PAKISTAN
Strategy Support Program

Economic Evaluation of the Diamer-Basha Dam

Analysis with an Integrated Economic/Water Simulation Model of Pakistan

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This paper describes the potential impact on the economy of Pakistan of building the Diamer-Basha dam. An integrated system of economic and water simulation models is applied to Pakistan to analyze the economywide impacts of changes in water resources in the Indus river basin, focusing on agricultural and hydropower benefits provided by the Diamer-Basha dam under different climate scenarios. The model framework links separate economic and water models, drawing on the strengths of both approaches without having to compromise by specifying either a simplified treatment of water in an economic model or simplified economics in a water model. The model system is used to simulate the impact of economic growth and changes in water resources over the long run, focusing on agriculture and hydropower. The results of scenario analysis indicate that the Diamer-Basha dam would improve the resilience of Pakistan to adapt to climate shocks, providing increased hydropower capacity and enhanced ability to manage the water system to offset climate-induced variation in river flows. Given the modest amount of existing water storage capacity in the Indus basin, extreme events such as an extended drought overwhelm the water management system. The proposed dam partly offsets the negative impacts and is an excellent investment under various climate scenarios, yielding benefit-cost ratios of 3.3 to 3.9 and Internal Rates of Return of 11% to 14%.

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1. INTRODUCTION

Dramatic economic impacts of climate change are likely to be felt most strongly through changes in the water system. Changes in the frequency and intensity of droughts and floods, as well as changes in the seasonality and intensity of precipitation, can disrupt any economy, but especially fragile agricultural economies characteristic of many developing countries. There are numerous studies of the impacts of climate change on water resources and agriculture, many using economic and/or water system simulation models. There are many examples of economic models that incorporate water in a simple manner (treating it as a factor of production in an annual production model), and water models that include a simplified treatment of economics (usually considering only the direct effects of water shortages on agricultural production and/or hydropower in a partial equilibrium framework).

In a country like Pakistan, which is water limited and relies heavily on irrigated agriculture (Briscoe and Qamar, 2005a), the water system is much more complex than can be considered by economic models that incorporate water in a simple manner. On the other hand, water basin models that include some economic production track only the direct effects of changes in the water system on part of the economy, and fail to encompass the direct and indirect repercussions on the broader economy, which are likely to be important in economies heavily dependent on water such as Pakistan. We need to integrate our knowledge of the entire economic system and its links to water systems to consider the challenges posed by climate change and potential adaptation strategies that involve a significant share of overall economic activity.

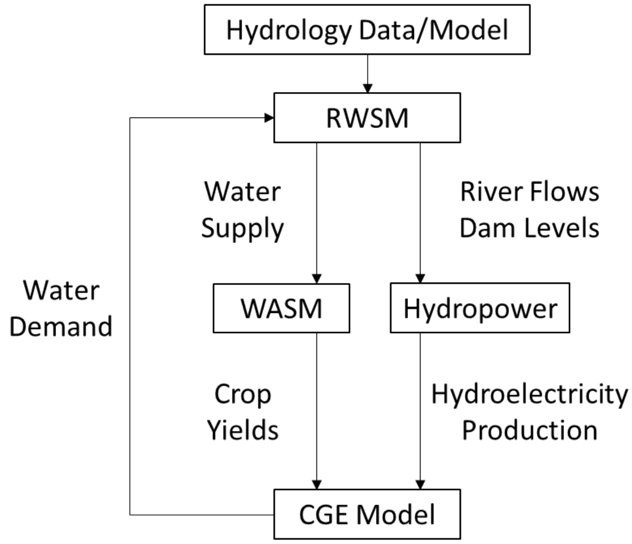
Our goal is to develop a model system that links economic and water models, drawing on the strengths of both approaches without having to compromise by specifying either a simplified treatment of water in an economic model or simplified economics in a water model. This study presents such a model system, the Computable General Equilibrium – Water simulation model (CGE-W) applied to Pakistan. The economic model is a national CGE model adapted to link with a suite of water models that include hydrology, water basin management, and water stress models. The CGE-W modeling framework and its underlying philosophy is described in detail in Robinson and Gueneau (2014). It provides a flexible and robust framework for linking and integrating separate economic and water models. In this paper, we describe the specifics of the CGE-W model applied to Pakistan and we use the model system to evaluate the benefits of building the proposed Diamer-Basha dam in the province of Gilgit-Baltistan on the economy of Pakistan under different climate-change scenarios. The simulation results indicate that increasing water storage in the Indus basin, and this proposed dam in particular, yields significant benefits and improves the resilience of the Pakistan economy to climate shocks.

2. THE CGE-W FRAMEWORK APPLIED TO PAKISTAN

The CGE-W model of Pakistan consists of an annual economywide computable general equilibrium (CGE) simulation model, a water demand module, a separate water basin management model (the Regional Water System Model for Pakistan, RWSM-Pak), an associated water allocation model that allocates available water to crops based on the impact of water stress on crop yields and crop values (called the water allocation and stress model or WASM), and a hydropower module. The water models all run on a monthly time step. A separate hydrology model calculates monthly precipitation and runoff to the river systems, given different climate scenarios. All the component models in this implementation of the CGE-W framework are coded in the General Algebraic Model System (GAMS), which allows for integrated solution of the suite of models. Figure 1 presents a schematic view of how the system of simulation models is linked in the CGE-W framework.[1]

[1] Robinson and Gueneau (2014) describe the CGE-W framework in detail.

Figure 1—The CGE-W system of models applied to Pakistan



2.1. The IFPRI Standard CGE Model of Pakistan

The data base for the IFPRI CGE model of Pakistan is based on a social accounting matrix (SAM) developed by Dorosh et al. (2006) and updated by Debowicz et al. (2012). The CGE model includes agricultural detail that allows for a good representation of water shocks on the economy, as well as disaggregated labor and household categories, to capture the distributional impacts of different policy choices. The SAM includes 45 sectors (or activities), 27 factors of production, and 18 household groups, allowing tracing of direct and indirect effects of potential scenarios through production and consumption linkages, including distributional effects. The model code starts from a new version of the IFPRI standard CGE model (Löfgren, Harris and Robinson, 2001).

The agricultural sector includes eight crops (rainfed wheat, irrigated wheat, basmati rice, irri rice, cotton, sugarcane, other field crops and vegetables/horticulture) in three regions (Sindh province, Punjab province and Rest of Pakistan). Land is divided between small and medium/large rainfed land (assumed to grow only rainfed wheat in the Indus basin), small irrigated farms, medium irrigated farms and large farms. Labor is also disaggregated in agriculture. Own-farm labor is disaggregated between small, medium and large farm tenants (the first two categories being further disaggregated by the three regions as they are assumed to be less mobile). The model also takes into account agricultural wage workers, and non-agricultural unskilled and skilled workers.

The shock due to water stress is defined as the ratio of crop yields for the current year compared to the base year yield. The base year data define the equilibrium of the water system in 2007-2008 under an average weather pattern. In the first run of the CGE model in each year, the external water shock anticipated by farmers is assumed to be the average of the four previous years, so farmers anticipate a short-term running average level of water stress which allows for some adaptation. The CGE model then solves for the allocation of crops to irrigated and rainfed land based on these expectations.

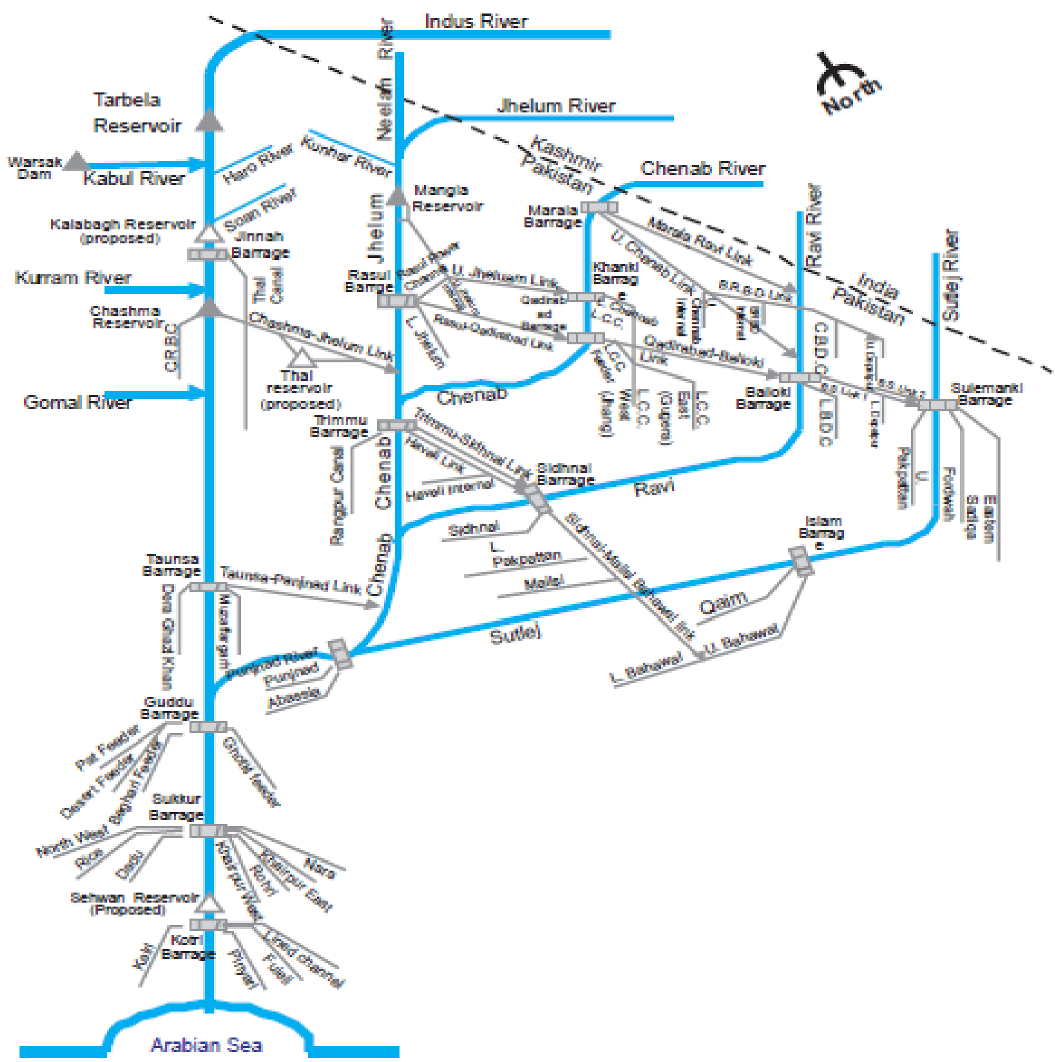
2.2. The Regional Water System Model for Pakistan

RWSM-Pak is a water basin management model, but does not include any economic measures since the economic links are handled in the CGE model. The water model covers only the Indus basin, which represents more than 90% of agricultural production in Pakistan. It is largely inspired by the original Indus Basin Model Revised, IBMR (Ahmad et al. 1990; recently updated by Yu et al. 2013). It models the nine main rivers of the Indus basin that flow through Pakistan and provide irrigation water—from East to West: the Sutlej, the Ravi, the Chenab, the Jhelum, the Soan, the Indus, the Swat, the Kabul and the Haro—as well as the main dams in the system: Tarbela, Mangla, Chasma and Chotiari. The water is routed through forty-seven nodes of the Indus system in Pakistan. These nodes include reservoirs, link canals between rivers and barrages for irrigation outlets. Inflows, precipitations, runoff and crop water need data are generated externally by a climate model downscaled to Pakistan using historic data. The routing model takes into account river routing time, reservoir evaporation and link canal capacity.

The model disaggregates the forty-five main irrigation canals of the Pakistan Indus basin into twelve agro-economic areas, based on provinces and crops grown. Four of these zones are in Sindh, five in Punjab, two in Khyber-Pakhtunwa, and one in Balochistan. Three other zones cover the rest of Pakistan, in Punjab, Balochistan and Khyber-Pakhtunwa respectively. These zones are assumed to have a constant water stress, allowing us to isolate the effects of investments in the Indus basin. Agricultural land area, irrigation capacity and groundwater pumping are disaggregated to this level. Groundwater pumping is allowed only in non-saline groundwater areas (each zone is disaggregated into fresh and saline areas, if relevant), though we place a cap on maximal annual abstractions consistent with a sustainable yield for the Indus aquifer (fifty million acre-feet, as per Briscoe & Qamar, 2005 and Yu et al., 2013). RWSM-Pak assumes non-irrigation water is drawn from groundwater only. For this study, all water data are drawn from the new IBMR model developed by NESPAK and WAPDA, while crop data come from the 2010 Agricultural Census of Pakistan. RWSM manages the reservoirs to maximize the share of demand for water that can be supplied.

The Water Accord of 1991, which reflects a highly sensitive political compromise, dictates the sharing of water between the four provinces and that dams should be managed with priority for irrigation (Briscoe and Qamar 2005b). Implementing the Accord in the model leads us to impose rule-based constraints on the simulated system. The objective function is constrained by these stringent rules on dam storage, while maximizing the water delivered to cultivated areas. However we do not constrain individual canal releases to follow historic patterns, as this is a usage not enshrined in provincial law. Eight million acre-feet of water are reserved as an outflow to keep the delta healthy, which is also mandated by the Water Accord.

Figure 2—The Indus River basin and irrigation canals (Briscoe & Qamar, 2005b) as modeled in RWSM-Pak

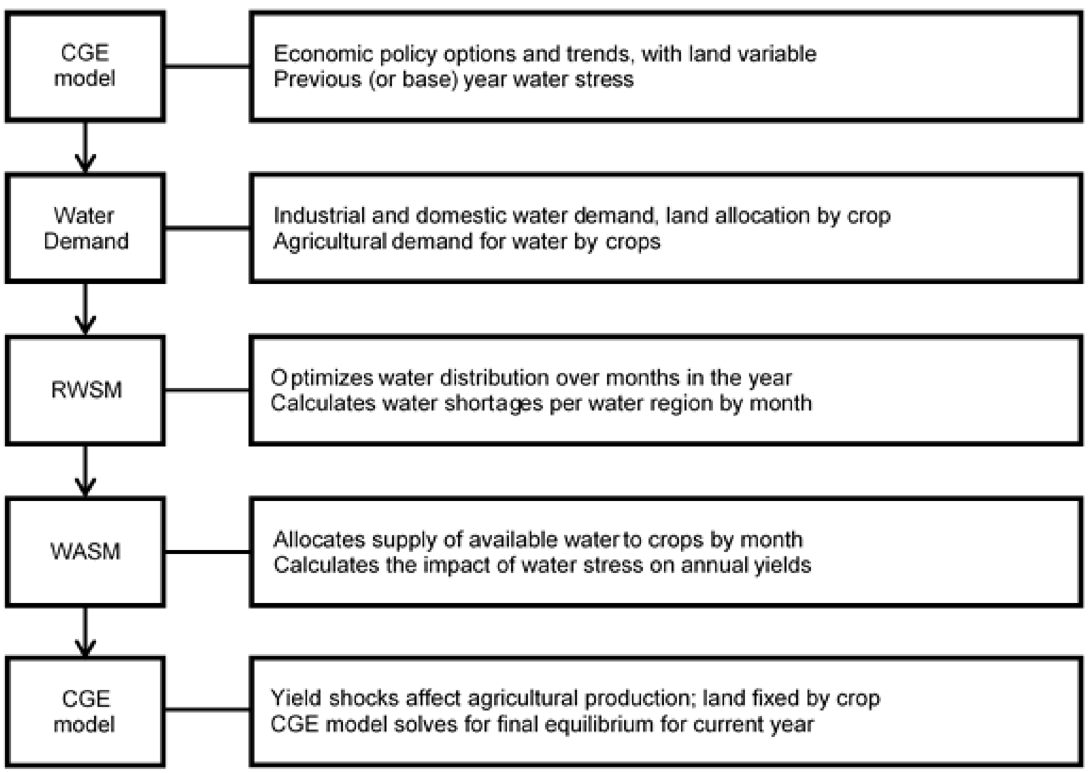


2.3. Linking the Models

The CGE-W model is solved dynamically (Figure 3) in a two-step procedure each year. The CGE model is first solved with average historical water stress to determine farmer decisions on cropping patterns based on expected water availability and economic trends. Expected water stress is set to the average of the previous three years, which sets harvest expectations for the allocation of land to different crops.

The Water Demand module then calculates water demand for crops, industry, households, and livestock. Crop demand is calculated for each crop using evapo-transpiration and effective rainfall; Industrial water demand is assumed to be related to the square root of industrial GDP; livestock demand to the square root of livestock GDP; and household demand linearly to aggregate household income. RWSM-Pak uses these water demands, along with river flows provided by a hydrology model (or historical data) and climate parameters, to provide the monthly repartition of water amongst crops and regions given the objective function (maximize the share of demand for water that can be supplied) and the various constraints described above.

Figure 3—The CGE-W framework: operation of the system of models in a given year.



The Water Allocation and Stress Module (WASM) then allocates water among crops in an area, given the economic value of the crop. We use the FAO Ky approach (Doorenbos and Kassam 1979) to measure water stress using a multiplicative approach to include seasonality of water stress impacts (Jensen 1968; Hanks 1974; Raes et al. 2006). Because optimizing total value of production given fixed prices leads to a tendency for specializing in high-value crops, we include a measure of risk aversion for farmers in the objective function, which preserves a diversified production structure even in case of a drought. The stress model produces a measure of yield stress for every crop—both irrigated and rainfed—in each of the twelve agro-ecological zones, which is then aggregated to the provincial level to match the regions in the CGE model.

Finally, the new yield shocks are calculated and applied to the CGE model, which is solved a second time for the final equilibrium in the current year, but now assuming that the allocation of land to crops is fixed since farmers cannot change their cropping decisions after planting. This solution yields all economic variables, including quantities and prices of outputs and inputs, and all income flows. We then move to the next year, update various parameters on trends and start the process again.

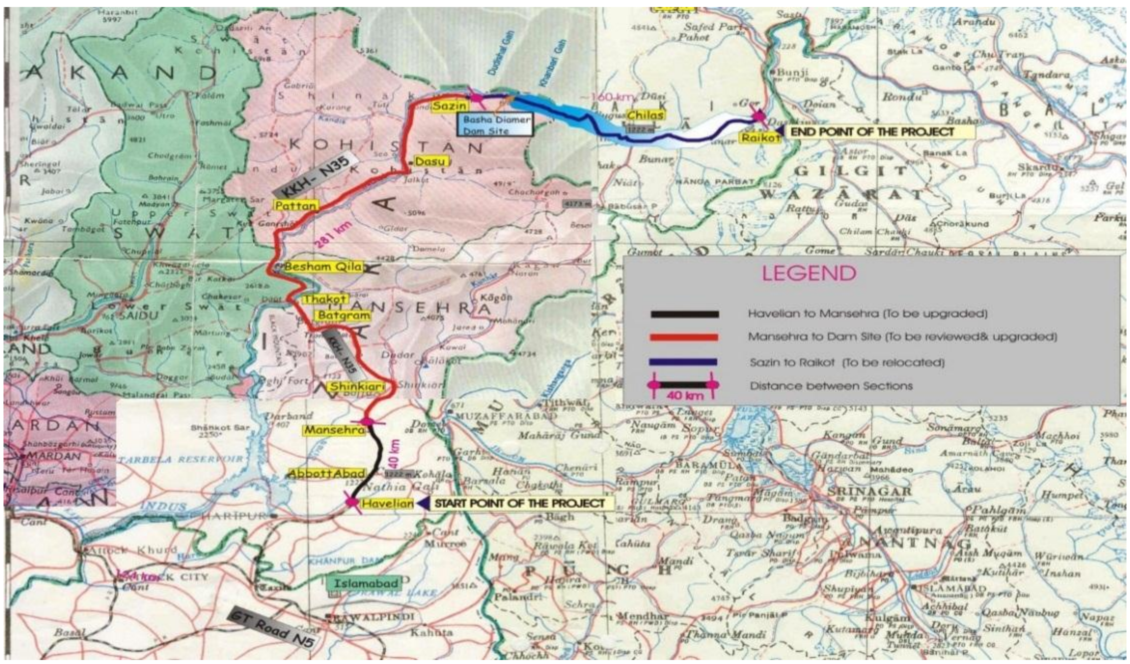
2.4. The hydropower module

Benefits from the Diamer-Basha dam include not only extra irrigation water, but also extra electricity production. We include a hydropower module to simulate the extra electricity that would be produced by the dam. Hydropower generation depends on water flow and head (height of the dam and water level of the reservoir). Given that Pakistan explicitly gives priority to irrigation, we do not include hydropower generation in the objective function of the RWSM-Pak model. Instead, we compute hydropower electricity production after allocating water to the crops and include it as a source of energy in the CGE model.[2] Hydropower is represented as a fixed quantity of the total energy production as we assume no other hydroelectric dam than Diamer-Basha is built. The additional energy production is included in GDP and valued as a benefit of the dam.

3. THE DIAMER-BASHA DAM

The Diamer-Basha dam (often called the Basha dam), whose construction has officially started, is a large dam situated in Gilgit-Baltistan, on the Indus river upstream of the Tarbela dam (Figure 4). It is projected to hold 8.1 million acre-feet of water, including 6.4 million acre-feet of live storage, and will be 272 meters high. The associated hydropower station will have a total installed capacity of 4.5 GW. As of 2011, its cost has been estimated at 13.6 billion dollars, with completion expected in twelve years.

Figure 4—Map of the location of Diamer-Basha dam. Source: WAPDA



Assessing the benefits of the Basha dam has been controversial in Pakistan. According to the Water and Power Development Authority (WAPDA, in charge of building and operating the dam), the live storage is valued at $0.63 billion annually for irrigation purpose and at $2.2 billion for hydroelectricity generation, paying back construction costs in eight years. Using the CGE-W framework, we re-estimate these benefits while: (1) explicitly modeling the impact of the new capacity on irrigation water supply and hydropower, (2) accounting for both direct and indirect effects of improved agricultural production and increased energy production on the economy, and (3) considering climate change impacts on crop production and hydropower.

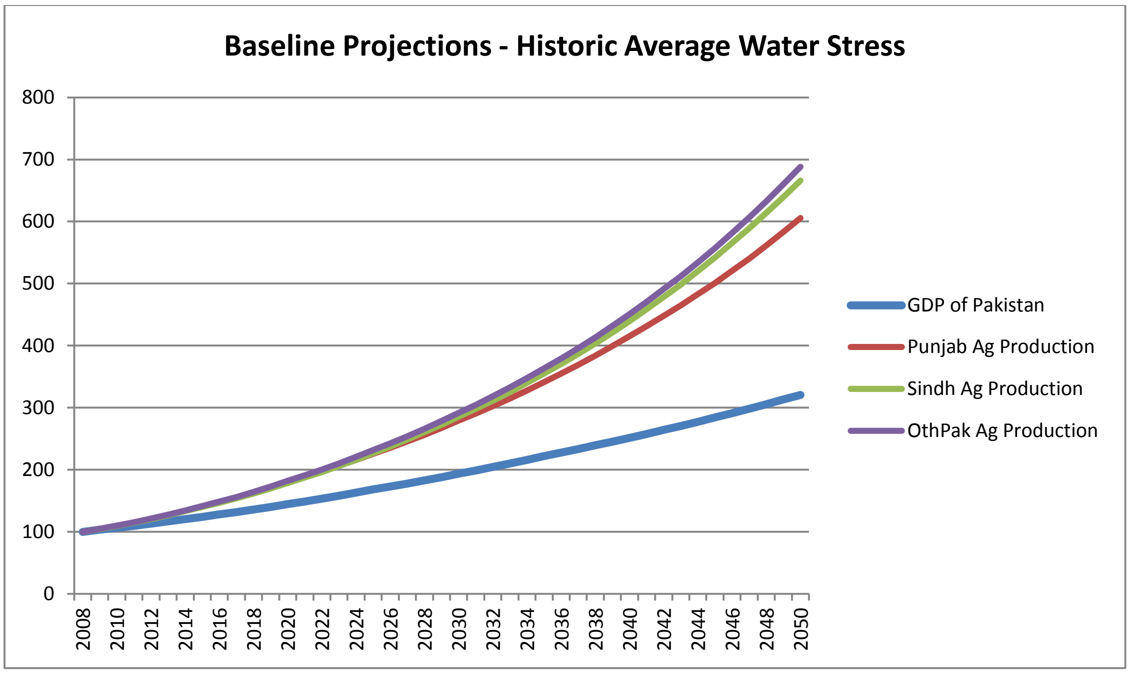
[2] The current CGE model does not disaggregate energy sources or consider substitution possibilities across energy types. A more detailed energy data set is currently being developed for the Pakistan SAM and will be included in future models.

4. SIMULATION RESULTS

The CGE-W model is run dynamically from 2008 to 2050. [3] All scenarios are run for this period and provide “what if” or counterfactual projections, not forecasts. Water shortages affect only the agricultural sectors and hydropower, ignoring the impact of floods.[4] The impacts are treated in the CGE model as shocks to total factor productivity of the production functions for crops, proportional to the shock in actual yields, and changes in the supply of energy.

Figure 5 describes GDP for the base scenario in the two main provinces of Pakistan (Punjab and Sindh) and in the rest of the country. In this scenario, we consider that water allocation never changes and is equal to the historic average every year. In the base in 2008, 63% of agricultural production comes from Punjab, 20% from Sindh and 17% from the rest of Pakistan. Most of the production in Punjab and Sindh is irrigated by the Indus Basin River system, while agriculture is rainfed in most of the rest of Pakistan. For the base scenario, we specify a growth rate of the economy of about 3% per year.[5] There is no increase in agricultural land. Under these assumptions, Sindhi agricultural production increases along with GDP due to improved yields, while Punjabi production increases along until 2035 and slows due to the pressure of rising industrial and domestic water demand on already stressed water supplies.

Figure 5—Baseline projections from CGE-W, base 100 in 2008. GDP and Agricultural production



4.1. Historical Climate Scenarios

The baseline scenario assumes historic average water flows, and so does not include dry and wet years. In the next set of scenarios, we reproduce the inflow conditions from 1966-1967 to 2007-2008, which include wet and dry periods, as compiled by the Water and Power Development Authority (WAPDA) of the Government of Pakistan. First, we add the Diamer-Basha dam to the baseline scenario (with constant average inflow) to consider the different contributions to total benefits of hydropower and irrigation improvement due to increased storage. In this scenario, every year experiences the same weather as the average year (which means no dry or wet spells), and the Diamer-Basha dam is installed in 2009. The results for this scenario are shown below in Figure 6.

[3] 2008 is chosen as a starting year as it is the year for which the Social Accounting Matrix (SAM) has been developed. All water data are also collected for 2008.

[4] We plan to improve the treatment of hydropower and include flood impacts in future versions of the model. Floods affect both agriculture and infrastructure (e.g., roads, bridges, and buildings). A major consideration is the negative impact of episodic electricity shortages and load shedding on the economy, which could be avoided with significant increases in hydropower capacity.

[5] The calibration of the growth rate is essentially done by specifying exogenous rates of total factor productivity growth. Labor force growth is also exogenous, while growth of the capital stock is endogenous, determined by aggregate annual savings and investment.

In the first years of operation of the dam, GDP rises to 0.4 percentage points above the baseline scenario values, almost entirely due to hydropower benefits. Agricultural benefits, on the other hand, remain flat until 2020, as water stress is not strong in the early years.[6] Over time, as water stress increases due to growth and population pressure, agricultural benefits rise to 0.65 percentage points over the baseline scenario by 2050, which represents more than 70% of total benefits in that year (just over 0.9 percent of GDP).[7]

Figure 6—Contributions of storage expansion and hydropower, respectively, to the GDP increase from Diamer-Basha dam building (in percent of GDP compared to a scenario with no dam)

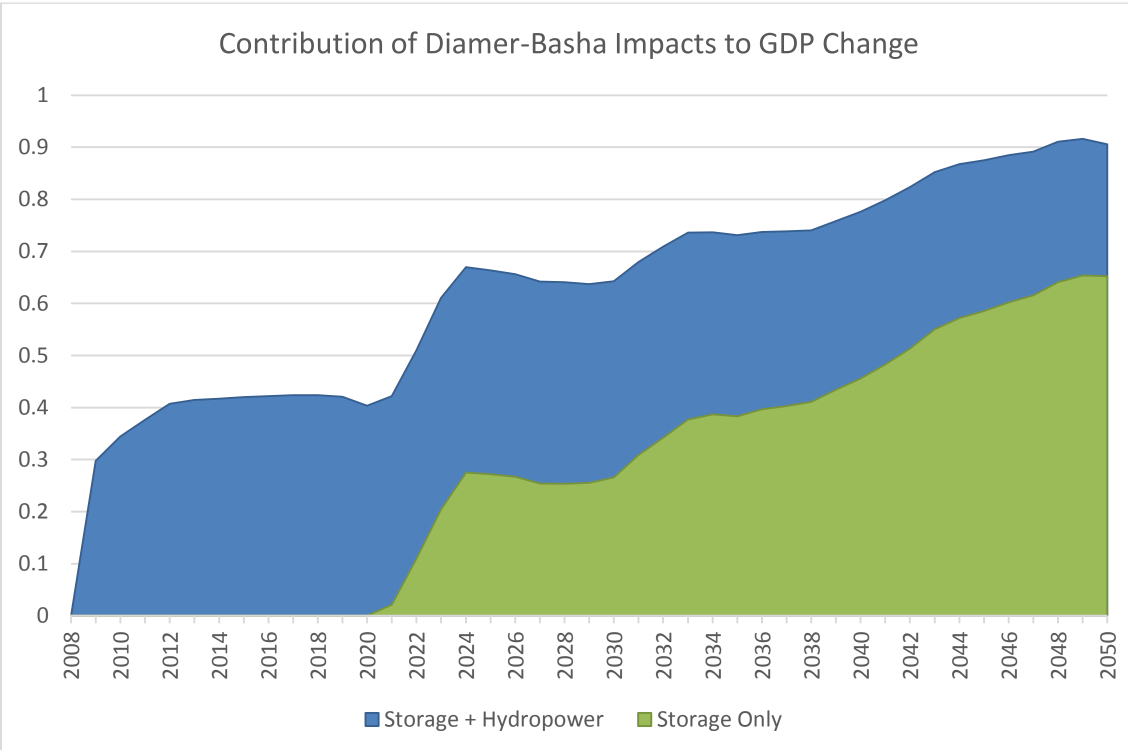
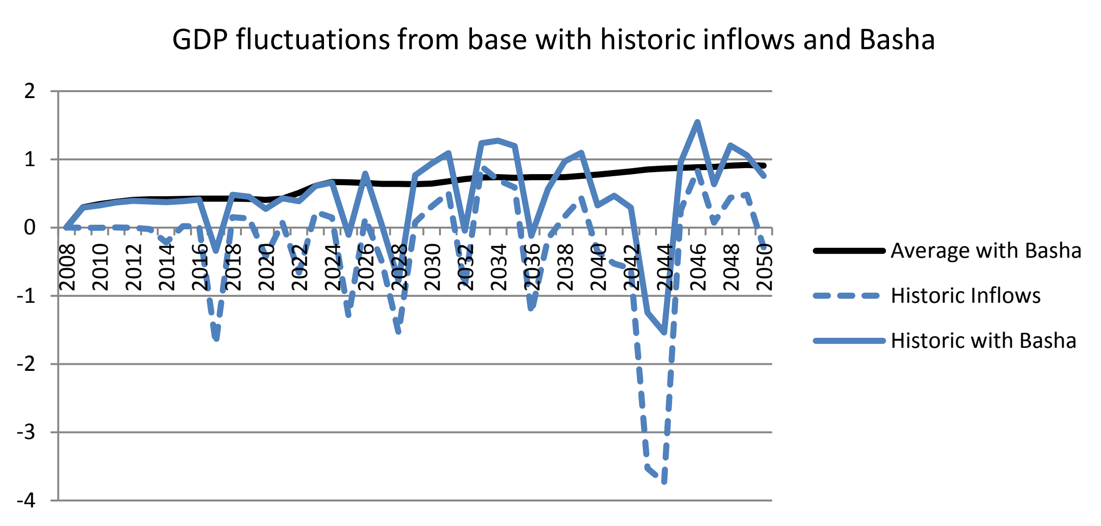


Figure 7, 8 and 9 present the evolution of GDP and agricultural production in Punjab and Sindh under three scenarios compared to the baseline. In the first scenario, represented with a black line and labeled "Average with Basha" in Figures 7, 8, and 9, every year is experiences the same weather as the average year (which means no dry or wet spells), but the Diamer-Basha dam is built in 2009. As specified above, under this scenario, GDP goes up by 0.9 percent in 2050 compared with the baseline.

[6] This comes from the fact that we are using the average historic water year, under which there is no large stress to the irrigation sector. Obviously droughts happen, so in a real world scenario, agricultural benefits would occur much earlier than 2020.

[7] We do not take into account the cost of building the dam in this analysis. Conceptually, the dam appears on the Indus on the first day of the 2009 water year. The model as implemented here measures benefits, but does not consider costs. Moreover we do not consider dam silting, which is likely to reduce storage over the years.

Figure 7—GDP fluctuations from the base with historic inflows and the construction of Basha dam (in percent of GDP)



As shown in Figures 8 and 9, total agricultural production goes up by 2.8% in Punjab and 0.6% in Sindh. Punjab gets higher benefits from the Diamer-Basha dam in 2050 as under our baseline scenario it is the most water-stressed province. Conceptually the dam helps Punjab alleviate increased water stress due to population and economic growth, while Sindh is somewhat protected by the 1991 Water Accords.

In the second scenario (dotted blue line labeled "Historic Inflows" in Figures 7, 8, and 9), we introduce annual variability. To do so we reproduce the time series of flows of the major rivers for the years 1966-1967 to 2007-2008. The impact of droughts range up to 3.7 percent loss in GDP (in 2043 and 2044[8]), while a relatively wet year may increase GDP by about 1 percent (in 2033). Drought impacts can be seen even at the beginning of the period considered. Non-agricultural water demand is growing along with the economy, so a drought or a wet year in the later years will have more impact on GDP than in the earlier years. Agricultural production figures show that the impact of droughts is somewhat stronger for Punjabi agriculture than for Sindhi agriculture (10% loss against 2% loss in the big drought of 2044). Indeed, Sindh is irrigated by the Indus, which is currently slightly under-exploited in terms of quantity, and the Water Accord of 1991 (signed between Pakistan's then-four provinces to share the water) allocates a higher portion (compared to the historic repartition) to Sindh for its agricultural development.

In the third scenario (blue line labeled "Historic with Basha" in Figures 7, 8, and 9), the addition of the Diamer-Basha dam improves GDP by approximately the same amount that we could observe in the first scenario under an average weather. The main difference is that it provides some insurance against droughts. For example, in 2014 the drought impact on agricultural production is reduced by three quarters due to the addition of the Diamer-Basha dam. In later droughts (after 2028), the Basha dam reduces the impact of droughts by about 3 to 4 percentage points in Punjab and 0.25 percentage point in Sindh, while most of the wet year benefits go to Punjab (once again, because Sindh is much less water stressed than Punjab in our simulation of the economy in the 2030s and 2040s under an average weather pattern). On the GDP side, the dam can save as much as 2 percentage points of GDP during a drought due to protected agricultural production alone, and add an extra 0.5 percentage points for wet years.

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[8] Due to our mapping to historic years in this scenario, the 2043-2044 drought corresponds to the historic 2001-2002 drought in Pakistan. The GDP shock we calculate here is in line with estimates of the impact of the drought from the State Bank of Pakistan (Annual Report of the State Bank of Pakistan, 2001-2002).

Figure 8—Punjab agricultural fluctuations from the base with historic inflows and the construction of Basha dam (in percentage)

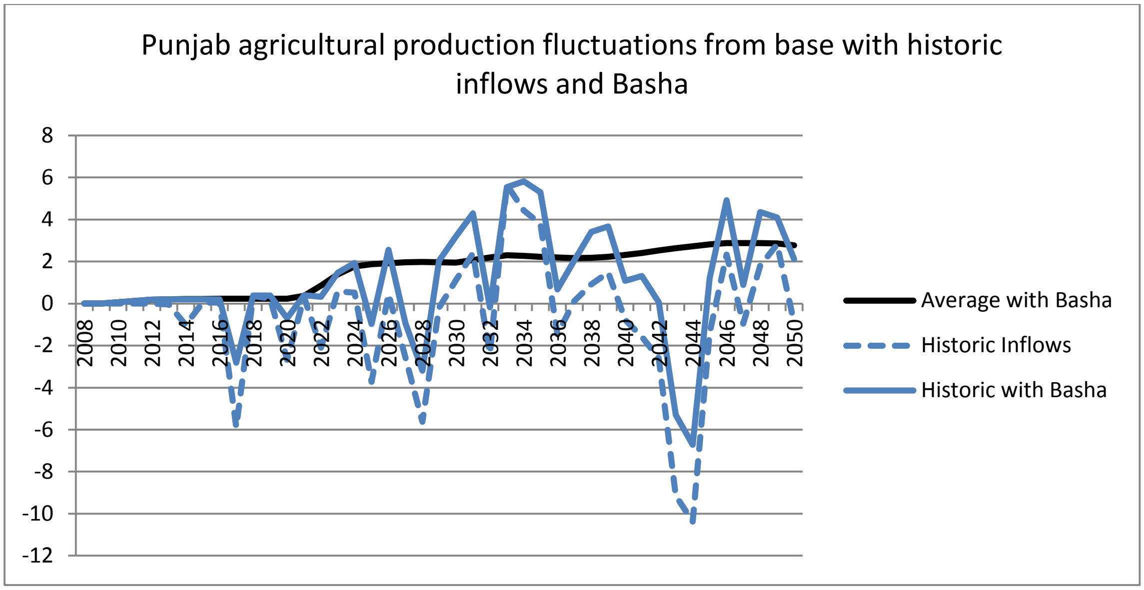
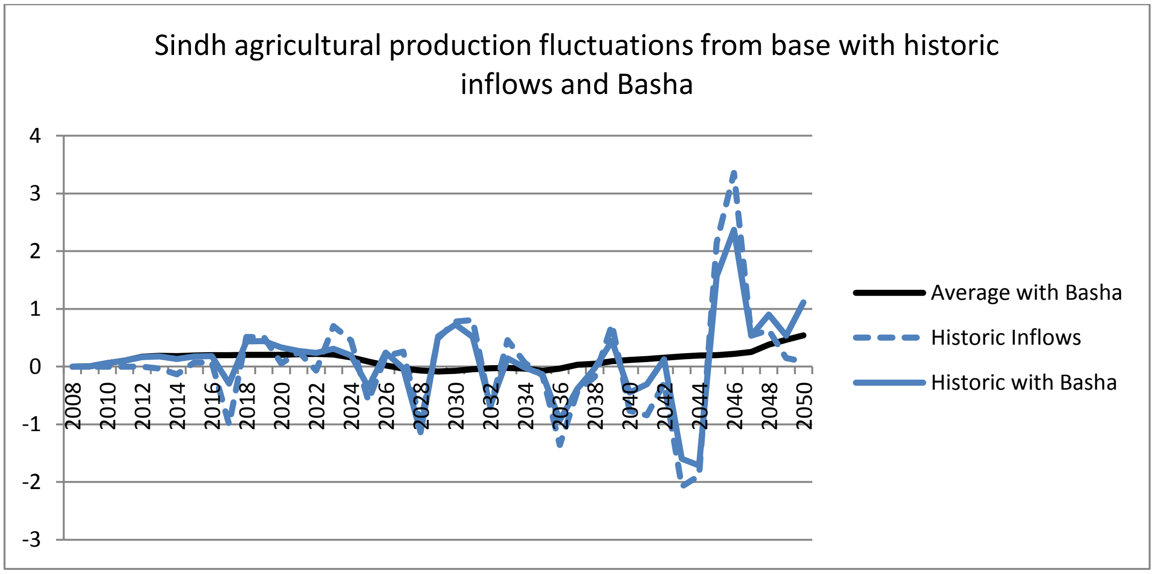


Figure 9—Sindh agricultural fluctuations from the base with historic inflows and the construction of Basha dam (in percentage)



4.2. Climate Change Scenarios

Tables 1 and 2 show the implication of climate change for Pakistani GDP and agricultural production under four climate scenarios compared with the base.[9] These climate scenarios are the those used in the first stage of the Agricultural Model Intercomparison Project (AgMIP) for agricultural economic models and are intended to provide a good range of results for purposes of comparing different models (Nelson et al., 2013). Each scenario is built by adding the smoothed monthly variation from a 2008 base to the historic time series. Inflows are affected by runoff in the Himalayas, minor river inflows by runoff in Pakistan, rain by precipitation change, and crop water requirements by the change in evapotranspiration.

[9] We are using climate change data from four different AR4 (Fourth Assessment Report) GCMs: CSIRO and MIROC, A1B and B1. CSIRO is based on a model produced by Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO) and MIROC on the Model for Interdisciplinary Research on Climate (MIROC), produced by the University of Tokyo's Center for Climate System Research (following the methodology of Jones & Thornton 2013). The two CSIRO scenarios have smaller but more evenly distributed precipitation increases. The two MIROC scenarios have greater increases on average.

All climate scenarios produce similar negative impacts on the Pakistan water system, driven mostly by temperature change and increases in evapotranspiration. On average, climate impacts on irrigated agriculture cost between 0.87 and 0.4 percentage points of GDP for Pakistan by 2050, and a 1.73 to 0.93 percent decrease in agricultural production compared to the historic baseline, with Punjab and Sindh bearing roughly the same impact.

The Diamer-Basha dam, while providing some benefits compared to the historic baseline in the earlier timeframe, appears to mitigate the impact on agriculture until the 2030s in the MIROC A1B scenarios and until the 2050s in the other scenarios. However, due to hydropower benefits, the overall GDP of Pakistan is still higher with the Diamer-Basha dam in 2050 than it would be without climate change and without the dam construction.

Table 1—Average decadal GDP variation from no climate change/no dam scenario (in percent)

	2010s	2020s	2030s	2040s
MIROC A1B	-0.09	-0.26	-0.46	-0.87
MIROC A1B with Basha	0.46	0.47	0.33	0.28
MIROC B1	-0.07	-0.21	-0.38	-0.61
MIROC B1 with Basha	0.47	0.51	0.39	0.48
CSIRO A1B	-0.05	-0.16	-0.34	-0.70
CSIRO A1B with Basha	0.47	0.54	0.39	0.41
CSIRO B1	-0.02	-0.07	-0.18	-0.40
CSIRO B1 with Basha	0.48	0.61	0.53	0.55

Source: Authors' calculations.

Table 2—Average decadal agricultural production variation from no climate change/no dam scenario (in percent)

	2010s	2020s	2030s	2040s
MIROC A1B	-0.20	-0.95	-1.24	-1.73
MIROC A1B with Basha	0.31	0.37	-0.01	-0.15
MIROC B1	-0.17	-0.78	-1.03	-1.32
MIROC B1 with Basha	0.33	0.52	0.14	0.18
CSIRO A1B	-0.12	-0.60	-0.93	-1.36
CSIRO A1B with Basha	0.36	0.63	0.19	0.12
CSIRO B1	-0.05	-0.32	-0.52	-0.93
CSIRO B1 with Basha	0.37	0.87	0.62	0.09

Source: Authors' calculations.

5. ECONOMIC VALUATION OF THE PROJECT

5.1. Crop Production Effects

As the SAM is fairly disaggregated in the agricultural sectors, we can look at the impact of the Diamer-Basha dam on production of different crops. Table 3 below shows the increase in production in different crop in the 2030s compared to the base. Because of its sensitivity to water supply and its high value, cotton is the biggest beneficiary of the dam.

Table 3—Effects on Different Types of Household Incomes (in percent change compared to a baseline without Basha)

	MIROC A1B	MIROC B1	CSIRO A1B	CSIRO B1
Wheat	1.30	1.25	1.13	0.92
Basmati	0.91	0.57	0.90	0.59
Irri	0.98	0.79	0.91	0.60
Cotton	3.43	3.42	3.19	3.38
Sugarcane	0.62	0.61	0.58	0.63

Source: Author's calculations.

5.2. Benefit-Cost Ratio and Internal Rate of Return

Standard measures to evaluate large engineering projects include benefit-cost ratios and internal rates of return. The analysis requires a comprehensive measure of the benefits of the project, including both direct and indirect, which are usually hard to measure (Cestti and Malik, 2012). CGE-W solves this problem by including a comprehensive view of the country's economic conditions, which facilitates construction of counterfactuals that include all benefits.

Using the CGE-W system of models, we can compute the benefit-cost ratio and the internal rate of return (IRR) of the Diamer-Basha dam based on the change in GDP between the scenario with the dam and without the dam. Under the base scenario (without weather variability), the benefit-cost ratio is 2.7[10] and the IRR is 10.1%. Under a historical climate, the numbers are 3.0% for the benefit-cost ratio and 10.9% for the IRR. The project passes the standard benefit-cost test (discounted benefits exceed discounted costs), and the results also show that the benefits are increased when taking into account weather variability—increased storage improves resilience to weather shocks. As Table 3 shows, the IRR and benefit-cost ratio of the project are also increased when climate change is included.

Table 4. Benefit-Cost Ratio and Internal Rate of Return under different scenarios

	Benefit-Cost Ratio	IRR
Base	2.7	10.1%
Historic	3.0	10.9%
MIROC A1B	3.4	11.5%
MIROC B1	3.3	11.3%
CSIRO A1B	3.2	11.2%
CSIRO B1	3.0	10.9%

Source: Author's calculations.

5.3. Household Income Effects

Using the household disaggregation of the Social Accounting Matrix, we can look at the effects of Diamer-Basha on different classes of households. For this purpose, poor households are the ones that fall in the bottom two quintiles of the expenditure distribution in Pakistan. It is interesting to note that Diamer-Basha has a larger impact on non-farm populations. This is because the improved agricultural productivity helps agricultural prices go down.

Table 5. Effects on Different Types of Household Incomes (in percent change compared to a baseline without Basha)

	MIROC A1B	MIROC B1	CSIRO A1B	CSIRO B1
Medium and Large Farmers	0.38	0.40	0.37	0.33
Small Farmers	0.56	0.55	0.53	0.49
Landless Farmers	0.56	0.54	0.51	0.50
Agricultural Workers	0.75	0.72	0.69	0.68
Non-Farm Rural Poor	0.88	0.85	0.81	0.80
Non-Farm Rural Non-Poor	0.91	0.90	0.88	0.89
Urban Poor	0.99	0.96	0.92	0.90
Urban Non-Poor	0.83	0.83	0.81	0.82

Source: Author's calculations.

6. CONCLUSION

Pakistan has a large and delicate agricultural sector, heavily dependent on irrigation and the hydrology of the Indus river basin. The large economic impact of the great drought of 2001-2002 demonstrated how susceptible Pakistan is to climate shocks, and long-run climate change represents a significant threat to Pakistan's economy. Analysis of these impacts using long-run simulation models is especially useful, given the need to provide policy makers with the ability to explore the benefits and costs of different adaptation scenarios. In particular, we consider the potential benefits of constructing the Diamer-Basha dam on the Indus River.

We analyze the impact of the proposed dam using a model framework that links an economywide computable general equilibrium (CGE) model of Pakistan with a suite of water models. This "CGE-W model" is used to analyze the economic

[10] We use a discount rate of 5% per year in the benefit-cost analysis.

impacts of the proposed Diamer-Basha dam under different climate scenarios. The scenario analysis provides a number of conclusions:

- The dam provides significant economic benefits in all scenarios through increased energy production from hydropower, and in dry years, through reduced water stress for agricultural production. Benefit-cost ratios for the dam range from 3.0 to 3.4 under different climate scenarios and Internal Rates of Return range from 11 to 11.5 percent.
- Climate change, through water resource scarcity, reduces the GDP of Pakistan of 0.4 to 0.9 percent in 2050, depending on the scenario. This is mainly due to water shortages in the irrigation sector.
- An increase in water storage capacity from the proposed Diamer-Basha dam increases resilience to climate shocks, mitigating the negative impact of climate change on agriculture and on the overall economy.
- Simulation analysis of the impact of the great drought indicates that increased water storage capacity, however, is not sufficient to manage entirely the impact of extreme droughts. The dam does not increase storage capacity enough to offset the water loss in the river system when flows are erratic, and increased storage cannot help when low flows persist over a long period.
- In an environment of persistent low river flows because of climate change, policy attention must focus on increasing efficiency of water distribution and use rather than only increasing storage capacity.

The CGE-W model system provides a robust, integrated framework to study intricate water resource problems under climate change and to trace their implications as the damage and benefits spread across the economy. The model system is flexible in that it can accommodate and link different economic and water models in a consistent framework, depending on the needs of the particular country or water shed being modeled.[11] When analyzing such linkages, the CGE-W framework is a significant improvement over economic models with a limited treatment of water or water models with limited economics.

[11] The system has been applied to Egypt, using a CGE model of Egypt similar in design to the Pakistan CGE model, and a different water basin management model applied to the Nile basin. There is work underway to apply the model system to Ghana.

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