Is there a net economic loss from employing reference class forecasting in the appraisal of hydropower projects?

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Abstract

This paper investigates the potential effects of the use of reference class forecasting on the World Bank's financing decisions and quantifies the net economic impact of such decisions in the long run. A set of 57 World Bank-financed hydropower projects constructed between 1975 and 2015 were selected based on data availability. The findings show that reference class forecasting can help reduce net losses by preventing some hydropower projects with negative economic net present values from being executed. However, it also leads to the forfeiture of even larger amounts of net economic benefits by causing the rejection of some projects that are found, from ex-post analysis, to be economically worthwhile. Furthermore, because of the increased ex-ante rejection of projects, the loss of potentially economically positive projects from the portfolio of hydro dam projects is greatly increased. The errors in the estimation of economic net present values of these hydropower projects are highly positively correlated to the errors in the estimation of the benefits and only weakly negatively correlated to the errors in the estimation of costs.

Keywords: Reference Class Forecasting, Planners Fallacy, Hydropower, Cost Overruns, Economic Welfare, World Bank

JEL Classification: D61, G31, O13, Q42

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1. Introduction

This study seeks to determine whether raising the estimates of the ex-ante real cost of hydropower projects through reference class forecasting has a positive or negative long-run effect on the economy. Due to the World Bank's status as the largest and probably most influential financier of hydropower projects [1], hydro dams financed by the World Bank serve as the data source for this study.

Hydropower is the largest renewable energy source in the world. With an installed capacity of 1,267 GW, it provides 16.4% of global electricity [2]. Investments in hydropower continue to grow rapidly. In 2017, new investments totaling US$48 billion were committed to hydropower projects. On an annual basis, the use of hydropower in place of coal helps the world avoid 148 million tons of particulates, 62 million tons of sulfur dioxide, and 8 million tons of nitrogen oxide [2].

1.1 The case for using reference class forecasting in the estimation of investment costs

The construction of hydropower plants generally involves very complicated planning and execution. Proper project planning and execution in the face of these associated complexities become extremely difficult in the absence of adequate and reliable information at the project appraisal stage. Hydropower projects are thus often exposed to significant cost overruns [3-7]. Cost overruns represent a source of uncertainty in hydropower projects and can cause huge losses that are damaging to its stakeholders [8-10]. Improving the accuracy of estimated costs for a hydropower project is therefore very important.

Traditionally, hydropower projects are evaluated using the 'inside view' approach, which focuses on the unique characteristics of the project at hand. This method is intuitively preferred in forecasting; after all, the human way to think about a problem is to apply the knowledge one has of it while considering the specific project's unique characteristics. Advocates of this approach are referred to as evolution theorists. Psycho-strategists, however, argue that this approach ignores the lessons learned from similar projects that have already been executed – the 'outside view' [11]. Taking an outside view makes it possible to pool relevant information from past similar projects. Hanson [12] argues that a comparative application of both approaches will clearly show that the outside view is able to generate the most realistic estimates.

Kahneman and Tversky [13], Kahneman and Egan [14], and Flyvbjerg and Budzier [15] suggest that project planners, when faced with uncertainty, should support their decision-making with information collected from an already implemented reference class of projects. Such information may be employed to establish a likelihood of alternative outcomes and possible deviations from estimated costs. Awojobi and Jenkins [16] make a strong case for reference class forecasting when appraising hydropower dams by claiming that it equips decision-makers with information on the likelihood of occurrence of cost overruns, thereby helping to minimize forecast errors due to cognitive bias and strategic misrepresentations. Reference class forecasting has already been endorsed by the American Planning Association, the British Department for Transport, and the governments of Australia, Denmark, and Norway [11, 16, 17].

It is generally claimed that the underlying root causes of cost overruns and benefit shortfalls are due to one of three factors: technical, psychological, and politico-economic (8). Technical factors most commonly manifest in the form of faulty forecasting techniques, lack of experience of the forecasters, limited data, inability to properly predict future occurrences, and innocent mistakes by forecasters [8, 18-20].

Psychological factors show up in the form of planning fallacies and optimism biases [21-23]. These are errors in human judgment that are psychological in nature when using the inside view. Optimism bias refers to the tendency to overestimate the probability of positive outcomes and underestimate the probability of negative outcomes. Most people tend to view future outcomes more positively than what real-life experience suggests due to overconfidence and disregard for distributional information [13, 15, 21]. Project planners therefore often underestimate project costs and overestimate project returns. This is commonly referred to as the planner's fallacy.

Politico-economic factors refer to the tendency of project planners and supporters to intentionally underestimate project costs and overestimate project benefits as a strategy to increase the chances of one project being implemented over competing projects [18-20]. In the opinion of these researchers, this problem is caused by political and organizational pressures that induce project planners and supporters to amplify the likelihood of success and downplay the potential for failure in order to obtain funding.

A number of researchers have concluded that in forecasting estimation errors, technical factors are not as important as psychological and politico-economic factors [8]. Therefore, it is concluded that to prevent cost overruns, cost estimates require de-biasing and not error correction [22, 24]. The use of reference class forecasting to correct the potential biases has been strongly recommended. This is done by establishing optimism bias uplifts that are added to the cost estimates obtained through the inside view approach.

1.2 Reference class forecasting and the risk of rejecting good investments

There is, however, a potential flaw in the use of reference class forecasting that has yet to be closely investigated. Reference class forecasting involves establishing optimism bias uplifts to estimated costs. When these uplifts are added to the cost estimates, on the one hand they raise the project cost and lower the likelihood of overruns, but on the other, they also increase the probability that a project will be rejected when a cost-benefit analysis is conducted at the appraisal stage. The reason is obvious: reference class forecasting tends to raise the cost estimates while leaving the benefit estimates unchanged. This will, in turn, lower the project expected returns in most cases and could lead to projects being rejected at the appraisal stage that, if implemented, would have been viable. In other words, while reference class forecasting may help prevent bad projects with a negative economic net present value (ENPV) from being approved, it may also lead to the rejection of good projects (projects that would have had a positive ex-post ENPV if implemented). In reality, many projects that experience cost overruns during construction often record benefits that far outweigh the associated costs. A typical example is the Chukha Hydel power project in Bhutan, which experienced a very severe cost overrun of about 159% in real terms, yet was still able to create a present value of economic benefits that greatly exceeded the present value of its actual costs [25]. Ultimately, whether the use of reference class forecasting when planning hydropower projects helps or hurts economic welfare is an empirical question. We therefore wish to investigate how the ENPV of this set of World Bank-financed hydropower projects would have been affected by the use of reference class forecasting of investment costs.

Against this background, the structure of this study is as follows: Section 2 describes the research methods used; Section 3 presents the empirical results, and the final section provides the conclusion and policy implications of the findings.

2. Research methods

The research methodology is conducted in two phases. In the first phase, we compute the actual cost overruns for each of the hydropower projects, then calculate the ENPVs associated with each of the projects. The objective is to determine whether some of the projects turned out net economically beneficial in the long run, despite the cost overruns experienced during construction.

In the second phase, we employ reference class forecasting to determine whether the hydropower project outcomes could have been improved by taking an outside view. We calculate the uplift size required to limit the probability of cost overruns to certain percentages and apply the uplifts to each of the projects. We then identify and quantify the value of the bad projects (projects that eventually resulted in a negative ENPV) that would have been avoided if the uplifts had been applied to the ex-ante cost estimates. This value is then compared with the value of good projects (projects with positive ENPVs) that would have been rejected ex-ante if the uplifts had been applied to the original cost estimates. The World Bank decides on the suitability of projects for funding using the criterion that the estimated ENPVs must be positive at a hurdle discount rate or the economic internal rate of return (EIRR) must be larger than the discount rate. Thus, our aim is to examine how the use of reference class forecasting might have affected the World Bank's financing decisions ex-ante and to quantify the overall effect of such decisions.

2.1. Determination of costs and cost overruns of the hydropower projects

The study sample is made up of 57 World Bank-financed hydropower projects completed between 1975 and 2015. Due to the high level of complexity involved in the measurement of the benefits of multipurpose dams and pumped storage dams, only purely hydropower projects are considered. Of the 57 power projects in this sample portfolio, 16 are located in East Asia and the

Pacific, 16 in Latin America and the Caribbean, 12 in sub-Saharan Africa, 8 in Europe and Central Asia, and 5 in South Asia. Information was made available by the World Bank Group that allowed the estimation of the actual ex-post economic performance of each of these hydropower projects. Furthermore, for 43 of these hydro dams, information is available to allow the ex-ante World Bank estimates of costs, benefits, and ENPVs to be derived for each of the dams. Information about the sampled projects is reported in Table A1 of the appendix.

In preparation for the estimation of the project cost overruns, the following costs are determined: estimated nominal cost, estimated real cost, actual nominal cost, and actual real cost. The estimated nominal costs are collected on a project-by-project basis from the World Bank's Staff Appraisal Reports (SARs) and Implementation and Completion Reports (ICRs). The estimated nominal costs reported in the World Bank documents include both the project base cost and the provisions for contingencies (price and physical). The estimated real cost is derived by subtracting the provision for price contingency from the estimated nominal cost. This is because the price contingency represents provision for changes in the prices of inputs [7, 26].

The actual nominal costs (expressed in nominal US dollars) are collected directly from the ICRs of the World Bank. The actual real costs are obtained by deflating the actual nominal costs. To convert the actual nominal costs to actual real costs, the actual nominal cost is first distributed over the entire period of project construction as shown in equation 1.

$$\mathrm{Y_i} = \frac{1}{2+\mathrm{p}}\left[(\mathrm{s}+1)\left(\frac{\mathrm{i}}{\mathrm{I}}\right)^{\mathrm{s}}\left(\mathrm{p}+\pi\sin\left(\pi\left(\frac{\mathrm{i}}{\mathrm{I}}\right)^{\mathrm{s}+1}\right)\right)\right] \quad (1)$$

where Y_i represents the proportion of project capital expenditure allocated to the ith year of construction, S stands for the cost lay-out curve skewness, which is assumed to be 0.2 for a positively skewed curve over the construction cycle, and *P* denotes the flatness of the curve, which varies with construction cycle length.

The annual nominal costs are then divided into their domestic and foreign components. The domestic component is next converted from nominal US dollars to its domestic currency equivalent at the prevalent exchange rate, and then deflated with the prevalent domestic price index. It is again reconverted to its US dollar equivalent for the project start year. The foreign component of the actual nominal cost is deflated with the prevalent price index of the United States. Equation 2 is the formula for obtaining the actual real cost.

$$\text{Actual real cost} = \sum_{i=0}^{T} \frac{C_i^{n\$} * FCX}{I_{o,i}^{F}} + \frac{1}{E_0^m} \sum_{i=0}^{T} \frac{C_i^{n\$} * (1 - FCX) * E_i^m}{I_{0,i}^{D}} \qquad (2)$$

where $C_i^{n\$}$ represents the actual nominal cost, *FCX* denotes the foreign component of total cost, and I^F and I^D stand for foreign and domestic price indexes, respectively.

To determine the real cost overrun in percentiles, two approaches are adopted. In the first approach, the difference between the actual real cost and estimated real cost is given as a percentage of the estimated real cost, as shown in equation 3.

$$\text{Cost overrun} = \frac{(C_a - C_e)}{C_e} \times 100 \qquad (3)$$

where C_a is the actual real cost of the project and C_e is its estimated real cost.

The second approach expresses the difference between the actual real cost and estimated real cost as a percentage of the actual real cost. It is specified as follows:

$$\text{Cost overrun} = \frac{(C_a - C_e)}{C_a} \times 100 \qquad (4)$$

2.2. Measuring benefits and benefit overruns of the hydropower projects

The ex-post real benefits of each of the hydropower projects are estimated. Following Awojobi and Jenkins [7], the real benefits of each of the hydropower projects are taken to be equivalent to the cost of building and operating alternative fossil fuel-powered plants capable of generating the same quantity of electricity as the hydropower plants. The configuration of the alternative generation technologies selected was based on those specified by the electricity system planners in the World Bank SARs. The calculation is done in two parts. First, cost savings on the fixed capital cost of the alternative fossil fuel-powered plant are estimated. Second, the marginal running costs of the alternative fossil fuel-powered plants are estimated. The ex-post real benefits are obtained using equation 5.

$$\text{Actual real benefit} = \sum_{t=0}^{Z+40} \left\{ \left| k \frac{r(1+r)^N}{(1+r)^N - 1} IC \right| + VOM + (f_t p_t) G_t \right\} (1+r)^{-t} \qquad (5)$$

where Z is the actual completion period, 40 years represents the life cycle of the hydropower project, k is the capital cost, N is the economic life of the fossil fuel-powered alternative energy plant, IC stands for installed capacity, VOM is the variable operating and maintenance cost, f_t represents fuel requirement at time t, P_t refers to fuel price at time t, and G is the equivalent output of electricity generated from hydropower plant at time t. Readers are referred to Awojobi and Jenkins [7] for a detailed explanation of the calculation of the net benefits.

The real benefit overrun in percentiles is also estimated as the difference between the actual real benefit and estimated real benefit as a percentage of the actual real cost. The actual costs are used as the common denominator for making comparisons between cost overruns, benefit overruns, and deviations between the ex-ante estimated NPV and the ex-post NPV. The formula is shown in equation 6.

$$\text{Real benefit overrun} = \frac{(B_a - B_e)}{C_a} \times 100 \qquad (6)$$

where B_a is the actual real benefit of the project and B_e is the estimated real benefit of the project.

2.3. Estimating ENPVs and ENPV overruns

Once the costs and benefits for the hydropower projects have been derived, the ENPV of each project is obtained by subtracting the actual real cost from actual real benefits for each year. The difference is then expressed as a stream of net economic benefits over time and then discounted back to the year in which construction started for each project. These ENPVs are then all expressed in the 2016 price level in order to be comparable. To arrive at the ENPV overrun in percentiles, we take the difference between the ex-post real net present value and estimated ex-ante real net present value as calculated from data provided in the World Bank SARs. Both calculations are expressed in 2016 US dollars. These differences are then expressed as a ratio of the actual real cost. The formula is presented in equation 7.

$$\text{Net benefit overrun} = \frac{(ENPV_a - ENPV_e)}{C_a} \times 100 \qquad (7)$$

where $ENPV_a$ is the actual (ex-post) real net present value of the project and $ENPV_e$ is the estimated (ex-ante) real net present value of the project. The rationale behind the computation of overruns (cost, benefit, and ENPV) presented in equations 4, 6 and 7 is that it makes for ease of comparison. All three equations are set to the same base, which is the actual real cost (C_a) of the project.

2.4. Applying reference class forecasting to World Bank-financed hydropower projects

We now attempt to de-bias the ex-ante appraisal cost estimates through reference class forecasting. We determine the required adjustments to the ex-ante real cost contingencies of the hydropower projects so as to limit the probability of cost overruns to a given percentage. We then recalculate the cost overruns for each of the hydropower projects using the uplifted ex-ante real cost contingencies and determine how many of the projects that actually recorded negative ENPVs would have been prevented.

In general, a reference class refers to a distinct project class containing projects that are statistically similar. Figure 1 summarizes the rationale behind reference class forecasting. The general idea is to regress the best estimate of the conventional forecast toward the mean of the reference class and also to expand the estimate of conventional forecast interval to the reference class interval.

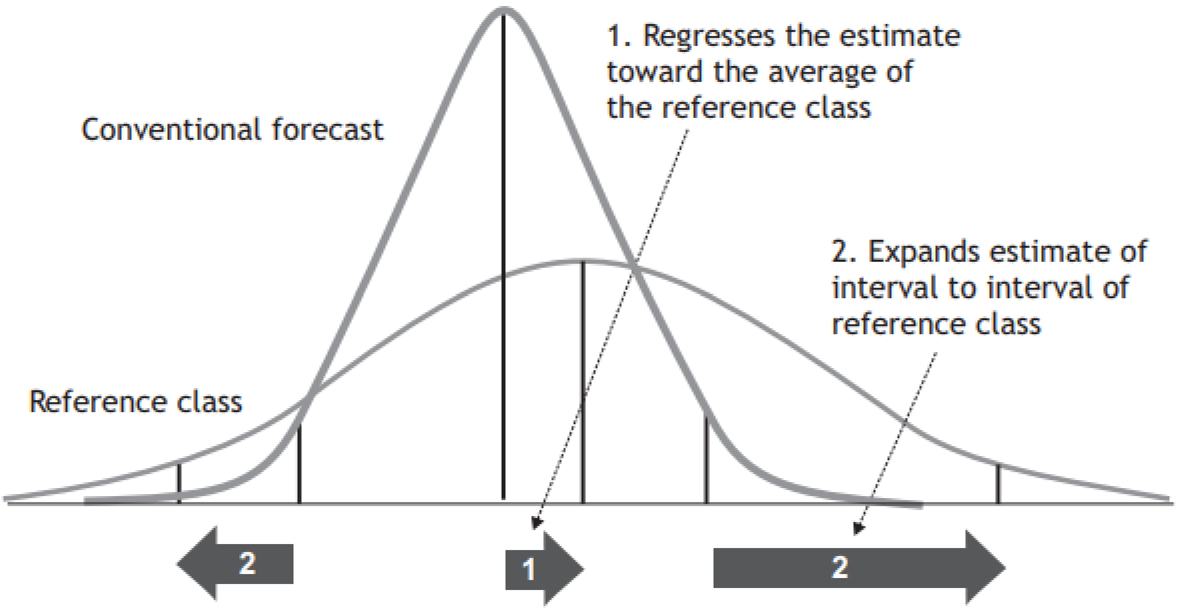

Figure 1. Reference class forecasting

The steps involved in reference class forecasting are as follows [27, 28]:

1) Determining the reference classes on the basis of past projects.
2) Generating probability distributions for the determined reference classes.
3) Establishing optimism bias uplifts for each of the determined reference classes.

According to Flyvbjerg et al. [16], a reference class, on the one hand, should not be so narrow that determining reliable optimum biases becomes too difficult, and on the other hand, should not be so wide that projects within the same reference class become incomparable. To avoid these problems, we begin by treating World Bank-financed hydropower projects as a single reference class, relative to other types of power projects such as multipurpose dams, nuclear, thermal, wind, and solar. This is not a new approach, as Sovacool et al. [29] likewise considered hydroelectric dams as a single reference class in comparison to other types of power plants. Next, we generate a cumulative frequency for all the possible overruns for the sample data. We then proceed to determine the number of projects that fall within a specified maximum overrun figure. Finally, we plot the probability distribution of the model.

3. Results and discussion of findings

Computations are made of the ex-ante estimated costs, ex-post actual costs, and cost overruns as percentages of estimated costs.* Overall, 40 projects (70% of total projects) suffered from construction costs in excess of those projected at the appraisal stage. Average real cost overrun as a percentage of estimated cost for the entire project sample is about 24%. This figure, though slightly lower, is not far off the 27% reported by Bacon et al. [26] and Awojobi and Jenkins [7] for hydropower projects built during different periods, but using the same formula. Projects

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[*] Detailed results for the costs and cost overruns of the 57 hydropower projects are provided in Table A2 of the appendix.

executed in Latin American and Caribbean countries suffered the most cost overruns in real terms (average cost overrun of 52.19% for projects executed in the region), followed by projects in South Asia (average cost overrun of 30.18%) and then in East Asia and the Pacific (average cost overrun of 13.66%). On average, the real cost overruns were less than 10% for projects conducted in Europe and Central Asia, and in sub-Saharan Africa.

A key insight that can be gleaned from the findings is that the underestimation of costs is widespread and severe in hydropower projects. This is consistent with the claim by Awojobi and Jenkins [7] that project planners grossly underestimate the magnitude and range of physical contingencies required by hydropower projects. It also provides some justification for the claim by Flyvbjerg and Budzier [15] that project planners often underestimate project costs.

In the second phase of the analysis, reference class forecasting is employed to determine whether the hydropower project outcomes could have been improved by taking an outside view. Optimism bias uplifts for various levels of acceptable risk of cost overruns are determined from the probability distribution of the cost overrun values established in phase 1.

Figure 2 shows the probability distribution of the cost overruns for the sample data. It confirms that approximately 30% of the projects have a maximum cost overrun of 0%. This indicates that about 30% of the projects included in the sample have actual project costs that are equal to or less than the estimated project costs. Approximately 23% of the projects experience cost overruns within the range 1–20%. It also shows that about 24% of the projects experience cost overruns within the range 21–40%, and about 23% of the projects have cost overruns in excess of 40%.

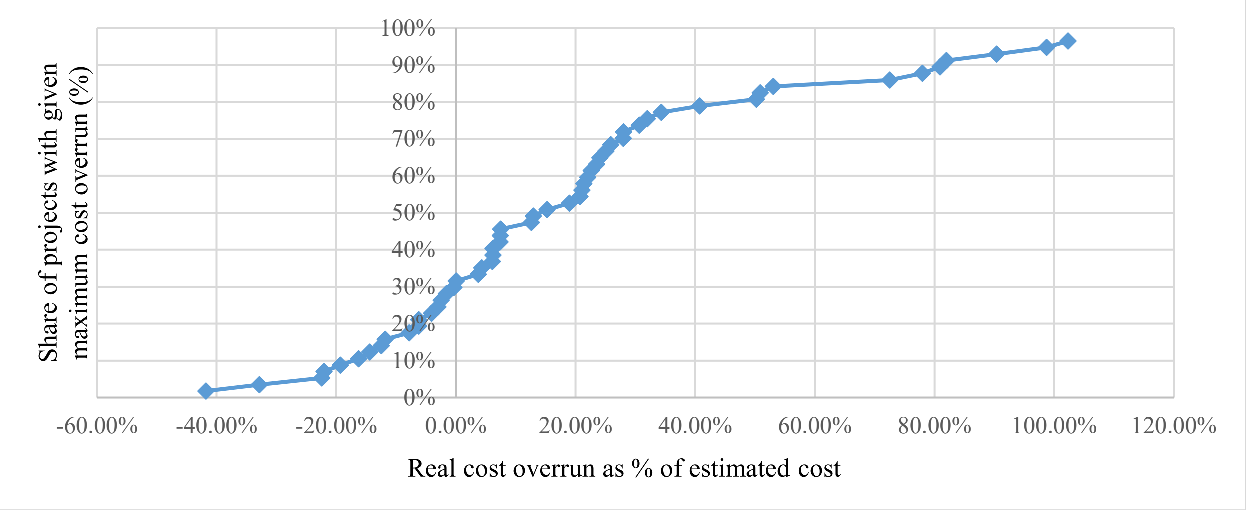

Figure 2. Probability of cost overrun, N=57

To determine the required optimism bias uplift for the hydropower projects on the basis of the probability distribution generated, we follow the method suggested by Bayram and Al-Jibouri [28]. The uplifts relative to risk appetite are established such that higher levels of risk averseness attract higher uplift, and vice versa. The required optimism bias uplift is calculated in the following way. First, the acceptable cost overrun choices are specified between 0% and 100% for the sample data, and the required uplift for each percentile is then calculated to determine the required uplifts. This is reported in Figure 3. This shows that with a willingness to accept a 40% risk of cost overrun in hydropower projects, an uplift of 22.38% will be required. Hence, to cover 60% of the risk of cost overruns, project planners will need to increase project funding by 22.38%. If, however, the willingness falls to 20%, an uplift of 48.33% will be required. In other words, project funding will need to be increased by 48.33%.

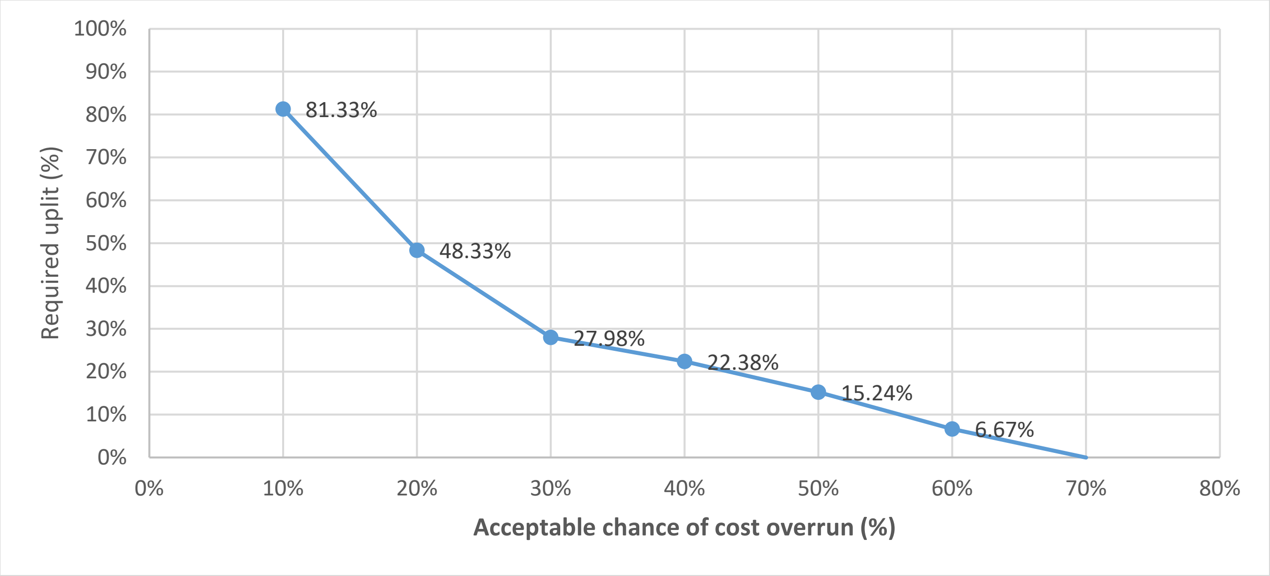

Figure 3. Required uplift as a function of the maximum acceptable chance of cost overrun

The calculated uplifts are applied to 43 power projects for which the ex-ante EIRRs are reported in the SARs (projects that fall into this category are represented with asterisks [*] in Table A1 of the appendix). Because the ex-ante estimated project benefits are reverse-engineered from the ex-ante EIRRs, the sample is reduced to 43 hydro dams.

3.1. Universal uplifts of estimated costs based on reference class forecasts

As reported in Table 1, row B1, column 2, according to ex-ante estimations, all the 43 hydropower dams were projected to yield positive ENPVs. However, in the estimates of the ex-post performance of these projects, 11 out of the 43 projects recorded negative ENPVs (Table 1, row A, column 1).

Table 1. Prevented bad projects vs. rejected good projects

	No. of negative ENPV projects (1)	No. of positive ENPV projects (2)	No. of negative ENPV projects that would have been prevented (3)	No. of positive ENPV projects that would have been rejected (4)
A. Ex-post (actual)	11	32	-	-
B. Ex-ante (estimated)				
1. No uplift	0	43	-	-
2. 6.67% uplift	2	41	1	1
3. 15.24% uplift	4	39	2	2
4. 22.38% uplift	11	32	4	7
5. 48.33% uplift	21	22	6	15
6. 81.33% uplift	29	14	7	22

With an uplift of only 6.67% (60% acceptable risk of cost overrun), 1 of the 11 projects that turned out ex-post to have negative ENPVs would have been rejected for financing by the World Bank (Table 1, row B2, columns 3 and 4). However, employing the uplift would also have led to the rejection of one project that turned out ex-post to be very viable and recorded a positive ENPV. With an uplift of 15.24% (50% acceptable risk of cost overrun), 2 of the 11 projects that turned out ex-post to experience negative ENPVs would have been rejected for financing by the World Bank (Table 1, row B3, columns 3 and 4). Again, employing the uplift would also have led to the rejection of two other projects that turned out ex-post to be very viable and recorded positive ENPVs. If the uplift is raised to 22.38% (40% acceptable risk of cost overrun), the number of projects with ex-post negative ENPVs that would have been rejected ex-ante with this uplift of costs increases to 4 out of the 11 bad projects. At the same time, this degree of uplift of costs would have caused the rejection of seven projects that turned out ex-post to have positive ENPVs (Table 1, row B4, columns 3 and 4). With an uplift of 48.33% (20% acceptable risk of cost overrun), we would be able to eliminate 6 of the 11 projects that eventually experienced negative ENPVs, but this would also have caused the World Bank to drop financing for 15 projects that were viable ex-post (row B5, columns 3 and 4). For a 10% acceptable chance of cost overrun, an uplift size that is almost as high as the original estimate (81.33%) is required. It would have caused 7 of the 11 negative ENPV projects to be rejected ex-ante, but would have also brought about the elimination of 22 of the 32 projects that eventually recorded positive ENPVs (row B6, columns 3 and 4).

Table 2. Value of prevented bad projects vs. value of rejected good projects

	Total negative ENPV of projects that would have been prevented (US$M)	**Total positive ENPV of projects that would have been rejected (US$M)**	**Net loss in ENPV (US$M)**	**Percentage of ENPV lost (%)**	**Ex-post (actual) ENPV (US$M)**
	(1)	**(2)**	**(3)**	**(4)**	**(5)**
1. Ex-post (actual)	**-**	**-**	**-**		**20,022.61**
2. 6.67% uplift	−28.42	62.12	33.70	0.2	**19,988.91**
3. 15.24% uplift	−43.00	287.23	244.23	1.2	**19,778.38**
4. 22.38% uplift	−228.16	2,738.77	2,510.61	12.5	**17,512.00**
5. 48.33% uplift	−349.17	4,069.63	3,720.46	18.6	**16,302.15**
6. 81.33% uplift	−444.87	6,361.21	5,916.34	29.5	**14,106.27**

In Table 2, the values of the net gains are quantified for the bad projects that could have been avoided if the uplifts had been applied to the ex-ante cost estimates. These values are then weighed against the value of the benefits that would have been lost because the uplifts raised the ex-ante costs of some other good projects and made them seem unviable at the appraisal stage. To begin with, Table 2 shows that the sum total of the ex-post (actual) ENPV amounts to US$20,022.61 million.[†]

With an uplift of 6.67%, the value of the losses (value of negative NPV) that could have been avoided as a result of the elimination of unviable projects ex-ante stands at US$28.42 million,

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[†] The NPVs that are summed for the projects are estimated as of the year of each project's initiation. The price level of the NPV value for each project has then been adjusted to the price level of 2016. In terms of the effect of discounting, carrying out the estimation of the NPVs in this way means that it is as though all the projects were started in the same calendar year. Otherwise, projects started many years ago would have larger cumulative benefits or costs than those that were implemented more recently, and this would have biased the results.

while the value of the positive NPV projects that would have been lost stands at US$62.12 million. This suggests that a 6.67% uplift would have resulted in a net loss of US$33.70 million, or 0.2% of the economic value of the portfolio of hydro dams (Table 2, row 2, column 4). Also, with an uplift of 15.24%, the value of the losses (value of negative NPV) that could have been avoided as a result of the elimination of unviable projects ex-ante stands at US$43 million, while the value of the positive NPV projects that would have been lost stands at US$287.23 million. This suggests that a 15.24% uplift would have resulted in a net loss of US$244.23 million, or 1.2% of the economic value of the portfolio of hydro dams (Table 2, row 3, column 4).

With an uplift of 22.38%, losses equaling US$228.16 million could have been prevented, whereas projects with ENPV total value of US$2,738.77 million could have been lost. This is a net loss of over US$2,510.61 million or 12.5% of the economic value of the portfolio of hydro dams (Table 2, row 4, column 4). When the acceptable risk of cost overrun is changed to 20% and the corresponding uplift size rises to 48.33%, preventable losses would rise to around US$349.17 million and forfeited benefits to approximately US$4,069.63 million at the same time. The implication is that a net loss of approximately US$3,729.46 million, or 18.6% of the economic value of the portfolio of hydro dams, would occur as a result of the application of reference class forecasting (Table 2, row 5, column 4). With an uplift of 81.33%, the losses that could have been prevented amount to US$444.87 million. The benefits that would have been lost come to US$6,361.21 million. A total net loss of US$5,916.34 million, or 29.5% of the economic value of the portfolio of hydro dams, would have been experienced before attempting to manage the risk of cost overruns by trying to correct for an alleged optimism bias (Table 2, row 6, column 4).

The overall results strongly suggest that when reference class forecasting is employed at the project appraisal stage, it may help to avoid the risk of cost overruns, but it greatly increases the risk of rejecting projects that would have made a positive contribution to the economic welfare of the country. The results show that as the willingness to accept cost overruns reduces (risk averseness increases) and the corresponding uplift size increases, the economic losses from preventing investments in bad projects are reduced while the ENPV lost from incorrectly not investing in good projects increases. The long-run effect of this positive correlation between losses avoided and benefits forfeited ultimately results in lower ex-post ENPV of the portfolio of projects under consideration.

3.2. Variability of benefits and ENPVs versus investment costs

This observation is further buttressed by the comparison of the cumulative distribution of costs, benefits, and ENPV overruns (with no uplifts) for the 43 projects presented in Figure 4.[‡] The graph shows that about 70% of the projects experienced cost overruns. This is an indication that actual costs are generally higher than those forecasted. This suggests that there may be other factors that have an influence in creating upward cost adjustments. For example, if opportunities to optimize the hydropower facility are discovered once work has started on the construction, one might find increases in costs above original estimates that are justified because the incremental benefits from optimizing the design are substantially larger than the incremental costs. For hydropower projects whose estimated benefits are believed, from a preliminary analysis, to be substantially larger than the estimated costs, such as in the case of the Chukha dam, it might not be justified to incur time delays and the losses of service associated with a longer planning period to develop a more finely calibrated estimations of costs when the revised

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[‡] Detailed results of the costs, benefits, ENPVs, and their overruns for the 43 projects are provided in Table A3 of the appendix.

cost estimates are not likely to change the approval decision. The issues associated with the costs inflicted on stakeholders due to delays in the implementation of hydro dams is discussed by Braeckman and Guthrie [30].

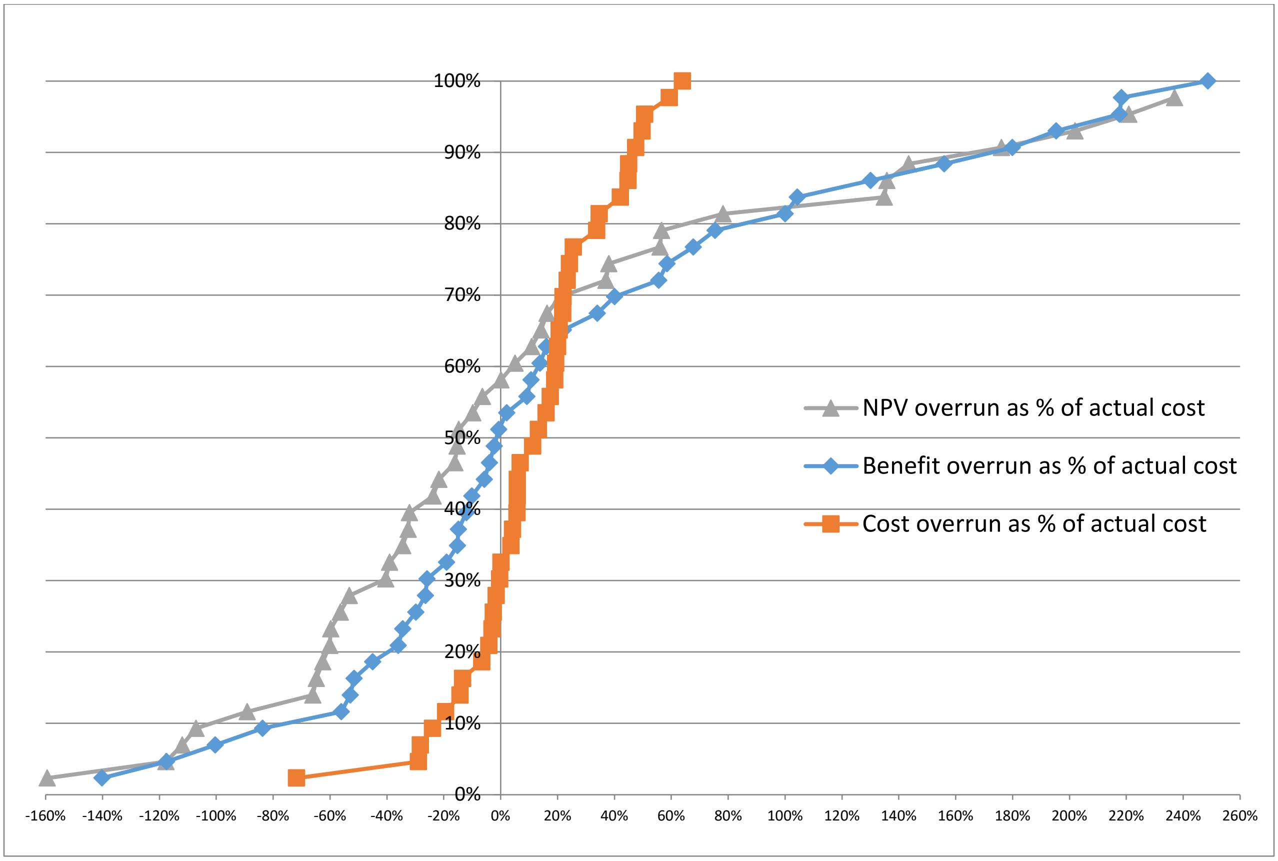

Figure 4. Cumulative distribution of costs, benefits, and ENPV overruns for the 43 projects

In Figure 4, the split between benefit overruns and underruns is a ratio of approximately 50-50. This is an indication that the mean of the distribution of forecast errors for benefits is approximately zero. The distribution of the benefit overruns thus shows that in spite of the imperfections in project forecasts, many of the projects still do well and there is no noticeable bias or skewness in the project benefit outcomes. This offers some evidence that runs counter to the claim by Flyvbjerg and Budzier [15] that project planners often systematically bias upward the estimated benefits of such projects. This outcome also lends some credence to the Benevolent Hiding Hand hypothesis of Hirschman [31, 32] and contradicts the Malevolent Hiding Hand hypothesis of Flyvbjerg and Sunstein [33]. According to Hirschman [31, 32], the hiding hand mechanism is a general phenomenon in which project planners go ahead and execute unrealistically optimistic projects that still end up with high net benefits as a result of unanticipated human ingenuity. A close examination of the individual projects shows that changes in work volume caused by the need to optimize project performance in line with client requirement is one of the leading causes of cost overruns. It may also be an important reason for the recorded improvements in project performances, as reflected by the benefit overruns.

Table 3. Correlation results

Variables	**Correlation coefficients**
Benefit overruns and NPV overruns	+0.96
Cost overruns and NPV overruns	−0.40
Benefit overruns and Cost overruns	−0.14

Figure 4 also shows that the distribution of ENPV overruns closely follows that of benefit overruns more than that of cost overruns. We statistically confirm this pattern by conducting correlations between benefit overruns and ENPV overruns and between cost overruns and ENPV overruns. The correlation coefficient of 0.96 reported in Table 3 indicates that there is a very strong positive correlation between benefit overruns and ENPV overruns. As shown in Table 3, however, the correlation coefficient of 0.4 indicates that the negative correlation between cost overruns and ENPV overruns is relatively weak. This suggests that the benefits derived from hydropower projects play a more important role than the costs incurred during construction in determining their overall long-run profitability. Although there is evidence that the inside view approach commonly underestimates the costs of hydropower projects, the ENPV results show that many of the hydropower projects with cost overruns still turn out to be economically worthwhile in the long run. Many even do better than initially estimated, as shown by the real ENPV overruns recorded in several projects. It is also worthy of mention that although the correlation between cost overruns and benefit overruns is negative, the size of the coefficient is quite small (−0.14). This further confirms the likelihood that projects that experience cost overruns will not likely be systematically suffering from benefit underruns.

4. Conclusion

This paper estimates cost overruns in 57 World Bank-financed hydropower projects constructed between 1975 and 2015 to determine whether some of the projects turned out to be beneficial in the long run in spite of cost overruns experienced during construction. Reference class forecasting was employed to determine whether the hydropower project outcomes could have been improved by taking an outside view.

The analysis showed that about 70% of the projects experienced cost overruns. Average cost overrun for all the projects stood at about 24%. The estimates showed that cost estimate errors are frequent occurrences in hydropower projects. This observation is consistent with the widely adopted inside view that the cost-benefit analysis approach to hydropower project appraisal to date has not been able to satisfactorily eliminate cost overruns.

We further examined whether the hydropower project outcomes could have been improved by taking an outside view. To this end, general project uplifts relative to risk appetite were established through reference class forecasting. The value of the bad projects (projects that eventually suffered net losses) that could have been avoided if the uplifts had been applied to the ex-ante cost estimates were then compared with the value of good projects (projects with positive

ENPVs) that would have been rejected ex-ante if the uplifts had been applied to the original cost estimates.

Our findings show that although reference class forecasting can help to reduce net losses by preventing some bad projects from being executed, it also causes substantial amounts of net benefits to be forfeited by the rejection of projects at the ex-ante appraisal stage of planning that, if implemented, would have yielded positive ENPV projects. The results show that as the willingness to accept cost overruns is reduced (risk averseness increases) and the corresponding uplift size increases, the losses from accepting projects that turn out bad are reduced, but at the same time the probability of rejecting positive ENPV projects increases by a greater amount. This suggests two important things.

First, if cost-benefit analyses and social and environmental impact assessments for hydropower projects are conducted to the standard required by the World Bank, project approval using reference class forecasting does not appear to improve the overall economic performance of the portfolio of the hydropower projects financed by the World Bank. It will, as a matter of fact, lower the overall economic welfare impact of its projects.

To support this position, Flyvbjerg [8] establishes that the comparative advantage of the outside view approach through reference class forecasting is more beneficial in non-routine projects, such as projects yet to be attempted by local managers or the introduction of new products into the market. As such, hydropower projects executed by experienced managers, using well-known technologies, are not likely to benefit very much from reference class forecasting. Love et al. [11] confirm that the use of quantitative tools, including stochastic modeling techniques such as Monte Carlo simulations, is a more effective means of mitigating project risks when compared with reference class forecasting.

Second, until now the focus has been on accounting for cost overruns and not economic welfare. Our findings, however, reveal that even when hydropower projects suffer huge cost overruns, they may still yield great net benefits [25]. We thus argue that it is the ex-post ENPVs that are most important for economic welfare and not errors in the forecasting of ex-ante costs. As a result, project planners need to be careful with the use of reference class forecasting in ex-ante cost estimations. While it can help reduce the risk of cost overruns, it is also likely to increase the probability that viable projects (projects that are able to generate positive ENPVs in the long run) will be rejected ex-ante.

This study recognizes that psychological and politico-economic factors are real challenges in infrastructural development. However, it clearly shows that the best way to deal with these problems is to ensure that very high standards in the quality of project appraisal are maintained. rather than relying heavily on reference class forecasting.

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Appendix

Table A1. List of World Bank-financed hydropower projects

#	Project ID	Capacity MW	Year started	Year construction completed
1	Gitaru HPP, Kenya*	145	1974	1978
2	Kapichira Hydroelectric, Malawi*	64	1992	2000
3	Ruzizi Hydroelectric, Burundi-Rwanda-CDR*	30	1983	1990
4	Kiambere Hydroelectric, Kenya*	150	1984	1988
5	Andekaleka Power, Madagascar*	56	1979	1982
6	Nkula II Project, Malawi	56	1977	1982
7	Mtera Hydroelectric, Tanzania*	80	1984	1991
8	Kidatu Hydropower Plant, Tanzania	200	1971	1975
9	Volta River Hydroelectric Project, Ghana	324	1977	1982
10	Kpong Hydroelectric, VRA, Ghana	160	1977	1982
11	Felou hydroelectric project, Mali, Mauritania, Senegal*	60	2007	2014
12	Bujagali, Uganda*	250	2007	2012
13	San Carlos, Colombia*	1,240	1980	1987
14	Fourth Guadalupe, Colombia*	213	1981	1986
15	Playas Hydropower, Colombia*	200	1983	1988
16	Itumbiara Dam, Brazil*	2,080	1974	1981
17	Pehuenche Hydroelectric Dam, Chile*	500	1988	1993
18	Nispero Power Project, Honduras	22.5	1979	1984
19	Guavio Hydro Power Project, Colombia*	1000	1983	1993
20	Paulo Afonso IV Complex, Brazil*	2,462	1974	1984
21	Aguacapa Power Project, Guatemala*	90	1978	1981
22	La Fortuna, Panama*	300	1978	1984
23	Chixoy Hydro-power, Guatemala*	300	1978	1982
24	El Cajon Hydropower Dam, Honduras	300	1981	1985
25	Aguamilpa Hydroelectric project, Mexico	960	1989	1995
26	Zimapan Hydroelectric project, Mexico	292	1989	1995
27	La Higuera, Chile*	155	2005	2010
28	Cheves Hydro, Peru*	168	2010	2015
29	GaziBarotha Hydropower, Pakistan*	1,450	1995	2003
30	Kerala Power Project, India	180	1986	1992
31	Rampur Hydropower project, India*	412	2008	2014
32	Allain Duhangan II, India*	192	2005	2012
33	Marsyangdi Hydroelectric, Nepal	69	1986	1989
34	Cirata Hydroelectric Site, Indonesia	500	1994	1999
35	Saguling Dam, Indonesia*	700	1981	1986
36	Bersia Hydroelectric project*	72	1980	1986
37	Kenering Hydroelectric project*	120	1980	1986

38	Ban Chao HPP, Thailand	360	1974	1979
39	Yantan Hydroelectric Project, China*	1,100	1987	1994
40	Lubuge Hydroelectric, China*	600	1985	1991
41	Ertan I, Sichuan, China*	3,300	1992	2000
42	Yonki Dam, Papua New Guinea*	30	1987	1991
43	Afulilo Hydropower project, Western Samoa*	6.3	1987	1992
44	Wailoa Hydroelectric, Fiji*	80	1977	1981
45	Dongping hydroelectric power plant, China*	110	2003	2008
46	Najitan hydroelectric power plant, China*	51	2003	2011
47	Songshuling hydroelectric power plant, China*	50	2003	2011
48	Xiakou hydroelectric power plant, China*	31.6	2003	2011
49	Guangrun hydroelectric power plant, China*	28	2003	2011
50	Karakaya Hydropower, Turkey*	1,800	1980	1988
51	Grabovica hydroelectric power plant, Yugoslavia*	116	1980	1989
52	Salakovac Hydroelectric power plant, Yugoslavia*	205.5	1980	1989
53	Mostar Hydroelectric power plant, Yugoslavia*	64.5	1980	1989
54	Sir Hydropower Project, Turkey*	282	1986	1991
55	Sigalda HPP, Iceland*	100	1973	1977
56	Berke Hydropower, Turkey	510	1985	1992
57	Pamir Private Power Project, Tajikistan	28	2003	2010

Note: * represents the 43 projects to which uplifts were applied

Table A2. Costs and cost overruns for the 57 projects (US$M, 2016 price level)

#	Project name	Ex-ante PV of estimated cost	Ex-post PV of actual cost	Real cost overrun as % of estimated cost
1	Gitaru HPP, Kenya	332.95	323.01	−2.99%
2	Kapichira Hydroelectric, Malawi	191.49	149.28	−22.04%
3	Ruzizi Hydroelectric, Burundi-Rwanda-CDR	111.54	109.18	−2.11%
4	Kiambere Hydroelectric, Kenya	439.63	438.15	−0.34%
5	Andekaleka Power, Madagascar	225.49	302.91	34.33%
6	Mtera Hydroelectric, Tanzania	223.05	214.00	−4.06%
7	San Carlos, Colombia	785.31	982.27	25.08%
8	Fourth Guadalupe, Colombia	298.08	369.81	24.06%
9	Playas Hydropower, Colombia	387.13	410.67	6.08%
10	Itumbiara Dam, Brazil	1,528.95	2,306.33	50.84%
11	Pehuenche Hydroelectric Dam, Chile	831.59	484.07	−41.79%
12	Guavio Hydro Power Project, Colombia	1,356.73	3,329.39	145.40%
13	Paulo Afonso IV Complex, Brazil	1,501.58	2,590.18	72.50%
14	Aguacapa Power Project, Guatemala	223.50	425.50	90.38%
15	La Fortuna, Panama	342.66	948.12	176.69%
16	Chixoy Hydro-power, Guatemala	850.09	1,122.01	31.99%
17	GaziBarotha Hydropower, Pakistan	1,721.28	1,678.49	−2.49%
18	Saguling Dam, Indonesia	968.59	1,239.77	28.00%
19	Bersia Hydroelectric project	136.75	110.35	−19.30%
20	Kenering Hydroelectric project	227.90	176.78	−22.43%
21	Yantan Hydroelectric Project, China	471.48	857.94	81.97%
22	Lubuge Hydroelectric, China	819.82	855.06	4.30%
23	Ertan I, Sichuan, China	1,805.45	2,033.30	12.62%
24	Karakaya Hydropower, Turkey	1,804.12	1,805.13	0.06%
25	Grabovica hydropower plant, Yugoslavia	154.38	163.95	6.20%
26	Salakovac Hydropower plant, Yugoslavia	273.49	290.44	6.20%
27	Mostar Hydropower plant, Yugoslavia	214.02	229.90	7.42%
28	Sir Hydropower Project, Turkey	314.24	388.10	23.50%
29	Sigalda HPP, Iceland	208.83	267.26	27.98%
30	Yonki Dam, Papua New Guinea	132.29	172.81	30.63%
31	Afulilo Hydropower project, Western Samoa	23.25	46.20	98.74%
32	Wailoa Hydroelectric, Fiji	174.68	207.84	18.98%
33	Rampur Hydropower project, India	448.26	516.57	15.24%
34	Dongping hydroelectric power plant, China	85.21	88.38	3.72%
35	Najitan hydroelectric power plant, China	35.51	33.30	−6.22%
36	Songshuling hydroelectric power plant, China	35.35	29.60	−16.26%

37	Xiakou hydroelectric power plant, China	26.77	23.60	−11.84%
38	Guangrun hydroelectric power plant, China	30.67	38.61	25.89%
39	Felou hydro−project, Mali, Mauritania, Senegal	167.19	146.33	−12.48%
40	Bujagali, Uganda	661.22	800.31	21.03%
41	La Higuera, Chile	170.85	309.06	80.90%
42	Cheves Hydro, Peru	343.96	526.43	53.05%
43	Allain Duhangan II, India	201.08	406.81	102.31%
44	Nkula II Project, Malawi	145.62	176.77	21.39%
45	Kidatu Hydropower Plant, Tanzania	196.05	239.09	21.96%
46	Volta River Hydroelectric Project, Ghana	424.51	456.32	7.49%
47	Kpong Hydroelectric, VRA, Ghana	489.60	597.44	22.03%
48	Nispero Power Project, Honduras	111.48	119.71	7.38%
49	El Cajon Hydropower Dam, Honduras	686.89	966.77	40.75%
50	Aguamilpa Hydroelectric project, Mexico	994.20	932.49	−6.21%
51	Zimapan Hydroelectric project, Mexico	511.05	909.35	77.94%
52	Cirata Hydroelectric Site, Indonesia	353.19	237.26	−32.82%
53	Ban Chao HPP, Thailand	426.84	523.39	22.62%
54	Kerala Power Project, India	399.53	600.21	50.23%
55	Marsyangdi Hydroelectric, Nepal	466.34	401.49	−13.90%
56	Berke Hydropower, Turkey	766.26	706.36	−7.82%
57	Pamir Private Power Project, Tajikistan	22.34	25.23	12.91%

Table A3. Costs, benefits, ENPVs and their overruns for the 43 projects (US$M, 2016 price level)

#	Project name	Estimated (ex-ante) real cost	Actual real cost	Real cost overrun as % of actual cost	Estimated (ex-ante) real benefit	Actual real benefit	Real benefit overrun as % of actual cost	Estimated (ex-ante) real NPV	Actual (ex-post) real NPV	NPV overrun as % of actual cost
1	Gitaru HPP, Kenya	333	323	−3%	491	600	34%	158	277	37%
2	Kapichira Hydroelectric, Malawi	191	149	−28%	392	183	−140%	200	33	−112%
3	Ruzizi Hydroelectric, Burundi-Rwanda-CDR	112	109	−2%	174	146	−26%	63	37	−24%
4	Kiambere Hydroelectric, Kenya	440	438	−0.34%	440	500	14%	0.14	62	14%
5	Andekaleka Power, Madagascar	225	303	26%	260	215	−15%	34	−88	−40%
6	Mtera Hydroelectric, Tanzania	223	214	−4%	226	186	−19%	3	−28	−15%
7	San Carlos, Colombia	785	982	20%	1,228	2,759	156%	443	1,777	136%
8	Fourth Guadalupe, Colombia	298	370	19%	389	667	75%	90	297	56%
9	Playas Hydropower, Colombia	387	411	6%	771	861	22%	384	451	16%
10	Itumbiara Dam, Brazil	1,529	2,306	34%	5,293	4,684	−26%	3,764	2,378	−60%
11	Pehuenche Hydroelectric Dam, Chile	832	484	−72%	988	1,493	104%	157	1,009	176%
12	Guavio Hydro Power Project, Colombia	1,357	3,329	59%	2,593	1,599	−30%	1,236	−1,731	−89%
13	Paulo Afonso IV Complex, Brazil	1,502	2,590	42%	6,738	3,695	−117%	5,236	1,105	−159%
14	Aguacapa Power Project, Guatemala	223	426	47%	354	330	−6%	131	−96	−53%
15	La Fortuna, Panama	343	948	64%	805	784	−2%	463	−164	−66%
16	Chixoy Hydro-power, Guatemala	850	1,122	24%	1,179	1,065	−10%	329	−57	−34%
17	GaziBarotha Hydropower, Pakistan	1,721	1,678	−3%	5,101	8,766	218%	3,380	7,087	221%
18	Saguling Dam, Indonesia	969	1,240	22%	1,897	1,470	−34%	929	230	−56%
19	Bersia Hydroelectric project	137	110	−24%	215	154	−56%	79	43	−32%
20	Kenering Hydroelectric project	228	177	−29%	360	280	−45%	132	104	−16%
21	Yantan Hydroelectric Project, China	471	858	45%	561	2,104	180%	89	1,246	135%
22	Lubuge Hydroelectric, China	820	855	4%	1,057	1,135	9%	237	280	5%
23	Ertan I, Sichuan, China	1,805	2,033	11%	3,448	4,826	68%	1,642	2,792	57%
24	Karakaya Hydropower, Turkey	1,804	1,805	0.06%	3,355	3,080	−15%	1,551	1,275	−15%

25	Grabovica hydropower plant, Yugoslavia	154	164	6%	185	184	−1%	31	20	−6%
26	Salakovac Hydropower plant, Yugoslavia	273	290	6%	327	316	−4%	54	25	−10%
27	Mostar Hydropower plant, Yugoslavia	214	230	7%	254	133	−53%	40	−97	−60%
28	Sir Hydropower Project, Turkey	314	388	19%	383	539	40%	69	151	21%
29	Sigalda HPP, Iceland	209	267	22%	225	492	100%	16	225	78%
30	Yonki Dam, Papua New Guinea	132	173	23%	262	117	−84%	129	−56	−107%
31	Afulilo Hydro-project, Western Samoa	23	46	50%	27	32	11%	3	−15	−39%
32	Wailoa Hydroelectric, Fiji	175	208	16%	270	303	16%	95	95	0.08%
33	Rampur Hydropower project, India	448	517	13%	1,138	871	−52%	689	355	−65%
34	Dongping hydropower plant, China	85	88	4%	112	331	249%	26	243	245%
35	Najitan hydroelectric power plant, China	36	33	−7%	48	113	195%	13	80	202%
36	Songshuling hydropower plant, China	35	30	−19%	48	113	218%	13	83	237%
37	Xiakou hydroelectric power plant, China	27	24	−13%	37	67	130%	10	44	143%
38	Guangrun hydropower plant, China	31	39	21%	42	65	59%	11	26	38%
39	Felou hydro-project, Mali, Mauritania, Senegal	167	146	−14%	267	215	−36%	100	68	−22%
40	Bujagali, Uganda	661	800	17%	2,018	1,215	−100%	1,357	415	−118%
41	La Higuera, Chile	171	309	45%	305	476	56%	134	167	11%
42	Cheves Hydro, Peru	344	526	35%	451	463	2%	107	−64	−32%
43	Allain Duhangan II, India	201	407	51%	392	343	−12%	191	−64	−63%