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Major Hydropower States, Sustainable Development, and Energy Security: Insights from a Preliminary Cross-Comparative Assessment

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Abstract: Hydropower remains, by a wide margin, the largest source of renewable electricity around the world, and hydropower dams supply a greater source of commercial energy than the world's fleet of nuclear power plants. Yet far less attention has been paid to the political, security, and governance elements underlying the continued use and growth of hydropower. Theorists from many disciplines—political geography, security studies, development studies, economics, public policy, and governance—have questioned both the proper role and ostensible benefits from the generation of electricity from large-scale hydroelectric dams, but have tended to approach the problem on a case-by-case basis. In this study, we provide the first systematic, cross-comparative assessment of five hypotheses about global hydropower states, using World Bank data from 1980 to 2010 and a research design which incorporates five reference classes of countries. Based on regression and comparative country analyses, we find tentative statistical evidence that hydropower countries do seem to perform worse on a series of security, economic development, and governance metrics.

Keywords: energy security; hydroelectric dams; hydropower; resource curse; water wars

Major Hydropower States, Sustainable Development, and Energy Security

1. Introduction

Hydropower remains, by a wide margin, the largest source of renewable electricity around the world, both in terms of installed capacity and global investment flows. According to the most recent data from the International Energy Agency (2016), hydropower generated about 16.3 percent of the world's electricity. Put another way, about 85 percent of global renewable electricity comes from hydropower. More than 150 countries generate at least some grid-connected hydroelectricity and hydroelectric dams supplied at least 50 percent of electricity in more than 60 countries and greater than 90 percent in more than 20 countries in 2014. Haas (2008) argues that dams are also the infrastructure that “most fundamentally affect human settlement patterns, livelihoods, health, and the environment” given that they impound about 14 percent of all global water runoff and fragment 60 percent of the world's 227 largest rivers.

Advocates of hydropower frequently credit it with having several advantages over other forms of electricity. These include very high levels of durability and reliability, high efficiencies, long operating lifetimes, small operating and maintenance expenses, and the ability to “store” large amounts of energy in reservoirs (International Hydroelectric Association 2003; Kammen 2004; Cernea 2004; International Energy Agency 2014; Schneider 2013; Lejeune and Hui 2012; Kumar et al. 2011). The International Energy Agency (2012: 7) projects that annual hydropower capacity and generation will approximately double between 2010 and 2050. However, a variety of major thinkers have come to oppose large hydroelectric dams for a combination of economic, environmental, and social reasons (Leslie 2014; McCully 2001; Wolf 2007; Lindqvist 1998). Eissa (2008) and Zeitour and Warner (2006) even warn of “hydro-hegemony” and unjust domination as international conglomerates seek to

impose their development and energy agendas on poor and fragile nations, or a dominant nation is able to use hydropower to exert its influence over neighboring states.

Which is it? In this study, we explore the performance of major hydropower states from 1980 to 2010 on key indicators cutting across national security, poverty, economic development, financial debt, and corruption. We also investigate how their performance compares to that of low-income countries (LDCs), members of OPEC and non-hydro countries as a whole. Furthermore, we analyze the effect of countries' hydropower construction and production rates on key governance, economic and development indicators.

Our exploration of the contested role of hydropower helps give meaning to current debates over energy governance, resource extraction, security, technology, and policy—over the provision of reliable, affordable, safe, and environmentally benign energy services. Bakker (1999) calls hydropower one of the most visible aspects of a global shift in the geopolitics of resource exploitation. Put another way, the debate over hydropower is symbolic of future global struggles to simultaneously expand access to energy services and minimize environmental degradation (Rafey and Sovacool 2011). Today's investment decisions in technologies like hydroelectric dams will lock-in future energy trajectories for decades to come (Arthur 1989; Unruh 2000). Plans to build large dams continue, especially given that 1.3 billion people reside in rural areas of the world, mostly in Africa and Asia, which do not have an electricity grid at all (International Energy Agency 2014). Of the \$11.1 trillion the world is anticipated to spend on energy infrastructure from 2005 to 2030, \$1.9 trillion is expected to go exclusively to hydropower (Haas 2008). For these reasons, the hydropower industry sits at a critical juncture where most global future capacity has yet to be built (Sternberg 2010: 713). That means properly understanding the broader impacts of the technology, as well as the assumptions underpinning the expansion of the industry, is essential to properly weighing its costs, benefits, and future role.

2. Research Design and Analysis

This section of the paper briefly describes how we generated five hydropower hypotheses. It then explains how we tested them. It presents the metrics which function as dependent variables and gives an overview and justification regarding our research design.

2.1 Generating Hydropower Hypotheses

To begin our study, we first conducted an extensive review of the academic literature to generate a list of five hydropower hypotheses to test. In sum, we selected the five hypotheses shown in Table 1 for our empirical analysis, each derived from a separate set of academic literature. We hypothesize that major hydropower states would exhibit more conflict, would see a greater extent of poverty, would have lower growth rates in economic development, would see greater rates of public debt, and would see a greater occurrence of corruption.

INSERT TABLE 1 HERE

Our hydropower and security hypothesis suggests that hydropower states will have more internal and external conflict, stemming largely from the water wars (Gleick 1993; Swain 2001) and water management (Wolf 2007; Wolf et al. 2005) literatures. Hydropower dams, the thinking goes, are one of the critical factors that can contribute to this conflict. As Hensel et al. (2006) write, “The presence of hydroelectric projects on the river will increase the value of the water supply to one or both sides. Previous research has demonstrated a strong relationship between issue salience and the occurrence of militarized conflict over territorial issues, as well as decreased effectiveness of peaceful conflict management efforts.” Other literature discusses how dams can become focal points during international disputes or targets for terrorism (Gleick et al. 2014; Wolf 2007; White 2002).

The hypothesis that hydropower projects can contribute to poverty finds support from a variety of disciplines as well. One is that hydropower projects will exacerbate poverty because they interfere

with food security, especially the vitality of fisheries or the availability of agricultural land (Sarkkula et al. 2009; Pearse-Smith 2012; Wolf et al. 2005; Tilt et al. 2009) or interference with inland transport (Ping et al. 2008). Another supporting argument is that hydropower projects can contribute to the elite capture of resources, exacerbating the concentration of wealth and/or marginalizing ethnic minorities and indigenous groups (Rothfelder 2003; Smith 2003; Homer-Dixon 1994: 35; Magee 2006; Matthews 2012; Simpson 2007; Greacen and Greacen 2004). A final strand of this argument is that resettlement and forced relocation plans for hydropower projects often cause excessive, irreversible social or environmental damage (World Commission on Dams 2000; Terminski 2013: 16; Rew et al. 2000: 91).

Our hydropower and development hypothesis looks at rates of development between them (gross domestic product, or GDP), and it suggests that hydropower states could be prone to mal-development, slower or stunted growth (Imjof and Lanza 2010: 2; Salazar 2000). One mechanism is by creating boom towns during construction which give the appearance of economic development that may show up on national indicators, but are ephemeral and fade once the project is completed (Cernea 2004). Another is that hydropower projects are sometimes done as tied aid where the real goal of the project is not to build a dam, but to promote foreign policy goals such as democracy promotion or the selling of arms (Lankester 2013). Fox and Sneddon (2007) go so far as to argue that dam development is a way of subverting the global south by promoting the development goals of industrialized nations. Another reason relates to externalities beyond poverty, and the large (and often unaccounted for) social and environmental impacts that result from dam development (Holdren and Smith 2000: 79; Burke et al. 2009; Sovacool 2008; Valença et al. 2007; Adams et al. 1986; Lerer and Scudder 1999).

Our hydropower and fiscal responsibility hypothesis holds that hydropower projects are corrosive to fiscal discipline given that they often suffer from cost overruns and diseconomies of scale (Green et al. 2015; Leslie 2014; Merrow et al. 1988). The historical record does seem to confirm this

hypothesis. One recent study utilized reference class forecasting to assess the outcomes and costs of 245 dams—186 of them hydroelectric dams—built between 1934 and 2007 across five continents and 65 countries (Ansar et al. 2014). These dams collectively involved more than \$353 billion worth of investment. The study found overwhelming confirmation that budgets were biased below cost and that actual costs were on average 96% higher than projected costs. The authors highlighted that these cost overrun figures were conservative as they excluded inflation, substantial debt servicing, and other environmental and social damages. A follow-up study of 401 electricity infrastructure projects around the world also concluded that cost overruns also afflicted more than three out of every four (75.4 percent) of the hydroelectric projects in the sample and that these exhibited a mean cost escalation of 70.6 percent per project (Sovacool et al. 2014a; Sovacool et al. 2014b).

Our final hypothesis is that hydropower projects facilitate corruption (Butterworth and Harpe 2009; Transparency International 2008: xxv; World Commission on Dams 2000: 6). The complexity of dam building that makes it so prone to cost overruns also can generate a lack of accountability and opaque project management (Bossard et al. 2008; Haas 2008). Complexity in contracting can further obfuscate accountability—with separate contracts usually spanning across equipment, civil works, materials, construction, management, and external consultancies—involving local, national, and international actors, each with their own requirements. Resettlement activities which involve large sums of money can also create lucrative opportunities for graft (Haas 2008; Scudder 2008; Sohail and Cavill 2007).

2.2 Choosing metrics and dependent variables

With our hypotheses laid out, our second step was to select metrics and data to correspond with each of our five hypotheses. As Table 2 summarizes, to measure conflicts we relied on the UCDP

database from Uppsala. To measure poverty, we chose the “poverty gap,” a measure that reflects both the depth and incidence of poverty. To examine economic development, we selected GDP per capita, to evaluate debt, we investigated total debt stocks, and for corruption, we depended on the World Bank’s Worldwide Governance Indicators dataset, a source of data drawing from more sources, and offering a greater range of dates, than the (perhaps better known) Corruption Perceptions Index from Transparency International (World Bank 2014b).

INSERT TABLE 2 HERE

2.3 Research design and country reference groups

Generally, three major challenges exist regarding an empirical analysis of the effect of hydropower on security, economic and development indicators. First, the effects of hydropower construction—dam design, excavation, building, financing, etc.—have to be treated separately from the effects of hydropower electricity production, since they deal with very different things—one civil and engineering works, the other operating and maintaining an electric power plant. The second challenge concerns the long timeframe, missing data and the presumed high variability of when exactly the effects of hydropower begin to materialize—immediately upon construction? After five years of operation? And third, there are various other variables which influence economic and development country indicators (e.g. commitment of the country’s government to democratic values), which could confound the relationship between hydropower construction and production and performance on our indicators.

The design of our research was specifically chosen to account for these three challenges. We relied heavily on both method and data triangulation techniques (for an overview see Hussy et al. 2010: 276f.) to increase the reliability and validity of our research findings. Regarding data triangulation, we

chose two long timeframes (timeframe 1: 1980-1995; timeframe 2: 1996-2010) and calculated the average score per dependent variable and country for each of these two timeframes. Thus, we were able to counter the challenge of missing data points (of which they were many) and to conduct the analysis for two periods separately.

Regarding method triangulation, we conducted two separate analyses to test our five hypotheses per timeframe: First, we conducted a comparative country analysis to analyze the differences in the selected five dependent variables between (1) countries high in hydropower construction, (2) countries high in hydropower production, (3) non-hydro countries (countries which are not part of either group 1 or group 2), (4) Low income countries and (5) members of OPEC. We selected Low income countries to tease out whether hydropower states outperformed those with some of the world's least developed economies and lowest levels of government capacity, and we selected OPEC countries, rich in oil and gas, to see if hydropower states outperformed those traditionally associated with the "resource curse." Table 3 gives an overview of our countries and inclusion criteria of the two hydropower state reference groups within the two timeframes. For hydropower state classification, two datasets of the World Bank were used: electricity production per country and year from hydroelectric sources (kWh), and electricity production per country and year from hydroelectric sources (% of total). We used the non-parametric Wilcoxon rank-sum test to analyze the differences between the country classes, since some groups were quite small and this test yields more robust results than the parametric t-test. For hypothesis testing, we focused on significant differences between non-hydro countries and the two hydropower country classes –findings derived from our comparative country analysis were treated as additional, more anecdotal evidence.

INSERT TABLE 3 HERE

Second, we conducted a linear regression analysis per hypothesis with hydropower construction and production rates per country as independent variables (see the footnote of Table 3 for a more detailed description of the variables). Following the guidelines offered by Field (2009), Gardner and Altman (2000), and Sheskin (1997), such an analysis gives an idea whether hydropower has an effect on the selected metrics at all, and how this effect is pronounced (positively or negatively). To be candid, such regression analysis captures only a static picture of hydropower performance; this is why we have labelled our study as “preliminary.” All of our five variables, "violent conflict", "economic growth", "poverty rate", "public debt" and "Corruption" are dynamic in nature. A regression therefore does not completely capture the complexity of these variables over time. Nonetheless, it does generate a useful analytical picture that can inform future analysis and policymaking.

In sum, our research design allowed us to conduct four tests per hypotheses and separately for the effect of hydropower construction and production, namely the difference in the research variable between hydropower constructing (producing) countries and non-hydro countries between 1980-1995 and 1996-2010, and the effect of the hydropower construction (production) rate on the research variable between 1980-1995 and 1996-2010. In accordance with Field (2009: 57), we treat $r = .1$ ($R^2 = .01$) as the threshold for a small effect or association, $r = .3$ ($R^2 = .09$) as the threshold for a medium effect or association, and $r = .5$ ($R^2 = .25$) as the threshold for a large effect or association.

2.4 Limitations

Admittedly, our research design has some drawbacks. Many of the security, poverty, development, and governance issues we examine occur at local scales, yet our analysis focuses entirely at the level of the nation state. This is because, firstly, data for most countries was only available at the national scale, and secondly, we wanted our study to move beyond locally isolated case studies that so dominate the literature we reviewed. Moreover, we maintain that for our hypotheses to be true among

major hydropower states relying on dams to generate 50% or 80% of their electricity, such infrastructure would be spread across large enough parts of each state to have a meaningful effect on national trends and statistics. Moreover, we do not attempt to deal with the issue of reverse causality in any instance. Each country has different energy needs and has its own domestic energy portfolio - yet none of these factors are ever accounted for in the analysis.

3. Results and Discussion

This section of the paper presents the results of the two conducted empirical analyses in relation to each of our five hypotheses. Figure 1 presents statistical results that we refer back to and Table 4 provides more details as to the robustness of our regression analyses.

INSERT FIGURE 1 and TABLE 4 HERE

3.1 Hydropower and security

Our results, redrawn from the UCDP/PRIO Armed Conflict Dataset, do partially support this hypothesis, but only with regard to hydropower construction: 3 of 4 conducted tests showed significant results in line with the hypothesis, the non-significant one only by trend. When conflict-years are broken down by number of countries in reference group or mean number of conflicts by year or country, results of the comparative country analysis are shown in Figure 1. Countries high in hydropower production seem to experience less conflict than both OPEC and Low income countries in both timeframes. However, only the differences in the first timeframe reached significance, both regarding OPEC ($W_s = 198.00$, $z = -1.99$, $p < .05$, $r = -.37$) and Low income countries ($W_s = 318.00$, $z = -2.10$, $p < .05$, $r = -.29$). There are no significant differences between countries high in hydropower production and non-Hydro countries in both timeframes. On the other hand, countries high in hydropower construction do seem to experience the same level of conflict as both OPEC and Low income countries in both timeframes (no significant differences emerge). However, they experience significantly more conflict than non-Hydro countries, both from 1980 to 1995 ($W_s = 18\ 207.50$, $z = -2.15$, $p < .05$, $r = -.15$) and from 1996 to 2010 ($W_s = 18\ 354.00$, $z = -2.27$, $p < .05$, $r = -.16$).

A similar picture emerges when applying regression analysis to the data set (Table 4). In both timeframes, hydropower construction rate seems to have a positive effect on the number of conflict years (however, only the effect in timeframe 2 reaches significance), while the hydropower production rate seems to have a negative effect by trend. That is, countries constructing hydropower have more conflict years than those that do not, although the effect size is small.

3.2 Hydropower and poverty

Our empirical results partially support this hypothesis. While for both hydropower construction and production all effects were in line with the hypothesis by trend, only one out of four conducted tests for both hydropower construction and production showed significant results. As Figure 1 reveals, our non-parametric tests indicate that countries high in hydropower production have a significantly lower poverty gap than Low Income Countries (to be expected), both from 1980 to 1995 ($W_s = 81.00$, $z = -2.32$, $p < .05$, $r = -.45$) and from 1996 to 2010 ($W_s = 261.50$, $z = -2.92$, $p < .01$, $r = -.44$). The same is true for countries high in hydropower construction, which also have a significantly lower poverty gap than Low income countries both from 1980 to 1995 ($W_s = 197.00$, $z = -3.60$, $p < .001$, $r = -.61$) and from 1996 to 2010 ($W_s = 110.50$, $z = -2.05$, $p < .05$, $r = -.34$). However, it seems that countries high in either hydropower production or construction have a higher poverty gap than non-hydro countries as well, though apart from countries high in hydropower construction from 1996 to 2010 ($W_s = 5\,415.00$, $z = -2.08$, $p < .05$, $r = -.20$), these differences do not reach significance.

The application of regression analysis to the dataset lends further support to our finding. Both hydropower construction and production rates seem to have positive effects on the poverty gap by trend, meaning that the higher the rate, the higher the poverty gap. This effect is far more pronounced for the production rate which yields a significant and very strong effect from 1996 to 2010.

3.3 Hydropower and development

Our empirical findings partially support this hypothesis. For hydropower construction, all four conducted tests were in line with the hypothesis by trend, while only two showed significant results. For hydropower production, all four conducted tests were also in line with the hypothesis by trend, although the trend was far weaker, and only one test showed significant results. The non-parametric analysis, shown in Figure 1, suggests that both of the hydropower country classes seem to have a higher GDP per capita than Low Income Countries (perhaps expected), *but* a lower GDP per capita

than OPEC and non-hydro countries. Regarding the comparison of both hydropower country classes with Low income countries, all differences in both timeframes reach significance ($p < .01$); effect sizes are between $r = -.45$ and $r = -.61$, indicating strong effects. Regarding the comparison of both hydropower country classes with OPEC countries, only the differences from 1996 to 2010 reach significance. OPEC countries have a significantly higher GDP per capita than both countries with high hydropower production rates ($W_s = 251.00$, $z = -2.40$, $p < .05$, $r = -.42$) and countries with high hydropower construction rates ($W_s = 94.00$, $z = -2.52$, $p < .05$, $r = -.51$). The same is true for non-hydro countries: Non-hydro countries have a significantly higher GDP per capita than both countries with high hydropower production rates ($W_s = 1344.00$, $z = -2.22$, $p < .05$, $r = -.16$) and countries with high hydropower construction rates ($W_s = 640.00$, $z = -2.26$, $p < .05$, $r = -.17$), but only from 1996 to 2010.

Our two regressions analyses only strengthen this finding. Both hydropower construction and production rates seem to have negative effects on GDP per capita, at least by trend, since only one of the effects becomes significant.

3.4 Hydropower and fiscal responsibility

Our empirical findings partially support this hypothesis, but only for hydropower construction: All four conducted tests were in line with the hypothesis by trend, while only two showed significant results. The comparative analysis does not yield clear results, as Figure 1 illustrates. It seems that hydropower country classes have higher external debt stocks than both OPEC countries and non-hydro countries by trend. However, only the difference between countries high in hydropower construction and non-hydro countries from 1980-1995 reaches significance ($W_s = 4\,926.00$, $z = -2.07$, $p < .05$, $r = -.20$).

Our regression analyses adds some nuance to this finding. A high construction rate seems to have a positive effect on external debt stocks, while for production rates no clear image emerge. That is, the more hydropower you build, the more in debt you become; but once built, ostensibly because dams are being paid off (the more you have, the less you need to build), debt ratios decline over time.

One explanation here seems to be that even though hydropower projects generate debt and suffer from overruns, in the long-run they pay if off, in most cases, with positive economic gains. Hydroelectricity supports lighting, communication, transport, commerce, manufacturing, industry, and agricultural productivity (though as the hypothesis about GDP shows growth may be comparatively slower than in other countries). Still, the IPCC have indicated that large hydropower projects can bring salient “multiplier effects” of \$0.40 to \$1 for every \$1 invested beyond the cost of the dam (Kumar et al. 2011). Yang (2003) has also calculated in China that every Yuan invested into hydropower projects brings 5.13 Yuan in generated GDP. Electricity makes so many things possible that some have even viewed its provision as a fundamental human right (Bradbook and Gardam 2006). A secondary explanation may be that hydropower dams seem costly in an absolute sense, but are still better than some alternatives in a comparative sense. Levent (2010) noted that in the absolute sense the construction of dams have negative consequences for Turkey, but were comparatively less polluting—and ultimately better for the economy—than the coal-fired power plants that could have been built in their absence.

3.5 Hydropower and corruption

Our data does not support this hypothesis about corruption. Although the four conducted tests are all in line with the hypothesis by trend, none of them reaches significance. Results of our nonparametric tests are shown in Figure 1. Both hydropower country classes seem to have a more

negative score in the control of corruption index by trend than non-hydro countries; however, these differences do not reach significance. Also, both hydropower country classes seem to have a slightly higher score in the control of corruption index than both OPEC and Lower income countries; however, only the difference between countries high in hydropower production and Lower income countries reaches significance ($W_s = 725.50$, $z = -2.32$, $p < .05$, $r = -.32$).

Our regression analyses also did not support this hypotheses. While no significant effects emerged, it seems that hydropower construction and production rates have a small negative effect on control of corruption by trend.

One explanation, sadly, may be that corruption is prevalent across all types of projects, not just hydropower dams or energy infrastructure. While Haas (2008) estimates that corruption in the hydropower sector accounts for \$5 to \$6 billion of lost revenue each year, this pales in comparison to corruption across the global economy. Plummer (2008) offers the “best-case scenario” that 10 percent of the budget of all infrastructure projects is siphoned off due to corruption and a “worst-case scenario” of 30 percent. Given that the World Economic Forum reports that global spending on infrastructure amounts to about \$2.7 trillion each year (Economist 2014), then the price tag for corruption ranges from \$270 billion to \$810 billion. The World Bank (2013) has similarly published a “conservative estimate” that annual worldwide bribery—only one type of corruption—is a \$1 trillion industry. Hydropower corruption, if Haas is accurate, amounts to less than 1-3 percent of these amounts.

4. Conclusion and Implications

In sum, of the five hypotheses derived from the academic literature about hydropower and security, poverty, development, debt, and corruption, our analysis of key country metrics from 1980 to 2010 partially supports all but one. Moreover, Table 5 only shows results if they reach significance – it

is interesting to note that even if the results did not reach significance, the trend (direction) of all conducted tests in both timeframes is always in line with what our hypotheses would suggest. With regard to the poverty gap, both hydropower constructing and producing countries had a higher poverty gap in both timeframes than non-hydro countries, and in the regression analysis both the construction and production rate had positive effects on the poverty gap in both timeframes (even though most of these effects did not reach significance). It is noteworthy that we found with significant effects that hydropower influences a country's governance, economic and development indicators even though it stands for such a small part of respective countries' economies.

INSERT TABLE 5 HERE

Therefore, we can tentatively summarize our results as follows: hydropower construction rates seem to decrease GDP per capita and increase external debt stocks and conflict years. Overall, hydropower countries seem to perform slightly worse than OPEC and non-hydro countries in selected economic and governance indicators, but better than Low income countries. Furthermore, it seems possible that hydropower production rates increase the poverty gap (this was the strongest effect by far in the conducted regression analysis). With this in mind, we advance three separate conclusions.

First, our analysis lends statistical support to the idea that there is such a thing as a sort of "hydroelectric resource curse," although effects were not always significant and varied from small, medium to large. The possible benefits of hydroelectricity—improved energy access, economic development, positive spillover effects—are real, but they are all too frequently constrained. Dams, while ostensibly championed for reasons of economies of scale and the ability to bring about industrialization, for some reason fail to address broader development goals such as raising income at a faster rate than other countries, especially members of OPEC and non-hydro countries. This finding does question the belief that electricity ought to be viewed primarily as a means to achieve economic

development, or at least growth in GDP. In other words, our study challenges the model that GDP growth and per capita energy consumption must go hand in hand and that the trickle-down benefits from industrialization and rapid economic growth will bring national competitive advantage.

Second, however, is that our analysis provides only partial support to our hypotheses. One weakness is that our approach relied on a static number of variables rather than a more dynamic methodology which could be utilized in future research. Moreover, even within this approach, we were unable to strongly confirm either one across both classes of hydropower countries, both conducted analyses and both time periods. Why? It may be that the studies from which we derived our hypotheses look at the very real consequences of dams in an absolute sense, detailing the incidence of cost overruns or the severity of poverty impacts. These shortcomings of dams, however, do not exist in a vacuum; at the same time, countries and planners are erecting many other types of infrastructure and embarking on scores of industrial projects. It could be that these other projects degrade and marginalize people to a greater degree than hydropower dams, to the extent that countries pursue hydroelectricity (compared to, say, nuclear power or coal) generally perform better on selected indicators than those that do not. Nor do hydropower projects always produce net costs—their benefits in some cases outweigh their costs, though these may occur in urban areas far removed from the dam itself. The question here is one of scale and scope: hydropower compared to what, and at what geographic scale? Change either of these assumptions and you may alter the perception of hydropower.

Third, our data suggests that current trends in hydropower generation must be closely scrutinized. The World Bank's support in recent years for large-scale hydropower as an aid in international development may be founded on mistaken assumptions regarding the long-range costs of given projects. These projects, such as the Bank-supported Grand Inga Dam in the Democratic Republic of Congo, are all planned on a transformational scale, and designed in part for their speedy

and far-reaching economic impact. Our data suggests that the nature of projected economic impact for such projects must be reevaluated. The likelihood is that projected debt for host countries is currently underestimated, as is the time span during which construction of these projects will tie up resources and distract from alternative development goals.

Moreover, and critically, planners, investors, and analysts may need to rethink their underlying assumptions about how they evaluate hydropower's risk. Hydropower projects are almost always site-specific in their size, management, costs, and benefits. This suggests that there may not be a "one-size-fits-all" method of evaluating them, or determining their social and environmental impacts. These will play out differently at each particular location, forcing evaluators to examine hydropower on a case-by-case basis. Some projects may place their reservoirs in high mountain areas or remote deserts with no local populations to relocate and minimal impacts on the environment. Others in low-lying riverbanks may see substantial risks to fisheries, flooding, and food security. Still others in may involve the inundation of highly valued land and the involuntary resettlement of thousands or even millions of people. The question "is hydropower good for security" or "is hydropower good for development" is never predetermined—it demands we ask different questions about not only the magnitude of costs and benefits, but the equitable nature and timing of their distribution.

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