Optimal Water Policy for an Interconnected World

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Motivation

Globalization: local consumption $\rightarrow$ global environmental consequences

- Why? Complex input-output (IO) linkages across the globe

High attention on CO2 emissions (Copeland and Taylor, 2004, ...)

- Main target of (and issues with) international policy (Nordhaus, 2015)
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This project: focus on **global water** resources.

Motivation – Why Water?

Crucial for domestic consumption and as an input of production

- Agriculture, livestock, textile, steel, brewery, ...

Globalization $\rightarrow$ **virtual water trade** (Hoekstra and Chapagain, 2011)

- Factor trade $\rightarrow$ spatial economy (Vanek, 1959; Davis and Weinstein, 2001)
- Heckscher-Ohlin "*works for water*" (Debaere, 2014; Carleton et al., 2024)

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Policy concern: upcoming **global water crisis** (OECD's Mazzucato et al., 2023)

- Locally stressed basins → systemic issue (Mekonnen and Hoekstra, 2020)

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Differently than CO2, water is renewable

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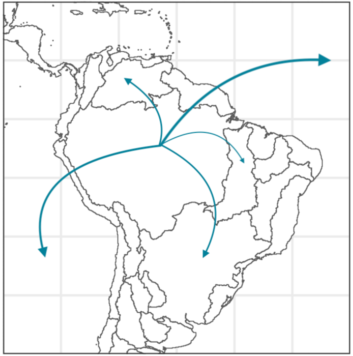
Water cycle → **interconnected water resources**

- Atmospheric moisture flows ≡ spatial links
- Local water depletion → global effects
- Evidence of anthropogenic disruption

Fig. Atmospheric flows from Amazon



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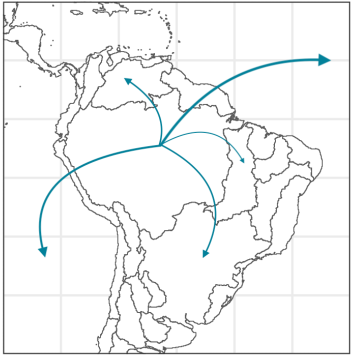

Need: *"policies that values the water cycle as a **global common good**"* (GCEW, 2025)

Research Questions and Outline

Question: What is the **optimal water policy** for our interconnected world?

1. Optimal trade/industrial policy $\rightarrow$ sustainable (global) water governance?
2. Are there economic vs. water policy trade-offs (or local vs. global)?

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For that, **theory + empirics**

- Spatial Integrated Assessment Model (S-IAM) of the Global Water Cycle
- Global data: economy + geographic features + atmospheric modeling

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Exercises of interest:

1. Descriptive: evolution of the global water economy (status quo & others)
2. Normative: optimal policies for a sustainable water future

Academic Contribution

Global environmental policy for GHG (Nordhaus, 1994, 's DICE IAM model)

- S-IAM for CO2 (Desmet and Rossi-Hansberg, 2024); **I add optimal water p.**

Water-economics for local water policy (Dinar and Tsur, 2021)

- Local empirical evidence (Hornbeck and Keskin, 2014; Sekhri, 2022), global agric. studies (Carleton et al., 2025); **I add IAM + non-ag. industries**

Hydrology studies: sophisticated water modeling + "exogenous" economy

- Water cycle disruption → future water/food crisis (Mekonnen and Hoekstra, 2016, 2020; Porkka et al., 2024); **I add a water-economy IAM**

Optimal (dynamic) spatial policies for inneficient economies (long list ...)

- Optimal policies for welfare (e.g., GDP); **I study environmental outcomes**

Roadmap

1. Data + Motivating Facts
   - Consequences of anthropogenic disruption of water cycle
   - Importance of agriculture, but also non-agricultural (downstream) industries
   - Sizeable role of (atmospheric) interconnection of water basins
2. Theory: a S-IAM for the Global Water Cycle
3. ... stay tuned for updates!

Theory – Modeling the Economy and the Global Water Cycle

The Global Economy and the Water Cycle

Start with the **water cycle**. W/o economy, water basin b's stock $W_{b,t} \in \mathcal{W}$ is:

$$W_{b,t} = w_b + \overbrace{R_{b,t-1}}^{\text{Recharge}} - \overbrace{S_{b,t-1}}^{\text{Surface runoff}} + \varepsilon_{b,t}, \quad \text{where} \tag{1}$$

- Recharge $\leftrightarrow$ precipitation (basins $\equiv$ geographical "sinks")
- Surface runoff $\rightarrow$ water flows into the oceans (such that $\sum_b W_{b,t}$ is fixed)

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Define

$$R_{b,t-1} - S_{b,t-1} = \phi W_{b,t-1} \quad \rightarrow \quad \mathbb{E}\left(W_{b,t}\right) = w_b/1-\phi \quad \text{if } |\phi| < 1$$

That is, shocks are not persistent, dissipating over time (i.e., $W_{b,t}$ is stable)

The Global Economy and the Water Cycle

Now, consider economic activity A_b such that $\sum_b A_b = 0$ **(fixed global stock)**

$$W_{b,t} = w_b - A_b + \phi W_{b,t-1} + \varepsilon_{b,t} \tag{2}$$

That is, water use shifts water availability $\rightarrow \mathbb{E}\left(W_{b,t}\right) = (w_b - A_b)/(1 - \phi)$

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Time varying water use would be equivalent; e.g., "economic growth"

$$A_{b,t} = A_b \times t, \quad \sum_b A_{b,t} = 0 \ \forall t \rightarrow$$

different water trends across basins b (as in Carleton et al., 2025)

- Important: includes $W_{b,t}$ into the oceans (as in Tapley et al., 2019)

The Global Economy and the Water Cycle

Now, consider the global water cycle where recharge depends on all basins $\mathcal{W}$

$$W_{b,t} = w_b + R_b(\mathcal{W}_{t-1}) + \varepsilon_{b,t}, \text{ where} \tag{3}$$

- $R_b(\mathcal{W}_{t-1}) = \sum_{b'} r_{b,b'} W_{b',t-1} \equiv$ interconnection between basins (incl. oceans)
- Spatial weights $r_{bb'} \in \mathcal{R}$ link basins through atmospheric and surface flows

Important: define $\mathbf{R} \equiv \mathcal{R}$ in matrix notation,

$$\mathbb{E}\left[\mathbf{W}\right] = \left(\mathbf{I} - \mathbf{R}\right)^{-1} \mathbf{w}$$

is stationary if $\mathbf{R}$'s spectral radius < 1 (i.e., stable global water cycle)

The Global Economy and the Water Cycle

Now, define **economic activity** $A_{b,t}(.)$ as an endogenous process

$$W_{b,t} = w_b + R_b(\mathcal{W}_{t-1}) - A_{b,t-1}(\mathcal{W}_{t-1}; \Theta, \theta) + \varepsilon_{b,t} \tag{4}$$

determined by a global economic (trade) model, where

- $\Theta \equiv$ fundamentals of the economy (factor endowm., techn., trade costs, ...)
- $\theta \equiv$ industrial/trade **policy parameters** (tariffs, subsidies, ...)

The model can feature (population) growth, technical change, ...

- Important: agents must be short-sighted $\rightarrow$ tragedy of the commons!

Optimal Water Policy

Now think about a planner designing **optimal water policy** $\{\theta^*_{b,t}\}_{b,t}$ for basin b

$$\theta^*_{b,t} = \arg\min_{\theta} ||\mathbb{E}\left[W_{b,t}\right] - A_{b,t-1}(\mathcal{W}_{t-1};\Theta,\theta)|| \tag{5}$$

subject to

- Global water cycle "clears" (surface runoff $\rightarrow$ fixed global water stock)
- Economic GE forces (e.g., growth, minimum consumption of food, ...)

Important: with economic activity, **water will be depleted** in some basins

- This exercise finds the less agressive "depletion path"
- Convex extraction costs $\rightarrow$ inequality in water scarcity matters!

Optimal Water Policy

Optimal policies at **country or global level** would yield $\neq$ recommendations

- How does optimal global policy contrast with real-world policies?
- What are the (economic) trade-offs of optimal water policy?

Methodologically, I stand in shoulder of giants, e.g.,

- Optimal place-based (spatial) policies (Fajgelbaum and Gaubert, 2025)
- Optimal trade policy... (Lashkaripour and Lugovskyy, 2023)
- ... for the climate (Farrokhi and Lashkaripour, 2024)
- Optimal dynamic (spatial) policies (Donald et al., 2023; Dávila et al., 2025)

Final remarks

Loads of work ahead – stay tuned! Current work on $A_{b,t}(.)$ + Pareto frontier:

- Toy (static) model w/ Armington demand + (convex) water extraction costs

Full-fledged economic model will ideally feature:

- Prod.&population growth, non-homothetic demand (water, food), ...

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More than a paper, **this is an agenda** with several ramifications!

- Optimal water policy (with Massoni and others)
- Environmental burden of the Green Revolution (with Budí-Ors)
- Water abundance and renewable energy, geopolitical consequences, ...

Thank you

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