Research Statement for Christa Brelsford

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As the world's urban population doubles over the next century, the new infrastructure necessary to build in order to house and care for all of these new residents will be almost equivalent to all of the urban infrastructure that has been built in the history of our species. We need to develop both a better empirical understanding of spatial patterns and evolution in cities, and also better theories about urban function in order to cope with our rapidly growing urban population. I use empirical methods, especially spatial analysis and remote sensing, to link individual choices to aggregate outcomes in order to build better theories about the function of cities and urban water systems.

In my dissertation research, I use econometric methods and remote sensing to estimate how and why water consumption patterns changed between 1996 and 2007. I estimate the effect of infrastructure and vegetation change, weather variability, and water policy on residential water consumption from a panel dataset in Las Vegas, Nevada. To measure vegetation change, I create a new vegetation index based on Mixture Tuned Match Filtering estimates of sub-pixel vegetation area from LANDSAT images. I then calibrate these estimates against a large ground truth dataset digitized from aerial photography. I go beyond the typical interpretation of marginal effects from a regression and use several decomposition techniques to estimate the relative importance of changes in vegetation, infrastructure, and policy on the city's changing consumption portfolio. I find that roughly one third of the total observed reduction in household water consumption is accounted for by changes in infrastructure and vegetation, and a change of equivalent magnitude occurred the year in which Las Vegas announced its first drought alert (2003). The causes of Las Vegas' declining consumption are highly spatially contingent. The largest cause of change I can account for in established neighborhoods is vegetation change, while in newly constructed areas smaller lot sizes and newer homes have the largest influence. These results show that while there is significant scope for policies that influence infrastructure and vegetation to reduce household water consumption, behavior changes in response to drought can also have a large conservation effect.

There has been a long term and widespread decline in household water consumption across the US since the 1980's. Urban water demand research has thus far been primarily concerned with explaining the effects of individual water conservation policies. However, determining how and why a city's consumption patterns have changed is just as important for managing water scarcity as estimating the conservation effects of a specific water policy. I apply decomposition analysis techniques that have been widely used in labor economics, though not resource economics, to estimate the relative importance of household infrastructure, vegetation change, and policy choices in causing water consumption declines in Las Vegas, NV. Understanding which factors are most important in explaining this change, how much of the change is due to policy compared to other factors, and within-city spatial heterogeneity in the importance of these effects is important for helping many Sun Belt cities cope with the harsh reality of water scarcity.

The vegetation estimation aspect of this research is published in the *Journal of Applied Remote Sensing* and was presented at the International Society of Optics and Photonics Conference in 2013. A paper titled "Growing into Conservation" based on this research focuses on broad scale drivers of change in Las Vegas' portfolio of water consumption, and will be submitted to the *Journal of Regional Science* in November 2015. This paper has been presented as an invited talk in the Economics Department at the University of New Mexico, at two conferences of the American Water Resources Association, and World Water Week in Sweden. A second paper on the water demand portion is a policy evaluation of the "Water Smart Landscapes" program and will be submitted to *Water Resources Research* in Spring 2016.

In a second major project, I study the shape of cities from a very general perspective. I consider the topology, rather than the geometry, of slum neighborhoods in cities, and mathematically formalize the topological transformations that are necessary for a slum neighborhood to build the access spaces to allow it to physically integrate into the broader city. I show that the topology of urban access systems is consistent across any city where all places in the city have road access. The Euler characteristic of the city's access system gives a topologically invariant measure of city size, where sections of one city can be mapped to another provided they share the same number of blocks. These results formally establish the universal character of urban built spaces, and show how they can be transformed without loss of function – the key insight for transforming any neighborhood over time and especially for creating cities without slums. This work is in review at *Science* and *Environment and Planning B*.

Much of the research on both cities and water systems has been focused on large scale, aggregate behavior, but these average effects are the result of interactions occurring at local scales. I use highly disaggregated data to understand how individual choices influence aggregate outcomes in cities: using local scale infrastructure and policy measures to understand how and why water consumption patterns are changing within cities, and characterizing how heterogeneous local social dynamics are connected to the coarse-grained agglomeration effects (scaling laws) that are well understood across cities. This local perspective is necessary to understand how urban water consumption is changing and is also a key insight towards building better theories of cities.

In my next two research projects, I continue my approach of using detailed household and block level data to better understand aggregated outcomes for cities and water systems. In the first project, I look at how social processes in household water consumption influence the cities water consumption portfolio. This project applies the topological methods I have used to analyze urban slums to a detailed model of the effect of Las Vegas' conservation policies on water consumption patterns. I will estimate a social-contagion effect of one household's vegetation reduction on their neighbors' likelihood of engaging in water conservation through two different mechanisms: landscape change and less costly behavior changes. This research uses a 12 year long monthly panel dataset of 0.75 million Las Vegas household's water consumption, participation in a cash-for-grass water conservation program, and household infrastructure and vegetation characteristics.

In the second project, I focus on how structured spatial heterogeneity in socio-economic variables is related to aggregate scaling relationships in order to create a more local scale theory of cities. Current conceptual models of cities in geography, economics, and complex systems rely primarily on systematic agglomeration effects on the aggregate of large functional urban areas. This gap between the local heterogeneous processes in cities and theories of global agglomeration effects is a key obstacle to a deeper understanding of the causal effects of urban change and to effective urban planning and policy. This project shows how aggregate agglomeration effects at and across the level of whole urban functional areas are expressed statistically at the local level, relying on data from the most recent Brazilian census. I show how to characterize complex socioeconomic patterns of local variation in cities, which reveals a general connection between coarse-grained agglomeration effects observable across cities and heterogeneous local dynamics observed within cities.