Economic Evaluation of the Diamer-Basha Dam: Analysis with an Integrated Economic/Water Simulation Model of Pakistan

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Motivation

- Climate change is now visible and affects economic decisions, such as investment in infrastructure projects
  - Foolish to plan major infrastructure investment assuming climate stability—New IPCC report
- Long run perspective: economic drivers and population are also changing rapidly
  - Need to consider economywide links, national and global
- How do we integrate our knowledge across sectors to reflect potential interactions?
  - Important role for simulation models

Simulation Models

- Need for integrated simulation modeling and scenario analysis for consistent projections
  - Water and agriculture are tightly linked
  - How to link water and economy models?
- Two modeling frameworks, one philosophy:
  - Economics: agricultural partial equilibrium models (global, regional) and CGE models (national)
  - Water system: hydrology, water basin management, water allocation and stress

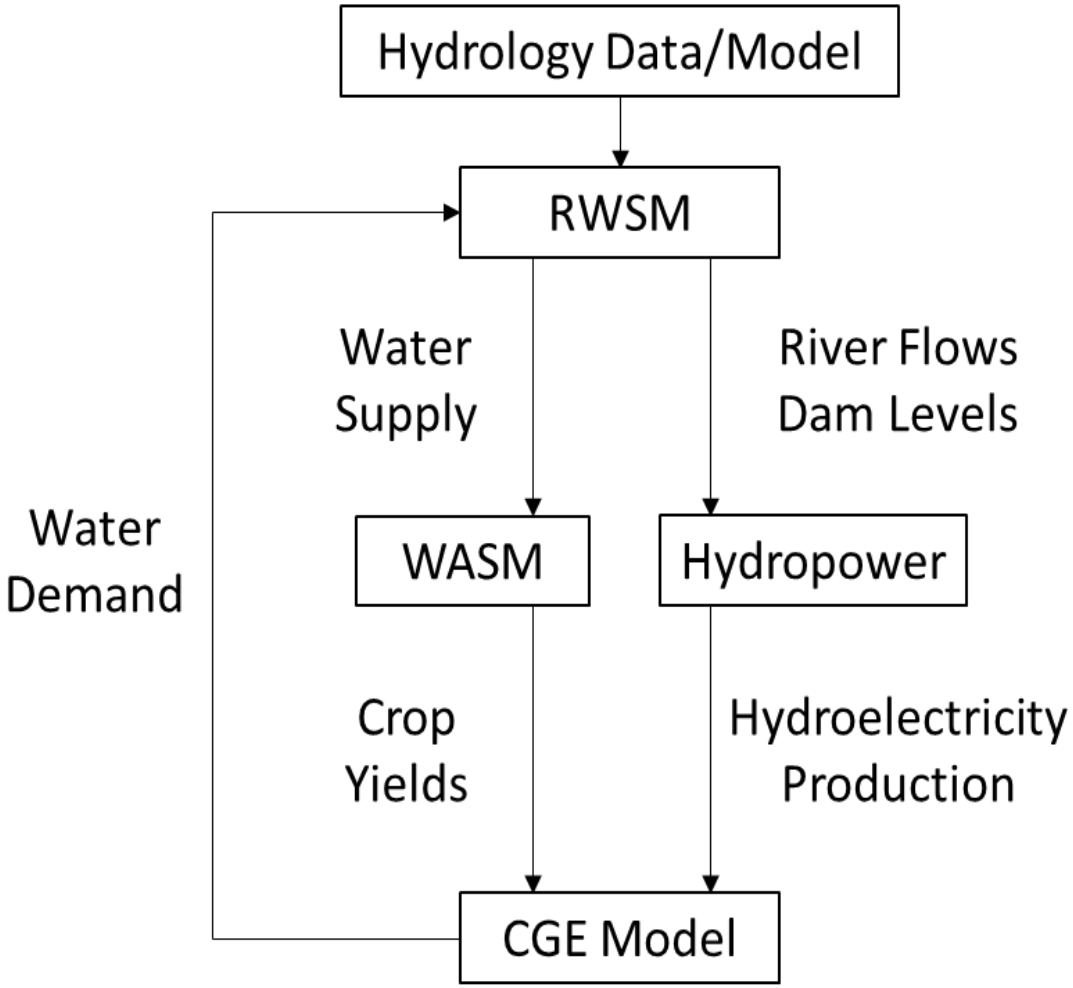
CGE/W Model Framework

- CGE-W is a water/economic simulation model
  - Water policies influence distribution of water
  - Repercussions on crop yields and supply
  - Hydropower production
  - Economy reacts by reallocating production factors through market mechanisms, direct and indirect
- Economic policies affect water system
  - Growth, demand, international trade, prices
  - Much economic activity is linked to water, directly and/or indirectly

Coupled Economic/Water Models

- There are economic models with water factors
  - Do not capture the complexity of the river basins
  - Highly simplified treatment of water in production
- There are water models with economic variables
  - Do not capture economywide links between agriculture and the rest of the economy: “partial equilibrium”
  - Highly simplified treatment of economic forces
- Our paradigm: Let each model do what it does best and make them talk to each other
  - Achieve “consistency” by linking the models

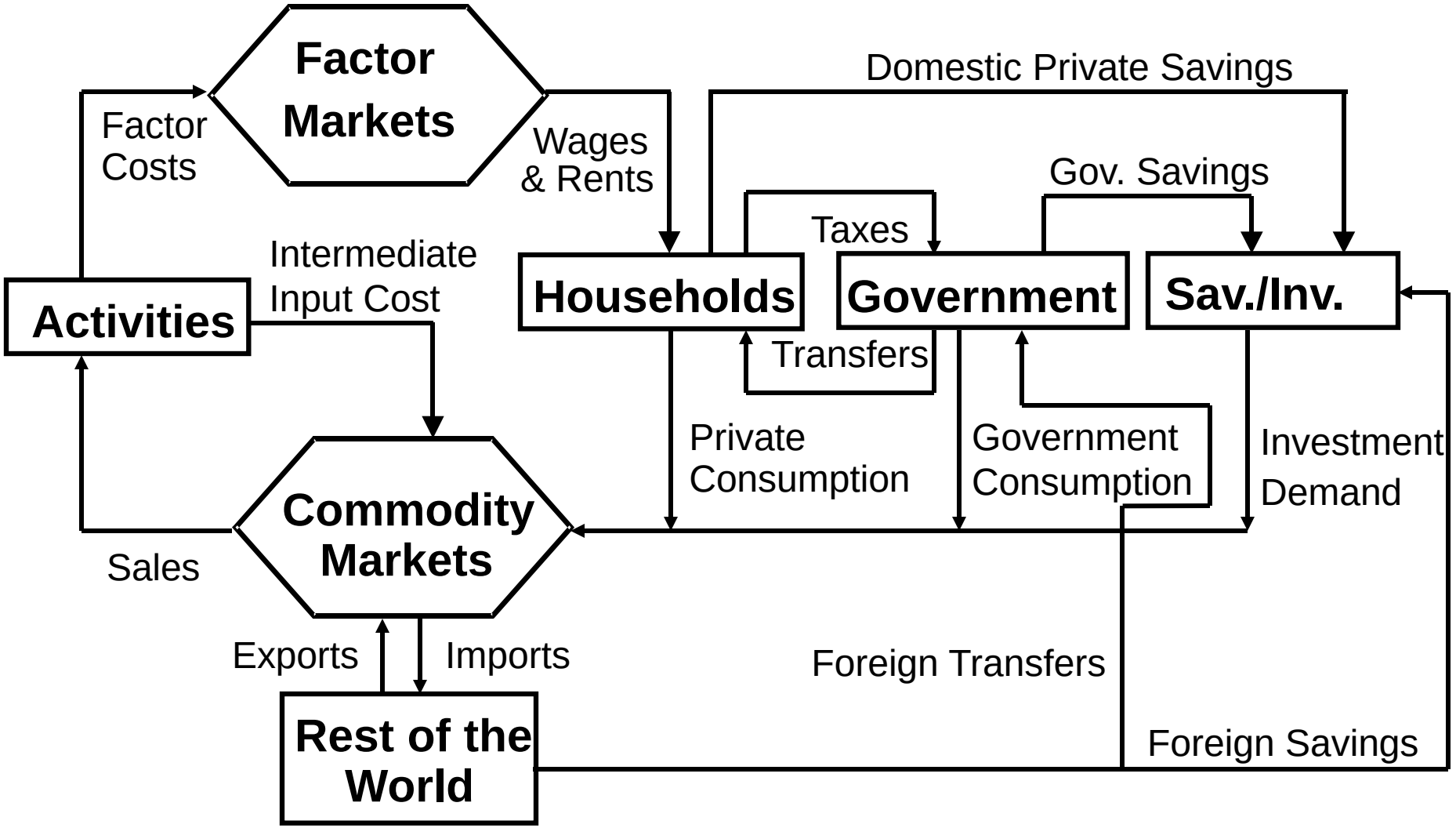
The CGE/W Model System



Computable General Equilibrium (CGE) Models

- A standard tool of economic and policy analysis for the past 40 years
- Simulates operation of a market economy with supply/demand equilibrium determining prices
- IFPRI Standard CGE model (Lofgren and Robinson)

Stylized CGE Model Structure



The CGE-W Country Model

- CGE-W simulates the entire national economy
  - Includes agriculture/non-agriculture links
- Includes regional disaggregation and links to detailed water system simulation models
  - River basin management and yield stress models
- CGE-W models: Pakistan (Indus), Egypt (Nile), and Ghana (Volta)

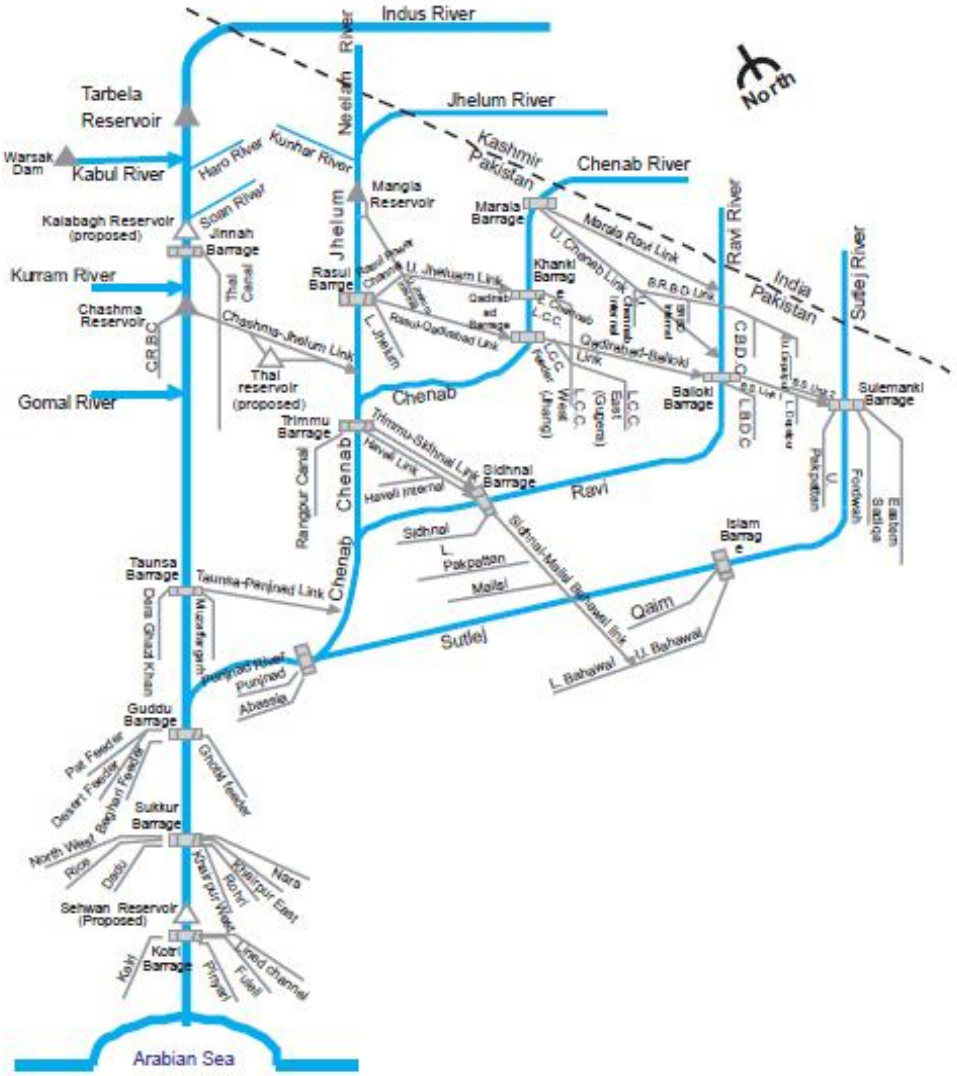
IFPRI Pakistan CGE Model

- Based on the 2007-2008 SAM of Pakistan (Dorosh et al., 2012).
  - 63 activities and 48 commodities
  - Special focus on agriculture (15 agric commodities)
  - Large, medium, and small farms
- Distinguishes 19 types of households and 10 types of labor
- Distinguishes Punjab, Sindh, and other provinces for agricultural sector

Water Demand Module

- Computes agricultural cropped area based on the CGE model results
- The water demand is then computed using FAO guidelines
- Industrial and Livestock water demand are proportional to the amount of activity in the sector
- Domestic water demand is proportional to household revenues

The Indus Basin Water Model



Source: Hasan, 2005.

The Indus Basin Model Revised

- Models the main canals in the basin, along with water demand and storage.
- Has a rule-based optimization system.
- Can implement multiple policy options:
  - New dams
  - New way of sharing/allocating water
  - New or more efficient crops

IBMR Model

- The original model was built by the World Bank in 1989. It is still used today.
- It maximizes producer and consumer surplus, and has a variable cropped area.
- The goal was to see how different policy options would affect total agricultural output.
- It has been refined over time and the data have been constantly updated
- However, it neglects the broader economic picture of the country

CGE-W version of IBMR: RWSM

- Standalone water model: Regional Water System Model (RWSM)
  - Hydrology similar to IBMR
  - Added hydropower module
- RWSM does not have any internal representation of the economy
  - Links to CGE model for economic variables
- Objective is to minimize water shortages across Pakistan: optimizing model like IBMR

RWSM-Pak Overview

- Represents the 45 main canals, as well as the link canals between rivers
- Takes into account fresh and saline groundwater, as well as public and private tubewell pumping
- Can represent droughts and floods
- Includes 16 representative crops
- Takes into account industrial, domestic and livestock water demand (assumed to be drawn from groundwater mostly)

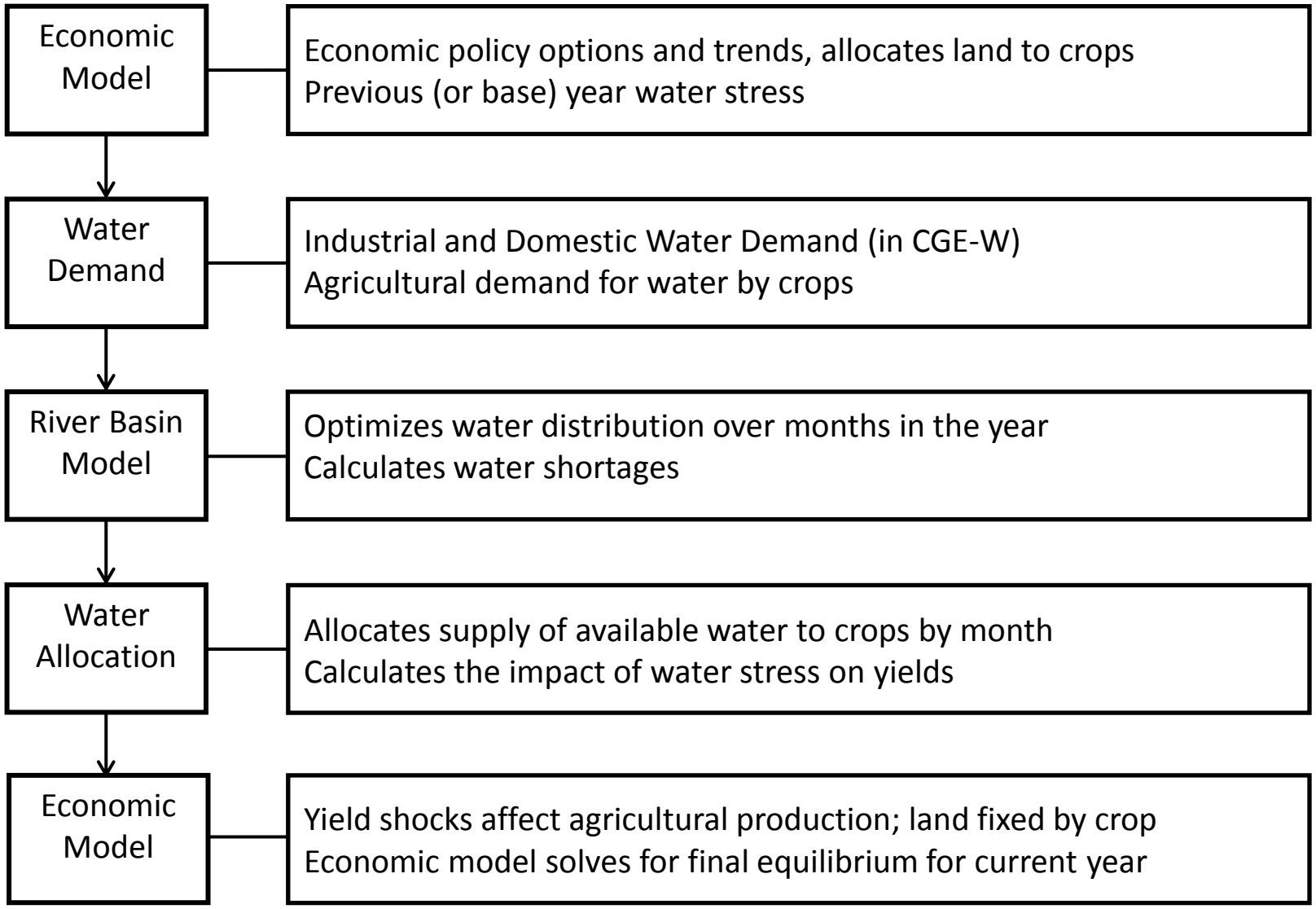
Water Demand Module

- Computes water demand based on the CGE model results
  - Cropped area is based on the demand for land factor from agricultural activities
  - Agricultural water demand is then calculated using the water demand per acre cropped
- Industrial and Livestock water demand are proportional to the amount of activity in the sector and domestic water demand is proportional to household expenditures
  - These demands are broken down by region, proportionally to their population

Water Allocation and Stress Model

- In case of water stress, the yield of crops is reduced using the FAO Ky approach (Doorenbos and Kassam, “Yield Response to Water”,1979)
- We separate the stress during the four main growing stages of the crops and use a multiplicative approach to get the final value
- The allocation objective is to maximize the value of production in each of the water model areas, while minimizing risks for the farmers

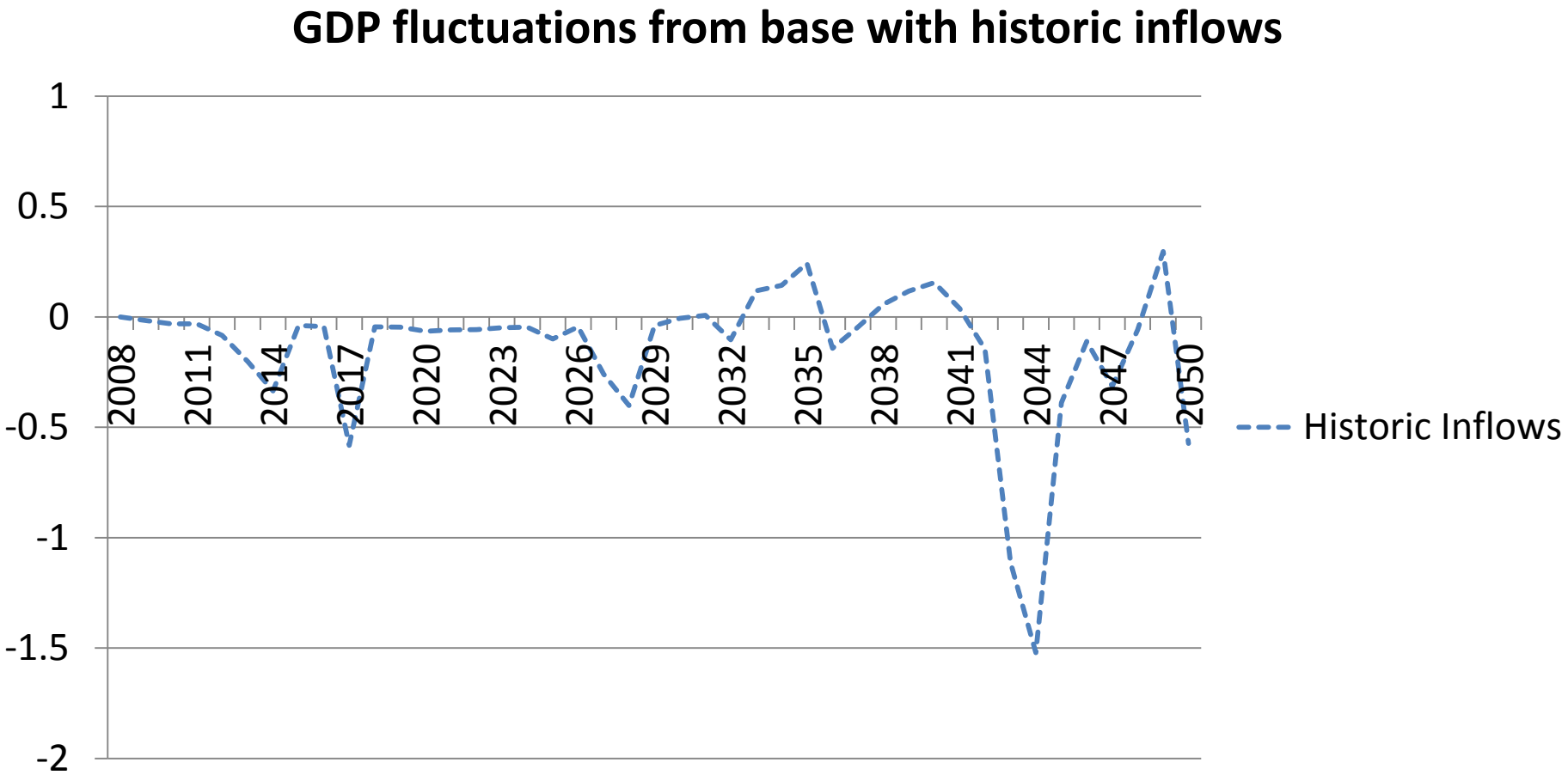
CGE/W: Modular System



Illustrative Results for Pakistan

- We look at the 2005-2050 period
- Our interest is to see whether the proposed Diamer-Basha dam in the upstream Indus is a good investment to adapt to natural flow variability and climate change
- We simulate impacts on irrigated yields and on the hydroelectricity production

GDP change adding variability and/or Basha dam



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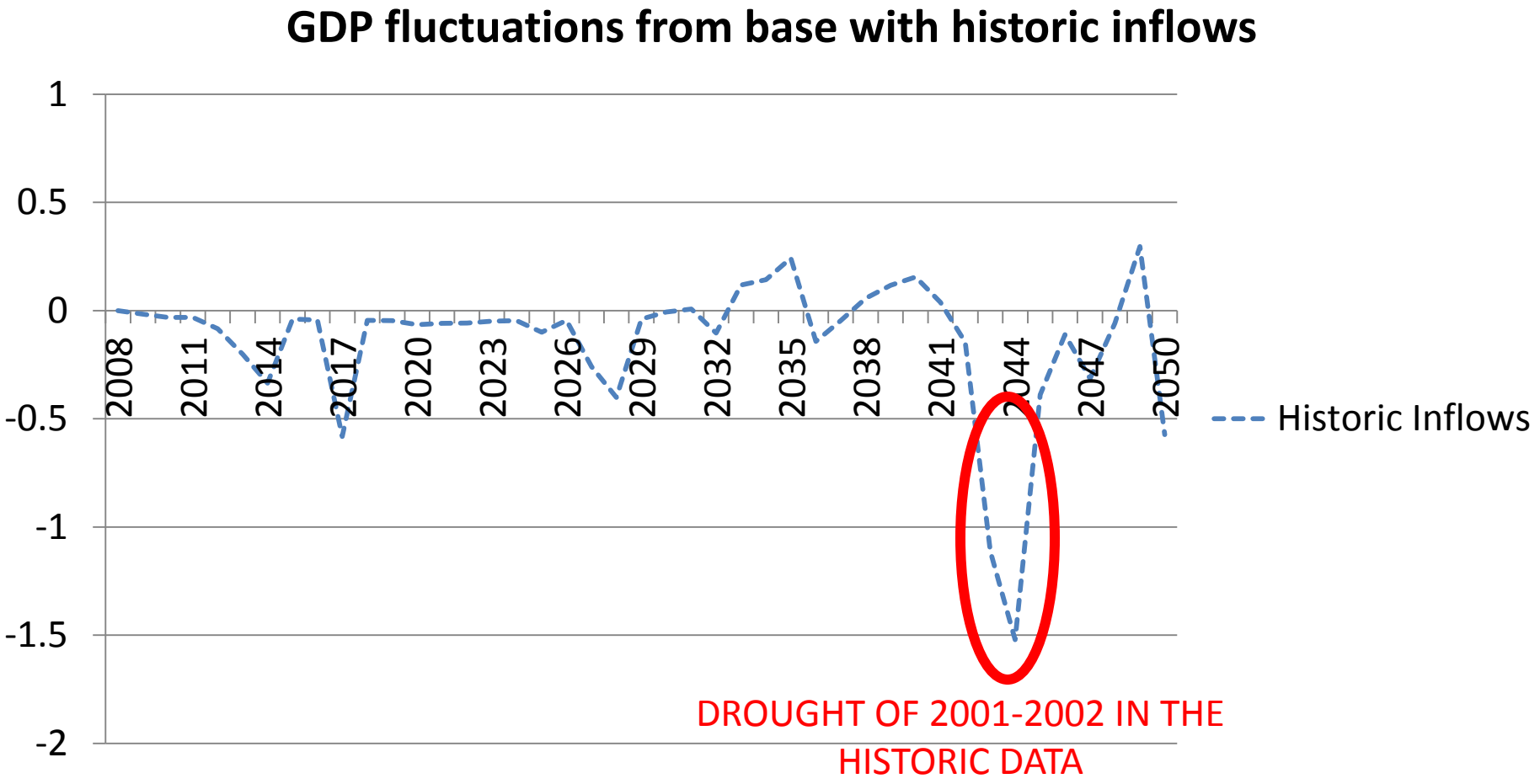

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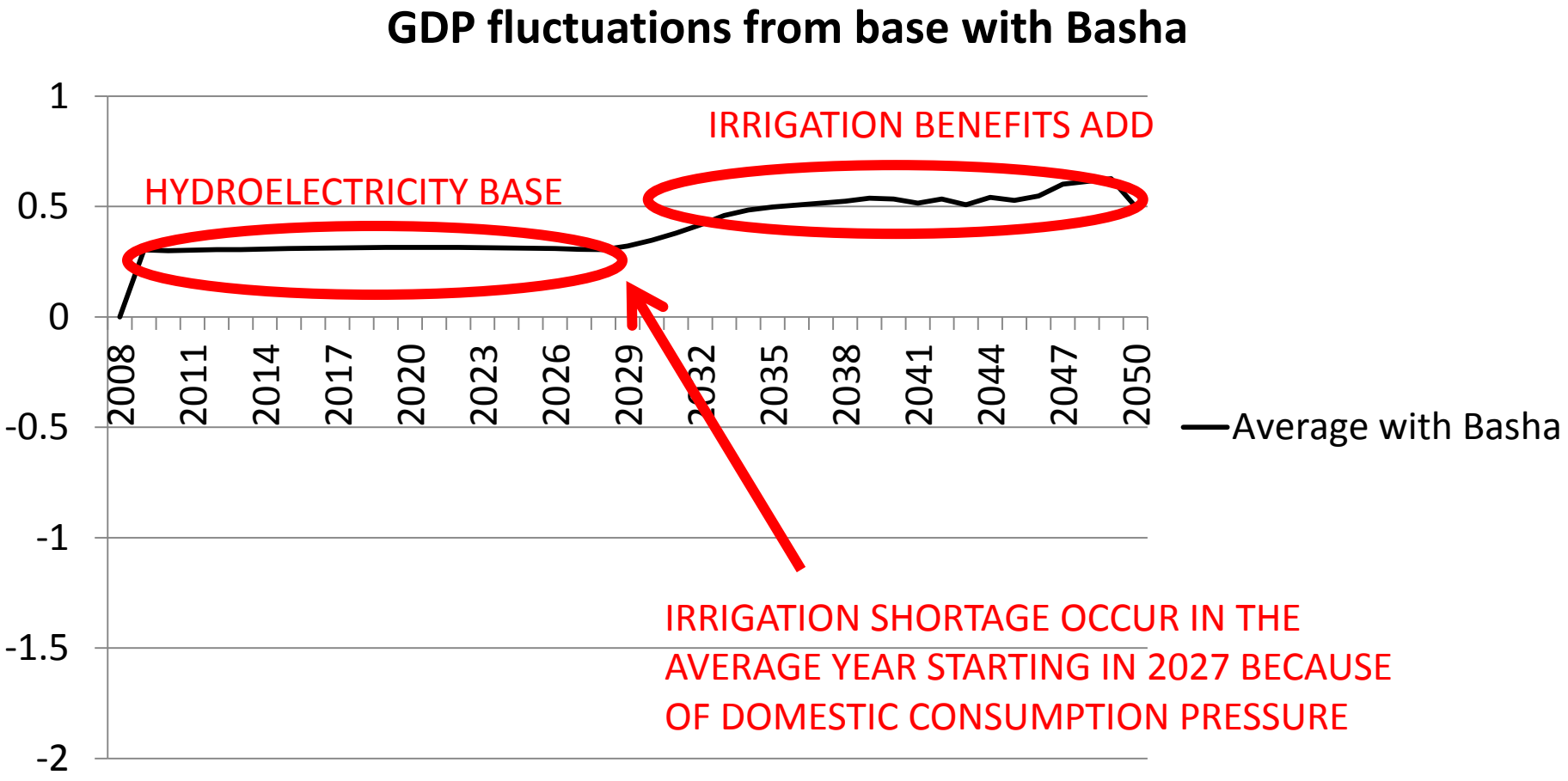

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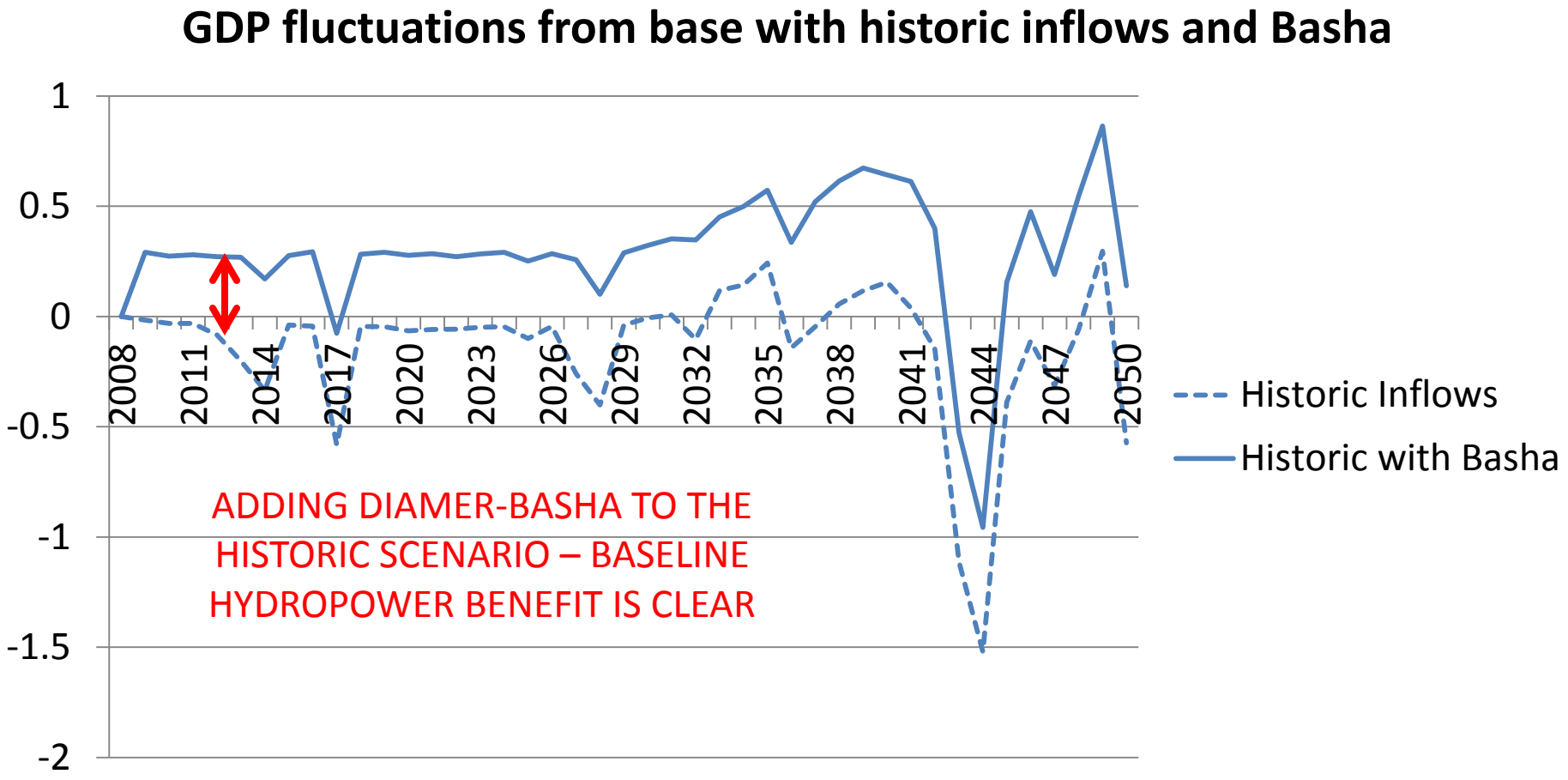
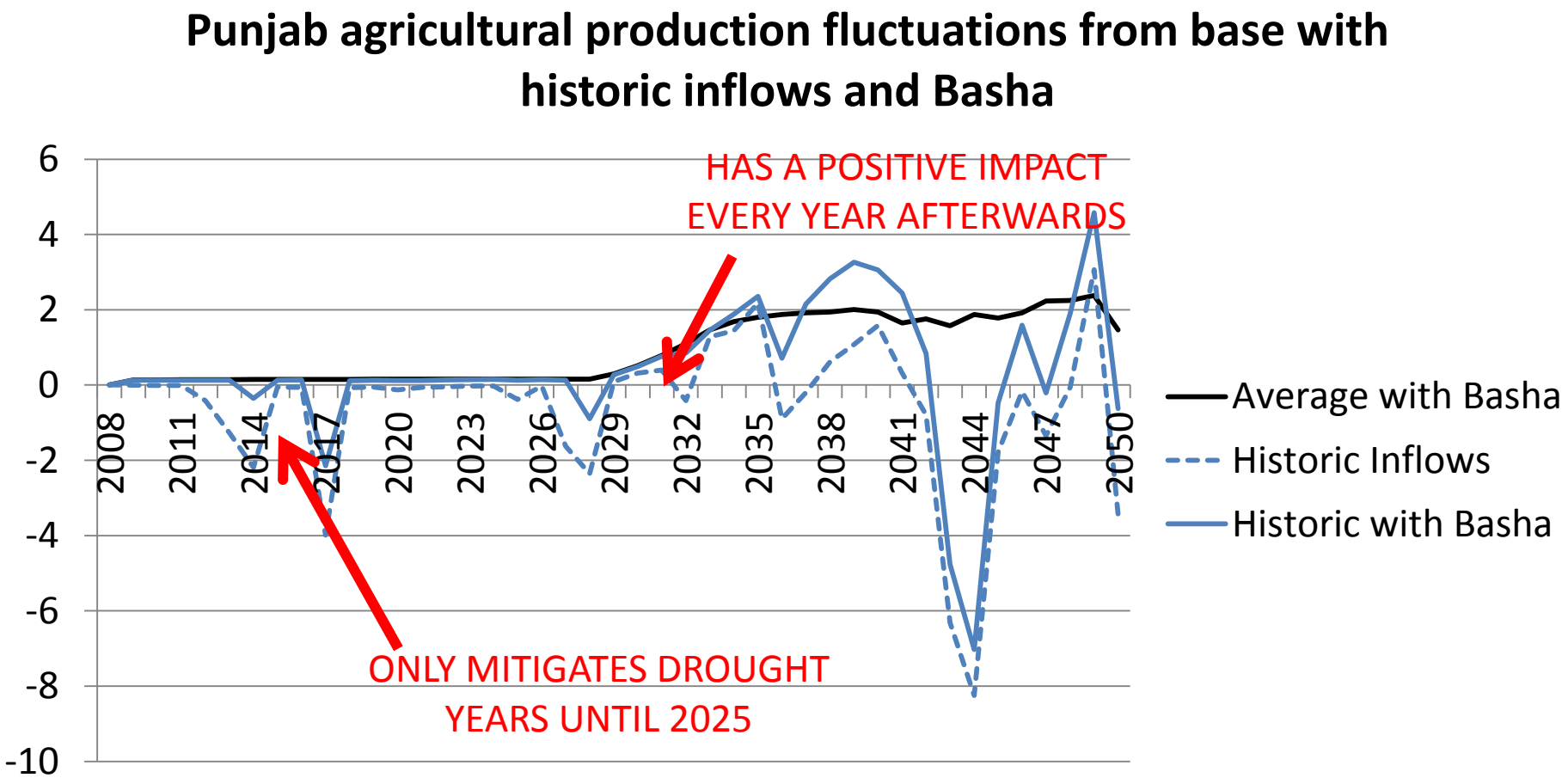


Agricultural Production change adding variability and/or Basha dam



Diamer-Basha in Simple Metrics

	Benefit-Cost Ratio	IRR
Base	2.4	9.3%
Historic Variability	2.7	10.1%
MIROC A1B	3.5	11.0%
MIROC B1	3.0	10.6%
CSIRO A1B	3.3	10.8%
CSIRO B1	2.9	10.4%

Conclusion

- Need for simulation models and scenario analysis at global, regional, and national levels
- Hard-linking economic and water models includes interactions between the food and water systems under global change
  - Philosophy of linking different models is important, capitalizing on strengths of separate model systems
  - Advances in methodologies of model communication facilitate this approach