Final Report
Water Scarcity and Economic Growth in Wyoming

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Abstract:

The persistence of drought conditions over much or all of the state of Wyoming in recent years has raised concern as to whether water availability relative to use may be limiting economic growth and development opportunities in certain regions or even state-wide. This research aims to address this issue by analyzing the relationship between relative water availability and economic growth across the counties and key water-using sectors in Wyoming, irrigated agriculture and other productive uses (municipal and industrial). Three broad results are anticipated: 1) An empirical analysis over time (i.e. annually) of a water-growth relationship for two key water-using sectors in Wyoming's economy: irrigated agriculture (i.e. the annual crop sector and fodder) and municipal and industrial users (for production). 2) Identification of possible future trade-offs and conflicts over water use by these two key production sectors in Wyoming. 3) Identification of those counties and sectors whose economic development is especially at risk from chronic water scarcity, as measured in terms of moderate and/or extreme hydrological stress conditions.

Problem and Research Objectives:

The persistence of drought conditions over much or all of the state of Wyoming in recent years has raised concern as to whether water availability relative to use may be limiting economic growth and development in certain regions or even state-wide. The primary objective of this study has been to analyze the relationship between relative water availability and economic growth across the counties and key water-using sectors in Wyoming. Jacobs and Brosz 2000) indicate that 80-85% of water consumed in Wyoming is for irrigated agriculture (approximately 2.6 million acre-feet). Ignoring evaporation from reservoirs, all other water uses in Wyoming (domestic, municipal, livestock and industrial – including mineral and energy) account for 160,000 acre-feet of water consumption. Thus this study has focused on analyzing water-growth relationships in Wyoming for two distinct, and potentially competing, uses: irrigated agriculture, and other productive water uses (municipal and industrial).

The modeling has been based on adapting the approach by Barbier (2004), which depicts the influence of water utilization on the growth of the economy through a model that includes this congestible publicly provided good as a productive input for private producers. The result is that the aggregate rate of water utilization by all producers is related directly to the growth of the economy. In Barbier (2004), this relationship was empirically tested through a statistical analysis across countries, and allowing for the fact that some countries face moderate or extreme conditions of water stress. The aim of this project's research has been to modify the water-growth model and apply it to two principal production sectors in the state of Wyoming.

The analysis has involved examining empirically the relationship between the rate of water utilization and economic growth across the individual counties of Wyoming and over time (i.e. annually) for the irrigated agriculture and the municipal & industrial sectors. Analyzing the latter category of use is particularly important, as surface water consumption for domestic and municipal use is anticipated to increase from 60,000 to over 148,000 acre-feet in 2020, and

industrial consumption is projected to rise from 85,000 to over 845,000 acre-feet in 2020 (Jacobs and Brosz 2000).

When fully completed, both the county and sector-level analyses will not only reveal the extent to which overall economic growth in Wyoming is affected by water availability relative to use but also identify those counties and sectors whose economic development is especially at risk from water scarcity. Such information may be critical to future water use planning in Wyoming, and for the design and implementation of institutional and allocation mechanisms for water supply in the state.

Both empirical studies will be completed in Fall 2005.

Methodology and Anticipated Results:

Analyzing water-growth relationships for the two main categories of sectoral use, irrigated agriculture and municipal & industrial use, requires two distinct modeling approaches.

For example, irrigated water is a privately provided good, usually supplied by farmers to themselves through exercising their prior appropriation rights. A different modeling approach is required to determine how the aggregate rate of water utilization for irrigated farming affects growth in this sector of the economy. Details of this model for water use in irrigated agriculture are summarized in Barbier and Chaudhry (2004). The work of applying this model to empirical data across Wyoming is likely to be completed in Summer 2005.

Analyzing municipal and industrial use involved combining the modeling approach developed in Barbier (2004) with a model of public capital and economic growth by Shioji (2001) and Barro (1990). In this approach we suggest that water is provided to producers as a publicly provided but congestible good, and we focus on investment in water-related infrastructure (e.g. water delivery, cleaning and storage) as well as the total volume of water availability (Chaudhry 2004). The result is that the aggregate rate of water utilization by all producers is related directly to the growth of production in this sector of the economy.

In sum, we anticipate the following three results from the study:

- An empirical analysis over time (i.e. annually) of a water-growth relationship for two key water-using sectors in Wyoming's economy: irrigated agriculture (i.e. the annual crop sector fodder and municipal and industrial users (for production).
- Identifying those counties in Wyoming where potential conflicts and tradeoffs between the two water-using sectors may occur in the future.
- Identifying those counties and sectors whose economic development is especially at risk from chronic water scarcity, as measured in terms of moderate and/or extreme hydrological stress conditions.

Summary of Progress in FY2003:

A graduate assistant, Ms Anita Chaudhry, was appointed to the project. Ms. Chaudhry is undertaking this project as part of her PhD studies, supervised by the principal investigator, Professor Edward Barbier.

Professor Barbier outlined the scope and aims of the project at the 2003 Stroock Forum at the University of Wyoming on 16 September 2003 in a presentation, “Water Scarcity, Wyoming and River Basins”.

One of the aims of the project in FY2003 was to develop the various methodologies for analyzing water use and growth in the two main sectors, irrigated agriculture and municipal & industrial use. It was decided that the Barbier (2004) model could be readily adapted to analyze

water-growth relationships for producers in the municipal & industrial use sector but not for irrigated agriculture. The main effort in 2003 therefore to develop an appropriate model for the latter sector, taking into account that irrigated water is a privately provided good, usually supplied by farmers to themselves through exercising their prior appropriation rights.

Another major focus in the first year of the project was to identify useful contacts in the State and Federal agencies concerned with water use in Wyoming, and to identify and collect the appropriate hydrological, demographic and economic data necessary for the project. The following summarizes our efforts in 2003:

People contacted

- State Engineer's Office: Patrick Tyrrell
- Wyoming Water Development Commission: Barry B. Lawrence
- United States Geological Service: Bob Swanson, Timothy T. Bartos
- Water Resources Data System: Jan Curtis, Debra Cook

Hydrological data

- United States Geological Service (http://water.usgs.gov/watuse/)

This source contains estimated water use data for Wyoming by county (or watersheds) for the year 1990 and 1995. For each year, data on surface and groundwater withdrawals and consumptive use is available for the following sectors: public supply, commercial water use, domestic, industrial, mining, livestock, irrigation, power generation (fossil fuels as well as hydroelectric power generation). These data are the most useful for our purpose because of its break-down by county and industry.

- Wyoming Water Plans (http://waterplan.state.wy.us)

This source contains data by basin. Data are available for water flows and use for different industries. But in almost all cases, there is a single estimate of water use, often a multiple year average, rather than time series information.

The water plans however, are useful because they provide an excellent overview of water uses, interstate compacts as well as current developments in the basin. They also contain projections of various water uses up till 2030.

All basins except Snake/Salt River Basin, Platte River Basin and Wind/Bighorn River Basin have a water plan that is ready and available on the web.

Economic and demographic data

- Bureau of Economic Analysis (http://www.bea.doc.gov)

This site contains data on gross state product, wages, and property income, by industry up till 2001. These data are available for each industry (e.g. agriculture, forestry, mining, construction, nondurable goods etc.) The site also contains personal income, per capita personal income and population data on Wyoming up till 2001. Moreover, personal income data broken down by industry and county is also available for the year 2001.

- US Bureau of Census (http://www.census.gov)

This site is very useful because it contains the demographic data for the State for 1990 and 2000. Data are also available for various social (e.g. school enrollment, urban-rural residence, children born per 1000 women etc.), economic (employment by industry, income distribution etc.) and housing characteristics. There are also projections available for the year 2002.

Summary of Progress FY 2004:

We finished developing an economic model of water use in the agricultural economy of Wyoming, taking into account that irrigated water is a privately provided good. A paper

summarizing this model was presented at a major international conference (Barbier and Chaudhry 2004). This model links relative water demand i.e. water withdrawal vs. water availability at a farm level to economic growth. One of the main results of the analytical model is that under conditions of moderate or mild water scarcity i.e. when water use is less than water availability, farm income will be positively related to water use. Under conditions of extreme water scarcity, when water use is reaching the limit of water availability we can expect to see decline in farm income. Our model shows that farm water availability is an important determinant of long run welfare of the agricultural sector.

A separate analytical model was developed for the case of water use in municipal uses. As mentioned earlier, water in municipal uses has been modeled as a publicly provided good as in Barbier (2004) and Barro (1990). A result that emerges from this study is that water use relative to water availability as well the level of water-related public capital owned by the municipality have long run effects on economic growth of the municipal sector. We are currently involved in finalizing the results of the analytical model for the municipal water use.

A major focus of this study is to test the hypotheses derived from the analytical models in Wyoming. To this end, the first step is to construct an index of relative water scarcity for Wyoming counties. As stated in Barbier (2004), the ratio of water withdrawal, *r*, to water availability, *w*, can be effectively used as a measure of relative water scarcity. USGS uses this index to measure water scarcity at a basin wide level in the US but these data are not available at the county level. County level information is important because all economic and demographic data are available at county or state level. One of the aims of the project FY 2004 has been to construct this data for Wyoming counties. Discussions were held with WWDC staff in Cheyenne as well experts in Laramie. A brief description of methodology used is given below.

Jacob and Brosz (2000) have provided data for unappropriated waters available for future consumptive use in Wyoming. These data are given for each river basin in Wyoming and they give us an idea about how much water is still available that could potentially be used in the future. These data capture the legal water availability of water within each basin by incorporating the interstate compacts and statues that govern water use in Wyoming and neighboring states. Water may be naturally available in the State but if interstate compacts award its use to another State, the effective limit to water use is in fact the legal right to water (Jacob *et. al*. 2003). Apportioning these basin-wide figures into counties contained in these basins would give us an idea how much each county can expect to expand its water use in future.

As mentioned earlier, the USGS measures water withdrawals and consumptive use for each county in Wyoming for the years 1985, 1990, 1995 and 2000. If water is being consumed in county it must be the case that it is legally available for use in that county. Summing consumptive water use and the unappropriated waters available for each county would provide legally available water supplies in that county.[1] Unfortunately, consumptive use information is not given for surface and groundwater separately. Hence the next best strategy is to use surface water withdrawals instead. Adding surface water withdrawal to the unappropriated waters available for use gives us a measure of the total water supplies, albeit a rough one. Using the data for water withdrawal and total water available we have computed r/w i.e. total surface water withdrawal/(total surface water withdrawal + unappropriated water available for future use).

[1] This is a very strong assumption since a large part of water withdrawn is returned to the water system via return flows. Hence, adding water withdrawn to the B1 may overestimate the legal availability of water in a county.

People Contacted

- Barry B. Lawrence, Jon Wade, John Jackson, Wyoming Water Development Commission
- Larry Otto Pochop, Office of Water Programs, University if Wyoming
- Garry Watts, Consultant

As the final step of the analysis we are using the above data to econometrically estimate the impact of water scarcity on agricultural and municipal & industrial sectors in Wyoming. The relative water demand index combined with the economic and demographic data from the BEA and US Bureau of Census will help us not only test the hypotheses proposed by the analytical models but also identify which sectors and counties are currently facing downward pressures on economic growth due to water scarcity. The results of these empirical estimates are likely to be available in Fall 2005.

Publications:

Barbier, E.B. 2004. "Water and Economic Growth." *Economic Record* 80: 1-16.

Barbier, E.B. and A. Chaudhry. 2004. "Water and Growth in an Agricultural Economy." Presented at the Thirteenth Annual Conference of European Association of Environmental and Resource Economists, Budapest University of Economic Sciences and Public Administration, Budapest, 25-28 June 2004.

Chaudhry, A. 2005. "Water, Public Capital and Growth in Municipalities and Industries." *Mimeo.* Department of Economics and Finance, University of Wyoming.

Student Support:

Ms Anita Chaudhry is the graduate research assistant employed fulltime on this project, as part of her PhD in Economics studies.

References:

Barbier, E.B. 2004. "Water and Economic Growth." *Economic Record* 80: 1-16.

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Chaudhry, A. 2005. "Water, Public Capital and Growth in Municipal and Industries." *Mimeo.* Department of Economics and Finance, University of Wyoming.

Jacobs, James J., and Donald J. Brosz. 2000. "Wyoming's Water Resources." University of Wyoming, Agricultural Experiment Station

Jacobs, James, Patrick Tyrell and Donald Brosz, 2003 "Wyoming Water Law: A Summary" University of Wyoming Agricultural Experiment Station

Shioji, Etsuro. 2001. "Public Capital and Economic Growth." *Journal of Economic Growth* 6:205-227.