the grants and their spatial effects with the HHW collection output levels that counties achieved. Establishing causal relationships is challenging but valuable to create deeper insights in my research. First, although the grants were pre-determined through grant award competitions that occurred before the beginning of my HHW data collection, they were not given out randomly to the counties. Second, the effects of any pro-environmental behavior that is present at the county level may spill over into the observation of HHW collection by county location and by year. So I employed a spatial random effects panel data model with instrumental variables to address the issue of likely endogeneity. I also performed sensitivity analysis using other possible spatial weights, examined the HHW collection performance of counties that had grants over several years, and considered the autocorrelation of their year-to-year collection performance. I also performed robustness checks to analyze other alternative explanations to the effects on the waste collection outputs. Finally, my modelling and causality analysis enabled me to implement counterfactual assessment to develop a deeper understanding of how to make the allocation of grants more effective, and what their impacts are likely to be.

This research contributes to the new directions in research on geospatial policy analytics, the challenges of establishing causal results, and the use of counterfactual assessment to develop a deeper understanding of how to make environmental sustainability programs more effective in the regions where they are implemented.

Assessment of Future Electric Power Generation and Water Use Planning Outcomes

The research assesses transition pathways in electricity generation and their future water impacts using a power system model. To analyze the scenarios, I developed an electricity generation capacity expansion model that uses mixed integer programming to estimate a cost-effective electricity generation technology and cooling system mix that complies with CO_2 emission regulations in the United States. By using this model, I have been able to analyze how future scenarios related to carbon pollution standards will affect water use for electric power generation [4].

For this modelling and simulation case study, I used price and electricity generation data from Texas. My research evaluates possible scenarios in Texas for meeting electricity demand with or without carbon pollution regulation and water constraints. I considered scenarios that do or do not comply with the U.S. Environmental Protection Agency's proposed carbon pollution standards – the New Source Performance Standards and the Clean Power Plan from 2015. The findings contribute insights for policy-makers about the consequences to the environment in the future when making the decision to implement carbon pollution regulations.

The scenarios with carbon regulations are shown to have lower water use from the power sector than with the higher-carbon externalities-based continuation of the status quo, with more electricity generation from coal than natural gas. This is due to an increase in electricity generation from renewable sources and natural gas combined cycle plants that is influenced by the CO_2 allowance price. The scenario that considers retrofitting carbon capture and storage (CCS) to existing coal and NGCC plants has a similar total electricity generation cost, but higher water use compared with the low-carbon scenario that does not consider a CCS retrofit.

In addition, sensitivity analysis of various market prices shows that water withdrawal may be ~20% higher when the CO_2 allowance price reaches US$40 per short ton in the carbon regulation-compliant scenario because of more electricity generation from existing coal-fired EGUs with once-through cooling. Also, if retrofitting CCS to existing fossil-fuel-fired plants is considered, water withdrawal may be about 41% higher than the estimate when the CO2 sale price for EOR is US$15 per short ton or higher. Even so, this is still lower than in the status quo pathway, when the cost of electricity generation from coal is lower than from natural gas.

The findings in the research contribute insights to the management of energy, water, and carbon pollution issues of the future. They provide a clearer picture to energy and electricity production policy-makers about the sustainability consequences in the future when making the decision to implement carbon pollution mitigation regulations.

The Future of Policy Analytics

My dissertation demonstrates the power of data analytics in uncovering policy insights. I use impact assessment, information elasticity analysis, and numerical simulation with publicly-available data. The insights I offer are valuable to policy-makers in evaluating current policies and circumstances, and making more informed decisions for planning their next policies and strategies in the areas of waste, energy, and water management.

My future studies will include other contemporary analytics methodologies, such as data mining, text analytics, and deep learning to obtain more fine-grained data from various data sources, and to develop a more holistic model for understanding the impacts of related policies on people and the environment. Due to uncertainties and unexpected changes in the future, I am also exploring how to implement adaptive empirical research designs in my research.

Living in Asia, I also have been considering the application of policy analytics in this region [5]. A large amount of hazardous waste is not properly disposed and recycled in Asian developing countries. This is due to ineffective HHW collection facilities, the lack of a legal framework, poor environmental awareness, and low level of public informedness. Environmental sustainability-focused data analytics, combined with deep learning via AI and cognitive systems can help policy-makers allocate their resources more effectively and find ways to enhance and automate some waste management tasks. I am excited to contribute new knowledge in this problem area through my future research work, and investigate how to increase household informedness level to improve HHW collection and water quality in Asia.

Sustainability has become increasingly important in the modern world – with growing cases of environmental deterioration, pollution, and loss of diversity. Policy analytics for environmental sustainability is a potentially high-impact research area. It will support more informed policy-making and environmental management that contributes to a more sustainable future.

References

[1] **Lim-Wavde, K.**, Kauffman, R.J., Dawson, G.S. Household Informedness and Policy Analytics for the Collection and Recycling of Household Hazardous Waste in California. *Resources, Conservation and Recycling* 120, 2017, 88-107.

[2] **Lim-Wavde, K.**, Kauffman, R.J., Kam, T.S., Dawson, G.S. Location Matters: Geospatial Policy Analytics over Time for Household Hazardous Waste Management in California. *Proc. 2017 iConference*, Wuhan, China, March 2017, 13-27. Finalist, best paper award.

[3] **Lim-Wavde, K.**, Kauffman, R.J., Kam, T.S., Dawson, G.S. The Effects of Location and Grant Funding on Household Hazardous Waste Collection. Working paper, UNICEN, SMU, September 2017. In preparation for submission to *Applied Geography*.

[4] **Lim-Wavde, K**., Zhai, H., Kauffman, R.J., Rubin, E.S. Assessing the New Carbon Pollution Standards: Electric Power and Water Impacts. Working paper, UNICEN, SMU, September 2017. In preparation for submission to *Energy Policy*.

[5] **Lim-Wavde, K**., Kauffman, R.J. Global Garbage Cans: Towards Better Household Hazardous Waste Management in Developing Countries in Asia. Forthcoming in *Asian Management Insights*.

[6] Turner, D. From Household Trash to Policy Treasure. Research@SMU, June 2017.