

Is hydropower worth it? Exploring amazonian resettlement, human development and environmental costs with the Belo Monte project in Brazil

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ABSTRACT

Nations in the Global South have turned to massive hydropower projects to provide for the energy needs of their growing economies. Large-scale hydropower projects cause untold environmental damage to river ecosystems, to fish biodiversity, and displace millions of people globally. Much research documents these impacts, yet we do not know if these populations support the development of hydropower. In this paper, we aim to understand how direct experiences with resettlement might influence the support or opposition to hydropower development considering energy justice, particularly the restorative and procedural tenets, as a motivating framework. Our research is based on social survey data from a population resettled during the construction of the Belo Monte dam in the Brazilian Amazon. Results from partial proportional odds models suggest that a slim majority feel that hydropower is worth the cost, yet even this support declines as perceived impacts increase. These populations hold nuanced views and are not uniformly negative about dams, regretting the negative outcomes for them but believing the government discourse that the energy needs of the country may require them to sacrifice for the larger good. Support for hydropower as well as energy injustices might vary considerably across communities that are impacted differentially by Belo Monte.

1. Introduction

Global energy consumption is predicted to increase by 50% by 2050, led by growing demand from developing nations [1]. The United Nations's Sustainable Development Goals emphasize that "Ensuring access to affordable, reliable, sustainable and modern energy for all", however this is a significant challenge given resource constraints and population growth. Although renewable energy technologies like wind and solar are enjoying greater market penetration, these technologies have not yet supplanted conventional fossil fuel sources to any large degree. In developing countries and emergent economies, several nations have turned to build large-scale hydropower dam projects, presented as a renewable energy source, even as developed nations

increasingly decommission a growing number of large dams built before 1970 [2–4]. Nations build hydroelectric dams because of their desire to produce ostensibly clean, affordable energy while fostering energy independence [5]. However, evidence shows that dams negatively impact the social-ecological system where they are built [6–8]. One of the most significant social impacts of hydropower development is that it often involves large scale resettlement of people to make way for vast water reservoirs and their lives are rarely better off from it [9–11,12].

In 1997, the World Commission on Dams (WCD) was created to formulate policy recommendations for hydropower development that might mitigate the negative impacts of dams [15]. The WCD and many scholars and activists called for reforming the process of hydropower development. Unfortunately, many of the countries most deeply

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¹ The report includes 26 guidelines that some organizations that finance dam construction such as the World Bank are not following because they consider that they may interfere with the rights of sovereign states [13]. Furthermore, leading hydropower building nations, like China, Brazil and India refused to endorse the recommendations of WCD [14] and continue to ignore most of the recommendations that would reduce the impacts on people living closest to dams.

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engaged in hydropower development refused to follow these recommendations, as was the case with China and Brazil, because those might constrain their future energy development. Even after the WCD recommendations, states and dam builders have rarely meaningfully engaged with impacted populations, although they may hold meetings and negotiations, especially when pressured by NGOs and social movements [16]. These meetings are rarely intended to change the outcome (i.e. completion of the project), or to mitigate the impacts for local communities (i.e. consulted compensations), rather they are an instrument to show that the project allow for “participation on civil society”. Indeed, in terms of procedural justice, understood as a fair and equitable process [17], hydropower projects do not involve the local population in the decision-making processes that will affect their lives.

The purpose of this paper is to understand how direct experiences with resettlement might influence support or opposition to hydropower using energy justice as a motivating framework. There are several studies of the social and economic consequences of resettlement from hydropower, but we do not know if populations experiencing resettlement would like to see *more* or less hydropower after their direct experience. Do these groups believe that hydropower was worth the environmental and social costs that they experienced? Most of the research on support for energy projects has focused on developed nations, and surprisingly little has examined hydropower views on this subject in developing countries. Resettled populations may come to accept hydropower projects and their own resettlement, especially if appropriate and generous compensation is offered to restore the harms done [10]. Yet, to the best of our knowledge, this is the first paper to evaluate support for hydropower among a resettled population in the Global South using a social survey. This is an important aim for three reasons. First, since governments in the Global South have largely embraced hydropower to further their development aims, millions of people will continue to be directly impacted by hydropower megaprojects. Secondly, there is a need to promote fair and equitable process to reduce injustices in the implementation of hydropower projects, and to do so it is necessary to understand the perspectives and experiences of those most directly impacted by dams. Thirdly, we consider the case of the Belo Monte dam in the Brazilian Amazon. Belo Monte was opposed by indigenous and environmental groups for decades, with significant mobilization against the dam by both domestic and international groups. Belo Monte became a poster child for hydropower and came to represent much of what is wrong with how it treats local and indigenous demands and notorious as an example of the peddling of influence by the construction companies. Not only did Belo Monte become a symbol for hydropower but it became reviled for its ties to corruption uncovered by the Lava Jato investigation and Odebrecht's department of bribes [18 19]. In the end, the project went ahead by Presidential fiat overlooking the environmental and social impacts [20 18 21] and the civil society opposition, which exemplifies the energy injustices of these megaprojects. Indigenous people and social movements such as Xingu Vivo maintained their resistance throughout the construction of the dam. Many times they were able to bring about work stoppages through protests and judicial interventions. On the other side the construction company brought a significant presence of National Public Security Force (Força Nacional) to keep protests from interfering with the 24/7 schedule of construction. Given this contestation and top-down implementation, it is worth paying attention to the viewpoints of resettled populations after the project was completed.

In the next section, we describe the national context of energy in Brazil, the known impacts of large-scale hydropower, then we review the literature on local responses to energy development and procedural and restorative energy justice.

2. Conceptual background

2.1. Belo Monte: A portrayal of hydropower development

Brazil is the 9th country in the world in terms of total energy consumption [22]. Hydropower in Brazil accounts for 67% of energy consumption, compared to the world average of 16% [23], making it the world's most hydropower dependent nation. China generates more total hydropower production, but it depends more on coal for its total energy consumption. Brazil's dependence on hydropower has its pros and cons. The nation is increasingly vulnerable to climate change, particularly declining precipitation that reduces water available for energy generation [22]. Brazil emits comparatively less greenhouse gases than if it were more dependent on fossil fuels, hydropower is more immune to the volatility of oil prices, the costs of electricity generation are usually lower than fossil fuel alternatives, and the reservoirs can provide opportunities for tourism and recreation that add value to the infrastructure.

Hydropower has immense deleterious social and ecological negative impacts. Dams disrupt fish migration patterns and fisheries, subsequently damaging the livelihoods of people who depend upon rivers for transportation and fisheries [24 25 26 27 28]. Farmers see declining crop yields due to loss of farm labor to the dam and associated commercial sector [29]. The construction of dams involves a sudden influx of workers into rural communities, often straining infrastructure (e.g. sewage and sanitation) while engendering a boom in crime [30 31]. Although hydropower has often been touted as a “clean” energy source in comparison to fossil fuels, it generates significant greenhouse gas emissions [32 33 34].

The impacts of large-scale hydropower and the costs and disruptions borne by impacted populations are often underestimated [35 36 36 37]. Costa Doria (2018) examined 245 large dams built between 1934 and 2007 and found that actual costs were typically 96% higher than initially estimated [38]. According to Richter et al (2010) some 472 million people living downstream from dams are negatively affected and are never compensated [15]. Populations from areas flooded to make way for reservoirs are routinely displaced [10 11 9]. Displacement tends to impact marginalized populations most intensely, often intensifying pre-existing social inequalities in the process [39 40]. Dams also disrupt subsistence livelihoods for vulnerable populations, such as reducing fish stocks and access to arable land, potentially creating food insecurity [24 25 26 27]. In the Tucuruí dam region of the Brazilian Amazon, the fish catch declined by 60% almost immediately, and more than 100,000 people living downstream were affected by the loss of fisheries, flood-recession agriculture, and other losses of natural resources [41]. Displacement from dam projects is also associated with a loss of social capital and subsequent mental distress [42]. Some evidence implies that compensation programs may mitigate some of the direct economic problems caused by displacement [43 11] but compensation is often not available to all impacted groups, most notably those downstream from a dam [15 25 44] and certain losses are difficult to quantify (e.g. social capital, cultural heritage) and rarely included in compensation programs [45 46].

In Brazil, installed capacity is over 157 GW, of an estimated potential of 260 GW [1]. An important contributor to this growing installed capacity was the construction of the Belo Monte Dam. Belo Monte has an estimated 11.23 GW installed capacity, however, it will produce on average only 4.46 GW throughout the year due to the hydrological conditions in the area [22].

After years of opposition (Moran 2016 for an overview of this history; also Fearnside 2012), Belo Monte construction began in 2011 in the Xingu river, and by 2014 resettlement of an estimated 22,000 people had started. Belo Monte was supposed to be the first hydropower project

end, in the rush to do the project, consultation was poorly executed and did not live up to Article 169 requirements [47].

Randell [11] studied the displacement impacts among rural dwellers of the Belo Monte dam who had lived closest to the construction area, finding that residents reported improved wealth and subjective well-being *after* being resettled due to the favorable compensation provided. This is one of the few studies that reports improvement after resettlement, but it is important to note that this early group was generously compensated for their land, buildings, cattle, and cocoa. They were able to acquire good quality land and restore their productive capacity and therefore did not have to change their economic activities. However, most of the literature on resettlement is a story of broken promises and declining livelihoods [48]. Belo Monte led to significant declines in food production due to loss of agricultural labor from the farm as a result of better paying jobs in the dam or associated commercial sector [49–29] groundwater contamination [30–31] and reduced fish stocks far downstream [25].

In Belo Monte, a large portion of the resettled population were moved into collective urban resettlements (Reassentamentos Urbanos Coletivos or RUCs) built by the dam authorities. Five RUCs were built in vacant land in the periphery of the city of Altamira, the main staging area for the dam construction, located 52 km upstream from the dam [30]. The first RUC completed was *Jatoba*, the community that we study in the present analysis. In the next section, we describe how populations impacted directly by energy development experience and perceive said impacts.

2.2. Conceptual framework

A large body of research has documented local responses to energy development projects that can vary from mass mobilization against energy development to a relatively high degree of acceptance [50–51–52–53]. Impacted populations' reaction to energy projects is determined by a matrix of complex processes, ranging from media framing, to place attachments, to the degree of public engagement, and procedural injustice during the siting process [54–55–57–56].

Prior research implies that support for local energy projects is, to a significant degree, a function of the perceptions of the positive and negative impacts of said project [57–58–59]. In the current context, our respondents experienced a sometimes traumatic experience with displacement and resettlement, yet many were also financially compensated and offered new housing opportunities. As mentioned above, a scholar has noted that, in the rural area of influence of Belo Monte, resettled and compensated populations report improvements in livelihoods [10], but the restorative effect of compensation and resettlement seems to vary extensively from location to location and the impacts that researchers choose to track even within the same dam (e.g. see Vanclay (2017) for a review). Further, hydropower is often framed by the national government and the hydropower industry as beneficial, whereas the anti-dam movements show the problems and inequalities that arise with dams [18–60]. This implies that our respondents may hold complex views about it. On the one hand, they may have serious negative perceptions because of their direct experiences with displacement and everything that this entail, yet may also have some positive perceptions because of the compensation and housing program. They may also be influenced by media and state actors to perceive positive benefits to their region or nation (e.g. affordable electricity, economic development). These concerns may be more psychologically distant and abstract than the direct effects of displacement or compensation.

A related body of work has evaluated issues of justice in energy projects. Early environmental justice scholarship emphasized the distributional nature of environmental problems, highlighting how marginalized populations often bore the brunt of harms generated by

work has pioneered the concept of “energy justice”, arguing that it contains both distributional, procedural, recognition and restorative justice elements [63,64]. In this paper we aim to understand how direct experiences with resettlement might influence the support or opposition to hydropower development considering energy justice, particularly the restorative and procedural tenets, as a motivating framework.

In the context of energy justice, restorative justice aims to repair the harm done to society or environment by energy projects. Restorative justice can help point out where prevention strategies and restorations need to be done and operationalize it into policy [64]. Researchers have noted that restorative justice actions should include Environmental Impact Assessments (EIAs) and Social Impact Assessments (SIAs) conducted before the energy decisions are made [39], which usually include mitigation and compensation strategies to society and the environment. Some aspects of restorative justice overlap with the procedural justice sphere [64]. For instance, have substantial engagement with affected communities to prevent, mitigate and compensate the harms done by a project.

Procedural justice occurs along a spectrum ranging from simply providing impacted populations with information or holding public meetings, to ceding substantive decision making power to communities [65]. Efforts to engage impacted populations can increase acceptance of energy projects, even those that carry significant negative impacts. For instance, several studies have considered procedural issues related to wind energy facility siting [66–67–68]. Walker and Baxter [67], studying two wind farms in Canada, challenge the “technocratic” approach to design and siting decisions, finding that empowering local populations with a fair and open planning process is associated with an increase in support for local wind development. Other analyses find that populations that engage and participate in the planning and development of an energy project are more supportive of said project [69–70]. Importantly, views on what procedures are just, vary from person to person within an impacted population—that is, procedures that seem just to one person may seem unjust to another [69]. Much of the research on communities' perceptions of impacts, procedural and restorative justice related to energy projects has been conducted in the Global North. Examples include the large volume of research on oil and gas development in the United States [71–72–73] and wind energy in the UK [69–70].

Procedural justice is often overlooked by dam authorities. Hay, Skinner and Norton [74] argue that large-scale hydropower projects, especially those in the developing world, rarely involved consultation with impacted populations. The authors trace the history of hydro development and argue that, as time progressed, operators and central governments began to consider procedural justice issues, but this was most often in the form of a few public meetings and offering compensation (e.g. cash payments, land, housing) for displaced or otherwise impacted populations. Moreover, operators, utilities, and central governments rarely consult local communities to determine culturally and economically optimal siting locations. Affected communities must be part of the decisions related to dam construction including aspects for resettlement and compensation [75–74]. If they are involved in the process of decision-making they are more likely to adapt and recover from the stress of displacement or other impacts [45].

In Brazil, consultation processes happen after the government has decided where and when dams are going to be constructed [8], and this “consultation” is just to inform the affected population and local authorities that the dam is going to be built. In fact, for the case of Belo Monte, Fearnside [37] mentions that dam authorities organized public hearings to provide information about the dam in the city of Altamira, but they limited the participation of the local community by booking small spaces as well as providing little information about the project. That is, impacted populations were not given true decision-making power. Marques et al. [76] provide one of the few studies of proce-

more positive attitudes about their construction.

Dam projects cause immense deleterious impacts on displaced populations, some of which might be partially repaired by compensation programs. Yet it is unclear if impacted populations *support* or *oppose* further hydropower development after their experience. Batel, Devine-Wright and Tangeland [77] draw a difference between acceptance and support, noting that support implies purposeful action while “acceptance” is more top-down and passive. However, to date no studies have asked population resettled by dams whether they would support the development of additional hydropower, even if they accept existing projects. This is not a trivial question, since much of the regional dam development projects have several dams planned in the same river, and thus the views of people affected by the first dam, are likely to affect how other communities will respond to another dam. These populations are remarkably well-connected by cell phones and social media and thus views in one community are likely to diffuse rapidly to other communities.

3. Hypotheses

Above we reviewed the relevant literature on the impacts of energy development on host communities, procedural and restorative justice, and support for energy development with a focus on hydropower. From this framework, we test three hypotheses that have been little-explored in the broad literature on hydropower. First, we expect that *support for hydropower will decline as perceptions of negative impacts increase, or as negative experiences with resettlement increase* (Hypothesis 1). We also expect that *procedural justice, in the form of engagement, will increase support to hydropower* (Hypothesis 2). Finally, we hypothesize that *restorative justice, in the form of fair compensation for resettlement, will increase support to hydropower* (Hypothesis 3). We address these significant gaps using the data described in the next section.

4. Study site and data collection methods

4.1. Study site

Jatoba is one of five urban collective resettlement communities built by the Belo Monte consortium, Norte Energia, to provide housing for those relocated from their riverine locations on the islands, river margin, and low lying neighborhoods of Altamira that would be flooded. As such it became the show piece for the resettlement program as it was located during its first year across from the dam builders’ headquarters at the outset. The homes were standardized, built on site from reinforced concrete, and had running water and sewage disposal in-house. While they were not supposed to be modified from the standard, it took little time for the families to make modifications: adding porches, fences, perimeter walls, garages, businesses, and gardens.

Most of the resettlers in Jatoba came either from riverine locations or had businesses near the riverfront, serving the riverine population, and the downtown areas of the city. Some of the houses in these flood-prone areas were known as *Palafitas*, houses built over wood stakes without water, energy, and sewage services [78]. The river underneath the homes provided the water and the sewage removal, while energy was sometimes obtained by wildcat connections to houses nearby that had electrical connections or by the use of kerosene. Houses located in these areas were considered as under flooding risk due to the construction of the dam, therefore they had to be resettled by the dam authorities [78]. This sample represents what Vanclay (2017) calls an “involuntary resettled” population as they were given no choice whether to resettle or not. Our sample was compensated with housing that was of higher quality, from the developer’s perspective, than their previous homes, and the dam consortium promised to build also community infrastructure

resettle, it probably included some who were eager to move, rather than those most resistant to being resettled who ended up going to communities built later. Most (some 95%) stated that their previous location was “urban” and they were settled into an urban setting. Thus, our analysis is of primarily urban-to-urban resettlement.

Several energy injustices are manifest in the case of the Belo Monte project and in the more narrow case of the Jatoba residents. As we noted earlier, Belo Monte was constructed without much input from the impacted populations, many of who were not compensated for the impacts they bore —indicating a lack of procedural and restorative justice. Regarding Jatoba, the resettled group had little say in the type of compensation they would receive and could not provide meaningful input regarding the compensation mechanisms and resettle policies. Thus, there are energy injustices apparent in the case of Belo Monte. Houses given to families, as a form of compensation, were not supposed to be sold but within a couple of years, many houses bore “For Sale” signs. Some families did not find the location of Jatoba amicable to their social needs and to make a living from wages given its location.

Jatoba was nearly one hour and a half from the commercial center of Altamira. Initially, no public transportation was provided and this became a major problem for its residents because many basic activities require going to the city center. Banks, hospitals, doctors, and other businesses like grocery and clothing stores are in the downtown commercial areas of Altamira. Besides, it became prohibitive to take private taxis. A sense of isolation and lack of services permeated the community in its first couple of years, and many wished to move elsewhere. The other four RUCs were also in the city’s periphery and had similar problems of initial lack of public services. See Fig. 1 for a map of the location of Jatoba and other resettled communities, in relation to Altamira and the region.

Altamira was an entrepot in the rubber trade during the late 19th century and early 20th century. It sits above the rapids that block traffic from the main Amazon river to the upper Xingu, and the city of Vitoria do Xingu some 20 km away was how people moved between the main river and up and down the Xingu. Altamira was connected to Vitoria do Xingu by road. Until the Transamazon Highway was built, most goods and people had to go to Vitoria. After the highway, Altamira became connected to the rest of Brazil by road, and goods and services began to come from all over the country [79 80].

Altamira has been host of two large infrastructure development projects that increased its population abruptly. The first one was the construction of the Trans-Amazon Highway in the early 1970 s and the second is the construction of the Belo Monte hydroelectric dam between 2011 and 2016 [21]. The population grew from 1,000 people to 10,000 people in less than two years at the start of the 1970 s and it grew into a regional center for agropastoral development by 1985 when it reached a population of 85,000. It stagnated at that population level but its economy was stable and based around cattle and cocoa production. One of the co-authors has conducted research in this area for decades and witnessed this process of regional change. The arrival of Belo Monte brought huge investments to the region with more than 31 billion reais (13 billion USD at that time) spent on the construction, which supported growth in the commercial sector to support the construction. This resulted in huge inflationary pressures in the first three years, as the city was unprepared for the influx of population, jobs, and businesses. It is in this context that one needs to place the experience of the resettled population.

Due to population growth and a lack of land-use planning there was a significant number of homes built in flood high-risk areas and they later became the first to be required to resettle when Belo Monte came. In the next section, we describe our data collection procedures.

4.2. Data collection



Fig. 1. Map of the Jatoba RUC and Altamira.

collected by 9 undergraduate student enumerators from universities in the region supervised by one of the co-authors of the current manuscript. All students underwent extensive training before starting the survey. Jatoba was divided into 28 blocks constituting 1,043 houses. The sampling was done by randomly choosing houses evenly divided between the two sides of each of the streets. Because of the possibility of some failures in the completion of surveys, 269 households were sampled with the target of having 250 completed surveys. Each student carried out approximately 30 surveys, and each was responsible for one or two streets in the Jatoba settlement. The survey had a combination of opened-ended and closed-ended questions, and it contained information about respondents' experiences with displacement, health information (e.g. fertility), among other topics. This survey was part of a much larger, more extensive project evaluating the social, economic, and ecological impacts of dams in the Amazon region. The data collection

section).

In addition to the survey, two of the authors of this paper did numerous interviews with stakeholders such as the managers of the dam building, the department in charge of resettlement, the public prosecutors (both state and federal), the department of urban planning for the city, hospital and education directors, health post doctors, local merchants, taxi drivers, and other business owners or employees, real estate companies, and university department chairs and faculty. In total, we interviewed more than 120 people across Altamira and Jatoba during the 5 years of the FAPESP-funded project (see above).

5. Variables

5.1. Outcome: Support for hydropower

34% stated “No” and 16% stated “don’t know”. We provide the distribution of this variable in Fig. 2.

6. Predictors

6.1. Impacts of Belo Monte

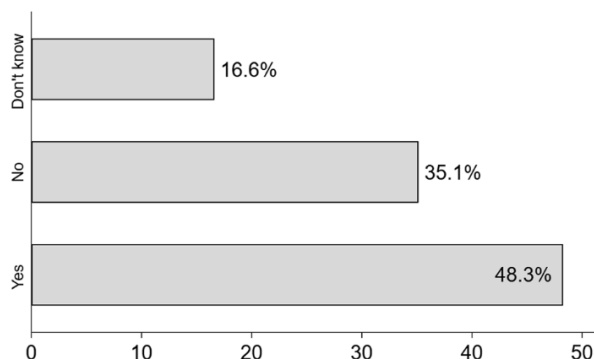
The survey included a series of questions to determine perceived impacts of the Belo Monte dam on the community of Jatoba, Altamira, the region (Amazon), Brazil, the environment, and the local population with the response categories of “good”, “acceptable” and “poor”. Fig. 3 provides the distribution of these items. Strong majorities reported that Belo Monte’s impacts on Jatoba, Brasil and the region were “good” yet responses were decidedly more mixed for other impacts. A majority (54.7%) stated that the environmental impact of Belo Monte was “poor”.

We conducted an exploratory factor analysis on these items using the iterated principal factors method with a varimax rotation—the varimax rotation assumes that the factors are correlated—and report the results in Table 1. The factor analysis strongly suggested a single factor solution. The eigenvalue for the first factor was 5.525, while the eigenvalue for the second factor was well below the standard criteria of 1.0. Further, all of the variables loaded strongly on the first factor, with very modest loadings on the second factor. We also inspected an unreported scree plot, which again indicated a single factor solution. From here, we calculated a standardized factor (mean = 0, standard deviation = 1) score for use in our regression models below, where higher scores correspond to greater perceived impact.

6.2. Changes after migration

Respondents answered a battery of questions about their experiences with the resettlement process and if various aspects of their lives had improved since relocation. Respondents were asked “In comparison to your former house, how would you rate nowadays...” with questions for their home, neighbors, neighborhood, water, electricity, health, transportation, violence, education, garbage, pollution, and life in general. The distribution of these items are provided in Fig. 4. On several fronts, respondents reported that their lives had improved since migrating to Jatoba—improvements were especially pronounced for homes, the neighborhood and “life in general”. Nearly half reported that neighbors and education were the same as before, while exposure to violence had gotten worse since being resettled to Jatoba.

Like the impact items, we performed an exploratory factor analysis using the iterated principal factors method with a varimax rotation, with results reported in Table 2. The results generally lend themselves to a single factor solution. All the indicators loaded strongly on the first factor (e.g. above the conventional cut-off of 0.4) and the eigenvalue for the first factor was 5.525, while the second factor had an eigenvalue of



0.967. From here, we estimated a standardized factor score to use as a predictor in the regression models below. These two predictors—perceived impacts from Belo Monte and changes after migration—are used to operationalize hypothesis 1.

6.3. Procedural justice

The survey also included a question to assess respondent’s engagement with the process. Respondents could state that they did nothing, attended a meeting, participated in a social movement, or engaged in protests. Only 1 respondent participated in a protest, and only 4 reported joining a social movement. Most (nearly 52%) had no engagement and the rest (35%) attended a meeting. For our analysis, we created a binary variable from this data, where respondents who did something to engage with the process (e.g. meeting, protest, or social movement) were scored as a “1” and the “no action” group was scored as a “0”.² Another question asked if respondents had a choice to where they moved to using response categories of “yes” or “no”, with 34% indicating that they could choose their location.

6.4. Restorative justice

For hypothesis 2, we suggest that perceptions of restorative justice can influence support for energy projects independent of positive and negative impacts. Respondents were asked “Do you think your compensation was fair, with some 59% indicated “yes” and the remainder stating “no”³.

7. Modeling strategy

Oftentimes, analysts will code “don’t know” responses as missing to create binary variables, thus allowing relatively straightforward modelling approaches such as binary logistic regression. In our case, a non-trivial number of respondents (16.6%) stated “don’t know”, implying that “don’t know” might be substantively interesting. Rather than removing these cases, we have opted for a modelling approach that will facilitate their use and provide more qualified and nuanced results.

Given that our outcome variable is categorical, one obvious modeling candidate is the multinomial logistic regression model. However, the multinomial model is notoriously difficult to interpret, producing a unique coefficient for each predictor at each category of the outcome variable. Another option for multi-category outcome variables is the ordinal logistic regression model. However, our outcome variable is not truly ordinal because of the “don’t know” category and proportional odds assumption is likely violated. Rather than opt for a very complex multinomial model or an overly simplified ordinal model, we employ the partial proportional odds (PPO) model [81–82]. The PPO model relaxes the effect of a predictor across categories of the outcome variable when the proportional odds assumption has been violated—this assumption is tested via a Wald test. Thus, the PPO model is an excellent compromise between the overly complex multinomial approach and the ordinal logistic regression model. We use the *gologit2* package in Stata 15/IC to estimate the partial proportion odds models. We examine AIC and BIC statistics to determine the best fitting model [83]. We estimate and visualize predicted probabilities to render our modelling results

² Respondents who found employment in the Belo Monte project may have different perspectives than others. We asked respondents if anyone in their household had worked at any point at Belo Monte. Only 3% responded “yes”. Given this small number, we do not use this variable as a predictor in our regression models.

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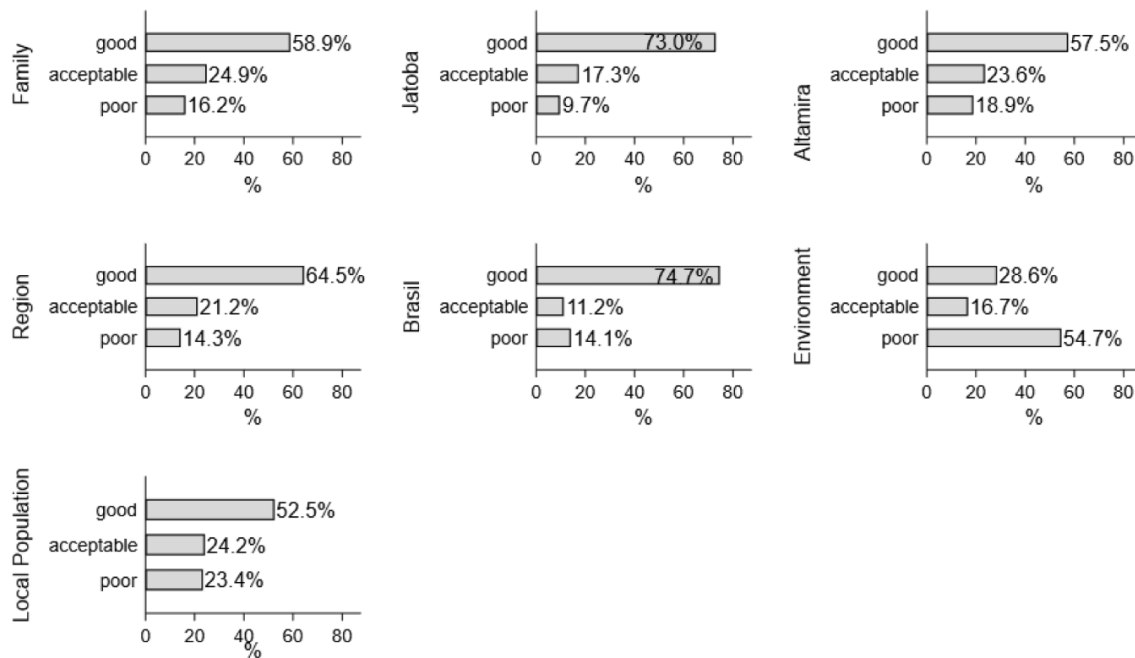


Fig. 3. Distribution of perceived impacts from the Belo Monte Dam.

Table 1
Factor loadings for impact items.

	Factor1	Factor2
Impact on Family	0.823	-0.288
Impact on Jatoba	0.867	-0.283
Impact on Altamira	0.927	0.077
Impact on Region	0.954	0.038
Impact on Brasil	0.881	-0.102
Impact on Environment	0.709	0.345
Impact on Local Population	0.880	0.250
Eigenvalue:	5.252	0.361

Note: Factors extracted from a polychoric correlation matrix using the iterated principal factors method with a varimax rotation. KMO = 0.8972. Factor 1 explains 53% of the interitem variance.

more intuitive because of the well-documented difficulties in directly interpreting logistic regression coefficients [84]. The probabilities are the primary way that we interpret our models.

8. Results

Table 3 provides the results from our partial proportional odds model. In the first model, we enter only our two factor scores as predictors. The factor score for resettlement has violated the proportional odds assumption in this model. Both the effects of resettlement and perceived impacts of Belo Monte are statistically significant in the “Yes” category. Model 2 drops the Displacement Factor Score and Impact Factor score and adds the items for procedural justice (fair compensation, choice of location, and engagement). None of the procedural justice items reach statistical significance, although the p-value for “Fair Compensation” (our indicator of restorative justice) approaches statistical significance for the “No” category ($p = 0.066$). Notably, the AIC and BIC have increased, implying a worse model fit. The lack of significant coefficients and the seemingly worse model fit imply that procedural justice does little to predict support for hydropower. In Model 3 we use both sets of predictors, again finding that the effects of displacement and

The predicted probabilities are displayed in Fig. 5. These probabilities were calculated from Model 3 in Table 3 by manipulating values on the displacement factor score and the impact factor score and holding all other predictors at their observed values. Panel 1 displays probabilities by different values of the impact factor score. The graphic indicates that as impacts increase, the probability of stating “Yes” decreases. For instance, if a respondent perceived little to no negative impacts (i.e. a score of “-2”) then their probability of “Yes” is some 0.70. However, a respondent who perceives large, negative impacts (i.e. a score of “2”), their probability of stating “Yes” hovers near 0.30. Thus, perceived negative impacts from Belo Monte sharply reduce support for additional hydropower. However, this finding comes with an important qualification that is revealed by examining the curves for “No” and “Don’t Know”. As impacts increase, the probability of stating “No” increases in tandem yet the probability of “Don’t know” also grows. That is, perceiving negative impacts seems to drive respondents away from stating that hydropower is worth pursuing yet many of those who perceived large, negative impacts are likely to say “don’t know” instead of “no”.

The second panel, which presents probabilities based upon manipulated values of the displacement factor score, also reveals several complicated findings about the effects of resettlement. Recall that higher scores are associated with a negative view of the effects of displacement and lower scores represent the view that various life conditions have improved since resettlement. Like our impacts factor score, the probability of “Yes” declines markedly as experiences with displacement become more negative. When the effects of displacement are low, the probability of stating “No” or “Don’t know” overlap, yet experiencing negative effects from displacement creates a stark difference in these curves wherein those who report negative impacts from displacement are much more likely to state “No”. Thus, the probabilities suggest that positive or modest negative effects of displacement (i.e. scores below the mean of zero) can alternatively drive individuals to state that “No” or “Don’t know” when asked if hydropower is worth it. Yet, as these negative experiences increase, the “No” and “Don’t know” responses are more closely aligned with the likelihood of “No” much higher when

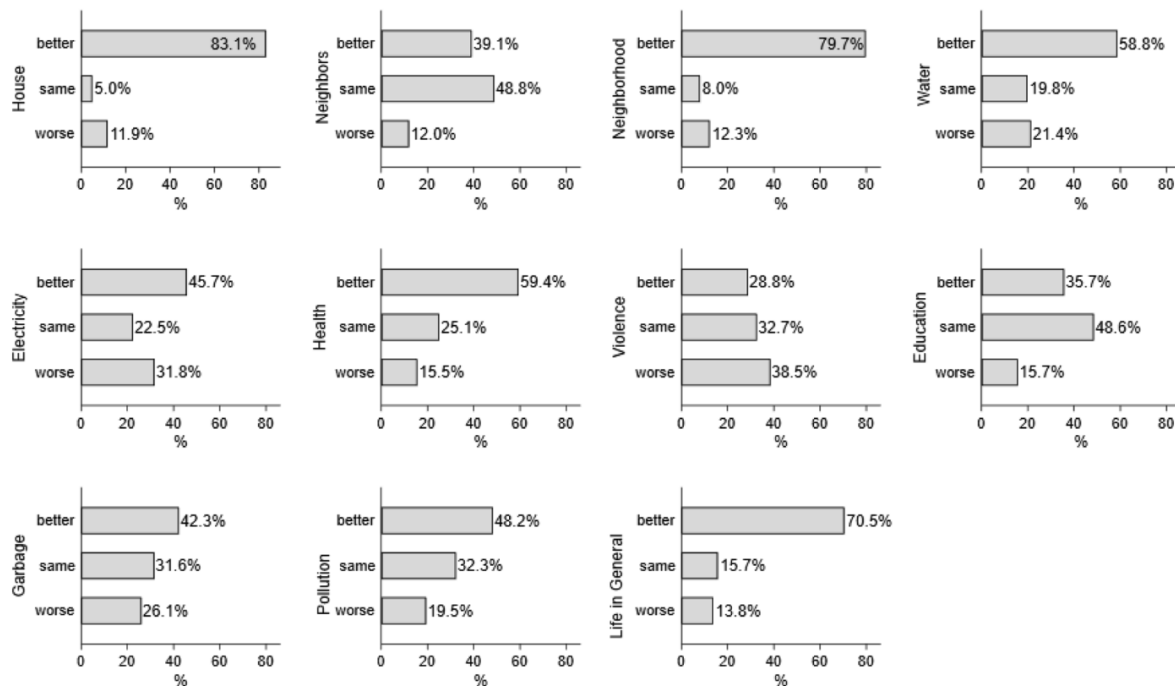


Fig. 4. Changes from displacement and resettlement.

Table 2
Factor loadings for changes after migration.

	Factor 1	Factor 2
Housing	0.704	−0.062
Neighbors	0.520	0.055
Neighborhood	0.748	0.080
Water	0.628	−0.063
Electricity	0.724	0.304
Health	0.807	0.255
Transportation	0.466	0.613
Violence	0.485	−0.408
Education	0.620	0.076
Garbage	0.686	−0.303
Contamination	0.706	−0.368
Better Life	0.852	−0.116
Eigenvalue	5.451	0.967

Note: Factors extracted from a polychoric correlation matrix using the iterated principal factors method with a varimax rotation. KMO = 0.8445. Factors 1 explains 93% of the interitem variance.

understanding of our results. Positive views about hydropower development are focused on the national level, they argue that it generates electricity and that it is a benefit for Brazil. Respondents also noted that a positive aspect is that the construction of the dam at the local level generated jobs and resettled people from flood-prone areas to new houses on higher ground. On the other hand, negative views about hydropower are focused on the local scale. They noted that hydropower has generated negative impacts in the environment; it has increased violence and insecurity in the city; there is a lack of public transportation; an increase in the price of goods and services such as electricity; and, that the benefits of the construction of the dam are for people living in other regions. This situation portrays a perception of injustice in the distribution of the benefits and negative impacts generated by hydropower development.

6. Discussion

Table 3
Partial proportional odds model for support for Hydropower.

	Model 1	Model 2	Model 3
	b/(se)	b/(se)	b/(se)
“Yes” vs. “No” and “Don’t Know”			
Displacement factor score	0.408*		0.370*
	(0.16)		(0.17)
Impact Factor Score	0.476*		0.420*
	(0.20)		(0.21)
Fair compensation		0.541	0.185
		(0.29)	(0.34)
Choice of location		−0.145	−0.349
		(0.27)	(0.34)
Engagement		0.359	0.386
		(0.26)	(0.33)
“No” vs. “Yes” and “Don’t Know”			
Displacement factor score	−0.227		−0.289
	(0.22)		(0.24)
Impact Factor Score	0.476*		0.420*
	(0.20)		(0.21)
Fair compensation		−0.562	0.185
		(0.41)	(0.34)
Choice of location		−0.145	−0.349
		(0.27)	(0.34)
Engagement		0.359	0.386
		(0.26)	(0.33)
AIC	344.938	459.243	317.714
BIC	361.013	479.686	342.464

Note: Data collected in 2014 in Jatoba, Brazil. * = $p < 0.05$, ** = $p < 0.10$. In model 1, the proportional odds assumption was violated for Impact Factor Score and Displacement Factor Score. In model 2, the assumption was violated for Choice of Location. In model 3, the assumption was violated for the displacement factor score. N = 249.

ecological impacts of dams [85 15 6] yet we know comparatively little about the degree to which populations directly affected by hydroelectric dams support hydropower development after their experience with it, even though hydropower megaprojects are routinely opposed by

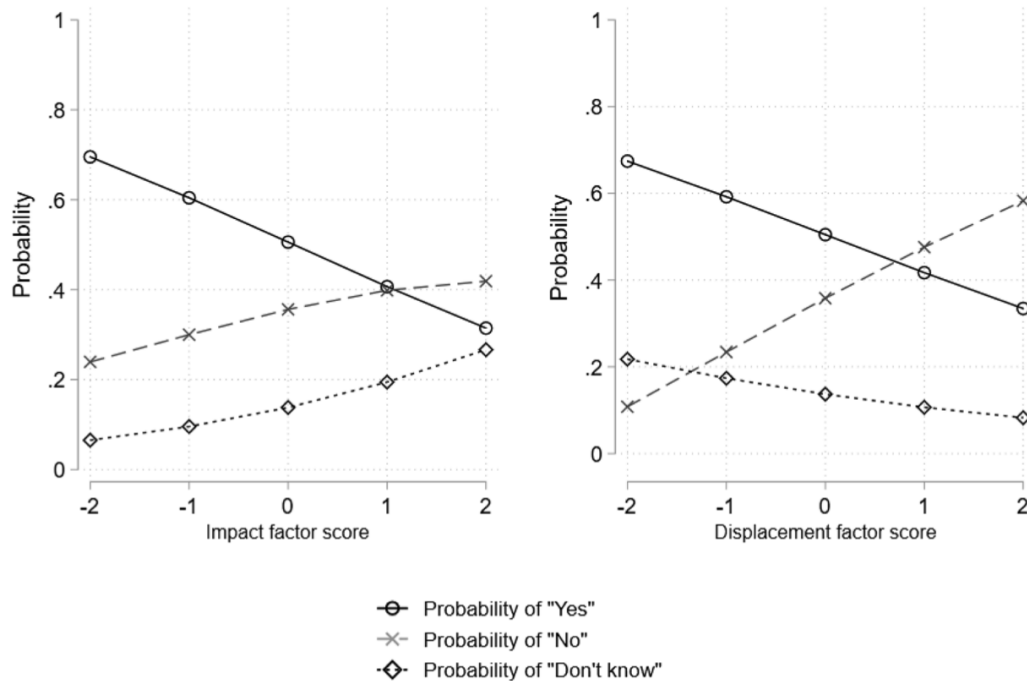


Fig. 5. Predicted probabilities for "In general, do you think hydropower plants are worth building?"

reduce support for hydropower—we operationalized this relationship using two series of questions to capture perceived impacts from the Belo Monte dam and household changes caused by the process of migration and resettlement. Our results reveal several implications. First, as perceived impacts increase, support for hydropower declines yet respondents were also more likely to state "don't know". We observed a similar pattern for the negative effects of resettlement—respondents were more likely to state "no" or "don't know" compared to "yes". That is, negative impacts appear to increase the likelihood of opposition to Belo Monte and uncertainty about it. Coupled with our descriptive results—in which we found that a non-trivial proportion of the respondents stated "don't know"—our study implies that there is some degree of uncertainty or perhaps ambivalence about hydropower among displaced populations, who see some aspects of their lives improved and others damaged. In particular, large negative impacts (captured by our impact factor score) seem to cause a situation wherein some displaced individuals are less supportive, but others become more uncertain. That is, perceiving negative impacts from hydropower seems to simultaneously intensify both opposition to hydro and uncertainty about hydropower. Exploring the reasons for this seeming uncertainty is an important task for future research.

From the intensive fieldwork in the area by two of the co-authors of this paper, in the years previous to and during the construction of the dam, they observed that the urban population of Altamira was very supportive of the building of Belo Monte, and they were unhappy with the opposition to it from indigenous peoples. The direct experience with the dam seems to have changed them from strong support to opposition or ambivalence. They recognize some truth in the advocates' claim that Brazil needs the energy production, but that the benefits to them personally were not commensurate. Recall that many of the impact questions were focused on impacts beyond the family, such as impacts on the region or the entire nation. Turning to the more personal effects of displacement (captured by our displacement factor score), we found less ambiguous effects in support for hydropower. Those who reported that various aspects of their lives were worse after displacement and

displacement and resettlement seem to have a more consistent and ultimately less ambiguous effect on support for hydropower than perceptions of broader impacts. Thus, we find qualified and mixed support for hypothesis 1. The builders made a lot of promises that were simply not kept. They promised local jobs, but these turned out to be temporary, sometimes lasting as little as three months. They promised improvements in the water and sewage system, and even years after the dam was completed, there were still neighborhoods with unreliable water supplies and the sewage connections in Jatoba performed poorly. Schools and transportation were not provided when people moved in, and the households felt burdened by the cost of taking taxis to do basic things like shopping and banking, because of a lack of public transportation to their part of town.

Following the literature on procedural justice and energy development [69–67], we suggested that procedural justice is associated with more support for hydropower (Hypothesis 2). To operationalize this hypothesis, we used predictors that captured the degree to which respondents participating in meetings held by the dam builder and if they were offered any choice of location. Contrary to our expectations, we find that procedural justice did not have any meaningful effect on support for hydropower—respondents' views appeared to be mostly motivated by perceived impacts, not the extent to which more just processes were built. We also hypothesized that restorative justice—captured as the perception of fair compensation—would lead to greater support (Hypothesis 3). However, our models imply that perceptions of fair compensation do not predict support.

We were surprised that procedural and restorative justice had little to no influence on support for hydropower, especially given that prior research indicates that procedural justice and engagement increases support for energy projects in other settings [67]. We suspect that our results diverge from those of other studies for a few key reasons. First, much of the research on procedural justice and support has focused on renewable projects (e.g. wind and solar) in European nations. Perhaps these studies do not generalize to the case of hydropower and Brazil which has a very different historical and social context. Secondly, our

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well as the construction of the dam, were top-down decisions. Energy justice scholarship emphasizes the democratization of energy and the meaningful participation of communities in local energy projects in terms of ownership, design features, and siting locations [63–86]. Of course, none of these are typically options for a large-scale hydropower project and definitely not for Belo Monte—which was built by presidential fiat and against the environmental agency's recommendations and social movements' opposition. Thus, our indicators of procedural justice differ somewhat from prior studies given the unique context of hydropower in Brazil where local participation and stakeholder engagement has not been encouraged and often actively discouraged. Then, Jatoba resettlers, and other communities affected by the Belo Monte dam have suffered procedural injustices.

As with all research, our findings come with caveats and qualifications. Prior research indicates that industry public relations efforts can influence public opinion, leading some populations to be more supportive of energy projects than they would otherwise [87]. Similar efforts have occurred in Brazil, which historically has had broadcast media under the control of the military government and has significant media concentration even now [88, 89]. Even though the military ended its control of the Presidency in 1985, none of the governments that followed repudiated the economic priorities they set, nor the role of hydropower in powering the economic engine of the country. We suspect that these government efforts promoting hydropower as the solution for Brazil's energy needs may have influenced our results. Brazil has also experienced periodic energy crises—this cultural backdrop might also create more public acquiescence to hydropower projects because the industry holds the specter of future blackouts as a possibility unless hydropower development proceeds without restraint [47]. Finally, as noted earlier, our sample was among the first resettled populations of Belo Monte, these families were resettled from an urban to an urban area and received housing, as part of the compensation. This population may be more supportive of hydropower than a group of people who received no compensation. Certainly, we found the old residents of Altamira are much less favorably inclined to Belo Monte than the Jatoba residents, a subject for another paper currently being developed. Support for hydropower as well as energy injustices might vary considerably across communities that are impacted differentially by Belo Monte. This variation could be fertile ground for future research.

There are several policy implications from this study. First, communities' opposition to hydropower seems to be largely driven by negative impacts, implying that compensation programs may often be inadequate. Secondly, our sample reported a loss of community resources that lend to a lack of support. More broadly, our results imply that confusion, uncertainty or ambivalence may be understudied, representing an important challenge for policy-makers and planners.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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