Climate change & water resources: adaptation options and their limits

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Regional estimates of water-related climate change costs

- Early estimates for individual river basins, or whole countries, with no adaptation.
  - Fankhauser (1995): average U.S. runoff reduction * average cost of water = economic cost

Problem: Impact of scarcity on prices, demand, supply, welfare?

- More recent efforts model major basins, assuming dynamically optimal water allocation.
  - Hurd et al. (2004), Hurd and Harrod (2001)

Problem: Where are the markets, prices to enable optimization?

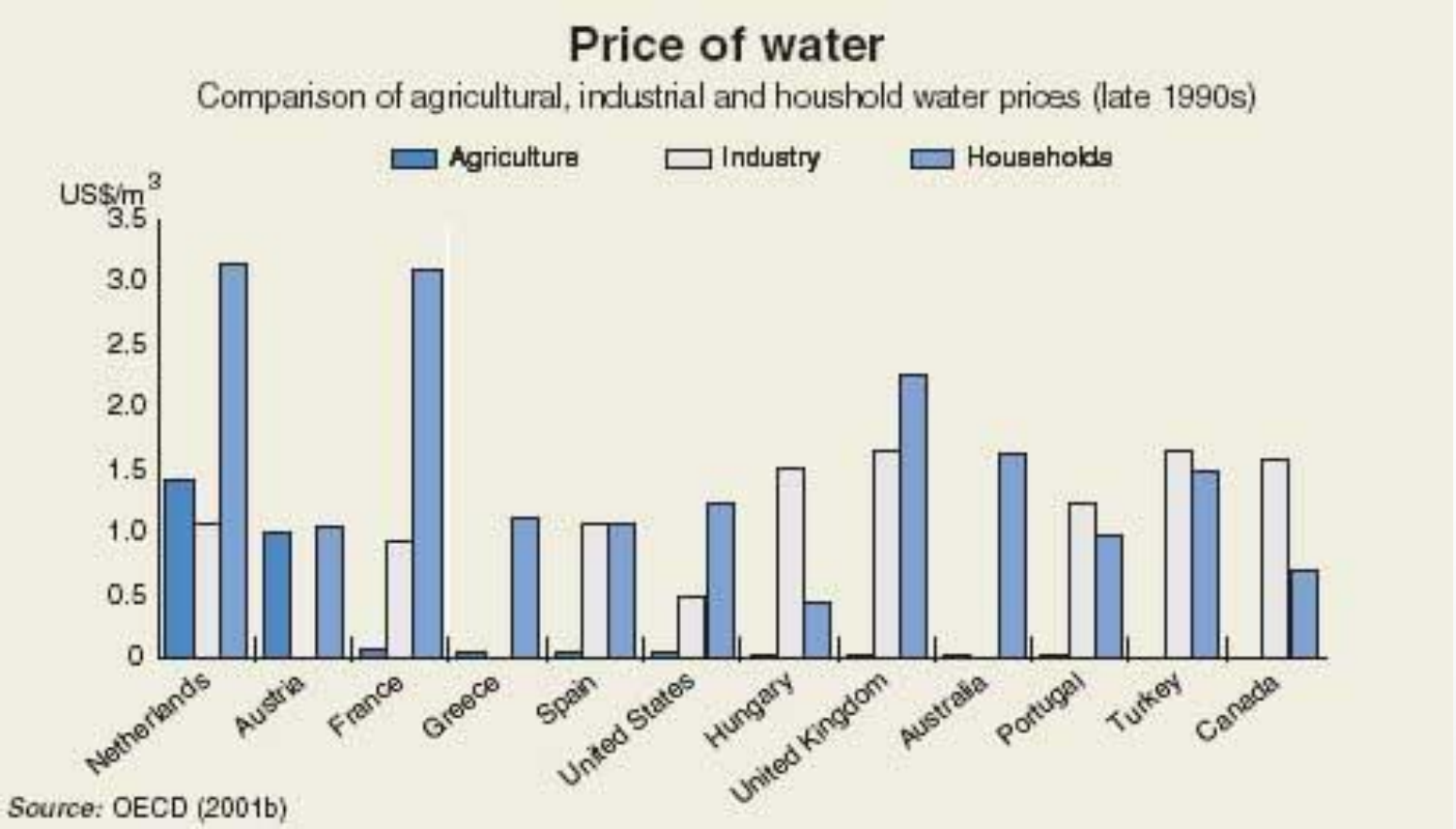
Adaptation to water-related climate impacts

- Water-related climate impacts will affect health, agriculture, urban and industrial water supply and demand, transport, energy supply and demand, non-market ecosystem services, fisheries, forestry, recreation, …

- Tools of adaptation to these changes include:
  - Water pricing and marketing
  - Infrastructure investments (e.g., dams/reservoirs, irrigation)
  - Insurance
  - Migration
  - Crop switching
  - International trade

Inefficient water allocation and pricing are ubiquitous.

- Especially true between urban and agricultural sectors.



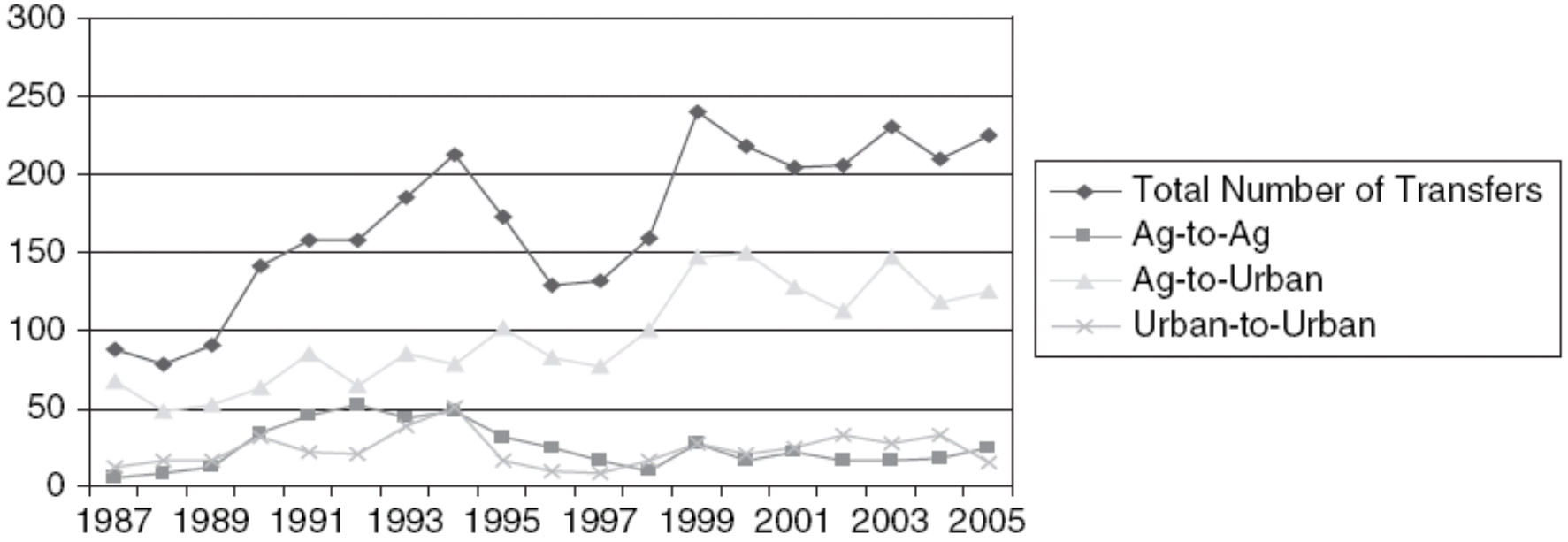
Water markets as an adaptation tool

- Robust water markets are needed for dynamically efficient allocation envisioned in economic models of adaptation.
- Have developed in some arid regions (U.S., Chile, Australia).
- How will markets evolve with climate change?
  - Libecap (2011) – historical water allocations are locked in, institutions inflexible, don't easily adjust to new circumstances.
  - Loomis et al. (2003, p. 242), "Climate change may finally break our anachronistic restrictions on the freedom of water rights holders to seek the most valued uses for their water."
- Current research (Rimsaite, Fisher-Vanden, Olmstead) is exploring impact of climate on water markets.

Water markets do reallocate water from low- to high-valued uses.

FIGURE 3

Water Transfers by Sector, 1987–2005



Source: Brewer J., Glennon R., Ker A., Libecap G. 2008. Water markets in the West: Prices, trading, and contractual forms. *Economic Inquiry*. 46:91-112.

But marketed water is a small fraction of total use, even where markets are present.

U.S. state	2010 Agricultural withdrawal (000 a-f)	2010 Traded to agriculture (000 a-f)	2010 Urban withdrawal (000 a-f)	2010 Traded to urban (000 a-f)
TX	7660	0.36	4480	6.4
CA	25800	70.2	7060	81.2
CO	10900	0.12	950	42.5

Sources: Agricultural and urban total withdrawals from Maupin, M. et al. 2014. *Estimated Use of Water in the United States in 2010*, USGS Circular 1405, Reston, VA: U.S. Geological Survey. Traded water quantities (for 2010) summarized from Smith, R.T., and R.J. Vaughan, eds. *Water Strategist* (1990-2010). Stratecon Inc., Claremont, CA.

Water supply infrastructure and operations

- Main purpose of water resource infrastructure is to smooth variability of natural supply – need is likely to increase.

- Adoption of irrigation is sensitive to climate (Schlenker et al. 2005); infrastructure will play a role in adaptation for other sectors, too.

- Municipal/industrial adaptive infrastructure examples:
  - groundwater recharge and storage infrastructure
  - increased reservoir capacity (raise dams, remove sediment, lower water intakes, increase reservoir size)
  - green infrastructure approaches
  - protection or relocation of low-lying water/wastewater treatment infrastructure

Cost estimates: adaptive water infrastructure

- Hughes et al. (2010): engineering cost estimates of adaptive infrastructure investments for OECD (water supply, treatment, sewage treatment).
  - Adaptation costs are <2% of total baseline current water infrastructure provision costs in OECD countries.
  - Substituting price increases for infrastructure dramatically reduces costs.
- Water supply, flood management infrastructure are among the top three categories of estimated adaptation costs for developing countries (Narain et al., 2011).
  - Global reservoir storage capacity may increase by 2800-3000 km3 thru 2050, at an annual average net cost of about $12 billion (Ward et al., 2010).

Concerns about transboundary water resources

- 261 international river basins cover 45% of Earth's surface.
- Countries, states, counties free ride in water quality (Sigman 2002, 2004; Lipscomb and Mobarak 2008; Gray and Shadbegian 2004).
- Anecdotal evidence that countries also free ride in water quantity/allocation, plus support in theory (especially non-renewable groundwater).
- Recent work suggests market failures in transboundary river basins may be significant (Olmstead and Sigman 2015) – could climate change exacerbate these?

Results from recent research (Olmstead and Sigman 2015)

- Regression analysis suggests more dams are placed upstream of international borders, all else equal
  - Consistent with significant common property problems – countries do not fully consider the welfare of downstream riparians in water development.

- Multilateral (World Bank) funding mitigates, but does not eliminate this free-riding in resource sharing.

- Weak evidence that treaties mitigate free-riding.

Conclusions

- Water resource implications of the changing global climate are significant, uncertain.
- Ultimate impacts of these changes on human welfare will depend critically on water management institutions – prices, markets, infrastructure, treaties…
- Empirical evidence suggests that these water management institutions don't yet support an efficient water management system in most places, which may be an impediment to adaptation.

Thank you!

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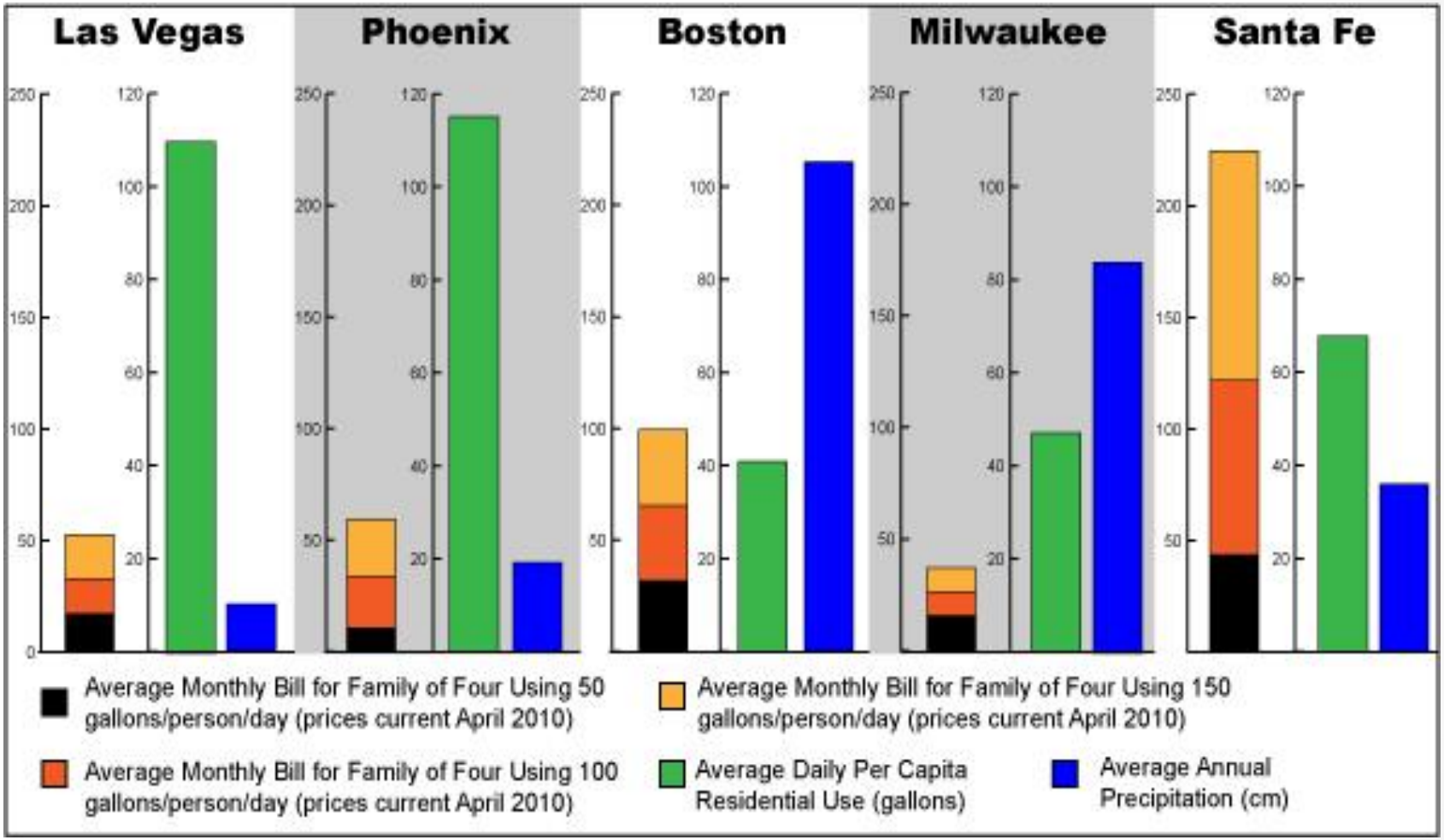
Suggestions for further research

- Rigorous modeling of the economics and political economy of water management is needed:
  - Level and structure of water prices
  - Use of non-price demand-side management
  - Legal property rights regimes for water
  - Extent of & constraints on water marketing
  - Investment in water supply infrastructure
  - Changes in infrastructure operations
  - Transboundary allocation institutions

Water prices & scarcity are decoupled



Source: Walton, Brett. 2010. The price of water: A comparison of water rates, usage in 30 U.S. cities. 26 April. www.circleofblue.org.

Complex welfare implications of dams

- Variety of services provided
  - Water supply, irrigation, hydroelectricity, flood control, fisheries, recreation, etc.
- But dams impose costs, as well
  - Reduction in flows/water availability downstream, changes in magnitude/timing of seasonal flows, increased water temperature, hindered movement of fish and other species, changes in rate and quality of sediment deposition, …
- Tradeoffs between services and disruption to rivers create mixed welfare effects (Duflo and Pande 2003)

International spillovers (spill-unders)

- Countries sharing a river may pass some of the costs imposed by dams (especially water supply, hydro, and irrigation) to downstream countries.
  - Or may fail to consider downstream benefits in some instances (flood control)

- Resulting spillovers/spill-unders create the potential for conflict across borders of countries sharing a river.

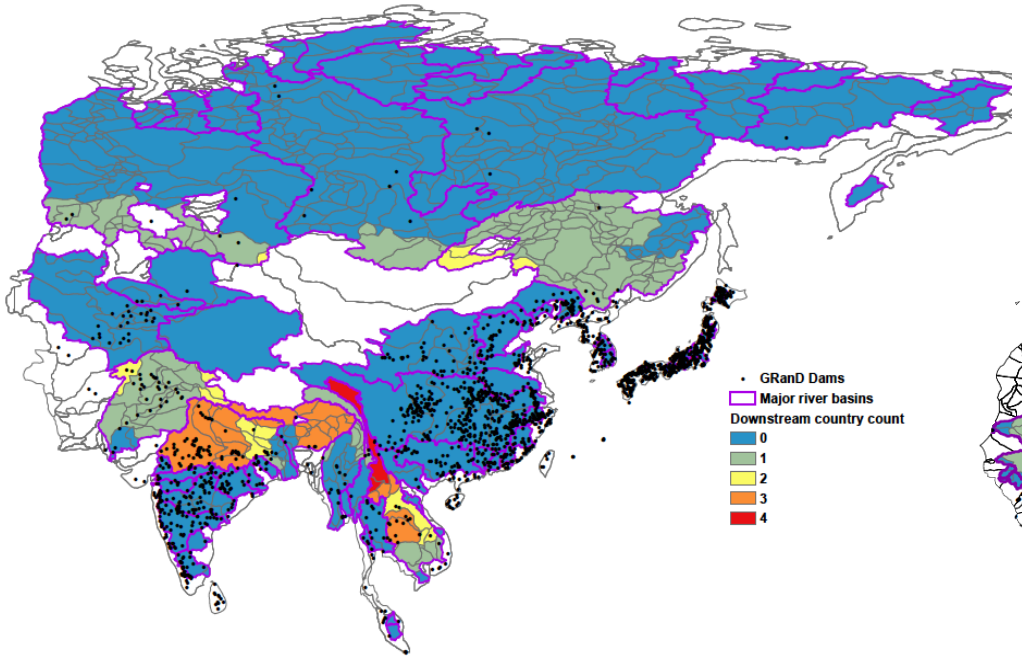
- Work in progress (Olmstead and Sigman 2015) examines:
  - Whether countries free-ride in water diversion on international rivers through placement of dams, size of impounded reservoirs, and dam height.
  - Role of multilateral funding and treaties in mitigating free riding.

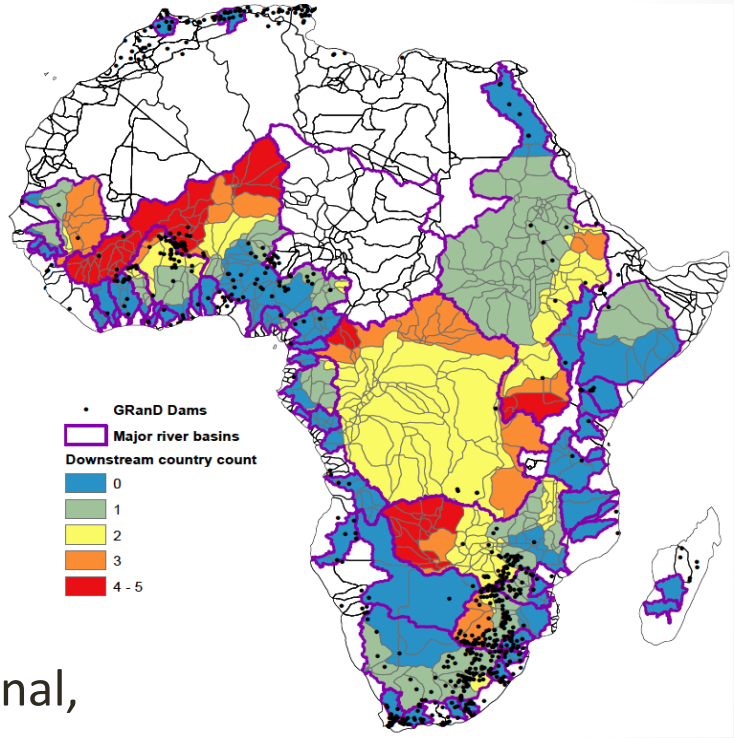
Anecdotal evidence abounds…

- "We will defend each drop of Nile water with our blood if necessary."
  - Former Egyptian President Mohammed Morsi, referring to the Grand Ethiopian Renaissance Dam, which may affect the flow of the Nile River into Egypt. (CBS News June 2013)

- "To fight for every drop of water or die: that is the challenge facing China."
  - Former Chinese Water Resources Minister Wang Shucheng, describing the nation's water policy, while discussing governance of China's 13 major transboundary rivers. (*The Economist*, October 2013)

Data for recent paper on dams

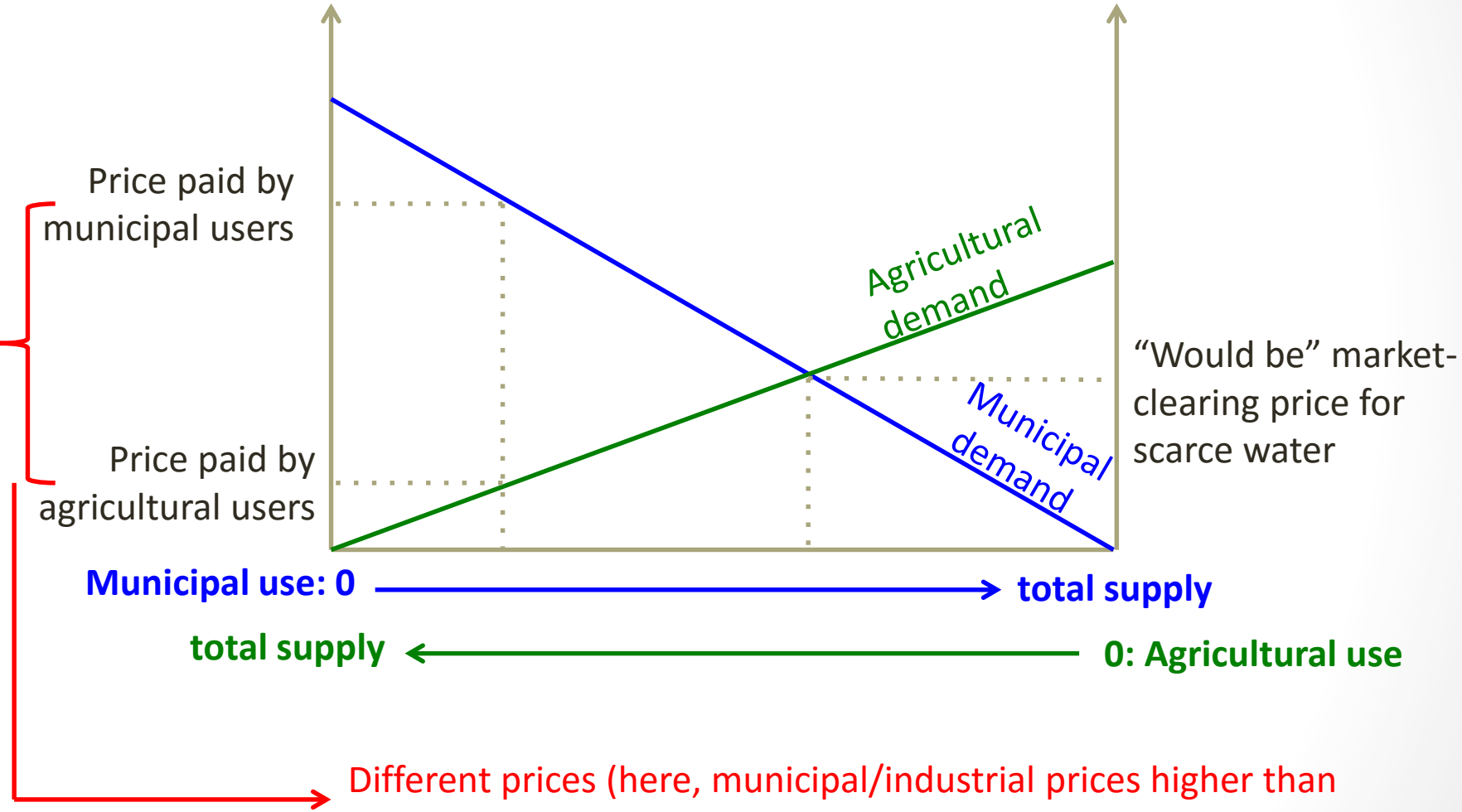




- 4954 geo-coded dams from GRanD
- In 2725 "sub-basin country areas"
- In 381 major river basins (115 international, 266 domestic)

Source: Olmstead, S. and H. Sigman. 2015. Damming the commons: an empirical analysis of international cooperation and conflict in water development. Working paper, under review.

Prices determine the allocation of water across sectors.



Different prices (here, municipal/industrial prices higher than agriculture), open up a big gap in the value of water used in different sectors.