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Choice modeling of system-wide or large scale environmental change in a developing country context: Lessons from the Paraíba do Sul River

James R. Kahn [a,b,*], William F. Vásquez [c], Carlos Eduardo de Rezende [d]

[a] Economics Department, Washington and Lee University, United States
[b] Universidade Federal do Amazonas, Brazil
[c] Fairfield University, United States
[d] Laboratório de Ciências Ambientais, Centro de Biociências e Biotecnologia, Universidade Estadual do Norte Fluminense, Brazil

HIGHLIGHTS

- Values the restoration of a highly degraded aquatic system where the degradation is caused by all types of human activity.
- Uses the responses to the choice-modeling survey to perform estimations in willingness to pay space.
- Adjusts for heterogeneous preferences among respondents
- Shows that the value of restoration is sensitive to both the level of restoration and the time needed for restoration.

GRAPHICAL ABSTRACT

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ABSTRACT

The Rio Paraiba do Sul is a highly polluted river in south central Brazil, that is contaminated by industrial, agricultural and municipal wastes, as well as being impacted by dams, water withdrawals and deforestation in the watershed. Since only very intensive and farreaching environmental policies could result in water quality improvements, valuing the restoration of the river presents many unique challenges. We develop a choice-modeling approach to valuation of the restoration of this river, with general tightening of environmental policy as the policy, and an increase in prices as the payment vehicle. The estimation is performed in willingness to pay space, adjusting for heterogeneity of tastes. We find that respondents, who are primarily low income, exhibit higher willingness to pay for complete restoration than moderate restoration, higher for moderate restoration in comparison to minimal restoration, and that they prefer restoration sooner, rather than later.

1. Introduction

Many choice modeling experiments have been performed with focus on a specific environmental resource or a specific environmental change, and this technique has great potential for measuring the

* Corresponding author at: John F. Hendon Professor of Economics, Washington and Lee University, Lexington, VA 24450, United States.
E-mail address: Kahnj@wlu.edu (J.R. Kahn).

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benefits of restoration of aquatic ecosystems. For example, choice experiments have been applied to investigate household preferences for risk reduction of oil spills (Casey et al., 2008), increases in biodiversity (Ohdoko and Yoshida, 2012; Stewart et al., 2005), solid waste disposal (Pek and Jamal, 2011; Sasao, 2004), improved treatment of wastewater (Birol and Das, 2010; Ndunda and Mungatana, 2013; Woldemarian et al., 2016), and improvements of specific attributes of wetlands and watersheds (Brouwer et al., 2016; Carlsson et al., 2003; Shrestha and Alavalapati, 2004), among other applications. These types of resources and environmental changes fit neatly into a choice modeling framework, as the definition of the attributes, payment vehicles and policy scenarios is usually fairly straightforward. However, when the focus of the research is complex system-wide change, the construction of a choice modeling experiment becomes more challenging. Examples of such system-wide change include the contamination, overuse and collapse of our ocean system, rapid and widespread loss of coral reefs, systematic deforestation, invasive species (in general), and the crisis of global climate change.

Restoring the Paraíba do Sul River represents another example of a large-scale environmental change. The Paraíba do Sul River drains the states of São Paulo, Minas Gerais and Rio de Janeiro in Brazil. This river is out of compliance with pollution standards, including dissolved oxygen, fecal coliforms and heavy metals such as lead, mercury and cadmium (ANA, 2001). Important environmental justice issues are associated with the degradation of the river. The contamination is associated with the production of wealth by the manufacturing, mining and industrial agriculture sectors and the wastes of upstream urban areas (ANA, 2001). However, many of the impacts of the degradation are felt by lower income people in the small cities and communities that depend on the river for drinking water, capture of fish, and recreation. Moreover, the diminished aesthetics associated with the degraded riverine and estuarine systems decreases the overall quality of life in the region.

Against this backdrop, a choice experiment can provide policy relevant information regarding household preferences for restoration of the Paraíba do Sul River, and it can estimate monetary tradeoffs that households would be willing to make in order to reach different levels of environmental improvement. However, environmental and socioeconomic complexities of achieving those improvements represent a challenge for designing and implementing a choice experiment. The purpose of this paper is to look at issues associated with conducting a choice-modeling assessment of a system-wide environmental change in a developing country context. We will base this discussion on a study performed on the Paraíba do Sul River. Our study also provides estimates of households' willingness to pay for different levels and times of river restoration that can provide valuable insights for environmental policy design.

2. The Paraíba do Sul River basin

The Paraíba do Sul River basin has an area of 57,000 km^2 and an extension of 1145 km, representing approximately 1% of Brazil's land area, and approximately 6% of the land area in the Southeast region. This river basin covers approximately 63% of Rio de Janeiro state, 5% of São Paulo state and 4% of Minas Gerais state (ANA, 2015). Although the city of São Paulo is not in the watershed, a good portion of the metropolitan area is, as are many of the smaller cities that contain manufacturing facilities in Brazil's most industrial state. The area within Minas Gerais state is also highly industrialized. Moreover, seven dams supply water and hydroelectric power for much of this region, including the major cities of São Paulo and Rio de Janeiro. As a result of the water withdrawals and other environmental changes, the river flow (measured at the mouth of the river) has diminished by 40% from historical levels (Rudorff et al., 2011).

Water quality also decreases substantially as the river descends from its headwaters towards the river mouth (Carvalho and Torres, 2002). Agriculture, deforestation, residential wastewater disposal, and industrial discharge have polluted the Paraíba do Sul River with agrochemicals, heavy metals, and nutrients (Dittmar et al., 2012; Pereira et al., 2006; Silva et al., 2001). Although sufficient data have not been collected to completely quantify the magnitude of anthropogenic impact on the river basin, there is no question that the river is highly impaired, not drinkable, swimmable or fishable, although people do catch and eat contaminated fish from the river and its estuary (ANA, 2001). Fish populations (at all trophic levels) are much lower than several generations ago, ecosystems are less productive and many organisms have high levels of mercury and other chemicals (Linde-Arias et al., 2008).

Restoration of the Paraíba do Sul system would require substantial investment in pollution control in the industrial and agricultural sectors, as well as municipal waste treatment. Since the states comprise the primary manufacturing areas in the nation, and a good share of the agricultural activity as well, pollution abatement (at least in the short run) would cause an increase in product prices and the cost of living as a whole, as well as within the watershed.

3. Implementing a choice experiment for system-wide changes

Choice modeling belongs to a class of environmental valuation techniques known as stated preference models (see Hoyos, 2010 for a recent review of choice experiments as applied in environmental valuations). These models ask a respondent to choose between two or more (hypothetical) alternative states of the world represented by different levels of specific environmental attributes and a payment vehicle. The inclusion of a monetary variable allows for estimating part-worth values for specific levels of the attributes exogenously varied in the choice experiment (Birol et al., 2006; Hanley et al., 2001). For example, in their valuation study of ecosystem management for biodiversity in Japan, Ohdoko and Yoshida (2012) developed alternative states of the world using four different amounts of species of familiar animals (20, 35, 50, or 65 species), familiar plants (100, 250, 400, or 550 species), rare animals (8, 16, 24 or 32 species), and rare plants (10, 25, 40, or 55 species), as well as an annual payment of a forestry charge (500, 1500, 2500, or 3500 Yens). In that study, as in many others, the definition of attributes and corresponding levels (i.e. number of species), the payment vehicle, and policy scenarios is fairly straightforward.

In the case of the restoration of the Paraíba do Sul River, the choice-modeling problem is much more complex due to the environmental, economic, and social complexity of the study sites. The source of the systemic nature of change in the Paraíba do Sul River stems from the economic activity in the region. This watershed constitutes a large proportion of industrial activity in Brazil, and a significant portion of the agriculture as well. Pollution emissions do not originate from particular economic activities, but from all economic activities, including manufacturing, agriculture, land use change, human-waste and urban-runoff (Feres et al., 2005; Ioris, 2009). In addition, seven large dams diminish the volume of water in the river, and block the flow of sediments. Sand mining further distorts the flow of the river (Ioris, 2009). Under these circumstances, it is challenging to define a policy program that would affect the whole suite of environmental variables simultaneously. Realistically, the only policy action that could have a significant impact on the recuperation of the river, is an overall tightening of the emission standards associated with the system of direct controls that Brazil uses for environmental protection (this tightening could be associated with more rigorous enforcement as well).

We have defined the study area to be the lower portion of the Paraíba do Sul River, including the estuary (see Fig. 1). This represents the most highly impacted area, as it receives all the pollution from upstream as well as the impacts of upstream water withdrawals. The choice of this region is also related to our concerns about social justice, where pollution is generated in the creation of wealth that does not accrue to the inhabitants of this region. The high proportion of low income families in the lower portion of the watershed further complicates the