WATER, ECONOMIC GROWTH, AND CONFLICT: THREE STUDIES

by

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PREFACE

As global water withdrawals increase, policy analysis increasingly requires refined understanding of the causes, correlates, and implications of such trends. The following dissertation presents three separate studies addressing water management issues. The studies are a combination of quantitative and qualitative analyses, intended to shed light on current issues in water resource economics and policy. While the focus of these studies is water, the methods and results are relevant to environmental and natural resource policy in general.

The first study investigates how patterns of water withdrawals and water use correlate with economic growth at the national and state levels. The goal of this study is to contribute both to the literature on the relationship between economic growth and the environment, as well as to the literature on water use forecasting.

The second study analyzes the correlation between national income and water footprints. A nation's water footprint represents the sum of water consumed directly plus the net import of "virtual water", a term coined to denote the amount of water necessary to produce agricultural and industrial goods. Thus, while the previous study addressed water withdrawals, this study looks at international trade in goods produced with the water. As such, the two studies can be seen as addressing the production and consumption sides of water. This study also complements the first in that it addresses the issue left unanswered by the first study of whether countries may alter their own water withdrawals by compensating with consumption of water intensive goods from other countries.

The third study presents evidence that warnings and threats of large scale violence over increasingly scarce water resources appear to be more common than past experience would suggest likely, and presents an analysis of reasons why such warnings are so common. It discusses incentives faced various stakeholders for stressing and even intentionally exaggerating the risks of violent conflict. The goal of this study is to contribute to the fields of environmental security, water management, and peace and conflict studies.

The hope is that each of these studies will serve to inform policy-makers and planners regarding the likelihood of water use patterns and their expected impacts, and allow for more accurate and sustainable water management.

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ABSTRACT

All three of the studies contained herein address issues of water policy and management. The first two are largely quantitative analyses of the relationship between economic growth and water use. A better understanding of this relationship will allow planners and policy-makers to better predict future water use patterns, and offers insight to larger questions regarding economic growth and natural resource management and environmental quality in general. The third study presents an overview of the literature on conflict over water resources and presents evidence that several actors face incentives to stress and even exaggerate such risks. Identifying such incentives will allow analysts to better evaluate the veracity and seriousness of conflict potential. Because the three studies are largely self-contained, separate abstracts are offered for each below.

Chapter 1. Water use and economic growth: Is there an EKC for water use?

Predictions of national and global water use have been criticized for being inaccurate and for not taking into consideration economic development. Of the little research that does address water use as a function of economic development, some claims no relationship, while other studies find a clear environmental Kuznets curves (EKC) or “inverted U” relationship. This research attempts to elucidate the relationship between income growth and freshwater use by a) evaluating a variety of cross-sectional and panel datasets on water withdrawals and consumptive use and b) employing both traditional least squares and non-parametric regression analysis, the latter of which offers the advantage of not assuming a given functional form. The research finds some support for the existence of an EKC, but results are highly dependent on choice of datasets and

statistical technique. Results are also sector specific and prove poor indicators of individual country behavior.

Chapter 2. Virtual water trade and income: Is there an EKC for water footprints?

The concept of virtual water – the amount of water needed to produce crops and industrial goods – has become an increasingly popular metaphor in water management and policy discourse. A nation's water footprint is a nation's water withdrawals plus its net import of virtual water. This paper investigates the correlation between national per capita water footprints and per capita income and compares this to research on per capita water withdrawals and income, for which previous studies have found an inverted U relationship, also called an environmental Kuznets curve (EKC). Least squares and nonparametric regression techniques are utilized. Water footprints do not display the inverted U relationship found for per capita withdrawals, but rather, a monotonically increasing relationship. Results suggest that at least some of the decline in per capita withdrawals by economically developed countries may be due to increased import of virtual water from poorer countries.

Chapter 3. Hydro-political hyperbole: Examining incentives for exaggerating the risks of water wars

Predictions of inevitable and imminent wars over scarce water are routinely made by prominent political figures, academics, journalists, and non-governmental organizations (NGOs). These statements continue to occur despite both a questionable theoretical foundation and relatively little empirical evidence to support them. This study demonstrates that several sets of actors each have differing incentives to stress and even exaggerate the probability of war over water. Policy makers, for instance, may use threats of war to highlight the importance of water issues otherwise seen as "low politics." Their target audience may be neighboring countries, the international community, or domestic constituencies. Journalists have incentives to highlight issues relating to violent conflicts, which are deemed inherently newsworthy. Academics and environmental and development NGOs have incentives to focus on the possibility of war because it can raise the profile of their work, increase access to decision-makers and journalists, and expand the types of funding available. Some elements of the private sector have an incentive to stress how water-related infrastructure may stave off war. All parties have incentives to use the specter of war as a way of highlighting related issues that might not otherwise receive public attention. This confluence of such an array of incentives has likely contributed to an overemphasis of the possibility of water wars in public discourse.

CHAPTER 1
Water use and economic growth:
Is there an EKC for water use?

1. Introduction

By some estimates, humanity has already appropriated over half of the world's available water resources (Postel, *et al,* 1996; Loh and Wackernagel, 2004). As growth rates for global water withdrawals continue to outpace even global population growth, several governments, international development agencies and leading researchers have pointed to global water scarcity as a potentially serious economic, health, and even security issue (e.g., Postel, *et al*, 1996; Gleick, 2000; World Water Commission, 2000). Projections of future water scarcity are numerous; however, measurements of actual water use and predictions of future water availability and consumption rates have proven difficult to estimate accurately (Shiklomanov, 2000; Gleick, 2000, 2003).

One of the difficulties in correctly calibrating such predictions lies in specifying the role that factors other than population play in determining water use. Among these factors are economic growth and associated changes in technology, management institutions, diet, and education, which are all believed to impact consumption patterns, but are rarely taken into account in global water use projections (Gleick, 2000).

Estimates of income elasticity of demand for water for domestic use are commonplace as part of standard demand curve estimations. Little published literature, however, has examined the relationship between income and overall water use at the state or national level. The few studies that have investigated such a relationship have produced conflicting results. For instance, Gleick (2003) found no clear relationship between national water withdrawals per capita and per capita income, while some others claim that the relationship follows an inverted-U or Environmental Kuznets Curve (EKC) type path, in which per capita water withdrawals initially rise and then decline with respect to income (e.g., Rock, 1998; Rock, 2001; Goklany, 2002). Study results vary depending on choice of dataset, model specification, and econometric technique.

This paper attempts to clarify this water-income relationship. The study goes beyond previous water-income research by analyzing multiple cross-sectional and panel datasets, using both traditional least squares and non-parametric regression techniques. In so doing, it also highlights some unique issues that arise when using natural resource use, rather than pollution levels, as environmental indicators in EKC studies.

The structure of this paper proceeds as follows: Section 2 presents a critical review of some of the methodologies and objectives of previous EKC and water-income studies. It also offers a brief discussion of some important distinctions between pollution based and resource based EKC studies. Section 3 presents this study's design and rationale. Section 4 presents the results of the analysis of the relationship between national per capita water use and per capita income using international cross-sectional data and panel data for OECD nations and U.S. states. Section 5 extends the analysis of the panel data to cover total water withdrawals, and, in the case of the U.S., per capita and total consumptive use. Section 6 offers a summary and conclusion.

2. Water Use and Income – Previous Empirical Studies

2.1 A Review of Water and Income Studies

Building primarily on the environmental Kuznets curve literature a small number of researchers have examined how water use correlates with national income. Rock (1998) analyzed cross-sectional data on national water withdrawals, as well as panel data on U.S. state consumptive use. He found that per capita water withdrawals and consumptive use both followed an inverted U path, consistent with an EKC hypothesis.[1] Gleick (2003) found no relationship when examining a dataset of per capita national water withdrawals and income. Goklany (2002) presented a qualitative assessment of water use showing that per capita agricultural water withdrawals in the United States seem to display an

[1] In a follow-up study, Rock (2001) also suggested that "wateruse intensity declines across the entire range of per capita incomes extant in the world today… [and] the relationship between intensity of use and income is mediated by an economy's natural water endowment, the structure of the economy, and government policies" (p.57).

inverted U form. Jia et al (2006) found an EKC for industrial water use for most OECD countries, and Bhattarai (2004) found an EKC for irrigated land for tropical countries.

Several empirical and conceptual issues bring into question the robustness of the results of these water-income studies. Rock's study was the first such water-income study. The international cross-sectional data on water withdrawals that Rock utilized, for instance, were from a wide range of different years for different countries, with little consistency among countries regarding estimation techniques.[2] Perhaps more importantly, in his regression model, Rock included explanatory variables other than income, such as dummy variables for geographic regions, measures of the efficiency of water in agriculture, trade openness, and others, while leaving out other variables known to impact withdrawals, such as price.

Like much of the EKC literature, Rock is not explicit about whether he is attempting to identify a general correlation between income growth and his environmental indicator (water use) or whether he is attempting to isolate the specific impact of income growth. By including several other explanatory variables, including those that covary with income, it seems that Rock was attempting to isolate the role of income. However, by not including relevant variables such as price, his model is subject to omitted variable bias. Thus, his analysis provides neither a simple net correlation between income and water use, nor the isolated impact of income on water use.

The question of whether the research is investigating correlation or attempting to discern a causal relationship is essential to the choice of an appropriate econometric model. Much of the early EKC research used a reduced form model in which an environmental indicator (usually some measure of pollution) was simply regressed on income and its square (and sometimes cube). The simple model is sufficient to highlight a correlation,

[2] Rock used data from the World Resources Institute (WRI, 1996), which in turn, took the data largely from Aquastat, a data-gathering program of the United Nations' Food and Agriculture Organization. The range of years in which individual country water withdrawals were estimated spanned from 1965 to 1995. Regarding this data, Gleick (2000) stated "Extreme care should be used when applying these data – they are often the least reliable and most inconsistent of all water-resources information. They come from a wide variety of sources and are collected using a wide variety of approaches, with few formal standards… The data also represent many different time periods, making direct intercomparisons difficult."

reflecting both direct and indirect effects of income (Grossman and Krueger, 1995). It does not identify more proximate relationships that may be more causal in nature (Moomaw and Unrah, 1997). Early on researchers recognized that other explanatory variables, such as institutional structure, level of education, political lobbies, and even the outsourcing of pollution production, may actually play an important role in driving decreases in pollution among rich countries. Such variables were intentionally omitted from the early regression equations, however, because they were seen as endogenous to economic growth (Seldon and Song, 1994).

The reliance on a simple reduced form model led to common critiques of omitted variable bias in EKC studies. Numerous subsequent studies included additional non-income explanatory variables such as literacy, income distribution, and trade openness, and found that these additional variables correlated positively with environmental quality and collectively reduce or even eliminate the significance of the income variable (e.g., Torras and Boyce, 1998). Such studies are attempting to isolate the direct causal impact of income on the environment. However, to the extent that non-income variables are themselves a function of income, such results do not necessarily detract from the EKC hypothesis, which, at its most basic level, simply implies a robust U-shaped correlation between some measure of environmental quality and income.

The decision regarding the choice of model – reduced form or comprehensive – should depend on what question the researcher is attempting to answer. The distinction is significant in terms of policy prescriptions stemming from the research. Identifying an overall correlation may be useful for predicting trends, for instance; while isolating the direct contribution of income vis-à-vis other relevant variables may be more important for planning policy interventions.[3] In either case, it is critical that the researcher be clear

[3] Comprehensive models which include multiple variables are common in studies estimating income elasticities of demand for water. These models attempt to isolate the effect of income by including all relevant explanatory variables including price. Many such studies have been undertaken for urban and residential water use, with the majority finding positive income elasticities of demand (e.g., Hanemann, 1998; Dalhuisen et al, 2001, 2003). However, elasticity studies have generally not been expanded to cover other large water consuming sectors, namely agriculture and industry, as these sectors use water as an input rather than as a final good; thus, they are generally modeled using profit maximization models, which presume that water is consumed at its rate of marginal productivity (Young, 2005).

about what question s/he is intending to answer Often researchers in the EKC literature have not been careful to make such a distinction.

In contrast to early EKC studies that used reduced form equations to identify an empirical relationship, which they then sought to explain, Rock began with an attempt at a comprehensive model. However, studies attempting to isolate the impact of income need to develop a model that includes all relevant variables, lest they themselves suffer from omitted variable bias.

While Rock's study was the first and most comprehensive of the water income studies, each of the other studies listed above also has significant limitations. Neither Gleick's nor Goklany's studies were quantitatively rigorous and essentially amounted to a simple eyeballing of graphical scatterplots. Both Bhattarai's (2004) and Jia et al's (2006) studies were limited to a single sector for a limited number of countries. Bhattarai (2004) tested both a reduced form and a comprehensive model and concluded that the EKC relationship was a robust finding (though he did not report whether he performed any specification tests of alternative functional forms). The dependent variable in his study, however, was not water for irrigation, but changes in the percentage of crop area irrigated, and so, served only as a proxy for agricultural water use.

Jia et al (2006) used a reduced form model to analyze time series data of several OECD nations' industrial sector water withdrawals and found most to follow an EKC. The authors did not find such a relationship when analyzing the same data as a panel with fixed or random effects models. They attributed this difference in results to wide variation across nations in terms of the income level at which a turning point was found. The authors therefore concluded that despite finding statistically significant EKCs, income was not a good predictor of a nation's industrial water use.

In sum, only a few studies have attempted to look at water use as a function of income at a national or state level. Most of those claim to have found some sort of inverted U type relationship. Because of questions of appropriateness of model choice, quality of data, or a focus restricted to a single sector or region, however, questions as to the robustness of such findings still remain.

2.2 Natural Resource EKCs

The majority of EKC literature examines pollution levels as a function of income. This has led to the criticism that such research ignores the natural resource component of environmental quality (Arrow *et al*, 1995). Of the studies that have examined resource use, the majority focused on deforestation (e.g., Shafik and Bandyopadhyay, 1992; Panayotou, 1993; Cropper and Griffiths, 1994; Koop and Tole, 1999; Ehrhardt Martinez et al, 2002; Culas, 2007), while only a few addressed other forms of resource use, including energy (e.g., Suri and Chapman, 1998) and water.[4]

These studies tend to treat resource use identically to pollution as an indicator of environmental quality. Like pollution, resource use can provide an economic benefit coupled with an undesired environmental impact. Thus, many of the theoretical explanations for the existence of EKCs for natural resources mirror those for pollution. These include, for instance, increasing income elasticity of demand for environmental quality, economies of scale in resource conserving equipment, outsourcing of environmental impacts (e.g. pollution havens), and structural development type rationales, under which nations' economies change sequentially from being primarily based on rain-fed agriculture, developing to intensive irrigated agriculture, then to manufacturing, and finally, to a less resource intensive service-sector orientation.[5]

Several characteristics distinguish natural resources from pollution in terms of their relationship to income, however. This is especially true for resources such as water that tend not to be traded in large quantities internationally. These include (1) limited

[4] A limited number of EKC studies addressed other forms of environmental indicators; for example Managi (2006) modeled exposure to pesticides. For reviews of EKC literature see Panayotou (2000) and Stern (2001, 2004).

[5] In the case of water, irrigated agriculture is by far the largest water consuming sector. Therefore, to the extent that manufacturing and services displace intensive agriculture (and not simply supplement it), the point at which the decline in water consumption takes place would be expected to come, according to such a structural development theory, at an even lower level of per capita income than in the case of pollution, which the theory predicts would reach its peak with development of the manufacturing sector.

supplies, and therefore, maximum levels of usage, (2) the role of natural endowments in influencing access to many resources, (3) the fact that natural resources are goods which generally command a positive market price, as opposed to pollution, which is simply an undesired byproduct of production or consumption of other goods, (4) the fact that, as goods, and not bads, a reduction is not necessarily desirable, and (5) a direct economic cost involved in resource extraction and acquisition.

According to Hotelling's Rule, the marginal net benefit of natural resource use (price minus marginal extraction costs), should, *ceteris paribus,* rise at a rate equal to the discount rate if the resource is being extracted at an efficient rate. If demand is a positive function of income, the Hotelling model itself could explain the existence of an inverse U shaped relationship for a given resource, provided increasing income and prices over time. In such a case, even if the actual impact of income is to raise demand, the increased scarcity and consequent rise in price could eventually overwhelm the income effect. Thus, despite the similarities between resource and pollution based environmental indicators in EKC studies, they should not be treated identically. In practice, however, these distinctions are rarely if ever taken into account.

3. Study Rationale and Methods

This study goes beyond previous water-income analyses in several ways. First, it uses cross-sectional and panel data covering international and U.S. state data. The datasets include cross-sectional data on per capita water withdrawals for 149 countries, panel data on total and per capita water withdrawals by 30 OECD nations, and panel data on total and per capita water withdrawals and consumptive use by the 48 continental U.S. states. Withdrawals and consumptive use are measured both in aggregate and by sector. Sectoral analyses are helpful, for instance, in evaluating structural development type theories of water-income patterns.

Critics note that cross-sectional data provide only a snap-shot in time, and indicate little regarding dynamic processes assumed to underlie an EKC (de Bruyn et al, 1998; Unruh and Moomaw, 1998; Dasgupta et al, 2002). Reliable and consistent international data covering developing countries are only available in cross-sectional form, however. While panel data is preferable, such data are available only for OECD countries and U.S. states. Though panel data are arguably more telling than cross-sectional data for EKC studies, several researchers have pointed out that questions regarding stationarity, integration, homogeneity, and cross-sectional dependence of data can limit the reliability of conclusions based on panel data as well (e.g. List and Gallet, 1999, Stern, 2004; Bradford et al, 2005; Dijkgraaf and Vollebergh, 2005; Muller-Furstenberger and Wagner, 2007). Furthermore, if fixed effects models are being utilized, results can be biased and inconsistent if country specific characteristics are correlated with income (Chimeli and Braden, 2006). This study therefore uses multiple datasets in order to assess the robustness of results.

Second, this study restricts itself to testing only a reduced form model. Such an approach limits the analysis to simply testing for correlations between water use and income, rather than isolating a direct income impact on water use. It is, however, in the spirit of the original EKC studies which were testing for general correlations between environmental indicators and income. Indeed, in the case of normal goods such as natural resources, it can be argued that the reduced form model is what distinguishes an EKC study from a traditional demand curve estimation model.

Any attempt to provide a comprehensive model would need to include price variables, else it suffer from omitted variable bias. Price data on water are not only difficult to obtain for many countries, but unlike other natural resources such as oil, water does not have a single global or national reference price. It often varies by sector, consumer, and geographic locale. Water is also often priced according to volumetric tariffs, making price a particularly unwieldy variable for large scale studies. Given these practical and theoretical reasons for not including price variables, a reduced form EKC model was chosen for the current analysis.

Third, this study tests various functional forms, with the independent variable included in level, quadratic, and cubic forms. As opposed to the case of pollution, there is no reason to suspect (or desire) a permanent decline in water use, as would be implied with a quadratic model. A cubic model allows for an initial reduction, without forcing this downturn to continue indefinitely. Several EKC studies have shown cubic models to be statistically significant (e.g., Grossman and Kruger, 1991; List and Gallet, 1999).

Several EKC studies have used statistical techniques other than least squares, including spline regressions (segmenting either by time or income) (e.g. Moomah and Unruh, 1997; Schmalensee, Stoker, and Judson, 1998; Panayotou et al, 1999) and, more recently, nonparametric or semi-parametric techniques (e.g. Taskin and Zaim, 2000; Zaim and Taskin, 2000; Millimet et al, 2003; Vollebergh et al, 2005; Deacon and Norman, 2006). Millimet et al found significant differences between the parametric and nonparametric results, indicating that assumptions about functional form may be biasing results.

In addition to least squares, this study uses the Lowess nonparametric regression technique[6] as an alternative method of analysis for the cross-sectional data. Lowess forms a best fit curve by conducting localized regressions over small, overlapping subsets of the data, often called bin size or bandwidth. The primary advantage of such a nonparametric regression method is that it estimates a best fit curve to data without necessitating any prior assumptions regarding functional form (DiNardo and Tobias, 2001). Such regressions do not produce functions easily represented by mathematical formulae, but can better represent the actual relationship between variables. To this author's knowledge, Lowess has not been used in prior EKC analyses, although Taskin and Zaim (2000) use Kernel regression, a similar nonparametric technique, to evaluate national carbon dioxide production efficiency.

In the case of panel data, because fixed effects allows one to control for factors such as natural endowments, climate, and other country specific variables, it is possible to measure and compare both per capita and overall water use vis-à-vis income. While per capita use is thought to be a more direct function of standard of living, total water use is a

[6] Lowess is sometimes referred to by other names, including LOESS and locally weighted polynomial regression (NIST, 2006).

more significant indicator in terms of environmental impact. It is therefore important to understand how each changes as a function of income. Depending on population and income growth rates, a country's per capita withdrawals may decrease with respect to income, while its total withdrawals do not. This study, therefore, analyzes total water withdrawals and consumptive use in addition to per capita measures with the panel data.

FAO and OECD datasets cover only water withdrawals. However, consumptive use of water – that amount not returned to the watershed in usable form – is often the relevant policy variable in water planning. This study uses U.S. state data on both withdrawals and consumptive use to identify the degree to which the former is a good proxy for the latter with respect to income growth.

4. Water Use and Income: A Reassessment

This section presents results of the empirical analysis for per capita water withdrawals for each of the three datasets, followed by results for total water withdrawals for the OECD and U.S. state panel data. It then compares withdrawals and consumptive use for the U.S. data.

4.1 Cross-sectional Data - National Water Withdrawals

Using a dataset formed of water and population variables from FAO's Aquastat database and GDP from World Bank's World Development Indicators database, I first analyzed a cross-sectional dataset of per capita national annual water withdrawals (AWW/N) and income (GDP/N).[7] Summary statistics for the dataset are presented in Table 1.1. Generalized Least Squares (GLS) regressions were run using the logs of AWW/N and GDP/N as the units of analysis for the dependent and independent variables, represented in Equation 1 below by *WATER* and *INC* respectively. Use of log-log regressions is consistent with much of the EKC literature (Stern, 2004). Various alternative functional

[7] Annual water withdrawal data were based on best estimates from the period 1998-2002. GDP data was measured in 2000 U.S. dollars. GDP per capita was calculated using World Bank national GDP figures and FAO population figures in order that the population estimates remained constant for both income and water consumption.

forms were tested, with the independent variable included in linear, quadratic, and cubic forms, following Equation 1 below.

(Eq. 1) $\text{WATER}_i = \beta_0 + \beta_1\text{INC}_i + \beta_2\text{INC}_i^2 + \beta_3\text{INC}_i^3 + e_i$

where *e* represents an error term, the subscript *i* represents the unit of observation - an individual country, and βs represent parameters to be estimated.

Results from the regressions showed that both linear and quadratic forms are significant at a 1% level, while all variables in a cubic function are significant at the 10% level (Table 1.2). Results for the quadratic equation are consistent with, and seem to be highly supportive of, the existence of an EKC. A positive income elasticity is found up until a turning point of $9,620 per capita GDP, beyond which the relationship turns negative. This per capita income level is less than half the income level at which Rock (1998) found a turning point for his EKC of international water withdrawals. The cubic functional form describes a monotonic increase at a declining rate for the range of data.

The results of a Lowess regression of log (AWW/N) on log (GDP/N) are shown in Figure 1.1a, together with a graph of the predicted values using the results of the GLS quadratic form regression.[8] The Lowess shows withdrawals monotonically increasing with respect to income, but at a decreasing rate. There is little evidence of the downturn predicted by the EKC hypothesis. Although the Lowess and the GLS graphs are quite similar, the inverted U found with least squares regression appears simply to be an outcome of the choice of a quadratic functional form, rather than a reflection of a genuine trend.

Examining water withdrawals by sector allows for a decomposition of trends and for testing of a possible scale effect, according to which countries would tend to develop out of agriculture and water intensive industry. Separate regressions were estimated using the log per capita water withdrawals for each of the three dominant water consuming

[8] A bandwidth of 0.8 was used for LOWESS regressions in this study. Additional regressions using alternative bandwidths did not produce qualitatively different results.

sectors: agriculture, industry, and domestic use. A strong quadratic relationship is found in the case of agriculture, by far the largest consumer of water (Table 1.3). The turning point predicted with a quadratic form is at a per capita income of only $1,953. A Lowess regression produces a result almost identical to that of the fitted quadratic form (Figure 1.1b), providing support that the inverted U relationship is robust for agricultural use.

In the case of water withdrawals for domestic sector use, the quadratic model is highly significant, with a predicted turning point at a per capita GDP of over $23,200, at the upper range of the data sampled. A Lowess regression is nearly identical, however, again it seems to show a relationship that is monotonically increasing with respect to income but at a decreasing rate within the range of the data (Figure 1.1c). This is consistent with results from previous estimates of income elasticity of demand for domestic water use.

In regressions of per capita industrial water withdrawals on income, the linear form is significant at the 1% level, while the square of the income variable in the quadratic form is significant only at a 9% level for the quadratic model (Table 1.3). This suggests a constant positive income elasticity of withdrawals. A Lowess regression of industrial withdrawals, however, shows a monotonically increasing trend (Figure 1.1d), which is actually better estimated by a higher order polynomial, such as a cubic functional form. A least squares regression using a cubic functional form was indeed significant at the 1% level. Cubic functional forms for domestic and agricultural use were not statistically significant and therefore are not shown in Table 1.3 below.

In sum, results from this cross-sectional dataset suggest that overall national water withdrawals per capita level off as a function of income, and the evidence for an EKC for water withdrawals is weak. The analysis of withdrawals by sector suggests that such an inverted U curve may be present for agricultural water use, but not for withdrawals for domestic and industrial uses, the income elasticity of which remains positive throughout the entire range of the data.

Table 1.1. FAO Dataset Summary Statistics

Variable	Mean	Standard. Deviation	Minimum	Maximum
GDP (billions of 2000 US$)	211	921	0.20	9,765
GDP per capita (2000 US$)	5,528	8,764	84	37,230
AWW (km^3)	25.05	84.88	0.01	645.84
AWW per capita (m^3)	536	634	6.55	5,142

Sources: Data on water withdrawals and population is from FAO's Aquastat database (2006). GDP data is from the World Bank's World Development Indicators database (2006). Sample size (n)=149.

Table 1.2. GLS Regression - FAO Log(AWW/N) on Log(GDP/N)

Dependent Variable	***Log (AWW/N) (m^3/cap/year)***		
Independent Variable	**Linear**	**Quadratic**	**Cubic**
Constant	3.316 (0.495) 0.000	-2.342 (2.078) 0.262	-18.063 (9.577) 0.061
Log(GDP/N)	0.311 (0.058) 0.000	1.871 (0.546) 0.001	8.502 (3.938) 0.032
$(Log(GDP/N))^2$		-0.102 (0.037) 0.004	-1.005 (0.522) 0.056
$(Log(GDP/N))^3$			0.040 (0.022) 0.079
Adjusted R-squared	0.146	0.185	0.198
Turning point		$9,620	n/a

Note: Sample size (n) = 149. Coefficient results are presented with robust standard errors in parenthesis and p-values below the standard errors. GDP per capita was measured in constant 2000 US$. .

Table 1.3. GLS Regression – FAO Log(AWW/N) on Log(GDP/N) by Sector

Dependent Variable	***Log (Agricultural AWW/N) n=148***		***Log (Domestic AWW/N) n=148***		***Log (Industrial AWW/N) n=148***		
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Cubic**
Constant	4.890 (0.832) 0.000	-5.838 (3.393) 0.087	0.120 (0.348) 0.730	-5.160 (1.279) 0.000	-2.090 (0.567) 0.000	-6.096 (2.453) 0.014	-41.224 (11.517) 0.000
Log(GDP/N)	-0.017 (0.112) 0.876	2.940 (0.942) 0.002	0.475 (0.046) 0.000	1.930 (0.346) 0.000	0.699 (0.073) 0.000	1.780 (0.656) 0.007	16.595 (4.792) 0.001
$(Log(GDP/N))^2$		-0.194 (0.064) 0.003		-0.096 (0.022) 0.000		-0.072 (0.042) 0.090	-2.085 (0.645) 0.002
$(Log(GDP/N))^3$							0.089 (0.028) 0.002
Adj..R-squared	0.000	0.0625	0.430	0.473	0.363	0.373	0.405
Turning Point ($)		1,953		23,204		233,541	n/a

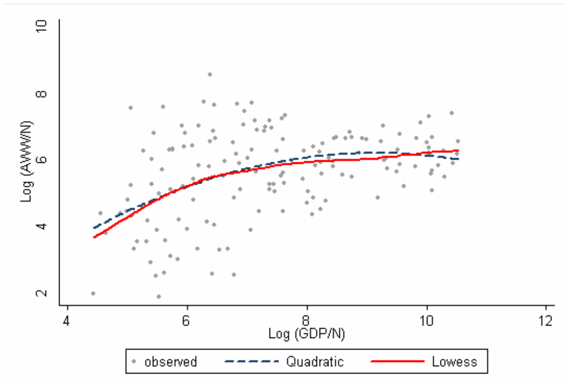

Figure 1.1a. AWW/N – All Uses

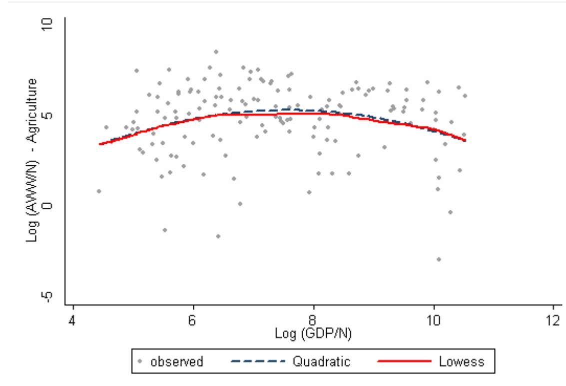

Figure 1.1b. AWW/N – Agriculture

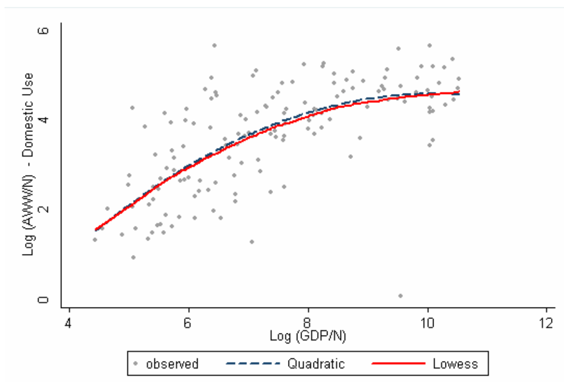

Figure 1.1c. AWW/N – Domestic

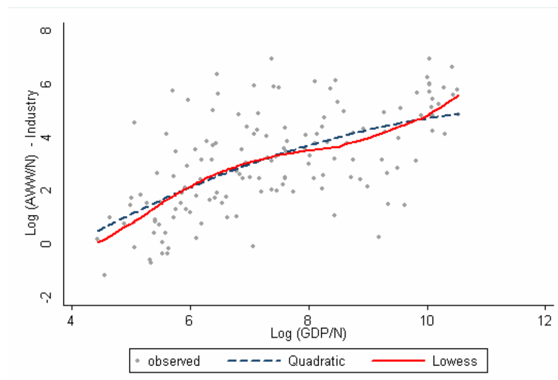

Figure 1.1d. AWW/N – Industry

Figures 1.1a-d. Fitted GLS and Lowess Curves of Log(AWW/N) on Log(GDP/N)

4.2 Panel Data - OECD National and U.S. State Withdrawals

4.2.1. OECD National Per Capita Withdrawals

Given the limitations of inference from cross-sectional data concerning the effect of income on water use, fixed effects regressions were also run using two datasets, one of OECD member withdrawals and one of U.S. state withdrawals. The first dataset was an unbalanced panel dataset of water withdrawals of the thirty OECD nations estimated for 1980, 1985, 1990, 1995, and 2000[9] (OECD, 2006) and population and GDP data from the World Bank (World Bank, 2006, 2007). Fixed effects were used to account for differences among nations in terms of climate,[10] initial endowments of water, and other country or state specific factors that may determine water use. Again, reduced form models were used, following Equation 2 below:

(Eq. 2) $$\text{WATER}_{it} = \beta_0 + \alpha_i + \beta_1\text{INC}_{it} + \beta_2\text{INC}^2_{it} + \beta_3\text{INC}^3_{it} + e_{it}$$

As in the cross-sectional case, the variables WATER and INC represent the logs of per capita annual water withdrawals (AWW/N) and per capita Gross Domestic Product (GDP/N) respectively. The country fixed effect is captured by the term α. The subscripts i and t represent the individual country and the year of observation, respectively.[11]

Summary statistics for the dataset are provided in Table 1.4. Again log values of per capita withdrawals and GDP were used as units of analysis. Local non-parametric density regressions are not amenable to fixed effects panel data, and so no such tests were performed with these data.

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[9] The dataset was an unbalanced panel, as values were missing from various countries for some years. The average number of observations per country was 4.0 out of the possible 5.

[10] Although climate varies and technically is not a fixed effect, broad differences reflecting average temperature and precipitation will be captured by a fixed effect variable.

[11] Some researchers have also included a time trend variable when using time series and panel data sets for EKCs, even in reduced form models. To some degree, because time and income are closely correlated, the decision whether or not to include a time variable begs the question of whether one is trying to isolate the impact of income or identify overall trends between income and an environmental impact. This study reports results without a time trend. All regressions were also run with a linear time trend. Results are not included herein, but in most cases, they do not change conclusions in any qualitative sense.

The OECD panel data provide stronger evidence of an EKC than do the international cross-sectional data. Coefficients on income and its square are significant at the 1% level for the quadratic functional form, the only functional form tested for which coefficients were significant at any conventional level (Table 1.5).[12] The predicted turning point for the EKC is at a per capita income level of $8,775. This is slightly lower than, but consistent with, the figure of $9,620 predicted using the cross-sectional data.

Among the advantages of panel datasets over cross-sectional ones are that they capture actual changes in country behavior over time and can account for variation due to inherent differences in the countries being observed. While the results of the regression provide strong evidence for an EKC, inspection of individual countries' withdrawal patterns shows little conformity to the predicted EKC model. Only three countries in the dataset, Korea, Portugal, and Spain, had per capita income levels that spanned both sides of the predicted turning point of $8,775. Of these three, Korea's per capita withdrawals increase monotonically with respect to income, Portugal's display no clear trend, and only Spain's follows an EKC-type trajectory. Furthermore, EKC patterns are displayed both by countries well below and well above the estimated turning point income, but so too are monotonically rising and monotonically falling relationships. One high-income country, the UK, even displays a U-shaped relationship. Lack of clear patterns for individual countries is perhaps not surprising, given a limited time series. The variation in the turning point by country, while in conflict with most EKC theoretical models which posit a single turning point, is, however, consistent with empirical findings in other studies (e.g., Lieb, 2004; Dijkgraaf and Vollebergh, 2005). In sum, regressions on per capita withdrawals seem to present strong evidence for an EKC relationship for water use, but regression results prove a poor indicator of actual water withdrawal patterns.

While the results from overall per capita withdrawals are generally consistent with those found in the cross-sectional regressions, a much different picture emerges when the OECD data are analyzed by sector. The quadratic functional form is highly statistically

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[12] None of the functional forms tested provided significant results when level values were used as units of observation and so results are not reported here.

significant for the public sector and for industrial manufacturing use, but not for irrigation or water used as coolant for power generation facilities (Table 1.6).[13,14] In fact, irrigation and coolant uses actually display a U shaped curve, with withdrawals declining with income up until income levels of $11,650 and $10,672 respectively, and increasing thereafter. This is in direct contrast to the cross-sectional results and to structural development explanations of EKCs. The results for the public sector also stand in contrast to most income elasticity estimates, which have found positive elasticities of demand for most industrialized nations (e.g., Dalhuisen et al, 2003). A possible explanation is that initial improvements in efficiency usually made at medium levels of economic development are eventually taken over by income effects.

[13] The public sector includes domestic and commercial uses drawing from public sources, and so is not completely comparable to the domestic figure for the cross-sectional data. Furthermore, the OECD provides data on water for irrigation rather than agricultural use as a whole.

[14] It is worth noting that most, but not all OECD countries provided separate data for industrial manufacturing and coolant uses. A log-log regression of the sum of industrial and coolant withdrawals on income was not significant at the 10% level for either the linear or quadratic functional forms, although the quadratic did have the expected signs.

Table 1.4. OECD Panel Dataset Summary Statistics

Number of countries: 30 Time period covered: 1980-2000 at five year intervals

	Mean	Standard Deviation	Minimum	Maximum
GDP per capita (2000 US$)	17,332.57	9,975.29	1,897	46,278
AWW (km^3)	37,406.92	95,317.09	57	517,720
AWW/N (m^3/cap/year)	726.15	749.32	136.02	4,524.35

Table 1.5. Fixed Effects Regressions – OECD Log(AWW/N) on Log(GDP/N)

no. of observations = 120 no. of groups = 30

Dependent Variable: Log (AWW/N)			
Independent Variable	**Linear**	**Quadratic**	**Cubic**
Constant	7.075 (0.886) 0.000	-6.509 (5.232) 0.217	-60.453 (45.358) 0.186
Log(GDP/N)	-0.080 (0.093) 0.393	2.851 (1.117) 0.012	20.588 (14.857) 0.169
$(\text{Log(GDP/N)})^2$		-0.157 (0.060) 0.010	-2.086 (1.612) 0.199
$(\text{Log(GDP/N)})^3$			0.069 (0.058) 0.234
R-squared (overall)	0.003	0.061	0.026
Turning point		$8,775	

Table 1.6. Fixed Effects Regressions – OECD Log(AWW/N) on Log(GDP/N) by Sector

	Dependent Variable: Log (AWW/N)							
	Public Sector Withdrawals		**Irrigation Withdrawals**		**Industrial Withdrawals**		**Coolant Withdrawals**	
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
Constant	2.549 (0.869) 0.004	-15.176 (5.279) 0.005	4.187 (2.454) 0.092	18.552 (15.537) 0.237	6.994 (1.875) 0.000	-30.178 (11.096) 0.008	3.333 (3.390) 0.330	24.923 (26.686) 0.354
Log(GDP/N)	0.226 (0.091) 0.015	4.061 (1.132) 0.001	-0.024 (0.259) 0.926	-3.146 (3.345) 0.350	-0.317 (0.198) 0.114	7.767 (2.390) 0.002	0.148 (0.355) 0.678	-4.378 (5.560) 0.434
$(\text{Log(GDP/N)})^2$		-0.206 (0.061) 0.001		0.168 (0.180) 0.352		-0.436 (0.129) 0.001		0.236 (0.289) 0.418
R-squared (overall)	0.188	0.126	0.021	0.007	0.050	0.044	0.050	0.007
Turning Point	$19,088				$7,384			
No. of Obs./ No. of Groups	115/29		98 /27		98 /27		80/22	

4.2.2. U.S. States Per Capita Withdrawals

A second panel dataset uses figures from reports by the United States Geological Survey (USGS) on withdrawals by state provided every five years between 1960 and 2000.[15] The regression model again is based on Equation 2 above, with state level fixed effects. In this case, the dependent variable WATER represents the log of daily water withdrawals per capita (DWW/N) measured in million gallons per day. The income variable INC is the log of per capita state personal income (SPI/N), obtained from the Bureau of Economic Analysis (BEA, 2006), and adjusted by a state consumer price index provided by Berry et al (2003), to provide real income in constant 2000 dollars.

Summary statistics are displayed in Table 1.7. As compared to OECD, the U.S. states exhibit less interstate variation in per capita income, but greater variation in per capita withdrawals. As with the OECD case, the U.S. data also provide evidence of an EKC for per capita water withdrawals, as shown in Table 1.8. The estimated turning point for the quadratic is at a real income of $18,620. To see if the pattern was particular only to humid or arid states, the dataset was divided into two based on whether states are located east or west of the 100th meridian, with separate regressions run for each.[16] Both cases follow an EKC. In addition, separate time-series regressions were run for individual states following Equation 3 below, where all symbols are identical to those in Equation 2. Forty-four out of the forty-eight states display patterns consistent with an EKC (i.e., a negative coefficient on the income squared variable), although only in 15 cases are these coefficients statistically significant at the 5% level. This is likely due to the small number of observations – 9 time periods for each state.

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[15] These reports are listed as MacKihan and Kammerer (1962), Murray (1968), Murray and Reeves (1972, 1977), Solley et al (1983, 1988, 1993, 1998), and Hutson et al (2004). Complete data was available only for the contiguous 48 states and Washington DC, and therefore the analysis included only these as units of observation. The panel was balanced for per capita withdrawals but was unbalanced for all of the sectoral analysis.

[16] The 100th meridian is a common demarcation between the humid East and arid West (e.g., Stegner, 1954). As is common in such East-West classifications, states through which the 100th meridian crosses were included with the Western states, as their climate and agriculture practices tend to be more similar to the Western states.

$(Eq.\ 3)$ $\text{WATER}_t = \beta_0 + \beta_1\text{INC}_t + \beta_2\text{INC}^2{}_t + \beta_3\text{INC}^3{}_t + e_t$

In fixed effects regressions run by sector, statistically significant EKCs are found for all sectors other than irrigation (Table 1.9). In the cases of public and industrial sector withdrawals, for which EKCs are found with both OECD and U.S. state datasets, the turning point at a somewhat higher income level for the U.S. data in both cases. The U.S. results differ from those of the OECD's in two significant ways. First, in the case of irrigation, the U.S. data display a clear positive linear relationship,[17] whereas the OECD data display no statistically significant relationship whatever. This result is contrary to what a structural development theory would predict – i.e., a general movement away from water intensive agriculture and towards less water intensive service industries. A second difference between the results is that per capita U.S. state withdrawals for coolant purposes in the thermoelectric industry display an EKC, whereas those for OECD nations do not. In the U.S., the decline in water withdrawals for coolant purposes is probably attributable to the switch from open loop to closed loop technology, which occurred by the mid-1970s (DoE, 2006). A fixed effect regression of the coolant withdrawals using U.S. state data from 1980 forward, thus more comparable to the OECD data, does not display an EKC.

In sum, parametric regressions find EKCs for national per capita water use in all datasets examined, though the non-parametric regressions in the case of the cross-sectional data indicate that this may be imposed by choice of functional form. Results for per capita withdrawals by sector show less uniformity, differing significantly between datasets. Results from the fixed effects regressions with the panel data provide seemingly stronger evidence of an EKC, but income in these regressions explains a small share of the variation in water withdrawals and is a poor indicator of individual country behavior.

[17] The same results were found when using the log of per capita agricultural (irrigation plus livestock) withdrawals as a dependent variable. The table above lists only irrigation so as to facilitate comparison with the OECD data, for which only irrigation figures were given.

Table 1.7. U.S. Panel Dataset Summary Statistics (1960-2000)

Number of states: 48 Time period covered: 1960-2000 at five year intervals

	Mean	Standard Deviation	Minimum	Maximum
SPI/N (2000 US$)	20,216.94	5,901.37	7,474	41,489
DWW/N (gallons/day/capita)	2,372.35	3,633.86	131.95	23,560
DWW (million gallons per day)	6,648.90	6,593.04	107.30	43,782

Table 1.8. Fixed Effects Regressions – U.S. Log(DWW/N) on Log(SPI/N)

no. of observations = 432 no. of groups = 48

Dependent Variable: Log (DWW/N)			
Independent Variable	**Linear**	**Quadratic**	**Cubic**
Constant	5.974 (0.628) 0.000	-125.057 (14.637) 0.000	-230.781 (318.735) 0.469
Log(SPI/N)	0.121 (0.064) 0.058	26.920 (2.990) 0.000	59.374 (97.761) 0.544
$(\text{Log(SPI/N)})^2$		-1.369 (0.153) 0.000	-4.686 (9.989) 0.639
$(\text{Log(SPI/N)})^3$			0.113 (0.340) 0.740
R-squared overall	0.000	0.054	0.052
Turning point		$18,620	

Table 1.9. Fixed Effects Regressions – U.S. Log(DWW/N) on Log(SPI/N) by Sector

	Dependent Variable: Log (DWW/N)							
	Public Sector Withdrawals		**Irrigation Withdrawals**		**Industrial (self-supplied) Withdrawals**		**Thermoelectric (self-supplied) Withdrawals**	
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
Constant	0.861 (0.257) 0.001	37.347 (6.293) 0.000	-3.934 (1.366) 0.004	-17.121 (34.969) 0.625	19.447 (1.192) 0.000	-250.992 (27.226) 0.000	-0.355 (1.445) 0.806	-158.214 (35.434) 0.000
Log(GDP/N)	0.404 (0.026) 0.000	8.221 (1.288) 0.000	0.820 (0.138) 0.000	3.518 (7.150) 0.623	-1.527 (0.121) 0.000	53.798 (5.567) 0.000	0.575 (0.146) 0.000	32.860 (7.243) 0.000
$(\text{Log(GDP/N)})^2$		-0.399 (0.066) 0.000		-0.138 (0.365) 0.706		-2.826 (0.284) 0.000		-1.649 (0.370) 0.000
R-squared (overall)	0.200	0.223	0.004	0.005	0.153	0.219	0.000	0.010
Turning point	$29,792		$343,306		$13,608		$21,239	

5. Total Water Withdrawals, Consumptive Use and Income

This section extends the analysis of the previous section by presenting results of fixed effects regressions with panel data for total water withdrawals for the OECD countries and U.S. states and for total and per capita consumptive water use for the U.S. states. Analysis of these additional measures of water use provides a robustness check for the results found in the previous section. Such an extension is also of value, however, in that total water withdrawals and consumptive use may translate more directly into environmental impact than do per capita withdrawals. Total withdrawals determine the extent to which natural systems are disturbed, and as much of the water withdrawn is not consumed and is available for reuse downstream, consumptive use of water – water withdrawn and not returned to the watershed – may provide a better indicator of scarcity and impact on the environment than do withdrawals. Analysis of total withdrawals may also shed light on whether declines in per capita withdrawals occurred due to increases in water use efficiency, or simply due to population increases.

5.1. Total Water Withdrawals – OECD Nations and U.S. States

Analysis of total withdrawal rates is of little use with cross-sectional data because of huge differences between nations in population, natural endowments, climate, etc. As these differences can largely be accounted for with fixed effects regressions using panel data, regressions identical to those presented in the previous sections were run based on Equation 2 above, but using total withdrawals as a dependent variable instead of per capita withdrawals.

For the OECD total water withdrawals, income and income squared are statistically significant at the 5% level for the quadratic functional form (Table 1.10). The cubic functional form is also significant at the 5% level, however, suggesting that the downturn may be temporary. Coefficients from the quadratic functional form indicate a turning point of just under $19,000, while estimates based on the cubic form have water withdrawals reaching a peak (local maximum) at an income level of $10,547, at which point they decrease slightly, only to begin a subsequent increase (local minimum) at an income level of $21,199.

As with per capita withdrawals, EKCs are found for the public and the industrial sectors, but not for irrigation or for coolant purposes (Table 1.12). Jia et al (2006) did not find an EKC for OECD industrial withdrawals when using a fixed effects model, but did find that several OECD countries' individual industrial water withdrawals followed an EKC type pattern. The estimated turning point for the EKC for industrial withdrawals is at an income level of $9,123, a figure below the lower end of the range reported by Jia et al. This may be simply due to use of different data sets, including the fact that Jia et al did not use data from several of the lower income OECD nations.

For both industrial and public sector specific EKCs, the estimated turning point is higher for total withdrawals than for per capita. In the case of total public sector withdrawals, the estimated turning point for the EKC is roughly $36,217, as compared to a level of just over $19,000 for per capita withdrawals. This higher turning point is at the extremely high end of the range of observed data,[18] and so this result should not be considered robust evidence of an EKC.

Data from U.S. state withdrawals display a highly significant EKC, though the turning point was nearly $5,000 higher than in the case of per capita withdrawals (Table 1.11). The cubic functional form is not significant for the U.S. data. In time series regressions based on Equation 3 above, 41 out of 48 states had coefficients compatible with an EKC, although only 20 were statistically significant at the 5% level.

[18] . Only 4 observations had income higher than the estimated turning point: the 1995 and 2000 per capita income of Luxembourg and the 2000 per capita incomes of Japan and Norway.

In terms of withdrawals by sector, total industrial and thermo-electric sector withdrawals display EKC patterns, both with estimated turning points at slightly higher income levels than those for per capita withdrawals (Table 1.13). Total public withdrawals display a highly significant positive linear relationship with income, in contrast to per capita public sector withdrawals which appear to follow an EKC. The signs on the coefficients of the quadratic functional form are consistent with an EKC; however, they are not statistically significant at the 5% level, and the predicted turning point using the estimated coefficients is at a per capita income level of over $400,000, well outside the sample range. These results are consistent with the empirical findings of others who found that water for domestic purposes (a large component of public use) has continued to grow, but at rates less than the rate of population growth (e.g., DoE, 2006). Total irrigation withdrawals show a strong linear correlation with per capita income, much like the case of per capita irrigation withdrawals.

In sum, analysis of total withdrawals tends to confirm the existence of an EKC in the case of U.S. states, although evidence from OECD nations suggests that any downturn may be minor and followed by a subsequent increase. The difference between the two results may derive from water use for thermo-electric purposes, which displays an EKC in the U.S., but not in the OECD. It may also simply reflect the longer time series of the U.S. data, as water use in the U.S. increased dramatically during the 1960-1975 period, whereas data from the OECD were only available from 1980 onward. In all cases, in which an EKC was found, the estimated turning point for total withdrawals was higher than for the comparable per capita measure. This may indicate that at least some of the downturn in per capita withdrawals is due to population increases rather than strictly due to increases in efficiency of water use.

Table 1.10. Fixed Effects Regressions – OECD Log(AWW) on Log(GDP/N)

no. of observations = 120   no. of groups = 30

Dependent Variable: Log (AWW)			
Independent Variable	**Linear**	**Quadratic**	**Cubic**
Constant	7.544 (0.972) 0.000	-6.175 (5.780) 0.288	-116.269 (49.097) 0.020
Log(GDP/N)	0.153 (0.102) 0.138	3.113 (1.234) 0.013	39.312 (16.082) 0.017
$(Log(GDP/N))^2$		-0.158 (0.066) 0.018	-4.095 (1.745) 0.021
$(Log(GDP/N))^3$			0.142 (0.063) 0.026
R-squared (overall)	0.019	0.002	0.002
Turning points		$18,982	$10,547 (local maximum) $21,199 (local minimum)

Table 1.11. Fixed Effects Regressions – U.S. Log(DWW) on Log(SPI/N)

no. of observations = 432   no. of groups = 48

Dependent Variable: Log (DWW)			
Independent Variable	**Linear**	**Quadratic**	**Cubic**
Constant	2.268 (0.511) 0.000	-103.958 (11.916) 0.000	58.871 (263.137) 0.823
Log(SPI/N)	0.606 (0.052) 0.000	22.337 (2.436) 0.000	-36.485 (79.542) 0.647
$(Log(SPI/N))^2$		-1.110 (0.124) 0.000	4.902 (8.128) 0.547
$(Log(SPI/N))^3$			-0.205 (0.277) 0.460
R-squared overall	0.047	0.070	0.071
Turning point		$23,429	

Table 1.12. Fixed Effects Regressions – OECD Log(AWW) on Log(GDP/N) by Sector

	Dependent Variable: Log (AWW/N)							
	Public Sector Withdrawals		Irrigation Withdrawals		Industrial Withdrawals		Coolant Withdrawals	
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
Constant	3.257 (0.911) 0.001	-12.592 (5.636) 0.028	5.118 (2.497) 0.044	20.709 (15.801) 0.194	8.057 (1.820) 0.000	-28.535 (10.745) 0.010	4.310 (3.463) 0.218	33.190 (27.141) 0.227
Log(GDP/N)	0.434 (0.095) 0.000	3.863 (1.208) 0.002	0.188 (0.264) 0.479	-3.201 (3.401) 0.350	-0.115 (0.192) 0.550	7.842 (2.314) 0.001	0.351 (0.362) 0.336	-5.702 (5.654) 0.318
$(Log(GDP/N))^2$		-0.184 (0.065) 0.006		0.183 (0.183) 0.321		-0.430 (0.125) 0.001		0.316 (0.294) 0.288
R-squared (overall)	0.001	0.000	0.018	0.032	0.024	0.025	0.001	0.006
Turning Point	$36,217				$9,123			
No. of Obs. / No. of Groups	115/29		98/27		98/27		80/22	

Table 1.13. Fixed Effects Regressions – U.S. Log(DWW) on Log(SPI/N) by Sector

	Dependent Variable: Log (DWW)							
	Public Sector Withdrawals		Irrigation Withdrawals		Industrial (self-supplied) Withdrawals		Thermoelectric (self-supplied) Withdrawals	
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
Constant	-2.846 (0.361) 0.000	-16.245 (9.228) 0.079	-7.650 (1.240) 0.000	3.867 (31.752) 0.903	15.741 (1.146) 0.000	-229.891 (26.542) 0.000	-3.904 (1.460) 0.008	-138.770 (36.087) 0.000
Log(GDP/N)	0.889 (0.037) 0.000	3.630 (1.887) 0.055	1.306 (0.126) 0.000	-1.050 (6.492) 0.872	-1.042 (0.116) 0.000	49.207 (5.427) 0.000	1.048 (0.148) 0.000	28.631 (7.376) 0.000
$(Log(GDP/N))^2$		-0.140 (0.096) 0.147		0.120 (0.332) 0.717		-2.567 (0.277) 0.000		-1.409 (0.377) 0.000
R-squared (overall)	0.165	0.163	0.027	0.027	0.016	0.041	0.015	0.021
Turning point	$426,892				$14,538		$25,849	

5.2. U.S. Consumptive Use

A large share of water withdrawn is returned to the watershed and is available for reuse downstream. In contrast, consumptive use of water is more directly bound by constraints of resource endowments, and may, therefore, be a better indicator than withdrawals of water scarcity and environmental impact. Data on consumptive use are often not readily available, however. Such data were available only in the USGS dataset and only for the years 1960-1995.

For the U.S., per capita withdrawals and consumptive use are highly correlated (Pearson's correlation coefficient of 0.796). To test whether per capita withdrawals and consumptive use are reliable proxies for one another, a least squares regression of the logs of daily consumptive use per capita (DCU/N) was run on the logs of daily water withdrawals per capita (DWW/N). An extremely strong, near linear relationship was found in the regression analysis ($p<0.000$), which suggests that withdrawals might be a reasonable indicator of consumptive use. Several issues complicate such a straightforward conclusion, however. As can be seen in Figure 1.2, the relationship between the logs of DCU/N on DWW/N is heteroskedastic and is weaker at lower levels of per capita withdrawals.

The relationship between withdrawals and consumptive use also differs strongly across states. For instance, for the entire time period of 1960-1995, consumptive use was only slightly more than 3% of total withdrawals in Illinois which relies primarily on rain-fed agriculture, while in Kansas, which has a much higher dependence on irrigated agriculture, consumptive use represented over 70% of withdrawals. Differences in consumptive use rates are also evident across economic sectors. In 1995, total withdrawals from all 48 states for irrigation and for thermo-electric plants were roughly equal at just above 130,000 mgd; however, consumptive use represented nearly 61% of irrigation withdrawals, but less than 3% of withdrawals for thermo-electricity purposes. Moreover, these ratios are not constant over time. Consumptive use as a share of total withdrawals for the thermo-electric sector, for instance, increased 10-fold between 1960 and 1995, as the power industry switched from open-loop to closed loop cooling systems (DoE, 2006).[19] Industry and the public sector also displayed substantial changes over time, albeit less dramatic ones. Thus, it seems that despite a strong correlation, data on withdrawals are not necessarily indicative of consumptive use.

Separate fixed effects regressions were run following Equation 2, using both per capita consumptive use and total consumptive use as dependent variables. Results for per capita and total consumptive use are shown in Table 1.15. For comparison, regression results for both per capita withdrawals and total withdrawals using only the 1960-1995 data are also presented. Per capita consumptive use displays an EKC similar to the case of withdrawals, although with an estimated turning point at a slightly higher income level. In the case of total consumptive use, however, while the data produce a statistically significant EKC, the estimated turning point is much higher than for total withdrawals, and is outside of the range of data.

Separating the states by region, states west of the 100th meridian, which tend to have higher rates of consumptive use than their more humid eastern counterparts, did display a statistically significant ($p<.05$) EKC for total consumptive use with a turning point within the range of data, while the eastern states displayed a statistically insignificant ($p>.10$) EKC with a turning point far outside the range found in the data. In running a regression on individual states using Equation 3, 29 states had coefficients consistent with EKCs, although only 8 (5 western and 3 eastern) of these were significant at the 5% level.

[19] In 1975, for instance, U.S. withdrawals for the thermoelectric power sector were nearly 200,000 mgd, while consumptive use was just over 800 mgd. In 1995, withdrawals dropped to 130,000 mgd, while consumptive use rose nearly four-fold to 3,300 mgd.

In sum, per capita consumptive use also seems to follow an EKC, although with an estimated turning point slightly higher than for per capita withdrawals. For total consumptive use, the data are consistent with an EKC, but with a turning point outside the range of data. This may be due to the change in technology in the thermo-electric coolant sector, which has allowed withdrawals to decline relative to the amount of water consumed.

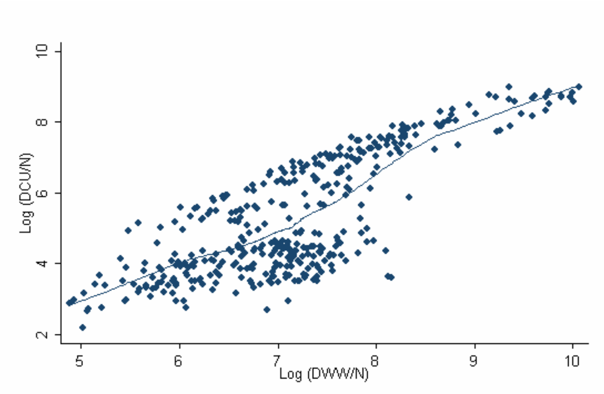

Figure 1.2. Lowess of Log(DCU/N) on Log(DWW/N)

Table 1.14. U.S. Panel Dataset Summary Statistics (1960-1995)

Number of observations: 48 Time period covered: 1960-1995

	Mean	Standard Deviation	Minimum	Maximum
SPI/N (2000 US$)	19,206.42	5,243.21	7,474	29,635
DWW/N (gallons/day/capita	2,418.61	3,725.35	132.41	23,559.88
DCU/N (gallons/day/capita)	806.56	1,458.93	8.99	7,953.17
DWW (million gallons per day)	6,584.30	6,564.00	107.30	43,782.00
DCU (million gallons per day)	1,832.73	3,477.44	7.72	25,495.63

Table 1.15. Fixed Effects U.S. Per Cap and Total Withdrawals & Consumptive Use

no. of observations = 384 no. of groups = 48

Dependent Variable:	**Log (DWW/N)**		**Log (DCU/N)**		**Log (DWW)**		**Log (DCU)**	
Independent Variable	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
Constant	2.673 (0.875) 0.002	-84.249 (24.972) 0.001	-0.853 (0.711) 0.231	-51.118 (20.476) 0.013	1.292 (0.564) 0.023	-100.765 (15.405) 0.000	4.818 (0.705) 0.000	-133.896 (19.030) 0.000
Log(SPI/N)	0.269 (0.089) 0.003	18.141 (5.132) 0.000	0.734 (0.072) 0.000	11.070 (4.208) 0.009	0.707 (0.057) 0.000	21.691 (3.166) 0.000	0.241 (0.072) 0.001	28.763 (3.911) 0.000
$(\text{Log(SPI /N)})^2$		-0.918 (0.264) 0.001		-0.531 (0.216) 0.015		-1.078 (0.163) 0.000		-1.465 (0.201) 0.000
R-squared overall	0.001	0.005	0.039	0.040	0.064	0.073	0.002	0.032
Turning points	$18,338		$19,550		$23,406		$33,649	

6. Conclusions

The primary objective of this study was to reassess the relationship between national and state level water use and income, given the limitations of previous studies on this topic. In order to test the robustness of findings, several indicators of water use were utilized from multiple datasets. In line with many early EKC studies, this study used only reduced form models to identify correlations between economic growth and water use. As stated above, this limited analysis is the only type of water-income analysis possible at the national or state level, given data limitations.

Many previous studies found EKCs for water withdrawals, either overall, or for specific sectors. Results from GLS regressions of cross-sectional national per capita water withdrawals and for fixed effects regressions of OECD and U.S. panel data are generally consistent with the existence of an EKC. As with findings in EKC pollution studies, however, the results of this study are sensitive to choice of dataset and method of analysis. In fact, no measure of per capita water withdrawal was consistently found to follow an EKC across all datasets examined (see table 1.16). Per capita withdrawals for all purposes were found to follow an EKC with all parametric regressions, but not with nonparametric regressions of the cross-sectional data, which indicated a monotonically positive relationship that seems to level off, but not decline. This suggests that the turning point found with least squares may simply be an artifact imposed by choice of the quadratic functional form.

Fixed effects regressions of panel data, both because they control for country specific factors such as water endowments and climate, and because they measure actual country behavior over time, are often felt to be better models for EKC studies. Panel data covered a relatively short number of time periods, especially in the case of the OECD. Still, even the relatively small datasets produced statistically significant results supporting an EKC for per capita water withdrawals. Income explained very little of the variation in water use for all datasets, however, and the estimated EKCs did not prove to be good predictors of individual country or state water use.

Table 1.16. Summary of Study Findings

	EKC found within sample range			Estimated Turning Point of EKC		
	FAO GLS / Lowess	**OECD**	**U.S.**	**FAO**	**OECD**	**U.S.**
Per capita withdrawals						
All Uses	Yes* / No	Yes	Yes	9,620	8,775	18,620
Domestic	Yes / No			23,204		
Public Sector		Yes	Yes		19,088	29,792
Agriculture / Irrigation	Yes / Yes	No	No	1,953		
Industry	No */ No	Yes	Yes		7,384	13,608
Thermo-electric Cooling		No	Yes			21,239
Total withdrawals						
All Uses		Yes*	Yes		18,982	23,429
Public Sector		Yes	No		36,217	
Agriculture / Irrigation		No	No			
Industry		Yes	Yes		9,123	14,538
Thermo-electric Cooling		No	Yes			25,849
Per Capita Consumptive Use			Yes			19,593
Total Consumptive Use			Yes			33,649

* Cubic function also statistically significant

EKCs as described by quadratic functional forms present an inverted U relationship, but decreases in per capita water withdrawals cannot go on indefinitely (nor is there any reason to hope that it should). However, no consistent results for an upswing or stabilization after an initial downturn were found for per capita water withdrawals with either the OECD or U.S. datasets. This indicates, that the income level at which such a stabilization or upturn will occur has not yet been reached by a sufficient number of nations or states to produce statistical significance. Evidence does suggest that OECD nations may have reached this point in the case of total water withdrawals.

Results from the cross-sectional and panel data differed in terms of the sectors primarily responsible for the downturn in per capita water withdrawals. According to the cross-sectional data it is agriculture, while the fixed effects regressions indicate industrial and public use. A structural growth type explanation for an EKC might suggest that water use would increase as intensive agriculture develops and then drop if the economy moves away from agriculture and into less water intensive sectors such as services. Such a theory is consistent with the results from the cross-sectional dataset, but not with the results from the fixed effects regressions, in which irrigation withdrawals (per capita and total) do not show a downturn, and, in the case of the U.S., appear to increase monotonically.

Both OECD and U.S. industrial sector water withdrawals followed an EKC, measured both in per capita and total terms, the only sector to do so consistently. The cross-sectional analysis, however, shows per capita industrial withdrawals increasing monotonically with income. While businesses in richer countries have been able to reduce their water use – largely as a result of water pricing policies and water treatment regulation – water use by the industrial sector in these countries is still significantly higher than in developing countries. Thus, one can expect industries in developing countries to continue to increase their water withdrawals. It is unclear, however, whether developing countries would be expected also follow an EKC with respect to industrial withdrawals, or whether they will adopt available water saving technologies already in use by industries in developed nations.

That calculated turning points for total water withdrawals and consumptive use were higher than for per capita withdrawals suggests that some of the downturn in the case of the per capita regressions may simply be due to an increase in population. In terms of environmental impact, total withdrawals are probably the more important indicator. Water withdrawals and consumptive use in the U.S. were highly correlated at high levels of use, but less so at lower levels, suggesting that the reliability of use of withdrawals as a proxy for consumptive use is limited. Calculated turning points for both per capita and total consumptive use were higher than the corresponding withdrawal measures, substantially so and out of sample range, for total use. The higher turning point for consumptive use indicates that the intensity of water use (the ratio of consumptive use per unit withdrawn) has increased as states have developed economically.

EKC studies are valuable for determining if a robust correlation exists between incomes and some environmental or natural resource indicator. If so, income may be useful as a general indicator of future trends. This is important for policy planning purposes and for anticipating future scarcity and environmental impacts. The research also has direct implications for limits to growth. To the extent that EKCs exist, and peak withdrawals and consumptive use come before irreversible damage is done, constraints may not be binding. If, however, those two conditions do not hold, then economic growth patterns would appear to be unsustainable in terms of water use. Results from reduced form models testing a series of datasets are generally consistent with the existence of an EKC for water withdrawals and consumptive use, although results did differ across datasets and based on whether per capita or total use figures were used. Income, however, proved to be a poor indicator of actual country and state water withdrawals. This significantly tempers the usefulness of the EKCs found in the study in terms of prediction and planning.

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CHAPTER 2
Virtual water trade and income: Is there an EKC for water footprints?

1. Introduction

Since its introduction in the mid-1990s, the term "virtual water", meant to represent the amount of water used to produce a given agricultural commodity or industrial good, has become increasingly common in water policy discourse. Several researchers have attempted to measure the amount of virtual water traded internationally. According to Chapagain et al (2005), virtual water traded internationally represents 16% of global water withdrawals. Hoekstra and Hung (2002) and Chapagain and Hoekstra (2004) combined their calculations of net virtual water imports with data on withdrawals to produce national water footprints. Thus, these water footprints are an attempt to measure the impact of nations' consumption patterns on global water resources.[20]

A separate body of research has investigated how national water withdrawals vary as a function of national income. Several of these have claimed to find an inverted U curve relationship, or environmental Kuznets curve (EKC), for per capita water withdrawals and/or for sector specific water withdrawals (e.g., Rock, 1998; Goklany, 2002; Jia et al, 2006; Katz, 2008a). Recently a few researchers have addressed the relationship between virtual water use and income (e.g., Chapagain and Hoekstra, 2004; Ramirez-Vallejo and Rodgers, 2004; and Hoekstra and Chapagain, 2007). Surprisingly, none, to this author's knowledge, have attempted to relate their findings to the existing literature on environment and income, and none have explicitly tested the existence or lack thereof of an EKC for virtual water.

[20] The term "water footprint" was intended to be analogous to that of ecological footprints, which attempt to measure the ecological impact of a given nation's consumption patterns (Wackernagel and Rees, 1996).

This study analyzes national per capita water footprints as a function of per capita income, and explicitly tests for the existence of an EKC. Such an analysis offers insight into the role that income plays in determining global water use patterns. Results indicate that the downturn found for water withdrawals as a function of income is, at least in part, offset by the tendency of richer countries to import more virtual water. These results are consistent with a pollution haven explanation for EKCs, which proposes that at least some of the decline in pollution or resource consumption by economically developed nations is due to an outsourcing of these impacts to developing nations. While no concrete conclusions can be made from this research as to whether or not the downturn in per capita withdrawals for richer countries is due to an increase in imported virtual water from developing nations, results seem to indicate that such a scenario may be a reasonable explanation.

This study proceeds as follows: Section 2 reviews some of the virtual water literature. In particular, it focuses on discerning what exactly measurements of virtual water are attempting to measure and for what purposes. Section 3 presents a brief review of the existing work on water withdrawals and income and on environmental Kuznets curves in general. Section 4 is an empirical analysis of global water footprints as a function of income using least squares and nonparametric regression techniques. Section 5 offers concluding remarks and suggestions for further research on the topic.

2. Virtual Water and Water Footprints – What's Being Measured

The term "virtual water" was first used by Allan in the mid-1990s in discussions of efficiency in international water management (2002a). The phrase gained popularity as an increasing number of water managers stressed that the scarcity value of water should be considered when promoting agricultural and trade policies. Many scholars and professionals used the concept of trade in virtual water to stress that national water endowments need not be binding constraints on development. Furthermore, amid predictions of impending crises and even violent conflict due to increasing water scarcity (e.g., Starr, 1991), some scholars stressed that importation of virtual water offered an economically efficient way to alleviate local or national water scarcity and, thus, to avoid conflict (e.g., Allan, 2002b).

Since its inception, several researchers have attempted to quantify the amount of virtual water in international trade. Some researchers have focused on a particular crop (e.g., Chapagain et al, 2006). Others have looked at trade from a national or regional perspective (e.g., Earle, 2001; Guan and Hubacek, 2007; Velázquez, 2007; Wichelns, 2001; Yang and Zehnder, 2002; Zhao et al, 2005). Still others have attempted to analyze global trade in virtual water (e.g., Chapagain and Hoekstra, 2004; Hoekstra and Hung, 2002, 2005; Islam et al, 2007; Oki and Kanae, 2004; Ramirez-Vallejo and Rodgers, 2004; Yang et al., 2003; Yang and Zehnder, 2002; Zimmer and Renault, 2003). Estimates of global virtual water trade differ based on which goods were included and the calculations and assumptions regarding water demands of production of these goods. In one of the early such studies, Hoekstra and Hung (2002) offered an initial estimate that concentrated exclusively on trade in major agricultural commodities, as their production is responsible for over 80% overall global water withdrawals. Chapagain and Hoekstra (2004) expanded upon this by including water withdrawals necessary for production of industrial goods, which account for roughly 10% of global withdrawals.

A list of the water requirements, or virtual water content, of some of commonly traded agricultural and industrial goods is provided in Table 2.1.[21] The figures are average figures, as the water requirements of production of goods vary depending on climatic conditions and production methods. A list of the top ten importers and exporters of virtual water for the period 1997-2001 are included in Table 2.2. As can be seen, the list is dominated by the large industrialized nations. Because of the scale of trade, several nations, such as the United States, Germany, and China, are both among the largest importers and largest exporters. A list of the top ten countries in terms of *net* imports and exports of virtual water for the same period is provided in Table 2.3. Top net importing countries are almost exclusively high-income nations. Five had a per capita Gross Domestic Product (GDP/N) greater than US$ 20,000 in constant 2000 US$ for the period of reference, and only one, Iran, had a GDP/N less than $5,000.[22] This contrasts sharply with the top ten virtual water exporters, of which six had a GDP/N of less than $5,000 and four had GDP/N of less than $1,000. Such data indicate that income is likely an important driver of virtual water trade

Chapagain and Hoekstra (2004) combine estimates of net imports (imports minus exports) of virtual water with data on water withdrawals to produce a measure of national “water footprints”. Water footprints measure the amount of global water that a nation is responsible for via its consumption of agricultural and industrial goods, as well as through its domestic water use. Net importation of virtual water via international trade allows some countries to consume types and quantities of goods beyond what their local water endowments would allow. Other countries are net exporters of water, and therefore have footprints smaller than their withdrawal rates. A list of per capita water footprints for selected nations is included in Table 2.4. The countries with the largest per capita footprints are a mix of industrialized and developing countries, while those with the smallest per

[21] For Tables 2.1-2.4, data are taken from Chapagain and Hoekstra (2004).

[22] Data on GDP/N from World Development Indicators (World Bank, 2007).

capita footprints are exclusively developing countries, with the exception of Latvia. The calculations of water footprints allow researchers and policy-makers to determine the geographical distribution of the endpoints of global water withdrawals.

Table 2.1 Virtual Water Content of Selected Products

Product	Virtual water content (liters)
1 cup of tea (200 ml)	28
1 glass of beer (200 ml)	60
1 glass of apple juice (200 ml)	170
1 glass of milk (200 ml)	200
1 cup of coffee (200 ml)	224
1 potato (100 g)	25
1 orange (100 g)	50
1 apple (100 g)	70
1 slice of bread (30 g)	40
Cheese(10 g)	50
1 hamburger (150 g)	2400
1 sheet of A4 size paper	10
1 microchip (2 g)	32
1 cotton T-shirt (medium size)	4100
1 pair of leather shoes	8000

Source: Chapagain and Hoekstra (2004). Figures given in milliliters (ml) and grams (g).

Table 2.2. Top Ten Gross Virtual Water Importing and Exporting Countries

Rank	Importing Country	Gross Imports (bcm/y)	Exporting Country	Gross Exports (bcm/y)
1	USA	175.8	USA	229.3
2	Germany	95.3	Canada	105.6
3	Japan	98.2	France	78.5
4	Italy	89.0	Australia	73.0
5	France	72.2	China	73.0
6	Netherlands	68.8	Germany	70.5
7	UK	64.2	Brazil	67.8
8	China	63.1	Netherlands	57.6
9	Mexico	50.1	Argentina	50.6
10	Belgium-Luxembourg	47.1	Russia	47.7

Source: Chapagain and Hoekstra (2004). Average figures in billion cubic meters per year (bcm/y) for the period 1997-2001.

Table 2.3. Top Ten Net Virtual Water Importing and Exporting Countries

Rank	Net Virtual Water Imports (bcm/y)				Net Virtual Water Exports (bcm/y)			
	Country	**Export**	**Import**	**Net Import**	**Country**	**Export**	**Import**	**Net Export**
1	Japan	98	7	92	Australia	73	9	64
2	Italy	89	38	51	Canada	95	35	60
3	UK	64	18	47	USA	229	176	53
4	Germany	106	70	35	Argentina	51	6	45
5	S. Korea	39	7	32	Brazil	68	23	45
6	Mexico	50	21	29	Ivory Coast	35	2	33
7	Hong Kong	28	1	27	Thailand	43	15	28
8	Iran	19	5	15	India	43	17	25
9	Spain	45	31	14	Ghana	20	2	18
10	Saudi Arabia	14	1	13	Ukraine	21	4	17

Source: Chapagain and Hoekstra (2004). Average figures in billion cubic meters per year (bcm/y) for the period 1997-2001. Net figures differ slightly from gross figures due to rounding.

Table 2.4. Ten Largest & Smallest Per Capita Water Footprints by Country

Rank	Country	Footprint (m^3/cap/y)	Country	Footprint (m^3/cap/y)
1	USA	2,483	Yemen	619
2	Greece	2,389	Botswana	623
3	Malaysia	2,344	Afghanistan	660
4	Italy	2,332	Somalia	671
5	Spain	2,325	Ethiopia	675
6	Portugal	2,264	Namibia	683
7	Thailand	2,223	Latvia	684
8	Sudan	2,214	China	702
9	Cyprus	2,208	Kenya	714
10	Guyana	2,113	Democratic Republic of Congo	734

Source: Chapagain and Hoekstra (2004). Average figures in cubic meters per capita per year (m^3/cap/y) for the period 1997-2001.

Water footprints, as defined by Chapagain and Hoekstra, are "the volume of water used in the production of the goods and services consumed by the inhabitants of the country" (2004:9). The figures for agricultural crops include both "blue" and "green water". The term "blue water" represents ground and surface water extracted. This figure is captured in the withdrawals figures. The term "green water" represents moisture in the soil, utilized by crops directly, not through irrigation. Green water is not represented in water withdrawal data, complicating comparisons between the withdrawals and footprints. Because much of agriculture is rain-fed, however, not including green water would underestimate the virtual water embedded in crops.

Water footprints, according the definition cited in the previous paragraph, are meant to represent the amount of water "consumed" by countries. In calculating the virtual water content of products, Chapagain and Hoekstra use as measurement the amount of water withdrawals necessary for production. They do not measure the consumptive use (the amount of water withdrawn and not returned to the watershed) of product production. In the case of many goods, especially industrial goods, the consumptive use can be a small share of the water withdrawn for its production. Thus, the water footprint calculation represents the share of global water necessary for production of goods consumed, but not necessarily the water embedded in these goods.

3. Water and National Income

Income level has long been thought to influence the quantity of water consumed. Estimates of income elasticity of demand for water for domestic use are commonly made as part of standard demand curve estimation (for reviews of some such studies see Hanemann, 1998; Dalhuisen et al, 2001, 2003). Income elasticity studies have generally not been expanded to cover other large water consuming sectors, namely agriculture and industry, however. These sectors use water as an input rather than as a final good, and thus water demand for these sectors is generally modeled using profit maximization models, which assume that water is consumed at its rate of marginal productivity (Young, 2005), and not as a function of income.

Relatively little published literature has examined the relationship between income and overall water use at the national level. Of the few studies that have, several, though not all, found that national per capita water withdrawals follow an inverted U or EKC type relationship (e.g., Rock, 1998).[23] Possible reasons for such a phenomenon include a) increasing returns to scale in water-saving equipment, especially irrigation equipment, b) a positive income elasticity of demand for environmental conservation or restoration, including for instream flows, c) structural change in which countries' economies grow out of water

[23] Rock (1998, 2001), Goklany (2002), and Katz (2008) find EKCs for national water withdrawals. Bhattarai (2004) finds an EKC for irrigated land in Asia. Jia et al (2006) find an EKC for industrial water withdrawals from OECD countries. For a review of this literature, see Katz (2008).

intensive agriculture and industry and into less water intensive service sectors, and d) displacement of internal water withdrawals with imported virtual water.

The Heckscher-Ohlin model of international trade predicts that countries with abundant endowments of factors of production will trade with those lacking in those factors of production (Ohlin, 1933; Heckscher et al, 1991). Accordingly, one might expect water rich countries to export water intensive goods (or water itself) to more arid nations. Research has not found this to be the case, however. Ramirez-Vallejo and Rodgers (2004) found that trade flows of virtual water trade are independent of water resource endowments, in contrast to the Heckscher-Ohlin theorem. Yang et al (2003) and Oki and Kanae (2004) found that scarcity of arable land seems to play an important role in determining virtual water flows. Given that simple water endowment explanations do not satisfactorily explain trade in virtual water, it is interesting to discern what other drivers may be at work, and how they may be related to economic growth.

A few researchers addressing virtual water trade have recently begun to look at the role that national income plays in explaining virtual water consumption patterns. Ramirez-Vallejo and Rodgers (2004) find a positive elasticity of demand for virtual water in agricultural commodities. Chapagain and Hoekstra (2004) find a positive correlation between overall national water footprints income, as well as for domestic and industrial sector water uses and income, but no clear relationship between agricultural sector footprints and income. Hoekstra and Chapagain (2007) list income as one of four major drivers that they posit influence consumption of virtual water, and Berrittella et al (2007) include income in a general equilibrium model of virtual water trade in agricultural goods. None of these studies, however, relate their findings to those for water withdrawals mentioned above, nor do they test for the existence of an EKC relationship between income and water.

None of the studies on virtual water relate their results to the pollution haven hypothesis mentioned earlier.[24] Increased importation of virtual water as a function of income, may explain some of the observed downturns in per capita water withdrawals noted in the studies finding EKCs for water withdrawals. It is within this context then, that this study seeks to further explore the connection between income and national water withdrawals and footprints.

4. Water Footprints and Income – An Empirical Analysis

4.1 Data and Study Methods

The dataset used in this study consists of estimates of national water withdrawals national water footprints, for the years 1997-2001 given by Chapagain and Hoekstra (2004), who, in turn, base their calculations on data on water withdrawals and international trade from the United Nations Food and Agriculture Organization. Data on withdrawals is available only as single point estimate for the 1997-2001 period, rather than yearly figures. Because of this and because the time-series is quite short (5 years), this study takes an average of the annual footprints to construct a cross-sectional dataset, rather than treating the data as a panel dataset. Data on per capita income, also an average for 1997-2001, come from the World Bank World Development Indicators database (World Bank, 2007). Summary statistics for the dataset are presented in Table 2.5.

Cross-sectional data offers only a snapshot in time. Panel data would be preferable for an EKC study, as they show changes in individual country consumption over time.[25] This would allow one to test, for instance, whether

[24] Though the empirical evidence for a pollution haven effect remains inconclusive (Taylor, 2004; Brunnermeier and Levinson, 2004), some researchers have noted, that if true, the pollution haven hypothesis may be at least a partial explanation for the downturn in pollution observed in industrialized countries (Grossman and Kruger, 1995; Arrow et al, 1995; Copeland and Taylor, 2004).

[25] While panel data is preferable, it is not without problems. Several authors of EKC studies have pointed out that questions regarding stationarity, integration, homogeneity, and cross-sectional dependence of data can limit the reliability of conclusions based on panel data as well (e.g. List

declines in individual country withdrawals by rich nations were accompanied by increases in importation of virtual water withdrawals. The short length of the time series, however, does not allow for such an analysis. Changes in trade from year to year may be due simply to specific weather conditions in a given region for a particular year, and not reflective of a longer term trend.

Several of the early EKC studies used simple least squares regression models, regressing some environmental indicator on per capita income and its square (some also included the cube of income) (e.g., Grossman and Kruger, 1991; 1995). Such reduced form models, as they are often called, are useful in identifying general correlations between income and the environmental indicator of choice. Because they do not include other explanatory variables that may affect environmental impact or resource use, they do not isolate the effect of income holding other variables constant. Rather, they capture both direct and indirect effects of income. Later researchers included additional variables such as education and political governance structures likely also to affect environmental quality, but Seldon and Song (1994) argue that such variables were intentionally omitted from regression models because they were seen as endogenous to economic growth. Thus, if one is attempting to identify an overall income effect, including both direct and indirect impacts, a reduced form model is appropriate.

The choice of whether to estimate a reduced form or a more comprehensive model should depend on the intended application of the research. Identifying general correlations may be useful for highlighting and predicting trends, for instance; while isolating the direct contribution of income vis-à-vis other relevant variables may be more important for considering policy interventions. Many EKC studies have not been clear about the intended application of their research, adding to confusion in interpretation of results (Katz, 2008). This research will

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and Gallet, 1999, Stern, 2004; Bradford et al, 2005; Dijkgraaf and Vollebergh, 2005; Muller-Furstenberger and Wagner, 2007). Furthermore, if fixed effects models are being utilized, results can be biased and inconsistent if country specific characteristics are correlated with income (Chimeli and Braden, 2006).

use a reduced form Generalized Least Squares (GLS) regression model. As such, it is evaluating only a general correlation between income and withdrawals and footprints.

The regression model used in this study is given in Equation 1 below:

(Eq. 1) $\text{WATER}_i = \beta_0 + \beta_1\text{INC}_i + \beta_2\text{INC}_i^2 + \beta_3\text{INC}_i^3 + e_i$

where the dependent variable WATER represents either the per capita annual water withdrawals or per capita water footprint, depending on the specific regression estimated; INC represents per capita Gross Domestic Product; e represents an error term; the subscript i represents the unit of observation - an individual country; and the βs represent parameters to be estimated. As is common in EKC studies (Stern, 2004), the natural logs of both the dependent and independent variables are used as units of analysis, rather than the levels. This serves two valuable functions. First, it helps smooth out a highly skewed distribution of national per capita incomes. Second, coefficients on log-log regressions can be easily interpreted as income elasticities of demand.[26]

Separate regressions are run for per capita withdrawals and footprints. Additional regressions are run for per capita withdrawals and footprints by sector. In addition to GLS regression, Lowess,[27] a non-parametric regression technique, analysis is also performed on the data. Lowess regression forms a best fit curve by conducting localized regressions over small, overlapping subsets of the data, often called bin size or bandwith. The primary advantage of this method is that it estimates a best fit curve to data without necessitating any prior assumptions regarding functional form (DiNardo and Tobias, 2001). Such regressions do not produce functions easily represented by mathematical formulae, but can better

[26] It should be noted that these income elasticities of demand are not equitable to those from traditional demand curve estimates, which do, in fact, isolate the effect of income with respect to other explanatory variables.
[27] LOWESS is sometimes referred to by other names, including LOESS and locally weighted polynomial regression (NIST, 2006).

represent the actual relationship between variables. The Lowess regressions will serve as a check of the GLS results.

4.2 Results

4.2.1. Per Capita Annual Water Withdrawals and Income

Several EKC studies simply test a quadratic equation (income and income squared as explanatory variables), without testing alternative functional forms. In this study the logs of per capita annual water withdrawals (AWW/N), measured in cubic meters per capita per year, were regressed on linear, quadratic, and cubic functions of the logs of income, represented by per capita Gross Domestic Product (GDP/N) in constant 2000 U.S. dollars. Results of GLS regressions are presented in Table 2.6.

All three functional forms were statistically significant at the 1% level. The linear equation shows a monotonically increasing function; the quadratic, an inverted U or EKC equation, with a turning point at $7,158; and the cubic a function that increases with income up to a level of $1,825 per capita, after which there beings a slight decline, followed by an increase at a per capita income above $7,775. These results differ from those of Rock (1998), whose GLS results confirm only an EKC type function, with a turning point per capita income of roughly $20,000. Rock's analysis differed from the current analysis, however, in terms of year of data, sample size, and model functional form. The results are also slightly different than those found by this author (Katz, 2008) using an identical model, but slightly different sample size (n=149).[28] In that analysis, the quadratic form was significant at the 1% level, but the coefficients on the square and cube of GDP/N in that analysis were significant only at the 10% level. This is evidence to the fact that results are sensitive to datasets, a finding similar to those in other EKC studies.

[28] The slightly different sample sizes result from limitations regarding trade data used by Chapagain and Hoekstra (2004) to calculate footprints.

A Lowess regression of AWW/N on GDP/N produces a monotonically increasing relationship.[29] A graph of the fitted curve based on the quadratic and cubic models, together with the results of the Lowess regression, are presented in Figure 2.1a. As can be seen, while results from a least squares regression using a quadratic form are consistent with the finding of an EKC, results from the cubic form and the Lowess regression demonstrate that the turning point found with the quadratic is simply an outcome of the choice of functional form.

GLS regressions of AWW/N were also estimated by sector for the agricultural, domestic use, and industrial sectors. Domestic withdrawals conform to an EKC, industrial withdrawals increase monotonically with respect to income, and agricultural withdrawals rise, then fall, only to rise again at high income levels (Table 2.7). For both the domestic and agricultural withdrawals, the estimated turning points (local maxima and minima respectively) are quite close to the upper end of the range of data. Lowess regressions of the sectoral data show that these estimated turning points may not reflect of actual trends (Figures 2.1b-d), rather, they may simply be artifacts imposed by choice of functional form, as was found in the case of per capita annual withdrawals for all purposes. The somewhat lower per capita water withdrawals in the agricultural sector (by far the largest water consuming sector) in rich countries are what drive the findings of EKCs for overall withdrawals. According to both the quadratic and cubic functional forms, per capita industrial withdrawals increase with respect to income, but at a decreasing rate, while the Lowess regression shows them increase at an increasing rate for the richest countries. All regressions show that industries in richer countries tend to use more water, on a per capita level, than those in poorer countries. This is the case despite research showing significant reductions in industrial water use in developed countries over the past several decades (e.g., Jia et al, 2006).

[29] LOWESS regressions in this study used a bandwith of 0.8. Regressions using other bandwidths produced qualitatively similar results.

4.2.2. Per Capita Annual Water Footprints and Income

Log-log regressions of per capita footprints on per capita income do not show evidence of an EKC. Of the three functional forms tested, only the linear form is statistically significant at any meaningful level (Table 2.8). Poorer countries display a much wider range of both per capita withdrawals and per capita footprints than do richer countries. Whereas per capita withdrawals appear to level off as a function of income, per capita footprints for such countries appear to increase throughout the range of the data. Income accounts for less of the variation in footprints than for withdrawals, however, as indicated by the lower R^2 values in all models.

It is tempting to simply compare per capita footprints to per capita withdrawals in order to determine the extent to which countries are importing virtual water to live beyond their own endowments. However, given that "global virtual water export is overwhelmingly 'green'" (Yang et al, 2006a:14), it is not possible to simply compare agricultural or overall withdrawals and footprints in order to determine the degree to which water withdrawn is traded across boundaries.

Per capita industrial withdrawals and per capita footprints are comparable though. Both GLS and Lowess regressions show that industrial footprints increase monotonically with respect to income. In fact, all three functional forms and the Lowess regressions results provide very similar results (Table 2.8 and Figure 2.2c). Moreover, the high R-squared for all three functional forms indicates that income accounts for a great deal of the variation among nations. Per capita footprints rise at a substantially higher rate with respect to income than do withdrawals, indicating that, at least in terms of consumption of industrial goods, consumption in richer nations does, in fact, come at the expense of water withdrawn in poorer nations. Per capita withdrawals of the richest quintile in the sample are 251.7 m^3/cap/year, while those of the poorest quintile are 24.9; a ratio of just over 10.1. The comparable figures for industrial water footprints are 406.9

and 20.6 m^3/cap/year; a ratio of just under 19.8, nearly double that of industrial withdrawals. As industrial withdrawals constitute 22.3% of virtual water traded globally, it seems that a substantial share of the world's water is being directed from poorer countries towards richer ones in the form of industrial goods.

Chapagain and Hoekstra divide up nations' overall water footprints into internal and external footprints, where the "*internal water footprint* of a nation is the volume of water used from domestic water resources to produce the goods and services consumed by the inhabitants of the country. The *external water footprint* of a country is the volume of water used in other countries to produce goods and services imported and consumed by the inhabitants of the country" (2004:9). Regressions of internal and external footprints on income offers another method of evaluating the extent to which economic development correlates with utilization of global water resources. Log-log regressions of per capita internal water footprints and external water footprints on GDP/N reveal that internal water resource footprints decline with respect to income, while external water footprints increase monotonically (Table 2.9 and Figure 2.3a-b).[30] Moreover, the effect of income is greater on external water footprints than internal ones. Thus, at least on a per capita basis, wealthier countries rely less of their own water resources and more on those of other countries.[31]

Income accounts for a substantial share of the variation in external footprints, as evidenced by the R-squared figures (Table 2.9). Moreover, income accounts for a much higher share of the variation in external footprints than internal ones. Thus, income level seems to be a better predictor of increasing importation of water resources than of decreasing domestic water resources

[30] This is the case for internal footprints both including and excluding domestic water consumption, as this sector represents just 6.4% of total internal water footprints. A graphical presentation of internal water footprints including the domestic use sector is not included in Figure 3, as it is nearly identical to that of Figure 3a.

[31] This said, internal water footprints are still substantially larger that external ones. Average per capita internal footprints for the sample are 1011.4 m^3/cap/year, while average per capita external footprints are 340.3 m^3/cap/year.

Table 2.5. Annual Water Withdrawals and Footprints (1997-2001 Averages)

Variable	Mean	Std. Dev.	Min	Max
GDP (billions of 2000 US$)	222	9.32	0.04	9,340
GDP Per Capita (2000 US$)	5,546	8,737	91.12	37,036
Annual Water Withdrawals (km^3)	27.1	86.3	.02	633.3
Annual Water Withdrawals Per Capita (m^3)	575.1	645.5	5.42	4743.2
Annual Water Footprint (km^3)	52.8	134.2	0	987.4
Annual Water Footprint Per Capita (m^3)	1349.0	442.3	619	2483

Sources: *Chapagain and Hoekstra (2004), FAO (2007), World Bank (2007).*
Number of observations (n) = 134

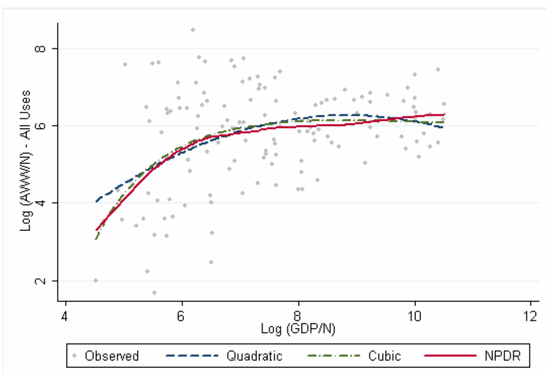
Table 2.6. GLS Regressions of Log (AWW/N) on Log (GDP/N)

Independent Variable	Linear	Quadratic	Cubic
Constant	3.650 (0.590) 0.000	-3.004 (2.541) 0.239	-30.026 (10.137) 0.004
Log (GDP/N)	0.280 (0.069) 0.000	2.097 (0.649) 0.002	13.419 (4.134) 0.001
Log $(GDP/N)^2$		-0.119 (0.040) 0.004	-1.652 (0.547) 0.003
Log $(GDP/N)^3$			0.067 (0.023) 0.005
R-squared	0.115	0.166	0.202
Turning Points		$6,927	$1,526 $9,020

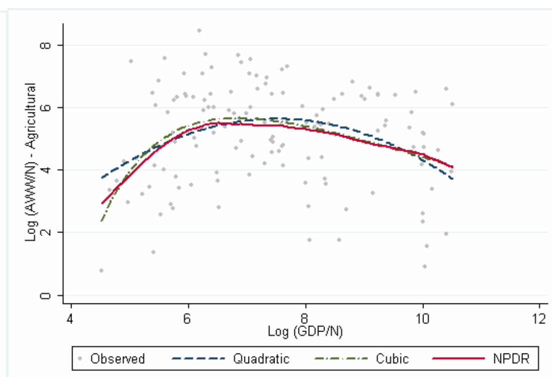
Note: Coefficient results are presented with robust standard errors in parenthesis and p-values below the standard errors. Annual water withdrawals per capita are in cubic meters. GDP per capita is in 2000 US$. n=134.

Table 2.7 GLS Regressions of Log (AWW/N) on Log (GDP/N) by Sector

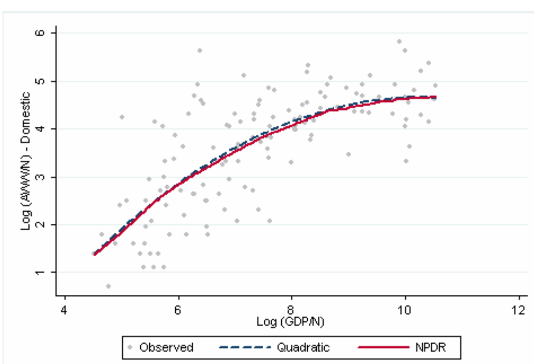
	Agriculture *(n=130)*			Domestic *(n=134)*			Industry *(n=131)*		
Independent Variable	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**
Constant	5.551 (0.802) 0.000	-6.267 (3.431) 0.070	-36.471 (14.577) 0.014	-0.218 (0.374) 0.561	-5.817 (1.505) 0.000	-4.815 (6.976) 0.491	-2.820 (0.646) 0.000	-8.584 (2.698) 0.002	-48.581 (13.100) 0.000
Log (GDP/N)	-0.060 (0.104) 0.565	0.170 (0.913) 0.001	15.842 (6.078) 0.010	0.516 (0.046) 0.000	2.045 (0.394) 0.000	1.625 (2.847) 0.569	0.794 (0.080) 0.000	2.361 (0.708) 0.001	19.099 (5.374) 0.001
Log $(GDP/N)^2$		-0.211 (0060) 0.001	-1.930 (0.825) 0.021		-0.100 (0.025) 0.000	-0.043 (0.376) 0.909		-0.102 (0.046) 0.027	-2.367 (0.715) 0.001
Log $(GDP/N)^3$			0.075 (0.036) 0.040			-0.002 (0.016) 0.878			0.099 (0.031) 0.002
R-squared	0.004	0.112	0.143	0.492	0.537	0.537	0.408	0.424	0.459
Turning Points		$1,819	$972 $26,248		$27,584	n.a.		$106,248	n.a.



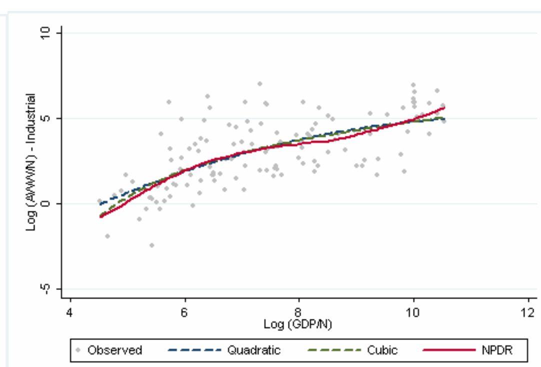
2.1a. AWW/N – All Uses



2.1b. AWW/N – Agriculture



2.1c. AWW/N – Domestic



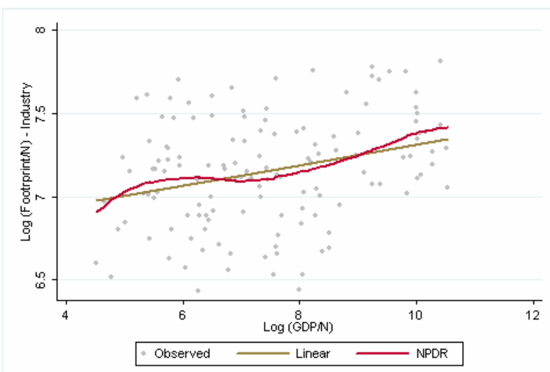
2.1d. AWW/N – Industrial

Figure 2.1a-d. Fitted GLS and Lowess Curves of Log(AWW/N) on Log(GDP/N)

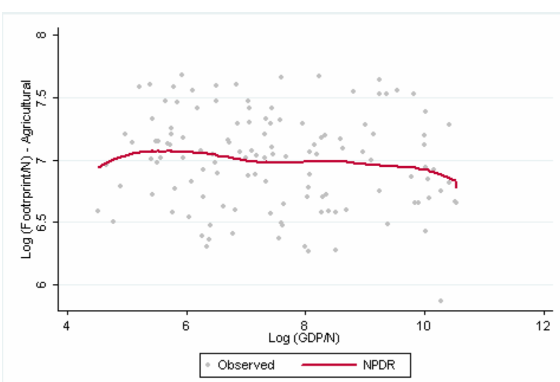
Note: Fitted curves from GLS regressions are provided only in cases in which the model was statistically significant at the 10% level or less.

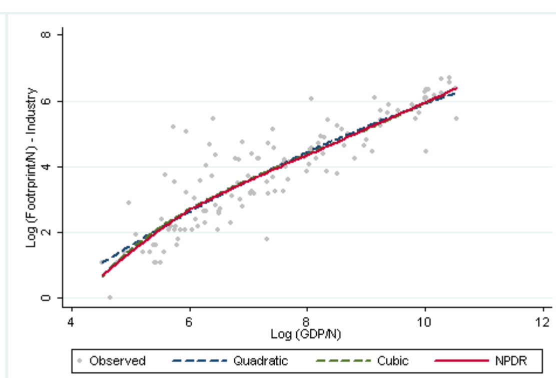
Table 2.8 GLS Regressions of Log (Footprint/N) on Log (GDP/N)

	All Uses ***(n=134)***			**Agriculture** ***(n=127)***			**Industry** ***(n=131)***		
Independent Variable	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**
Constant	6.695 (0.123) 0.000	7.562 (0.646) 0.000	4.604 (3.142) 0.145	7.211 (0.160) 0.000	6.882 (0.743) 0.000	-6.847 (3.775) 0.072	-2.435 (0.340) 0.000	-4.836 (0.023) 0.001	-45.486 (12.964) 0.001
Log (GDP/N)	0.062 (0.016) 0.000	-0.175 (0.171) 0.307	1.064 (1.302) 0.415	-0.029 (0.021) 0.177	0.060 (0.200) 0.763	0.075 (1.566) 0.962	0.847 (0.040) 0.000	1.500 (0.368) 0.000	5.873 (2.806) 0.038
Log $(GDP/N)^2$		0.015 (0 .011) 0.157	-0.152 (0.175) 0.386		-0.006 (0.013) 0.656	-0.008 (0.211) 0.971		-0.042 (0.023) 0.069	-0.634 (0.375) 0.093
Log $(GDP/N)^3$			0.007 (0.008) 0.338			-0.0001 (0.009) 0.992			0.026 (0.016) 0.114
Adj. R-squared	0.088	0.101	0.108	0.015	0.016	0.016	0.760	0.765	0.769
Turning Points					$183			$46.8m	



2.2a. Footprints per Capita – All Uses





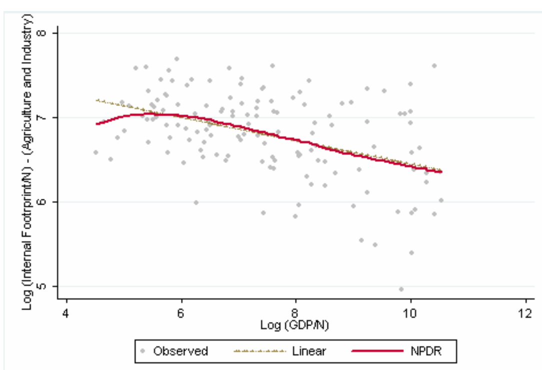
2.2b. Footprints per Capita – Agriculture **2.2c. Footprints per Capita - Industry**

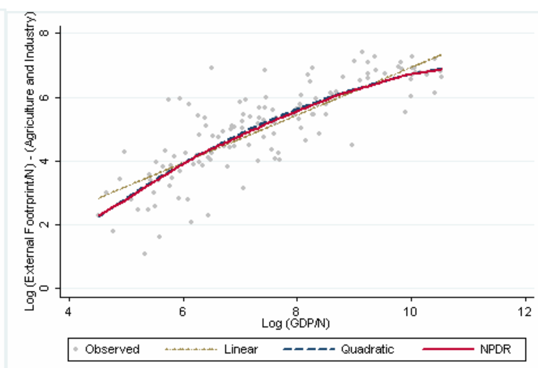
Figure 2.2a-c. Fitted GLS and Lowess Curves of Log(Footprints/N) on Log(GDP/N)

Note: Fitted curves from GLS regressions are provided only in cases in which the model was statistically significant at the 10% level or less.

Table 2.9 GLS Regressions of Internal & External Footprint/N on GDP/N (Log-Log)

	Internal Footprint Agriculture, Industry, and Domestic *(n=134)*			**Internal Footprint Agriculture and Industry** *(n=134)*			**External Footprint Agriculture and Industry** *(n=133)*		
Independent Variable	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**	**Linear**	**Quadratic**	**Cubic**
Constant	7.831 (0.123) 0.000	6.819 (0.863) 0.000	1.043 (4.050 0.855	8.121 (0.246) 0.000	6.741 (0.948) 0.000	-0.867 (4.652) 0.852	-0.541 (0.355) 0.130	-4.918 (1.463) 0.001	-4.154 (6.493) 0.523
Log (GDP/N)	-0.138 (0.029) 0.000	-0.138 (0.241) 0.567	2.694 (1.679) 0.111	-0.191 (0.036) 0.000	0.186 (0.268) 0.490	3.373 (1.987) 0.092	0.748 (0.043) 0.000	1.940 (0 .378) 0.000	0.988 (2.883) 0.733
Log $(GDP/N)^2$		-0.018 (0 .016) 0.272	-0.364 (0.232) 0.118		-0.025 (0.018) 0.185	-0.456 (0.274) 0.099		-0.078 (0 .024) 0.001	0.051 (0 .385) 0.894
Log $(GDP/N)^3$			0.015 (0.010) 0.145			0.019 (0.012) 0.124			-0.001 (0.017) 0.735
R-squared	0.184	0.192	0.204	0.231	0.240	0.253	0.677	0.695	0.695
Turning Points								$267,950	





2.3a. Internal Footprints/N **2.3b. External Footprints/N**

Figure 2.3a-b. Fitted GLS and Lowess Curves of Internal and External Water Footprints/N on GDP/N (Log-Log)

5. Conclusion

Some research has suggested that per capita water withdrawals follow an inverted U or EKC type form. Whereas water withdrawals represent a production aspect of water used to produce goods, water footprints represent a consumption aspect, in that they relate to the ultimate destination of those goods at the point of consumption. This research shows that differences between footprints and withdrawals with respect to income are significant. The two indicators are not directly comparable as footprints include both “green” and “blue” water. However, results from analysis of overall footprints, industrial sector footprints, and the differences between internal and external footprints all indicate that wealthier countries are responsible for more of the world’s water resources consumption than for its extraction.

Because this study uses only cross-sectional data, it cannot confirm or refute a pollution haven type explanation, whereby wealthy countries decrease their extraction of water resources by increasing consumption of water intensive goods from poorer countries. The study’s results are, however, consistent with the contention that such an outsourcing of water production is occurring. Panel datasets of national water withdrawals and water footprints over time, which could better address this research question, have yet to be published.

The results of this research are not only important from a perspective of equitable resource use, but as countries industrialize, it is valuable to be able to predict the impact of economic growth on consumption habits, and to understand how these consumption habits are likely to impact water withdrawals. Water withdrawals, while not strictly constrained by water endowments the way consumptive use is, impact the environment, and a certain level of withdrawals is necessary for basic economic development. If, as seems the case based on the results of this research, income increases a country’s use of external water resources, new research questions arise concerning the limits to such outsourcing, as eventually developing countries will not have additional external water resources from which to draw as they develop.

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CHAPTER 3
Hydro-political hyperbole:
Examining incentives for exaggerating the risks of water wars

1. Introduction

Predictions of coming wars over water are commonly found in statements by political officials, research studies by academics, popular journalistic sources, and reports by environmental and development oriented non-governmental organizations. A search on any popular search engine of the term "water wars" will turn up thousands of such references. Claims by analysts regarding the possibility of future water wars range from those who present such a scenario as a possibility which can be avoided with cooperation and proper planning (e.g., Frey and Naff, 1984, Postel and Wolf, 2001), to those who predict that such wars are likely (e.g., Cooley, 1984; Naff and Matson,1984; Starr, 1991; Bulloch and Darwish, 1993; De Villiers 1999, Ward 2002), to those who confidently predict that they are "certain" (e.g., Myers, 1993:47).

Many authors buttress their claims by quoting high level officials such as former Egyptian Foreign Minister and former Secretary General of the United Nations Boutrous Boutrous Ghali, who purportedly claimed that "The next war in the Middle East will be fought over water, not politics" or the vice president of the World Bank, Ismail Serageldin, who stated that "the wars of the next century will be over water."[32] As will be shown, several of those making the case that water will lead to violent conflict offer case studies of past water related conflict, and more recently, a few have provided statistical analyses showing some evidence that water scarcity is correlated with the outbreak of both domestic and international conflict.

Since the first publication of such warnings of the imminent potential for violent conflict over water, however, a mounting literature has challenged both the

[32] These quotes have been reproduced in numerous books and articles. See, for instance, De Villiers (1999).

empirical and theoretical foundations of such a water war hypothesis (Lonergan 2001; Dolatyar 2002; Wolf 2007). Critics note, for instance, that relatively little systematic empirical evidence exists of violent conflicts over water (Yoffe et al, 2003), and that the evidence that does exist is inconclusive at best. Furthermore, they note that proponents of the water war hypothesis often rely on a very limited number of cases and statements by officials (Dinar, 2002). In addition, as will be discussed more at length below, several researchers have offered theoretical arguments based on strategic, economic, and technological rationales, suggesting that the risk of violent conflict over water resources is highly exaggerated.

Given the relative paucity of supporting evidence of past water-motivated conflict, and theoretical arguments why they are unlikely, it is then perhaps surprising that proclamations that water wars are imminent remain so prevalent. While much of the literature on the topic has attempted to either promulgate, refute, or in some other way test the veracity of the water war hypothesis, little if any has addressed the various incentives that different key actors have for emphasizing, and even exaggerating, the risks of such wars. This article will attempt to address this gap. It will describe incentives that each of several different actors face to stress the possibility of violent conflict over scarce water resources. The confluence of interests by different parties to stress such risks is likely to have contributed to the persistence of such warnings and predictions in political, academic, and journalistic circles at levels far beyond what is justified by empirical data. While this article specifically addresses violent conflict over water, its premises and conclusions are likely relevant to much of the discourse in the rapidly developing field of environmental security.

The article will proceed as follows. The next section will specify what is meant by "water wars" and violent conflict over water for the purposes of this discussion. It will then lay out the main arguments for and against the water war hypothesis, and provide a review of empirical studies on the matter. The subsequent sections will outline incentives for stressing the risks of war over water resources by five different actors involved in promulgating the water war hypothesis: political officials, journalists, academics, non-governmental organizations, and the private sector. The final section will offer concluding thoughts and implications for analysis of other aspects of environmental and resource security.

2. The Water War Hypothesis: Examining the Evidence

2.1. Defining Water-based Conflict

Beginning in the 1980s, a flurry of academic articles were published predicting that growing water scarcity would lead to increasing international conflict (e.g., Cooley, 1984; Naff and Matson, 1984; Starr and Stoll, 1988). Several of these quoted leading international figures such as former Egyptian President Anwar Sadat and Foreign Minister Boutrous Boutrous Ghali. These predictions and warnings were duly repeated in the international news media (e.g., Asser, 2007; Cowell, 1989; Vesilind, 1993) and in publications of international development organizations (e.g., UN, 2006; WCED, 1987). Over the last two decades, the number of articles in academic journals and the popular press referring to imminent water wars increased exponentially; and the water war hypothesis, as it is sometimes called, has become a cornerstone in the burgeoning literature linking the natural environment and security.

Before delving into the arguments supporting and refuting the likelihood of "water wars", it is helpful to define the term. Perhaps because of its alliterative value, the expression "water wars" is often used to describe any level of conflict between parties involving water.[33] Clearly such a loose use of the term is not helpful for the current analysis. Singer (1981) notes that most studies of war fail

[33] For instance, a search of the New York Times online archives (1981-2007) using the keywords "water war" produced 34 articles, only 4 of which actually mentioned actual or potential violent conflict of any sort (performed using online database at: http://query.nytimes.com/search/ on 6 February, 2008). Several books also have the phrase "Water Wars" in the title, but do not focus on violent conflict over water resources (e.g., Annin (2006) on the history of U.S.-Canadian water management in the Great Lakes).

to distinguish between war, which is uncommon, and conflict, which is more common. Of concern for this article is the potential for armed conflict between politically organized groups over control over or access to freshwater resources, as this is a meaning commonly used by both proponents and detractors of the water war hypothesis. Thus, both domestic and international armed conflict could be considered under such a definition, but violent conflict between individuals would not, nor would conflict over other issues in which water infrastructure was damaged. In this sense, this paper is not restricting itself to wars per se, but rather, a broader range of violent conflict stemming from water-related issues.

2.2. Arguments Supporting the Water War Hypothesis

Support for the water war hypothesis is given by declarations of public officials, theoretical models, and empirical evidence. In addition to the numerous quotes of Sadat, Boutrous Ghali, and Serageldin already mentioned, other commonly cited figures warning of the risks of water wars include former United Nations Secretary General Kofi Anan, former U.S. Secretary of State Madeline Albright (both cited in Amery, 2002), the late King Hussein of Jordan who made a warning similar to that of Sadat (Starr, 1991), and former Israeli Prime Minister Ariel Sharon, who, in his autobiography, claimed that the Six Day War of 1967 actually "started two and a half years earlier," with Israel's bombing of Syria's attempted diversion of the Jordan headwaters (Sharon and Chanoff, 1989: 167), and who, decades later, made declarations that upstream use of the headwaters of the Jordan River within Lebanon could again lead to war (Amery, 2002).

The potential for water wars was included in Our Common Future, the Bruntland Report on sustainable development (WCED, 1987), and figured prominently in a book written by former U.S. Senator Paul Simon on the challenges of water supply around the world (Simon, 1998). Starr (1991) claims that already in the 1980s, U.S. intelligence services had a list of ten areas in the world in which the prospect of wars over water was viewed with concern.

The typical version of the water war hypothesis posits that countries will be willing to wage war over threats to existing water resources that may arise, for instance, from upstream diversions. Some of the more developed of theoretical models incorporate additional explanatory variables such as riparian position, relative military might, measures of relative scarcity, and level of economic development (e.g., Frey and Naff, 1984; Hauge and Ellingsen, 1998). A stronger version of the water war hypothesis claims that countries experiencing acute water scarcity will be compelled by a "hydrological imperative" to obtain additional water supplies from neighboring countries, and will resort to violent means if needed (e.g., Cooley, 1984; Stauffer, 1982; Stork, 1983).

Still other theoretical models stress that water scarcity alone may not in and of itself often serve as a casus belli between nations, but rather, may aggravate existing international or domestic conflicts (e.g., Gleick, 1991). Water scarcity may, for instance, result in population displacement ("environmental refugees"), leading to competition and political destabilization (Homer-Dixon, 1994). Similarly, droughts may reduce returns from agricultural labor, thereby improving the relative returns from initiation of violent competition between groups or revolt, and as such may be a contributing factor to wars (Collier and Hoeffler, 2002). Water scarcity may be a result of a number of factors, including internal population increases, increased use by other riparian nations, increased per capita demand due to changes in standards of living, decreases in quality of available resources, or unequal access to available resources (Homer-Dixon, 1994). In addition, the impacts of climate change on water availability may also contribute to local water scarcity, raising the potential for conflict (Van der Molen and Hildering, 2005).[34] These theoretical constructs are in line with the larger literature on environmental security.[35]

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[34] A special issue of Political Geography, Volume 26, Issue 6, (2007) was dedicated to the links between conflict and climate change. Some articles in this issue addressed the effect on precipitation as a driver.

[35] Although deriving from a different theoretical construct, violent protest over privatization of water resources has also been described as a form of "water war" in some of the literature (e.g., Olivera and Lewis, 2004).

By far, the majority of the empirical evidence presented in support of the water war hypothesis consists of case studies and anecdotal references. Among the most popular are Israel's bombing of Syrian bulldozers attempting to divert the headwaters of the Jordan River and the Palestinian Liberation Organization's (PLO) attempt to blow up Israel's National Water Carrier (e.g., Naff and Matson, 1984; Starr, 1991; Gleick, 1993; Lowi, 1993). While the Middle East is the most cited example, other regions have also been cited as having experienced violent conflict over water. Most recently, skirmishes in Sri Lanka have been described as water-related (Bajpaee, 2006; The Economist, 2006; Reddy, 2006), and several commentators, including U.N. Secretary General Ban Ki Moon, have characterized the violence in the Darfur region of Sudan as stemming, at least in part, from struggles over scarce water resources (Ban, 2007).

Until relatively recently, the water war hypothesis lacked any systematic empirical support. Over the past few years, however, several researchers have published large sample size statistical studies on the subject (although such work still pales in comparison to that relying on a few case studies). In one of the first such studies, Hauge and Ellingsen (1998) found water scarcity to be statistically correlated with the outbreak of civil wars between 1980 and 1992 and with armed conflict within nations between 1989 and 1992. Gleditsch et al (2006) found that dry countries have more conflict than humid ones. Toset et al (2000) and Furlong et al (2006) found that, holding other variables constant, countries that share a river are more likely to engage in violent conflict than neighboring countries that do not, and the higher the number of rivers, the higher the likelihood of conflict. Levy et al (2005) found that regions with high levels of variability in rainfall were statistically more prone to high (but not to low) intensity domestic conflict. Miguel et al (2004) also found a correlation between rainfall and violent conflict within Africa. Both Furlong et al (2006) and Hensel et al (2006), while noting the small number of militarized disputes over rivers, nonetheless found that militarized conflict over rivers is more likely when an initiating state is experiencing greater water scarcity.

2.3. Arguments Against the Water War Hypothesis

Despite the proliferation of articles and research supporting a water war hypothesis, a substantial amount of research demonstrates that actual risks of the outbreak of violent conflict over water resources may be minimal. In a critique of the environmental security literature, Gleditsch (1998) decried the fact that "postulated events in the future are cited as empirical evidence" (p. 381). Clearly statements from the 1980s and 1990s that claimed that "the next war in the Middle East will be over water, not politics" have already proven to be wrong. Research has shown, however, that even the more general predictions of imminent water wars based on comments by officials may lack credibility. Warnings and even threats of water wars by public officials are commonplace, and are often considered critical evidence of the potential for water related violence, but it is important to distinguish between threats of conflict and actual conflict. Leng (1980), for instance, found no correlation between frequency of threats of war and the onset of war. In a study specifically looking at conflict and cooperation over water resources between 1948 and 1992, Yoffe et al (2003) noted over 400 incidents of verbal exchanges by political figures between 1948 to 1999 that were conflictive in nature, but only 37 instances of violent conflict of varying levels of intensity (most from the Middle East), and no all-out wars.

Much of the theoretical justification for water wars is simplistic and deterministic. Singer (1981) claims that at least three sets of attributes need to be considered when analyzing the background conditions for causes of war: material (geographic, demographic, and technological), structural (institutional and organizational), and cultural (including psychological). Most theories on water wars, however, are based exclusively on the material attributes, ignoring broader institutional and cultural factors. Studies of war, such as the numerous research projects using the Correlates of War database (Singer, 1980), have identified numerous variables that seem to influence the likelihood of the outbreak of violent conflict, including level of democracy, relative power parity, economic development and others (e.g., Vasquez, 2000). Yet, notes Singer, in a history of empirical research on war, "many popular models reduce war to single deterministic causes" (2000: p.17). This seems to be the case for many of the proponents of the water war hypothesis, especially those promulgating a hydrological imperative line of reasoning.[36] Theories based on water scarcity as a single driver ignore other clearly important variables and enabling conditions such as historical relationships between parties, riparian position, relative military balance of power, governance and decision-making structures, trade relationships, and others. Theoretical models that have attempted to incorporate some of these additional variables still remain largely untested.

Another critique of the conclusion that water wars are imminent comes largely from economists, who point out that the economic value of water to be gained from military conquest is unlikely to outweigh the economic costs of military preparation and battle, much less the loss of life (e.g., Allan, 2001, 2002a, 2002b; Deudney, 1999; Fisher, 1995; Fisher and Huber-Lee, 2005). While proponents of water war scenarios often premise their conclusion on the fact that water is essential for life and non-substitutable (e.g., Elhance, 1999) – and therefore likely to be fought over – others have noted that water for basic needs represents a small share of total water use, even in arid countries (Gleick, 1996; Toset et al, 2000). The majority of freshwater consumption (over 80% of world withdrawals) is by the agricultural sector, a relatively low value use and one in which large gains in efficiency could easily be made by changes in irrigation techniques and choice of crops. Thus, economists and others have made the argument that a war over water is really a war over water for agricultural goods of little economic value. Furthermore, they argue that markets provide a cheaper and morally superior

[36] Gleditch (1998) levels a similar claim against much of the environmental security literature in general.

alternative means of attaining either the water or the agricultural goods.[37] Allan (2001; 2002a, 2002b) has stressed that countries can obviate the need for conflict over water by importing, rather than growing, water intensive crops (what he dubbed importation of 'virtual water'). Some economists argue that even if water is valued at its replacement cost – the cost of desalination plus delivery – rather than at its shadow price, it would still be cheaper than the costs of waging war, and with no loss of life (e.g., Fisher and Huber-Lee, 2005).

Of course, most political leaders do not view water as merely an economic good, but rather, one that has important implications in terms of national identity, sovereignty, and environmental quality. Moreover, realists note that leaders rarely if ever decide to wage war based on arguments of economic efficiency; indeed, history is replete with examples of wars that made little sense from an economic perspective.[38] Decision-makers' assessments of benefits and costs often differ substantially from those of the market. The economic argument against water wars is valuable, however, in stressing that most uses of water are not essential, and therefore, fighting over water is rarely necessary for survival. Furthermore, the more policy-makers learn the economists' arguments, the lower the chances of water based conflict.

Perhaps the strongest case against the probability of water wars is the lack of systematic empirical evidence for precedents. Gleick (2006) lists several incidents of water-related violent conflict. His list, however, includes incidents in which water and water related infrastructure were tools and targets of violent

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[37] More general versions of the argument that most resources have substitutes, and, are thus unlikely to serve as causes of war, have been put forth by Deudney (1991), Simon (1996), Gleditsch (1998), and others.

[38] In his history of the study of war, Singer (2000), describes how Polish economist Bloch, writing prior to the first World War, correctly predicted that the invention of machine guns would allow a small number of soldiers to hold out against a superior number of enemy forces, and that this would substantially raise the costs of preparation for and execution of wars. Singer dryly commented that "being an economist, with that discipline's touching faith in the rationality of those in power, Block (sic) believed that the European elites would thus turn to other means of interstate conflict resolution" (p.6). The news magazine *The Economist* stated its critique regarding the link between rational decision-making and war somewhat more succinctly: "wars are usually fought for much stupider reasons than water." (The Economist, 1995: 53).

conflict, in addition to causes of it. In a review of interstate conflict, Wolf (1999) noted that only one case of war explicitly over water could be documented, and this took place over 4500 years ago. Moreover, he could document only seven cases of acute conflict over water. This may explain why only a limited number of case studies of water conflict are presented in the water wars literature.

In their systematic study of conflict and cooperation over water, Yoffe et al (2003, 2004) also found that armed conflict over water resources was uncommon, and that war over water was, in fact, exceedingly rare. Rather, in looking at behavior of countries sharing water resources, they found that cooperation was much more common than conflict overall and in all regions except the Middle East North Africa (MENA) region for the period 1948-1999. Of the 1,831 events included in their survey, only 28% were conflictive, versus 67% that were cooperative (with 5% neutral or insignificant). Of the conflictive events the overwhelming majority were limited to verbal exchanges. Only 37 events consisted of actual violent conflict, and 30 of these were in the Middle East. Such results have led many analysts to conclude that shared water resources may actually be more of a catalyst for peace and cooperation than for conflict (e.g., Wolf, 1998; Haddadin, 2000; Asmal, 2001; van der Molen and Hildering, 2005).[39]

In a review of the field of war studies, Singer (2000) noted that often first stage in a field of research is speculation, in which researchers "invent some plausible explanations, and then ransack history for those causes that seem to support our hypotheses" (p. 4). The most cited case study by proponents of the water war hypothesis is the violent conflict over water resources that took place between Israel and its neighbors in the 1950s and 1960s. Several even make the far-reaching claim that the 1967 war was itself a war over water (e.g., Pearce,

[39] Hensel et al (2006) found that water scarcity was also associated with higher levels of cooperation between states, which, while not providing evidence against a water war scenario, at least seems to indicate that scarcity need not lead to conflict.

2006).[40] Since the time of these events, however, the parties have endured the 1973 war, two Israel-Lebanon wars, and two Palestinian uprisings, but no violence primarily over water; this despite a more than a four-fold increase in the population of the region and the resulting decline in per capita water availability. On the contrary, the region has witnessed water sharing agreements as part of both the Israel-PLO and Israel-Jordan peace agreements of 1993 and 1994 respectively. If, as seems reasonable, past incidents of water related violent conflict were attempts by the Arab parties to prevent the fledgling Israeli state from establishing itself, now that Israel is established, the likelihood of conflict over water in the region may be declining, rather than increasing as predicted by proponents of the water war hypothesis.

The case study approach has also been criticized on methodological grounds. In their critiques of the environmental security literature in general, analysts have pointed out that because cases are chosen specifically in which both resource scarcity and conflict exist, there is no variation in the dependent variable, and thus, hypotheses on the role of scarcity as a cause of conflict remain untestable

[40] Several authors and some politicians have characterized the 1967 Arab-Israeli war as being driven at least in part by water resources. Some, like Pearce (2006), a popular science journalist, claim that the war was a "water war", while others make more modest claims that the war was fought, "partly" because of water related conflict (Cooley, 1984: 3), or that water-related tensions were "a major factor in the deterioration of Arab-Israeli relations that led to the Six-Day War in 1967" (Shemesh, 2004: 1). Proponents of the hydrological imperative theory have often pointed to Israel's capture of the West Bank and Golan Heights in this war as examples of their theory. The strong claim that the war was primarily over water is not well supported. Evidence provided by Pearce (2006), for instance, amounts merely to the statement of Ariel Sharon cited above, and the fact that Israel gained access to a large share of the Jordan basin as a result of the war. While conflict over water resources no doubt aggravated relations between the parties, it was not the proximate or primary driver of 1967 conflict (Haddadin, 2002). As Haddadin, a former Jordanian Minister of Water, points out, water was not even listed among the topics to be addressed in the United Nations' Resolution 242 outlining steps to be taken to resolve the crisis.

As in the case of almost all examples of water wars, it is extremely difficult to isolate the relative importance that securing water resources may have had in any decisions to initiate conflict or retain control over lands. Several commentators have also claimed that Israel's invasion of Lebanon in the 1980s and subsequent retention of a security zone in southern Lebanon was motivated by its desire for the waters of the Litani River (e.g., Myers, 1993). It is now clear, however, that this claim has little credence. There is no evidence that Israel utilized the Litani's waters (Wolf, 1995), and Israel has subsequently withdrawn from Lebanon, despite increased water scarcity within Israel. Indeed, Israel withdrew its forces in 2000, at the peak of a severe multiyear regional drought. This would seem to argue against a hydrological imperative being a primary driver of policy.

(e.g., Levy, 1995; Gleditsch 1998). Several of the recent statistical studies attempt to address this. They, however, suffer from their own limitations. The most significant is that they find correlations between water-related variables and conflict, but generally fail to establish convincingly any causal relationships. As noted above, in their study on the outbreak of domestic conflict between 1980 and 1992, Hauge and Ellingsen (1998) do find a statistically significant correlation between conflict and water scarcity. However, because they have data on water scarcity for only one point in time (1992), few, if any, conclusions can be drawn as to causal relationships. The results may simply reflect the fact that areas prone to conflict, such as the Middle East, just happen to be more arid than regions that have been more politically stable recently, such as Europe. A similar critique can be made regarding the results of Hensel et al (2006) for international conflict. For instance, one cannot determine if increasing scarcity results in increasing likelihood of conflict. Neither study made use of both water scarcity and changes in water scarcity (and perhaps an interaction variable between them) to attempt to tease out causal relationships.

Moreover, evidence from large sample size statistical studies is far from conclusive. Neither Esty et al (1999) nor Levy et al (2005) found measures of water availability to have any impact on the likelihood of domestic conflict, and Stalley (2003) found similar results in the case of international conflict. Gleditsch et al (2006) found no correlation between conflict, and nor between either drought, the number of river crossings, or the share of the basin upstream. While Toset et al (2000) found that countries sharing a river are more likely to go to war than those that do not, they found no evidence that this likelihood has increased over time, as would be expected if water scarcity were the driving factor behind conflict. Furthermore, Goldstone (2001) noted that even when environmental factors are statistically significantly correlated with the outbreak of violent conflict, they often are of relative unimportance when compared with other explanatory variables.

Finally, some authors have even questioned the empirical basis for the conclusion that freshwater resources are increasingly scarce, an assumption on which the water war hypothesis relies heavily. These "optimists" or "cornucopians", as they are sometimes referred to, claim that because of increases in efficiency due to improved irrigation technologies, metering and pricing policies, and reductions in delivery loss rates and costs for desalination and reclaimed sewage, increasing scarcity of water is not a foregone conclusion, even with increasing populations (e.g., Myers and Simon, 1994; Simon, 1996; Lomberg, 2001). To the extent that technological and management improvements do reduce scarcity, according to the premise of the water war hypothesis, they should also be expected to reduce the potential for violent conflict.

In sum, despite instances of violent conflict over water in the past, there is little systematic evidence of high level conflict, much less all out war over water resources. The evidence that such wars are likely appears inconclusive at best, and misleading at worst. This has led some leading scholars on the topic to tone down or qualify their statements about the likelihood of future water wars. Compare, for example, Homer-Dixon's declaration that 'the renewable resource most likely to stimulate interstate resource war is river water" (p. 19), with his later statement that "wars over river water between upstream and downstream neighbors are likely only in a narrow set of circumstances…[and] there are, in fact, very few river basins around the world where all these conditions hold" (p. 208). Despite such a reality, policy-makers continue to issue warnings and predictions of imminent water wars, and the topic remains prominent in headlines and articles in both the scholarly and popular press. This article will now turn to offering possible explanations for the persistence and popularity of such warnings.

3. Incentives for Stressing a Water War Scenario

3.1. Incentives Presented in Existing Literature

Observers have noted that various actors may have incentives for stressing or even exaggerating the risks of water wars. Lonergan (2001) notes, for instance, that in "many cases, the comments are little more than media hype; in others, statements have been made for political reasons" (p. 110). Beyond mere acknowledgement of the possibility of such incentives, however, little research has attempted to understand what these incentives are and how they may differ between actors. An understanding of the motivations of various groups of actors to stress the possibility of imminent water wars can help explain the continued seemingly disproportionate popularity of such messages and help to evaluate more critically the warnings that are issued.

Simon (1980), while not specifically addressing environmental conflict, suggests four possible reasons that academic researchers offer what he presented as overly gloomy scenarios regarding possible implications of resource scarcity (what he dubbed "an oversupply of false bad news"). The first reason is that international funding organizations are eager to fund research dealing with crises, but not that producing good news. The second is that bad news sells more newspapers and books, whereas good news does not. The third is a psychological predisposition to focus on bad news or worst case scenarios. The fourth is a belief, mistaken in his view, that sounding alarm bells can mobilize action to improve environmental issues.

Haas (2002) offers two reasons why "exaggerated beliefs about resource scarcity and their possible threats to environmental security persist." The first is "the absence of any consensual mechanism for reconciling interdiscourse (or inter-paradigm) disputes" (p.2). This, Haas argues, allows for ideological outlooks to remain without resolution. "The second reason is the elective affinity between environmental and security discourses on the one hand, and other dominant discourses in social discussions... on the other hand. Consequently self-interested political actors can borrow from discourses that are similar in their ontology and structure and that justify pre-existing political ambitions" (p.2). Both explanations stem from the interdisciplinary nature of the environmental security problems, which allows multiple approaches, with few common methods of analysis.

Trottier (2003) addresses the risks of water wars specifically. She suggests that certain private sector actors in the water industry have an incentive to stress or exaggerate the risks of water wars in order to promote additional water-related infrastructure as a means for reducing the likelihood and/or impacts of such conflict.

Straightforward explanations, such as "blood sells" given by Simon and the economic argument of Trottier, may have some merit, but ultimately are unsatisfying, in that they are not relevant for several actors and they oversimplify a multifaceted picture by ignoring other possible motives. Such simplistic explanations also risk giving the impression that those offering such statements were on a mission to intentionally distort or mislead the public, which most certainly is not the case for many such actors. Haas's explanations also seem reasonable, but do not distinguish between differing incentives for different actors. In sum, while the above are all interesting arguments, even taken collectively, they provide only a partial picture of existing incentives.

3.2. Multiple Incentives for Multiple Actors

This study goes beyond previous research by analyzing incentives of five different groups of actors, each of whom has played a role in the promotion of the water war hypothesis. These are: a) political leaders and policy-makers, b) academic scholars, c) the news media, d) non-governmental organizations

(NGOs) and e) the private sector.[41] For each group, possible incentives at work for stressing a water war scenario are offered. These are summarized in Table 3.1 below. The first entry for each group is the obvious case that they simply believe that water wars are imminent. Given that there is some empirical evidence of past water related conflict and a real perception among many that it may lead to conflict, such a straightforward explanation should be taken seriously. In addition, it can also be viewed as a credible null hypothesis. As can be seen from the table, however, each group has several other possible incentives to stress the water war hypothesis, some unique to it, and some that overlap with those of other actors. No attempt is made to verify that indeed these additional incentives have in fact played a role in the decision of a particular actor, though some examples are given in which such a scenario seems likely.

[41] An additional group, intergovernmental organizations, shares many of the incentives of some of the five listed, and it will be discussed along with those throughout the article.

Table 3.1. Incentives to Stress or Exaggerate Risk of Water Wars

Actor	Incentives to Stress or Exaggerate Risk of Water Wars
Political leaders and policy-makers	• Signal an actual risk of violence • Signal to riparian that water is considered high level politics • Signal to domestic population that water policy is taken seriously • Signal to third country desire for mediation • Serve as a negotiating tactic or intentional obstacle to negotiations • Raise profile of water related development or environmental needs
Academic scholars	• Assessment that water wars are actually imminent or likely • Serve as null hypothesis of research into water and conflict • Claim that political statements and/or media publications are worthy of study in their own right • Raise profile of research and expand the pools of funding • Raise profile of water related development or environmental needs
Journalists / Popular press	• Assessment that water wars are actually imminent or likely • Reporting of statements by "experts" • Need for gripping headline • Need to shorten analysis into sound-bite or article length segment • Practice of giving equal coverage to opposing views • Practice of focusing on aspect of most interest to target audience • Raise profile of water related development or environmental needs
Non-governmental organizations	• Assessment that water wars are actually imminent or likely • Raise profile of water related development or environmental needs • Gain media coverage for organization • Expand pools of available funding
Private Sector	• Assessment that such wars are actually imminent or likely • Desire to promote water related infrastructure to alleviate scarcity

3.2.1. Political leaders and policy-makers

3.2.1.1. Signal an actual risk of violence

The most straightforward reason that political leaders might warn of the dangers of a war over water is, of course, their belief that such a risk is actually imminent and/or to issue a meaningful threat to riparian countries that they are prepared to engage in warfare if actions are taken to deprive it of water resources. Such threats appear to be the case, for instance, in the case of statements in the 1950s and 1960s by Israeli leaders, such as Finance Minister and later Prime Minister Levi Eshkol and General Moshe Dayan, that Israel would be prepared to take action against Arab forces should they interfere with Israeli water development projects (Gat, 2005; Shemesh, 2004). This may well be the case too for statements by Sadat that Egypt would go to war to prevent Ethiopia from building dams, thereby threatening Egypt's share of the Nile (Dinar and Wolf, 1994). Threats have long been recognized as common methods for inducing action or communicating intent between nations. In order to make threats of war useful tools of influence, some analysts have suggested that they have to be considered credible (Schelling, 1960). Political leaders and policy-makers, however, have several other possible reasons for voicing water war risks other than to offer real and credible threats. Indeed, given that research has shown that public threats seem more often to be met with defiance rather than compliance (e.g., Leng, 1980), other reasons may in fact be primary ones.

3.2.1.2. Signal to riparian that water is considered high level politics

Issues of water management are often considered technical or bureaucratic issues far from the realm of "high politics", which traditionally has focused on security and economic development. Warning of risks of war over water can be a way to signal to a riparian country that their actions are being taken seriously at high levels of government. This may be done, for instance, to convince a country to refrain from or redesign a planned action or to induce them into engaging in negotiations. Turkey, Syria, and Iraq have long engaged in saber-rattling over the waters of the Tigris and Euphrates rivers (Naff and Matson, 1984; Kibaroglu and

Ünver, 2000). Threats by Syria and Iraq to go to war with militarily superior Turkey over water were (unsuccessful) attempts to dissuade Turkey from developing dams upstream. Güner (1998) describes the use of threats of war as a signaling tactic by Turkey and Syria in a game theoretic model of such interactions. Such use of threats of war may have been an important signaling device, even if the likelihood of the threat being realized was limited.

3.2.1.3. Signal to domestic population that water policy is taken seriously

Political leaders may not only wish to signal to rival governments, but to their domestic constituencies as well. Indeed, as Putnam (1988) and others have noted, national political leaders are often engaged in two-level decision-making in which they must simultaneously attempt to balance both domestic and international political demands. In many developing countries agriculture is both generally responsible for the bulk of water withdrawals and plays a large role in the national economy and national employment. In more economically developed countries, agriculture is also the largest water consuming sector, but generally plays a smaller role in both the overall economy and in national employment. Nonetheless, agricultural lobbies in industrial countries are often still quite influential. A public statement of willingness to fight for water rights is likely to send a signal to domestic constituencies that water rights are being taken seriously by the national government, whether or not they intend to back up such threats. Additionally, they may be issued with the intent of persuading a domestic audience to favor or oppose a particular political party or position who will prevent such wars from occurring.

In analyzing the "bellicose statements, even at the highest levels" of the Indian and Pakistani governments in the 1950s and 1960s, Alam (2000:349) suggests that "though the statements made by key decisionmakers in public may suggest a move towards war, the statements are used to generate domestic support for a political position. As seen in the Indus basin the political rhetoric did not match the governments' actions which sought to resolve an international water dispute through cooperation… The experience from the Indus basin, therefore, throws into question whether public statements made for a domestic audience are truly indicative of a country's intent to go to war over shared waters."

3.2.1.4. Signal to third country a desire for mediation

Another possibility is that threats or warnings of war are meant to influence third parties, who often play a role in mediating disputes between nations and in financing water development projects. Lebanese diversions of waters of the Wazzani River, a tributary of the Jordan, presented a very minor threat to the Israeli economy, especially in the amounts being withdrawn at the time that Israeli Prime Minister Ariel Sharon issued his warnings that continued diversions could spur military conflict (Amery, 2002). These warnings may have been meant to prevent a precedent for future more significant diversions that would present a significant threat to Israel. It is also possible that Sharon was attempting to engage a third party to mediate between Israel and Lebanon, with whom Israel has no direct diplomatic relations. Indeed, soon after the statements were made, U.S. officials became involved in surveying the existing waterworks, allaying the fears of the Israelis, and eventually, negotiating an agreement between the sides. American officials also reportedly requested from the Israelis that messages should be transmitted through them and not through threats of military reprisals (Walla!, 2001).

Similarly, Iraqi threats against Syria in the 1970s spurred intervention by the Soviet Union and Saudi Arabia, who helped negotiate a settlement. In addition, during this period Iraqi threats of military action against Turkey, a stronger upstream neighbor, may not have been intended only to send a signal to Turkey, but also to the international financial community, including the World Bank, which was contemplating funding of Turkish dams at the time (Kibaroglu and Ünver, 2000). Threats of war are likely to undermine possible credit options for nations seeking to finance large scale water projects. Thus, political leaders may issue them in order to deter institutions for offering finance or to encourage their intervention to change the terms of the projects being considered. Threats of violent conflict were also important in motivating World Bank efforts to help negotiate an agreement between India and Pakistan on the Indus River in the 1960s (Ward, 2002); and at least one analyst has suggested that the risk of regional instability is at least partly a factor in dissuading international agencies and governments from financing dams in Ethiopia (Collins, cited in Ward, 2002:185-186). Hensel et al (2006), in an empirical study of conflict and cooperation over international waterways, found that water scarcity was, in fact, positively correlated with third party assistance.

3.2.1.5. Serve as negotiating tactic or intentional obstacle to negotiations

Almost all scholars familiar with the water war hypothesis, whether or not they think water wars likely, readily admit that water policy is intimately intertwined with other political issues and conflicts. Another possible rationale for policy-makers to issue threats or warnings of war over water is as a negotiating tactic regarding issues that may or may not be directly related to water resources. Güner (1998) explains how threats of military and terrorist acts between Syria and Turkey, while ostensibly over shared water resources, were likely linked to other issues such as territorial disputes and separatist movements. He states that in 1993 then Turkish Prime Minister Tansu Çiller sent a message to Syrian President Hafez al-Assad stating that there would be no solution to water disputes between the nations unless Syria prevented the Kurdish separatist group PKK from acting within its territory.

Rather than serve to induce action in negotiations over issues other than water, it is also possible that threats or warnings of war by political officials are meant to prevent negotiations or concessions on such issues. Some authors have claimed that Israel's occupation of the West Bank and Golan Heights was motivated by its desire to control the water resources of those areas (e.g., Cooley, 1984; Stauffer, 1982; Stork, 1983). Regardless of the veracity of such claims, what is clear is that political figures have used the risk of future war over water as a justification for not relinquishing control of these territories. While many experts agree that accords over shared water resources between Israel and its neighbors are possible and need not be an obstacle to larger peace agreements (e.g., Haddadin, 2000, 2002), political officials and other parties opposed to territorial concessions have raised the risks of water wars in their litany of reasons to maintain control of territory.[42]

<u>*3.2.1.6. Raise profile of water related development or environmental needs*</u>

One reason to stress the risks of war over water, common to all groups of actors looked at in this study, is to bring attention to aspects of water management that may otherwise be deemed by policy-makers as less deserving of attention and/or funding. By raising the specter of war, an official can also draw attention to issues such as sanitation, pollution, or other environmental or development concerns that may not otherwise be on many people's political agendas. For instance, British diplomat John Ashton, the United Kingdom's "Climate Ambassador", reportedly said that global warming should be recast as a security issue to help mobilize support for cuts in global greenhouse gas emissions (Doyle, 2007). Such a rationale seems reasonable in explaining declarations concerning water wars made by other officials in governments and at bodies such as the World Bank or UNESCO (UN, 2006), which are formally charged with development and educational issues, not conflict resolution.

3.2.2. Academic Scholars

<u>*3.2.2.1. Assessment that such wars are actually imminent or likely*</u>

Again, the null hypothesis is that academic scholars truly believe that water wars are distinct possibilities. As noted above, such an explanation is supported by the existence of past violent conflict over water as detailed in case studies, plausible theoretical models, and some systematic empirical studies.

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[42] Sherman (2002), an Israeli academic, presents an argument against the provisions for water in the Oslo Peace Accords between Israel and the PLO, in which he cites several Israeli officials making such claims.

3.2.2.2. Serve as null hypothesis of research into water and conflict

Studies attempting to demonstrate that risks of water wars are unlikely or presenting the issue simply as a worst case scenario still serve to keep the issue alive in the public consciousness and in political and academic debates. Moreover, these studies implicitly give the water wars hypothesis at least minimal credibility by deeming it worthy of study and/or useful as a working hypothesis in empirical studies. In addition, because empirical studies in this field are still few, and theories remain speculative, publications both supporting and refuting the risks of conflict invite further work.

3.2.2.3. Political statements and/or media publications as fields of study in their own right

Many researchers may focus on the threats of water wars as topics of interest in their own right, even if they are not concerned with the probability of actual risks of conflict. Statements by public officials, media coverage of risks, the role of threats in international negotiations, the economic justifications (or lack thereof) of resource wars, are all legitimate subjects of study. [43] Researchers may focus on some aspect of the water war topic without needing to address the credibility of the threats. Furthermore, as Haas points out, the interdisciplinary nature of the topic allows researchers from a multitude of fields to apply their own theoretical framework to the issue and offers them a wide range of journals in which to potentially publish their results.[44] While these studies need not necessarily promote the water war hypothesis, they do keep the issue alive in public affairs and academic circles.

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[43] The topic of conflict over water resources has been the subject of special issues of several leading academic journals from a variety of such fields including, for instance, *Studies in Conflict and Terrorism* 20 (1-2), 1997; *Arab Studies Quarterly* Spring, 2000; *International Negotiation*, 5(2), 2000; *Political Geography* 25(4), 2006; *Society and Natural Resources* 15(8), 2002.

[44] Haas 2002.

3.2.2.4. Raise profile of research and expand the pools of available funding

Connecting water to issues of security and war that are of interest within high level policy circles and the general public also offers researchers a way to raise the profile of their work. Thus they are more likely to gain access to policy-makers and make a name for themselves. Furthermore, because the topic is interdisciplinary, they expand the number and types of journals in which they can publish, and gain exposure to audiences outside their particular field of expertise, which offers possibilities for further research collaboration.

Without necessarily supporting or denying Simon's claim that financial sponsors encourage exaggerated bad news, one at least should to recognize that financial incentives may play a role, resulting in an over-representation of such views. Water policy specifically, and environmental policy in general, are interdisciplinary in nature, and thus research on these topics is open to a range of fields from both the natural and social sciences, each with its respective sources of funding. Security studies has its own large pool of funding, which can be substantial given the importance attached to security in policy. Thus, those connecting the two issues of resource scarcity and security open up large new pools of possible funding.[45] This does not ensure that researchers will promote such linkage, but it does represent a financial incentive to do so. Again, even if results of such studies do not find concrete linkages between resource scarcity and conflict, they too serve to sustain the issue's profile in policy and academic spheres.

[45] As an example, the European Union's Research Framework Programme serves as a significant source of funding for academic and other research institutions in the EU and several associated countries. In the latest call for proposals at the time this article was being written, the Seventh Research Framework Programme (FP7), a budget of 200 million Euro was designated for environmental studies, and an additional 80.3 million Euro for security studies. In addition, several of the topics under other calls, such as social science and the humanities, would also potentially cover studies on environmental security issues (http://cordis.europa.eu/fp7/dc/index.cfm accessed on 1 May, 2007).

3.2.2.5. Raise profile of water related development or environmental needs

As in the case of political figures and NGOs, there is also a distinct possibility that researchers attach the risk of water war in order to draw attention to and increase understanding of other water management issues, or in order, as Simon (1980) stated, to mobilize action on particular environmental or development issues. Several books, for example, have the phrase "water war" in the title, although actual discussion of violent conflict over water represents a relatively minor portion of the book, with the bulk being dedicated to various water management issues.[46] The intent of such books appears to be an effort to raise attention to some aspect of water management. The authors use the risk of violent conflict simply as motivational device in that it highlights in their view the potential dangers of failing to take action.

3.2.3. Journalists and the Popular Press

3.2.3.1. Assessment that water wars are actually imminent or likely

The null hypothesis that journalists stress the risks of water wars because they feel them to be legitimate risks cannot be discounted. The job of the press, however, is primarily to relay information and analysis, rather than to conduct it itself. Therefore, in the case of the media, this explanation is really a statement that the press believes the assessments of experts who stress the risks of violence over water resources.

3.2.3.2. Reporting of statements by "experts"

A wealth of literature addresses both how the media covers both environmental issues and issues of security and conflict, and no attempt to survey this literature will be made here.[47] From this extensive literature, several trends have been established that are relevant to this study. Several observers have noticed that establishment figures have privileged access to media. Cottle (2003) notes that

[46] See for example: de Villiers (1999), Ward (2002), Shiva (2004), and Olivera and Lewis (2004).

[47] For surveys and edited volumes addressing environment and the media, see for example, Anders (1993) or Anderson (1997). For surveys and edited volumes on conflict and the media, see for example, Aubin (1998), Cohen (1990), or Cottle (2006).

elites are considered inherently worthy of media coverage. Becker (1967) describes the media's deference to establishment as part of a perceived "hierarchy of credibility". Davis (2003) states that journalists are drawn to government and institutional sources in positions of power and expect them to provide expert knowledge. Thus, he concludes, journalists grant such officials 'primary definer' status.[48] He also notes that because of concerns over cost competitiveness, journalists increasingly rely on outside sources considered credible for information and analysis.

The prospect of imminent water wars was first presented by authorities with "primary definer" status. Once established, it has remained a popular theme in the popular press, despite the subsequent evidence suggesting the risks of an actual occurrence of water wars are low. Furthermore, if political leaders continue to make reference to the possibilities of water wars, the media can be expected to continue to report such comments, regardless of the state of academic research supporting or refuting such claims.

3.2.3.3. Need for gripping headline

Dunwoody and Peters (1995) in their study on media coverage of technological and environmental risks, caution about claims of bias in media coverage, given that there is no objective standard by which to judge such claims. Simon's (1980) observation that "bad news sells" more than good news, however, has ample empirical support. Cottle (2003), for example, provides numerous examples to support his claim that the press tends to focus on exceptional or violent behavior. Disagreements over water allocations may be considered rather mundane and thus not newsworthy, while violence over such allocations is. Thus, the media is predisposed to favor coverage of a position presenting the possibility of water wars over positions suggesting that such conflicts are not likely. For example, an article on water in the Middle East written by Fried (2007) and published in the

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[48] Herman and Chomsky (1988) go even further, asserting that relations of economic dependency ensure that political leaders are given preferential access to and coverage by the media.

San Francisco Chronicle was titled "*Future of war will go with the flow"* with the byline *"Water promises to be flash point*"; this, despite the fact that experts quoted in the article itself actually stated that they felt water was unlikely to lead to violence.[49]

3.2.3.4. Need to shorten analysis into sound-bite or article length segment

Perhaps ironically, the article cited above was one of the more balanced portrayals of the current state of knowledge in that it bothered to present the viewpoint that water might not lead to warfare. Because the media is increasingly structured around presenting brief sound-bites or catchy headlines (Davis, 2003), they frequently reduce complex issues into memorable catchphrases and simplistic storylines, at the expense of nuanced explanation, and often at the expense of accuracy. Bird and Dardenne contend that "news stories, like myths, do not 'tell it like it is', but rather, 'tell it like it means'" (1988:337), or what the media feels should be the story, rather than what the facts actually depict. Aubin (1998), in a book titled *Distorting Defense*, noted how pressures to provide pithy coverage of complex security issues have resulted in inaccurate media coverage, and how, once established, this misinformation has managed to persist in subsequent coverage.

3.2.3.5. Practice of giving equal coverage to opposing views

The quest for "balanced coverage" itself, however, may be a contributor to the amount of media exposure granted to the risk of water wars. When confronted with differing expert opinions regarding highly specialized or technical issues, the press often attempts to provide equal coverage, regardless of the side with which

[49] The article included a quote from a high-ranking official in the Israeli Foreign Ministry stating that "(t)he idea of water wars is sexy and appealing but it's media hype… The reality of the situation is: If you have scarce resources it won't do any good to fight over them; you will only redivide the scarcity," and one from the Palestinian director of a regional environmental NGO who stated "I totally disagree with any suggestion of war over water. It doesn't make sense because war cannot solve the water problem. Peace will."

the weight of expert opinion lies (Dearing, 1995). Dunwoody and Peters (1992) refer to such a strategy of balance as "a surrogate for validity checks" (p.210). While journalistic ideals are to present facts and truths, the press is often not competent to evaluate the merits of opposing expert opinion. In lieu, of presenting the truth, they often present opposing sides of an issue equally, with the premise that they are providing the audience with information to decide for themselves. While this provision of equal coverage is ostensibly done in the spirit of fairness and balance, it can result in disproportionate coverage of a minority viewpoint. Press coverage of climate change is a well documented example, in which, the overwhelmingly minority viewpoint among climate scientists that climate change is not occurring has been given prominent media coverage (Boykoff and Boykoff, 2004). Although no content analysis of media coverage of conflict over war was undertaken for this study, given the lack of consensus on the water wars issue, journalistic protocol is likely to produce a similar outcome in which the prospect of water wars is given at least as much attention (and almost certainly more) as the viewpoint that such wars are unlikely.

3.2.3.6. Practice of focusing on aspect of most interest to target audience

While the conventional wisdom that "bad news sells" seems to be well established, researchers have found that not all bad news is the same in terms of newsworthiness. Singer and Endreny (1987) found a "lack of congruence between the size of the risk and the amount of media coverage it receives." Combs and Slovic (1979:841) found, for instance, that relative to actual objective risks, "disease appeared to be greatly underreported while violent, often catastrophic events… stood out as being overreported". Water related illnesses kill between 5 and 10 million people a year (UNDP, 2006; Wolf, 2007). This is several times the combined number of casualties from all the wars in the world each year. These deaths, however, are less newsworthy than the prospect of war, precisely because they are not new. They are long-standing, chronic problems. Moreover, they generally afflict the poorer classes in developing countries, but not the target audience of the media. Wars may be more likely to have some kind of spillover effect that could impact or interest the typical reader of the media, especially the Western media.

3.2.2.6. Raise profile of water related development or environmental needs

Like the other groups looked at in this study, journalists too may make reference to water wars in order to draw attention to development or environmental issues related to water that, on their own, would likely not be deemed newsworthy. Thus, for instance, the risk of water wars in often mentioned in articles in which it is not the primary topic, but rather, merely presented as a type of exclamation point or worse case scenario. The Boston Globe published an editorial provocatively titled, "The next world war will be over water", the text of which concentrated almost solely on presenting statistics on water scarcity and the health impacts of such scarcity (Rothfeder, 2002).

3.2.4. Non-governmental organizations

3.2.3.1. Assessment that water wars are actually imminent or likely

The number of nongovernmental organizations has increased exponentially over the past few decades and such organizations play an increasingly important role in shaping global environmental and development policy agendas in general (Princen and Finger, 1994; Wapner, 1996). Over the last few years, a number of NGOs have adopted environmental security issues as a field of concern.[50] Many have raised the issue of water wars in the course of their activities. Several NGOs have played a leading role in framing perceptions of policymakers and influencing parties regarding transboundary water management (Dinar, 2002). Some of their incentives to do so largely overlap with those of groups already discussed. Among these is the genuine belief that violent conflict over water is imminent.

[50] Examples include the Woodrow Wilson International Center for Scholars' Environmental Change and Security Program, based in Washington D.C., the Institute for Environmental Security, based in the Hague, and Adelphi Research, based in Germany.

3.2.4.2. Raise profile of water related development or environmental needs

Of all groups listed, NGOs face perhaps the strongest incentive to use the specter of water wars in order to raise the profile of water related development or environmental goals they happen to be championing. By tying their main issue – be it equitable water sharing, development of basic water infrastructure, pollution prevention, etc. – to conflict over water, they offer those that sympathize with their mission an additional reason to offer support and/or take action. The British based World Development Movement, for instance, lists as its primary objective the elimination of the underlying causes of poverty. On its website it lists water among its numerous and wide-ranging current and past campaigns topics, which also include: international trade, climate change, tobacco, asbestos, genetically modified organisms, transnational corporations, international debt relief, and toys. It provocatively named its water campaign "Stop Water Wars", though the primary goals of the campaign are advocacy in support of provision of basic water and sanitation services to the poor and opposition to privatization of the water industry. Similarly, a warning on the risks of war over water figures prominently on the top of the homepage of the website www.worldwaterwars.com, although relatively little on the website relates to the potential for water-related violence. Rather, it primarily lists environmental and development issues related to water quality and water privatization.

3.2.4.2. Gain media coverage for organization

Because a major objective of many NGOs is public education and raising awareness about their pet issue, they are often eager to access media outlets to spread their message. Anderson (2003) notes that the media constitute a primary public arena in which their claims "compete for access and public legitimacy". Press coverage not only helps NGOs highlight their cause, but also offers indirect financial incentives. Media exposure can increase visibility of the organization as well as its causes, thereby increasing the pool of potential members and donors. In addition, many NGOs use press coverage as evidence of their effectiveness in reporting to current and future sources of funding. Press coverage can also serve as a channel through which advocacy oriented NGOs can communicate to and exert influence on policymakers. As one analyst commented, the media provides a range of major services to third parties in need of external support (Cottle, 2003). Given the lack of media attention to chronic issues such as sanitation and pollution, NGOs have an incentive either to link such subjects to that of water wars or to simply add environmental security to their agenda in order to increase the potential for media coverage.

Many observers have noted that NGOs and other "non-elites" can face serious challenges in attracting media attention (Cottle, 2003). In order to gain access, some organizations, notably among them environmental NGOs, have resorted to "exceptionally strange or violent acts as a substitute for their lack of status or resources" in order to attract the media's eye (p. 37). However, as some have noted, "The benefit of outlandish behavior is media attention, the price is that you get stuck in this role or caricaturization" (Anderson, 2003). In order for their message to be taken more seriously, many environmental organizations have moved away from such tactics (Cottle 2003: 37). In order to attract media attention while toning down behavior, one option is for NGOs to increase the severity or immediacy of their message. Certainly linking an environmental or development related issue to the prospect of water war is one method of doing so, even if only presenting these wars as worst case scenarios to be avoided. Because similar warnings are being made by political figures and academics, whose standing with the media is better established, such claims may be perceived by the press as having additional credibility, which should improve the likelihood of media coverage.

3.2.4.2. Expand pools of available funding

Many, if not most, NGOs are in a constant search for funding. As in the case of academic scholars, combining issues can open up new pools of funding. Environmental and security or peace-related NGOs thus face an economic incentive to expand their focus to include some aspect of environmental security, and water wars can be a part of this. Several NGOs have combined some aspect of conflict resolution and environmental protection. Conca et al (2005) and others have noted the increased role of NGOs in environmental peacemaking. This is not to question the intent of such organizations or the sincerity of their missions; merely to point out the potential financial benefit in addressing such issues. Again, even if they are not explicitly promoting or supporting the water war hypothesis, in addressing the issue, they help to keep it in the public consciousness.

3.2.5. Private Sector

Conflict can affect possibilities for and terms of investment, and as such, the private sector tends to be a keen analyst of information regarding political and military risks. The private sector, like the other actors considered, may issue warnings about the risks of violent conflict over water because it considers such risks credible. As Trottier (2003) notes, however, certain private industry actors have an incentive to promote the risks of war in order to encourage policy-makers to invest in water infrastructure that would reduce scarcity Examples include desalination, inter-basin pipelines, and international water shipping.

A representative of a desalination facility under construction in Israel commented, for instance, that "unfortunately water is one of the reasons that create war. If you compare the cost of one F-16, it is more or less the cost of this desalination plant. I believe at the end of the day it will be much cheaper to solve conflict based on this type of plant than through buying new F-16s" (Leyne, 2004). A developer of large bags that can be filled with water and towed to facilitate international shipping of water is even more direct. The company's website quotes World Bank Vice President Ismail Serageldin's statement that the next century's wars will be over water, and then claims that "Waterbag technology will have a direct impact on the Peace Process in the Middle East."[51]

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[51] The website of the company "Waterbag", http://www.waterbag.com/, was accessed on 14 June, 2008.

Water industry leaders promoting such technological and supply-side fixes have an incentive to stress that their projects may reduce the risks of war over scarce water resources. This potential benefit of decreasing scarcity through additional infrastructure may be important in gaining an advantage over demand reduction policies, which are often economically more efficient options. Political figures may also have an incentive to promote such policy options, insofar as they are influenced by industry representatives.[52]

4. Conclusions

The prospect of water wars has been the subject of much political, academic, and media attention. It is not the aim of this article to claim, as others have, that the prospect of war is not at all realistic (e.g., Beaumont, 1994). Water has been and continues to be a source of political conflict, at times even violent conflict. Past instances of such violent conflict are rare, but as populations grow, economies develop, and climatic conditions change, past trends may not be indicative of future scenarios. Given both the relatively thin empirical evidence and the numerous theoretical critiques of the water war hypothesis, however, the prospect of wars over water resources is markedly over-represented in political, academic, and journalistic forums. As this study suggests, various actors face incentives to stress or even exaggerate the possibility of such conflict. This can explain the significant exposure and tractability that such warnings have received to date.

Some of the incentives discussed above are relevant to multiple actors, such as the use of the threat of war to highlight other water-related issues. This overlap in interests can serve to strengthen the incentive if parties understand that other

[52] Allan (2002a), a long-time analyst of Middle-east politics and water management, seems to support a connection between political risks and the adoption of water technology. He claims that Israeli policy-makers intentionally delayed initiating desalination technology so as not to reduce Israel's claims to water in negotiations with the Palestinians. Israel did begin development of large scale desalination plants in 2001-2002 following the deterioration of relations and cessation of negotiations with Palestinians.

actors will be receptive to such actions. Also, actions by different actors are mutually reinforcing. Policy-makers are not only covered by the media, but also react to it. NGOs may seek access to policy-makers via the media, or seek to use the media to mobilize action to pressure policy-makers, and, in turn the media may seek out NGOs for sources of information. Academics too may covet media coverage in order to publicize their findings, and may be sought out by the media as credible sources of information. Similarly, policy-makers often rely on academics for credible information on which to base policies, and academics often treat the behavior and statements of policy-makers as subjects of their studies. Furthermore, political motives are not limited to policy-makers, but may be shared by other actors who seek to influence public policy. This mutually reinforcing web of interactions, together with common incentives to stress the risks of water wars, may well be serving to maintain the issue of water wars in public discourse.

Overstating the prospects of conflict over water resources entails risks of its own. Raising the specter of war to raise attention to or mobilize action on related issues, for instance, may ultimately have the opposite effect of reducing attention to environmental or development causes. Attention and resources may get redirected towards preventing conflict rather than towards preventing pollution or providing sanitation. Policymakers and other decision-makers may feel that as long as violent conflict is avoided, they have been successful. Similarly, by focusing on water as a cause of conflict, attention may be drawn away from more important or proximate causes. These caveats noted, numerous examples suggest that the incentive to use the possibility of resource wars to highlight other issues is still very strong and influential.

This study presented incentives for stressing the risks of water wars, without addressing possible incentives actors may face to underestimate or deemphasize such risks, such as a desire not to undermine investment opportunities or ongoing negotiations. The study was also meant to be suggestive, rather than conclusive.

It did not attempt to estimate or quantify the actual influence of the various incentives laid out above in motivating the behavior of the set of actors described. Rather, it simply provided examples in which it seems reasonable that the incentives were relevant. Nor did it suggest methods for identifying when such incentives are in fact responsible for actions by a given party. Furthermore, because this analysis generates plausible hypotheses based on real world decision-making but supported by anecdotal evidence, it is subject to much of the same critiques leveled against much of the environmental security literature, including the water war hypothesis, as noted above. Such limitations noted, this study does provide analysts with a conceptual framework with which to start evaluating various claims regarding the prospects of violent conflict over water and other natural resources.

Systematic verification of the relative importance (or lack thereof) of the various incentives laid out in this study is left to future research. In many cases necessary information may be impossible to obtain. For instance, it may not be possible to identify with certainty the true motivations of a politician issuing warnings or of academics in choosing research programs, let alone the relative weight of multiple motivating factors. Nevertheless, possible avenues for such research include: a) content analyses of media coverage of international water scarcity, especially of treatment of the possibility of water related conflict; b) systematic review of the context in which references to water wars were made by political figures in order to draw issue linkage maps; c) documentation of changes in the level of funding supporting environmental security related issues, and analysis of changes in the number of grant proposals sponsored by major grant issuing institutions supporting research into water and conflict; and d) a systematic analysis of private sector declarations on the issue of water wars to identify whether the private sector tends to promote or dispel a water war hypothesis.

While the specific topic of this study was conflict over water, much of the analysis is relevant to discussions of conflict over other natural resources and to broader discussions of environmental security in general. Analysts in this field have long acknowledged "that one cannot dismiss the political motives of those who wished to elevate – or prevent the elevation – of environmental concerns to the same status as military ones" (Diehl and Gleditsch, 2001: 3). The intent of this study was to provide a clearer picture of these motives, with the hope that a better understanding of the various incentives to stress the risks of violent conflict over scarce resources will assist analysts in evaluating the credibility of the many diverse pronouncements on this subject.

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