AN APPROACH TO INTERNATIONAL WATER TRANSFERS IN THE WESTERN MIDDLE EAST

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Table of Contents

1. Introduction

When water becomes scarce, conflicts over access emerge and a water allocation process which addresses scarcity must evolve. Water is scarce when there is no longer enough available to allow all users to have as much as they want without giving up something else of value in order to obtain it. In the absence of water scarcity, there would be no reason to consider its allocation. Water is economically scarce in the Western Middle East where undeveloped water sources and unappropriated water is no longer available.

There are several approaches to the problem of scarcity at both a micro level and a macro level. One can concentrate on the demand for water by examining its pricing, various uses, distribution, and the regulatory and conservation policies that apply to water. One can concentrate on the supply of water by examining quality requirements for its various uses and the possibilities for increasing its quantity through water recycling, uses for brackish water, desalinization, and finally water imports. Every area of the Middle East has potential for improving water policies and technology so as to improve the efficient use of water and help relieve the problem of scarcity without introducing new supplies. At some point in the future, however, new water resources will be required for supply to meet demand. Water imports is only one way to increase supply.

The water problem faced in the Middle East is created by three interacting factors. The first is simple demand and supply. Demand has outstripped supply in parts of the Western Middle East (Lebanon, Syria, Jordan, Israel, the West Bank, and Gaza Strip) since the late 1960's. The deficit is sure to grow as populations increase and economies grow. The second factor is water quality which is under stress from overdraft of ground resources and pollution of surface resources. The third factor is the omnipresent geopolitical situation which is filled with distrust and animosity, so much that nations view their regional water crisis as competing players in a zero-sum game. Without this third factor, the entire situation might be dealt with as a simple issue of demand and supply. Even if that were so, water is a complicated resource difficult to control over space and time and is not normally managed as a commodity.

Actual water imports and water trade would necessarily involve a myriad of issues such as property rights or ownership rights, pricing of water, the costs of infrastructure to transport water, quantities of water traded, quality of the water traded, legal issues to be resolved, equity or justice issues, political issues, and so on. The data available on water qualities, supplies, uses, and the rest is very limited, and when it is available it often seems more like propaganda than fact. It is often old or has large gaps making it incomplete. In addition, the data varies considerably depending on the author or the author's sources. The complexity of the water issues and the lack of reliable data makes every analysis of the problem incomplete and often problematic. This study is not an examination of the data.

This study begins by presenting some of these issues in order to show how the prospects for water transfers in the Western Middle East are limited. It is an economic analysis which looks at the broad theoretical and practical difficulties with water markets and general water trade. It establishes a basic microeconomic framework for water markets or water trade. Much of this framework is borrowed from studies on intranational, intrabasin water transfers and is adapted to an international, interbasin setting. The desirable characteristics of water allocation are also defined. The economic criteria is inclusive. It includes everything of value considered in water transfers. It is not simply utility pricing. Using this criteria, one can determine the appropriate setting in which to examine potentials for water trade. It is argued that the appropriate setting is a game theoretic setting and not a market setting.

Section 3 is a short review of economic approaches to water imports in the Western Middle East. Two types of studies have developed. The first are social planning studies, which use market mechanisms, or an open market for water. The second is cooperative game theory. In Section 4, an exercise in the cooperative game approach is demonstrated and finally a noncooperative approach is introduced.

This study is only intended to be indicative of a single set of problems within the question of water imports which itself is only a single approach to the larger dilemma of water scarcity. It indicates real difficulties in operationalizing a market for water between nations. It shows that each transfer of water or project for water transfer must be negotiated by parties to an agreement. The factors which determine the quantities, qualities, and timing of water transfers will be broad in scope and multifaceted, not simply financial transfers. The seller of water is essentially a monopolist of the economic surplus gained from water trade. The seller is indispensable to water transfer and therefore is likely to determine the outcomes of a cooperative project to transfer water. Lastly, the issue of commitment to sell water is explored by introducing a noncooperative game. Given the ease at which sovereign nations can break a contract, risk averse nations may never enter into a cooperative project to sell water.

2. Framework for Analysis

Nature never gives anything to anyone; everything is sold. It is only in the abstraction of ideals that choice comes without consequences. -- Ralph Waldo Emerson

2.1 Initial Water Rights

The initial distribution of property rights to transboundary water resources is currently under dispute. This is the subject of much debate between the riparian states to the Jordan River and between Israel and the Palestinian Authority over the rights to the shared groundwater aquifers. It is a centerpiece of the current political negotiations between these parties. Property rights to water resources are also issues for dispute between Egypt, the Sudan and Ethiopia, between Syria, Iraq and Turkey, between Jordan and Saudi Arabia, and elsewhere. There are a variety of ideas and perspectives on resolving the initial property rights disputes.[1]

A water right in the international arena is defined by international law or treaty. There are two major types of water rights. One is the prioritized rights, or appropriative doctrine of water rights, and the other is the proportional, equal sharing or riparian doctrine. Both types of regimes exist in the Western Middle East but generally speaking it is the riparian doctrine which applies to surface water resources such as the Jordan river, and it is the appropriative doctrine which applies to ground water resources.[2]

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[1] To name only a few, see Berck and Lipow (1994), several articles from Isaac and Shuval (1994), or Moore (1994a). For general interpretation of international law see Hayton and Utton (1989) or Henkin, Pugh, Schacter and Smit (1987).

[2] Berck and Lipow, 1994, p. 289.

In order to discuss water transfers, it is first necessary to have initial rights that meet certain criteria which make them well defined. Saliba (1987) developed criteria for local rights in the US which can also be applied to national rights. These rights must be completely specified and enforceable by treaty so that all agents know the privileges and restrictions associated with holding a water right. This is essential to successful bargaining for and trade of water rights. Second, they must be exclusive so that the benefits and costs associated with water use and transfer accrue to the decision makers (buyers, sellers, rights holders), not to third parties. For example, Egypt cannot sell water from the Nile river if that transfer will infringe upon the water rights of the up-stream riparian countries of the Sudan and Ethiopia. These water rights must be comprehensive so that all attributes and uses of water that generate value can be represented by water rights, including water quality, in stream flows and so on. This is particularly important and difficult to discern when examining the shared groundwater aquifers of Israel and the Palestinian Authority. Lastly, they must be transferable so that water rights holders may transfer rights in response to an attractive offer.[3]

2.2 Conditions for Water Transfer

Certain economic criteria must be satisfied for a transaction of water rights to occur.[4] The economic analysis shows how gains from trade are made and by doing so allows the analyst to view the problem in a more objective setting.

First, the buyer of water must understand or perceive the economic returns on the water bought to be large enough to outweigh the costs of obtaining water through the

[3] Saliba, 1987, p. 23.

[4] Gruen (1994), p. 276.

transfer process. Costs include the price paid to the seller, water storage, treatment costs, conveyance costs, and legal and political costs. Second, the transaction must be attractive relative to all other processes by which buyers could achieve their water supply objectives.[5] The costs of the process, including political costs and legal uncertainties associated with the transfers, must be less than the costs of alternative means of obtaining water. Different methods of increasing a nation's water supply may have different types of cost considerations. Desalinization implies different costs and risks compared to long distance water transfers by sea, using tankers or Medusa bags, or by ground using pipelines or canals.[6] Sovereign nations prefer autonomy in their water supplies as opposed to dependence on other sovereign nations. The buyers must weigh these varying costs and risks based on their own preferences. These first two criteria determine whether or not a proposed transfer is economically and politically viable for the buyer.

Third, the seller must receive a price offer that equals or exceeds any cost the seller has incurred in transferring water including the opportunity costs to its own domestic economy, costs of the market process, costs of conveyance, and legal and political costs. It must be economically and politically viable for the seller. Only under these conditions will water transfers develop.

Most discussions of water exchange make a point to claim that a reallocation can offer welfare or efficiency improvements. A reallocation of water which can improve one individual's welfare without decreasing another individual's welfare is said to be a Pareto

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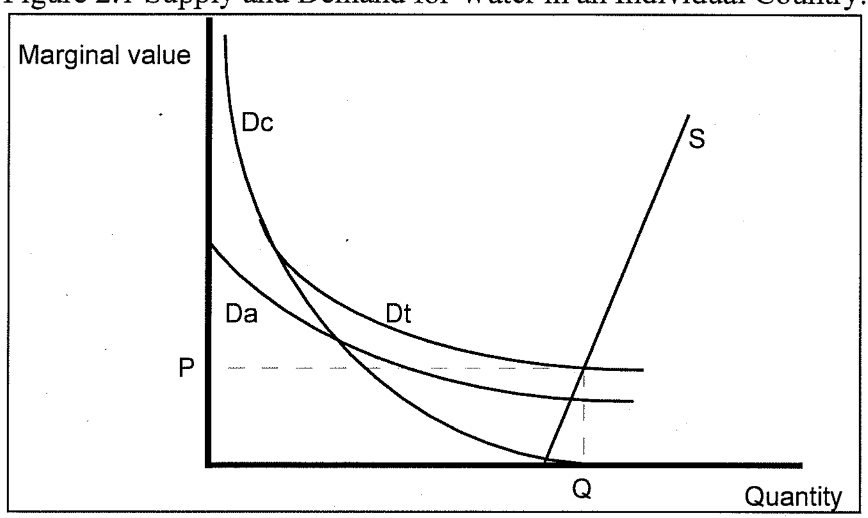
[5] Howe and Easter (1971), p. 21.

[6] A Medusa bag, created using Canadian technology, is made of thick nylon coated with vinyl and reinforced with nylon straps. Each bag is capable of holding 1.5 million cubic metres of water. It holds water transferred by pipe at one source, say Turkey, and while sitting in sea water it is pulled by boats to its destination, say Gaza City, where it is pumped into the water system at will. Costs for the complete system would depend on annual capacity of the system.

improvement. Water transfers can improve efficiency under the Kaldor-Hicks compensation criteria which states that a reallocation is efficient if it represents a potential Pareto improvement. Under the assumption of transferable utility, those who gain water from reallocation would be able to compensate (monetarily or otherwise) those who relinquish water making both parties better off. This definition of efficiency requires that the benefits from any resource transfer must exceed all costs. This is the standard approach for analyzing water project proposals and water policy alternatives. It is the definition of efficiency that will be used here to discuss efficiency gains from water transfer.

Figure 2.1 Supply and Demand for Water in an Individual Country.



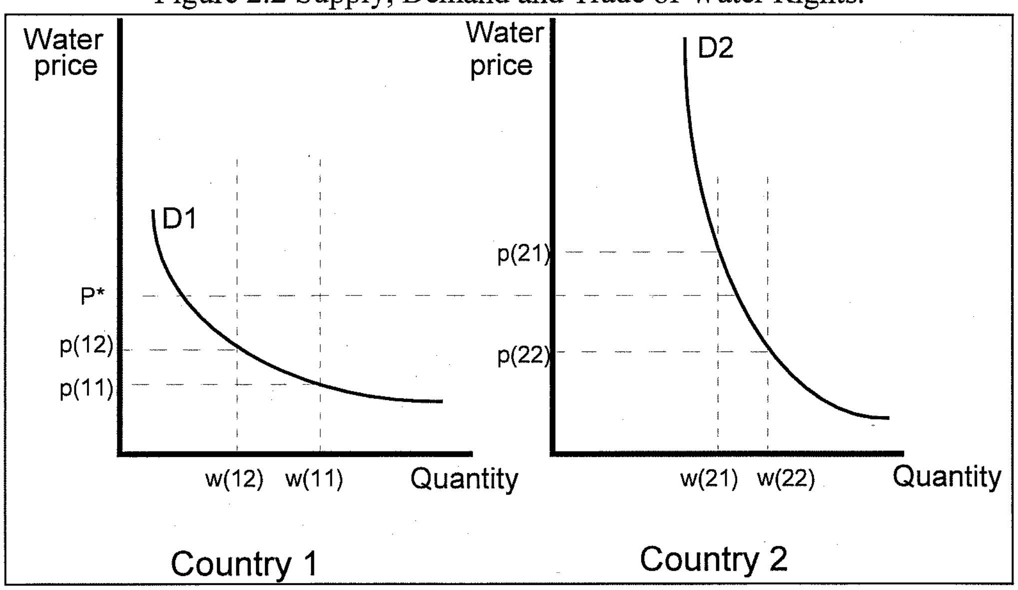
To illustrate conditions under which trade would take place, one could imagine a hypothetical demand function for water in each individual country. As is done in Figure 2.1, total demand (Dt) could be separated into agricultural demand (Da) and urban demand (Dc) which in turn is made up of industrial and household demand.[7] With complete demand information a formal demand curve may be represented for a particular

[7] Similar representations are presented in Saliba, 1987, p. 190.

use of water in a particular area. If enough price and quantity data are available, consumer or producer water demand curves can be estimated for each individual entity and even geographical areas within countries. In turn, estimates can be made of marginal values of water at different quantities demanded.

When marginal values are not equal among users or between areas, a transfer in water rights is possible and the exchange will bring marginal values toward a market equilibrium. The potential for exchange is demonstrated in Figure 2.2.[8] As population and income levels differ or agricultural productivity differs because of differences in technologies or other factors, transfers of water rights and new shadow prices for water may evolve. New technological adaptions in one area, or higher population growths in one area, could lead to a transfer of water rights to that area.

Figure 2.2 Supply, Demand and Trade of Water Rights.



[8] Dinar and Wolf (1994b), p. 45.

In Figure 2.2, two countries have different demand curves and water supplies resulting in different demand elasticity values. Prices p(11) and p(21) are the prices that equate local demand and supply of water, not actual prices. It may be possible for a transfer of water to occur from country 1 to country 2. Country 1 would be compensated for its water loss. P* could be the equilibrium price paid in the transaction. P* could fall anywhere between p(12) and p(21) depending on the bargaining power or savvy of the participants for country 1 and country 2. Once the transaction has occurred between the two countries, water supplies have changed and local shadow prices for water converge at prices p(12) and p(22). It is under these conditions, where there is discrepancy in the real values of water between two entities, that an international transfer of water may occur and improve regional welfare.

By incorporating economic value into an analysis of the problem, potential benefits gained from trade become apparent. This analysis requires a method for the valuation of water. In the Western Middle East, prices for water are decided not in a market but by government administration.[9] The quantities of water traded *within* countries are negligible compared to the total amount of water used. In the presence of growing conflict over water use, there is a pressing need to understand the underlying economics of water demand and value in various economic sectors. An examination of the marginal benefits in competing uses of water could help identify large disparities, and aid pressure for change, in water allocations both within countries and between them. By developing an analysis of efficiency prices for water, or "scarcity rents", disputes over water use rights and even property rights can be reduced to manageable and reasonable economic problems.[10] They may still carry difficult, even intractable, political problems.

[9] Fishelson, 1994, p. 322.

[10] Fisher, 1995, p. 378.

In addition, marginal benefits of water use should be compared to marginal costs of new water supply projects in the interest of promoting economic efficiency and fiscal responsibility.[11] This is important throughout the region which is full of proposals for desalinization plants, dams, international conveyance systems, water recycling plants, etc. Proper valuation of water does not necessarily mean that water should or could be traded using pure market mechanisms. It is very unlikely that water transfers will lead to parity in water prices across nations. The economic values for water across regions simply points to potentials for efficiency gains from trade.

2.3 What Are the Desirable Characteristics for Interregional Allocation?

The framework through which to consider water allocation, its prices and quantities is open to debate. There are six economically desirable characteristics for a water allocation process that Howe et al (1986) developed for market allocation in the Western United States.[12] They apply here as well but with greater difficulty given existing allocation regimes and the complexities of international transfers. The characteristics, nonetheless, remain desirable.

First, there should be ***flexibility*** so as to allow water to be transferred over space, time, and use in response to changing social and economic conditions. This is probably the most important and demanding characteristic of an economically beneficial regional allocation. There is inflexibility in international allocation of water for obvious reasons.[13]

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[11] Gibbons, 1986, pp. 2-3.

[12] Howe, et al, 1986.

[13] There is also inflexibility within countries. Water rights are not generally transferable within the countries being considered. Domestic policy reforms will need to take place on many levels and in all sectors of the participant countries for fair and efficient water use and for water trade. This is an essential consideration for any

Flexibility can be increased, but it will in all likelihood remain limited due to the restrictions of the social and political environment. Greater short term flexibility allows for beneficial transfers in times of drought while long term flexibility allows for changes in allocation for shifting population sizes and changes in economic structures. In both the short term and long term, ex ante and ex post valuations of traded water may differ and greater flexibility would lessen the degree of discrepancy.

Second, there should be ***certainty*** in water availability for rights holders, giving water users a basis for making long-term investment and planning decisions. This is an important condition for the development of the infrastructure necessary for the international transfers of water being discussed. Planners must be certain of the economic gains from the development of pipelines, canals and pumping systems. Certainty in water availability is necessary for agricultural development and investment, food security, and the price stability of water and water related products.

Third, the ***opportunity costs*** associated with water use and transfer must be accounted for by water rights holders so that their decisions are based on a complete assessment of costs and benefits. It does not seem likely that a country that chooses not to sell its water will be concerned with the opportunity costs of holding that water. Sellers of water get little monetary profit from selling their water. The opportunity costs are largely going to be political costs, or gains, that have no monetary price.

Fourth, ***predictability*** of the allocation process helps water users know what to expect and to adjust gradually to changes. Prevailing requirements or rules of the game must be clear and not subject to unanticipated changes. If transboundary allocations are

comprehensive solution to the Middle East's water crisis. Policy reform in the participating entities is a very large problem too complex and vast to be dealt with here. See Naff (1994) for a demand approach to the water shortage problem in the Middle East.

going to be efficient then the quantity and quality of the supply must be predictable and secure. This characteristic may exist in many water allocation regimes but it is currently absent in the Western Middle East where there are few international agreements on how to use transboundary water resources. Water allocations within the entities considered are currently predictable in their use of domestic supplies.

Lastly, the allocation should be perceived as ***fair*** by the public and water transfers should be ***noncompulsory***. Fairness requires that uncompensated costs must not be imposed on third parties and the public. Those affected negatively by the introduction of the new allocation system should be compensated for their loss. Currently, agriculture throughout the region enjoys heavily subsidized water use. The agricultural sectors in all of these countries hold political sway and unless they support the introduction of a new allocation system, it is unlikely that the system will succeed.

Howe, et al (1986) argues that market processes meet the above six criteria better than alternative processes such as arbitration or legal processes, but this conclusion is drawn from the context of trade within the Western United States.[14] The political and institutional context of the Western Middle East is dramatically different from that of the Western United States. International water transfers in the Western Middle East involve different priorities and problems, essentially because of differences in the political settings. Processes which develop from multilateral negotiations, ad hoc legal processes, may be more successful in achieving these characteristics than the market process. Indeed, attempts at the market process may fail to achieve any of these six desirable characteristics.

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[14] Howe, et al, 1986, p. 440.

2.4 Problematic Characteristics of the Market Model for Water

There are a number of reasons why a pure market model for trading water in the Western Middle East is inappropriate. Limitations for the market model can be both theoretical and practical. Water market theory provides many ideas for improving benefits from water use and allocation that will constructively address the problem at hand but there are also a wide variety of failures inherent in a water market process which are complicated further by international water transfer. In general, water is not distributed solely by supply and demand but has been viewed as a resource to be managed by government.

These problems can be separated into two categories. The first set of problems considered here relate to failures in setting prices and quantities traded by market forces. The second set of problems are related to the special physical characteristics of water.

2.4.1 Barriers to setting prices.

A market is made up of interactions between actual and potential buyers and sellers of one or more units of water. Participants negotiate transactions and by doing so generate prices and conditions for the sale and use of water units. The term market generally refers to a set of transactions occurring continuously over a period of time. When relatively few transactions take place the market is considered "thin", and the key market function of establishing a representative price for water may fail. In the optimal market model for water in the Western Middle East, the number of players would be limited unless the market functions without borders. Seven is the highest number of country participants considered in the literature reviewed by this author but this could be enlarged if particular regions within countries are considered separate entities based on their hydro geographical distinctions. In international water trade, countries will act as individual agents seeking to maximize their own collective benefits and so the number of transactions would be limited. This market will be too thin for prices and quantities to be set by market forces.

For a market to function efficiently, all economic agents must behave as price takers. This means that no entity should be able to strategically affect market prices if the market is to obtain an efficient allocation. Simultaneous exchange among many buyers and sellers is what determines the market price for tradable water rights.[15] A market is imperfectly competitive if the actions of certain buyers or sellers can influence the market prices. This is certainly the case in a market model for international transfers of water in the Western Middle East. Relative influence of buyers and sellers differ considerably. Sellers, such as Egypt and Turkey, could easily function as price setters. Buyers, such as Israel and Jordan, would carry different influence in a pure market depending on the wealth of a nation and their abilities to subsidize water use.

In a water market, participants enter and operate voluntarily if they believe it is in their own best interest given all the alternative opportunities available to them. Participants in the market are not obligated to sell their water. Price and other terms of transfer are negotiable. Water need not be sold at cost or without profit and any participant can refuse to sell water rights to any other participant. Indeed, they will not do so until they are offered a price they find attractive based on whatever criteria they chose. This fact about water markets renders simulations of trade based on pure market mechanisms dubious and academic.

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[15] Saliba (1987), p. 2.

Every player in this hypothetical market for water will have criteria for setting prices that conflict with optimal market settings. Political considerations will influence the price set by a seller of water so that it may not reflect what would normally be considered a market price or shadow value. As was discussed above, it does not seem likely that the opportunity costs associated with holding water will be calculated based on a narrow assessment of economic costs and benefits. For example, Egypt may ask a different price for its water if it is being sold to the Gaza Strip, which is historically, politically, and culturally tied to Egypt, than if it is being sold to Jordan or Israel. A pure market mechanism that does not account for these preferences will most likely fail to capture the potential values involved in a transaction. Again, the opportunity costs are largely going to be political costs.

A market allocation may create conflict or tension in the region in two ways: by conflicting with domestic political powers or by causing envy between nations. In a domestic setting, water has a social value beyond the value to the private user. Water is necessary for human life and therefore is a special resource. Every person is entitled to receive some minimal level of water regardless of their ability to pay for it. A market allocation could force drastic changes in agricultural sectors. In order for agricultural sectors to thrive, they must be secure in their property rights and confident in their long term supply of inputs. For these and security reasons, national policies around the Middle East are geared toward some degree of food self sufficiency or water self sufficiency.[16] Food self sufficiency is a totally unrealistic goal for most nations in the region but a market allocation of water may conflict with mild attempts at food self sufficiency and create harmful shocks to all agricultural sectors. National agriculture policies may often be economically questionable but are nonetheless legitimate and must

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[16] Allen, J. A., 1994, in Shuval and Isaac. Allan discusses the ambitious goals of food self sufficiency and their high costs in terms of water in most Middle Eastern countries.

be considered when pricing water. This may be an argument for the gradual or limited introduction of a market system *within* domestic economies so that policy reforms can occur smoothly and not create unnecessary turmoil. The fact remains that current policies for food self-sufficiency go against the economic realities of water in the region, but that does not mean that a market mechanism will successfully reallocate water internationally.

Interregional allocations of water by a market mechanism may create conflicts between competing entities by creating envy. If discrepancies in agricultural technologies between regions is wide enough then, theoretically, one region's agricultural sector may be able to buy out all water rights from another region's agricultural sector. Discrepancies in incomes between two regions, as they exist between the Gaza Strip and Israel, may create conflict for domestic use. The price mechanism under a purely market system may allocate water in a very inequitable manner.

If water allocation considers past conflicts or policy failures then allocations may be skewed to help resolve these disputes, not create more tension. Conflict resolution may require a water allocation that is not reflected in market prices for water. Although this may be desirable and necessary to establish a regional system for allocating water, it would be a deviation from the pure market model. Nevertheless, inefficiency in water allocation is a low cost alternative to conflicts over water rights. These costs and benefits can be viewed as additional factors in determining the real costs and benefits involved in water allocation.

2.4.2 Water as a fugitive public good.

The second set of problems relates to the special characteristics of water as a good. Markets may not function as an efficient allocation because of the fugitive and public nature of water as a good. Water is described by Saliba and Bush (1987) and

Gibbons (1986) as "fugitive" because it is difficult to control and distribute, a fluid constantly moving, often across boarders or other property lines, never fully contained. It is variable in supply, a common-pool resource, and a public good.

Market prices for water may not account for externalities created purely by the fugitive nature of water and therefore may not reflect certain values. Consider an example of a positive externality created by this fugitive characteristic: total water withdrawn from a source may differ from water consumed in the case of agriculture where water pumped for irrigation may drain into an aquifer. This contrasts with household uses where water is transformed into sewage. Pollutants introduced into a natural water system will change the value of the water. This is a difficult issue to resolve in a domestic setting which could be complicated in an international setting. Market prices will not reflect positive or negative externalities unless policies require market participants to consider those qualitative and quantitative impacts. Impacts associated with market activity should be considered and market prices adjusted accordingly. However, these values would be very difficult to discern and implement in part due to the fugitive nature of water.

Another perspective on the same problem is that water resources often have characteristics of public goods which are non-excludable. This property of water resources poses problems for the market model. Prices are supposed to perform a rationing function but individuals in particular areas may not be excluded from enjoying the benefits of a resource even when they do not pay for it. An example of this may be the in-stream flow of water from irrigation into the Jordan river basin or seepage of water into the coastal aquifer from irrigation in and around the Gaza Strip. The free rider issue will not be entirely avoidable in the market allocation and any attempt to charge free riders for these benefits may only be arbitrary. The issue can still be addressed and it certainly raises questions about the pricing system under a market model.

Water is unpredictable and therefore water markets face problems of uncertainty and imperfect information. Agents participating in water transactions would like to have information on water supply quality, quantity and prices in addition to agricultural commodity prices and other outside market factors. An efficient market system which accurately reflects values as prices would require that buyers and sellers obtain accurate information on a variety of commodities, not just water.[17] Instead, information is incomplete, or can only be estimated, and even potential market participants with the best possible information still face a wide variety of hydrological, legal, economic, and political uncertainties. Variations in river flow or water table levels occur season-to-season and year-to-year making water rights vulnerable and uncertain. Economic uncertainties occur because of the constantly shifting demand for water. Political uncertainties, possibly the most volatile of uncertainties in this potential regional market, can put entire sources for water in question. None of these uncertainties are avoidable. Hydrological uncertainties remain important even when assumptions are made about the other uncertainties.

The above discussion makes clear how the precise economic valuation of water would be a complex undertaking in any part of the world. Overall, estimates presented here and in the sighted literature are very limited. The calculations are crude and inexact, given merely to be indicative or illustrative of the characteristics of water values in different areas. None of them are precise.

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[17] Saliba, 1987. p. 197

2.5 The Game Theory Approach

The problem of allocating water internationally in the Western Middle East is best suited for a game theoretic approach. A game theoretic approach allows for the introduction of both the economic and political considerations necessary for a realistic approach to international water transfers in the Western Middle East. Game theory allows for the limited number of players participating in the market. The players can develop strategies according to a wide variety of preferences. The game theoretic approach will not necessarily lead to a more efficient allocation but it will provide a more realistic model of how water transactions would take place.

The common and very important question then arises, is this problem best suited for a cooperative game theoretic approach or a noncooperative game theoretic approach? Arguments can be made for both approaches.

2.5.1 The Cooperative Game Approach

In a cooperative framework, players pursue regional goals maximizing regional benefits. All nations have the identical goal of achieving a stable and efficient allocation of water resources in the region. The agreement will be stable if it is enforceable, binding and rational. Each player may find it individually rational to participate in a coalition involving water transfers.[18] Those players that are buying water may find it an efficient method for increasing its water supply while sellers of water may be involved mostly for political prestige and power or by moral commitment to the stability and prosperity of their neighbors. Both sellers and buyers find that their self-interests are found only

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[18] For a definition of "coalition", "individually rational" and other related concepts, see Appendix.

through cooperation. Each player joins the cooperative project voluntarily and accepts the outcome for the group.

The participants must then decide how to distribute the costs and benefits of the cooperative project. The distribution must make each player better off than if they had not been a part of the grand coalition. This is the necessary condition of individual rationality. Smaller, sub-coalitions must also find themselves better off in the larger coalition than they would be as a defecting coalition. This is the necessary condition of group rationality. These two necessary conditions make up the concept of the *Core*. The *Core* is the set of possible distributions of the costs and benefits resulting from the grand coalition where no sub-coalition or individual player can improve their payoffs by leaving the grand coalition.[19] The *Core* is defined by representing the game in characteristic form which summarizes the payoffs to each coalition. All the costs and benefits must be allocated to the participants of the grand coalition in a feasible manner, that is, a solution within the *Core*.

2.5.2 The Noncooperative Game Approach

In a non-cooperative approach the players pursue strategies individually and are not interested in maximizing regional gains but their individual gains.[20] Feasible options outside of the coalition may exist that improve their welfare. Most importantly, the noncooperative approach allows for games where contracts are not binding. In the case of sovereign nations, contracts are easily broken, often with very little consequence. Therefore the contracts must be self-enforcing for the cooperative solution to be a real equilibrium solution.

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[19] Mas-Collel, et al, p. 677.

[20] Harsanyi (1977), p. 110.

Some games may not be suited for either a fully noncooperative approach or a fully cooperative approach. Intermediate games or "almost noncooperative games" involve players that can be trusted not to break an agreement so long as they have no incentive to break the coalition.[21] The difference between the fully noncooperative and the "almost noncooperative" is that only dominant strategies are stable in the former while weakly dominant strategies will be stable as well as dominant strategies in the latter. Almost noncooperative games are used where contracts are only weakly enforced with some small penalty for breaking the contract. Intermediate games are not considered in this paper because they apply to special conditions found in the payoffs.

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[21] Harsanyi (1977), p. 111.

3. Previous Studies of Water Transfers

This section is a brief literature review of approaches to water trade or imports in the Western Middle East. It is in no way exhaustive of the literature on the approaches to resolving the water crisis in the Western Middle East. This literature is about water uses and not property rights, a very important distinction. This literature takes a supply approach as opposed to a demand or conservation approach. It is about improving water supplies and the efficiency of their distributions. It only reviews water trade as a way of increasing water supplies to water deficit countries or territories. They all show that there are gains to be made by opening markets for water trade.

Zarour and Isaac (1994) suggest a fully open market for water as a commodity. They are particularly concerned with the Palestinian situation and suggest that the water surplus in the West Bank be diverted to the Gaza Strip, which has a high water deficit. Water trade is introduced as a solution to the more immediate problem of initial rights to water.[22] Solutions to the disputes over initial property rights is not considered here. Zarour and Isaac do not discuss the mechanisms for trading water but simply sight the potential benefits of international water trade. Kally (1989 and 1993) also discusses the benefits for water transfers without examining the mechanisms used.

Becker, Zeitouni, and Shechter (1996) and Zeitouni, Becker, and Shechter (1994) consider international trade of water through a pure market mechanism. The earlier paper includes trade between Egypt, Israel, and the Palestinian entity while the later paper introduces Jordan, Syria, and Turkey. They run simulation exercises with real data in a social planner model (for comparative purposes) and two models of auctions for water supplies. Estimated scarcity rents for water, costs of transporting water, non-agricultural

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[22] Zarour and Isaac (1994), p. 396.

demand and marginal value products for water in agriculture are the parameters that determine the interregional distributions of water.[23] Final prices at which water is traded are endogenously determined by the three models while supplies are exogenously determined.

In the two auctions, there is perfect flow of information and governments are able to commit themselves to the outcome of the auctions. The auctioned water is devisable among the bidders. The auctions are justified because the market for water trade is thin and the process allows for the differentiation between buyers by sellers. Sellers can extract a greater amount of the surplus than would result from a social planner allocation. In the percentage claims auction, buying countries bid for a percentage of an uncertain quantity of water from seller countries. In a priority claims auction, buying countries bid for a position in a queue. Once they reach their position in the queue, they are allowed to take as much of the water as they wish that is left by the bidders higher up in the queue.

They conclude that there are real and substantial gains to be made by opening water markets to international trade and that the gains in the efficient use of water will depend on the type of auction chosen.[24] The percentage claims auction results in greater regional benefits or more closely resembles the social planner distribution. The priority claims auction distributes more of the surplus to the sellers in the form of monetary payments and therefore would be the mechanism preferred by sellers. No considerations are made for institutional and political barriers to trade. Their simulations are only intended to be indicative of potentials for economic gains and the possible mechanisms

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[23] Becker, et al (1996), p. 24; Zeitouni, et al (1994), p. 311.

[24] Becker, et al (1996), p. 28; Zeitouni, et al (1994) p. 317.

for achieving these gains. They show that trade should be considered before more expensive desalinization plants are constructed.

Auction theory suggests that the seller, or monopolist of the surplus, has all the bargaining power.[25] The willingness or ability of the seller to commit to the auction, as is assumed in the auctions designed by Becker, Zeitouni, and Shechter (1996) and Zeitouni, Becker, and Shechter (1994), becomes an important issue when considering different outcomes of an auction. The sellers, organizers of the auction, may find that they could have done better ex post and be tempted to renege on their commitment to the auction. Sovereign nations certainly have the option to renege on their commitments and often do. Sellers could offer water just below its highest valuation and above the highest bid. This is a problem particular to the auction mechanisms for reallocating water in addition to the many other problems of international water markets. The bargaining power of the seller and the issue of commitment are returned to in Section 4.

Yaron (1994) prefers an "allocation-pricing-policy" system which would combine a quota system with a market mechanism. The suggestion is for a system that mixes an institutional-political allocation while only at the margin would water be traded by market mechanism.[26] Yaron sights numerous problems with interregional water allocation by a pure market mechanism, some of which are sighted in Section 2 of this paper. The mixed system of market and institutional-political allocation takes place in the general negotiation process between the players in the region. Through the negotiation process there is a "straight forward selection of the preferred" allocation

[25] McAfee and McMillan (1987), p. 703.

[26] Yaron (1994), p. 278.

which provides efficiency gains beyond the status quo of no water transfer.[27] Yaron does not model this bargaining process or go into a description of the process and all its issues.

Fisher (1995) discusses the Harvard Middle East Water Project, a project involving scholars from the Western Middle East and North America. The project seeks an economic evaluation of water. "[It] shows that water ownership is equivalent to a water right to the monetary value that water represents."[28] It seeks efficiency prices for water, defined by supply and demand, in districts of Israel, Jordan, and the Palestinian Territories. It is argued that by estimating the true economic value of water, disputes over water rights become less formidable.[29] Also, by obtaining representative values for water, the parties to negotiations can informatively evaluate possibilities for water trade. These values can be used not only to evaluate water trade and imports but also to evaluate alternative infrastructure projects, conservation policies and more.

The approach for valuing water considers many of the difficulties in water transfers discussed in the framework for analysis of this paper. Attempts are made to place both private and social values on water so as to take account for national goals. The model attempts to construct demand curves that incorporate national water polices. This is done by taking the sum of private demands in domestic, industrial and agricultural uses and then adding demand created by national water policies. It notes the problem of externalities with shared groundwater resources, mentions the desirability of a dynamic model (but presents the results of a static model), and makes note of studying decision making under variable hydrological conditions.[30]

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[27] Ibid., p. 283.

[28] Fisher (1995), p. 377.

[29] Ibid., p. 378.

Fisher (1995) suggests that water trade would take place through joint water management and prices would be determined by each individual seller. Theoretically, the prices at which water would be traded would be similar to those generated by the model. The coordinating organization does not operate as a social planner making policy but only facilitates whatever joint management takes place including trade. No doubt, such an ambitious undertaking will provide the information about water values necessary for a variety of approaches to the problem of water scarcity in the Western Middle East.

Furthermore, and perhaps most importantly, by finding a value for water it then enables the separation of the question of who *uses* the water from the question of who *owns* the water. Fisher argues that these two questions become analytically separable if they are given appropriate values, values which incorporate both social and private benefits.[31] Fisher's point can be taken a step further. If a country chooses not to buy water from another country but instead chooses to desalinate water at a higher cost, then it must be placing a value on *owning* the water as well as using it. Certainty in water supply must then have a value or similarly, inability on the part of the seller to reliably commit to a transaction of water must have a cost. This value could then be implied by the failure of a transaction. This issue will be returned to when an original approach is presented in Section 4.

Dinar and Wolf (1994a and 1994b) use a cooperative game theoretic approach to evaluate regional water trade in the Western Middle East between Egypt, Israel, the West Bank and Gaza Strip. Their results are indicative of possible allocations through trade.

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[30] Ibid., p. 386-387.

[31] Ibid., p. 378.

Their approach, like that of the Harvard Middle East Water Project, attempts to incorporate both economic and political problems into the framework. However, the incorporation of political considerations is done only to show where economically viable trade might fail and does not attempt to show how these political and ideological factors may change the values placed on water by the parties involved in trade. In other words, the political analysis is done exogenously of the economic analysis. Determining the likelihood of cooperative trade failing is done by using the PRINCE Political Accounting System. The authors note problems with the Political Accounting System. It is said to be subjective, ordinal and may not be consistent.

The results of this cooperative game approach, using the players Egypt, Israel, the West Bank, and Gaza Strip show that Israel would be the major beneficiary in the cooperative project.[32] It would gain the most in comparison to non cooperation. Egypt would also gain but being the major supplier of water, it would most likely object to the distribution of benefits determined by the Nash product. Therefore, the likely strategy for Egypt would be not to cooperate. This raises the question of other methods of distribution used in cooperative game theory, particularly the Shapley value allocation which will be calculated in Section 4 in a full demonstration of a cooperative game for the same project.[33]

The cooperative game theory approach assumes that players may pursue regional goals maximizing regional benefits. But Dinar and Wolf (1994a), by incorporating the political considerations, show that "[e]ach party implicitly maximizes its own objectives and the outcome may satisfy all or part of participants."[34] Although all parties find

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[32] Dinar and Wolf (1994b), p. 57.

[33] The concepts of the Nash product and Shapley values will be returned to and explained below.

economic gains to be made through cooperation, their preferences are limited by political considerations. The cooperative game theory approach assumes that contracts are binding as was discussed in Section 2.

Lacking from the existing literature is consideration of the willingness or ability of the parties to commit themselves to agreed upon contracts. The literature that focuses on international transfers of water points to the gains to be made from open markets and trade. The literature does not go further to explain why water trade has not already developed in the region. One important factor is that in the current state of affairs in the Western Middle East there is little trust and good will. The only way contracts are held, without some system for enforcing contracts or making the contracts expensive to break, is by being mutually beneficial and individually rational. Once the agreed upon contract is no longer rational for any one party, that contract may be broken. This is why the parties to the conflict over water in the region are primarily interested in who *owns* the water and not simply who *uses* it.

[34] Dinar and Wolf (1994a), p. 343-4.

4. Two Game Theoretic Approaches

A game theoretic approach to the problem of international water transfers is proposed here to assist in the understanding of why water trade has yet to develop in the region and why it may not develop in the future.

First, a cooperative game theoretic approach is presented similar to the method used by Dinar and Wolf (1994b). It utilizes two type of solution concepts. This analysis first considers economic gains from a regional project to supply water from the Egyptian Nile Delta to Israel, the West Bank, and Gaza Strip. The economic gains are found by the Nash product, an axiomatic bargaining approach. It then considers the Shapley values taken from this cooperative game. The Shapley values are used to demonstrate the importance of the seller to the project. Should cooperative projects for water transfers be established, the seller will be able to demand a great deal of the surplus gained from trade. The results show that although there are economic gains to be made, the political nature of the region coupled with the importance of the supplier to the cooperative project make the proposal an uncertain proposition.

The problem of commitment to the international transfer of water is then presented in a two period, noncooperative framework. This game uses ordinal payoffs for Egypt and Israel comparing the different possible outcomes from a two period game. It shows that given some likelihood of the contract for water transfers being broken in a later period, the otherwise mutually beneficial project may never begin. One of the main issues preventing the transfer of water from the Nile river to Israel, the West Bank and Gaza Strip has been the issue of commitment to the project. The political climate and possibilities of future political crises has prevented its establishment.

The approach that deals with the problem of commitment can be applied to other seller- buyer relationships in the region. It can be applied to the sale of Turkish water and Syrian water to Jordan and the West Bank, to the sale of West Bank water to Israel or to the sale of Israeli water to the Gaza Strip. It can also be applied to multilateral transfers as opposed to bilateral transfers. The failure to obtain secure commitments on a bilateral basis can prevent the establishment of a multilateral project. For example, if Syria believes that there is potential for Turkey to break its commitment to sell water to Syria, then the larger project to supply Turkish water throughout the region will fail. The same holds true for any other buyer-seller relationship. The methods and results can therefore be applied to any potential projects for transboundary water allocation in the Middle East.

It is because of these uncertainties that the parties to the region are currently reviewing projects for desalinization while the potentials for international water transfer have been left untapped. Israel is studying a variety of proposals to increase its national water supply that do not make them reliant upon neighboring Arab states. It is reluctant to give up control of water resources in the West Bank or tacitly allow Syria and Jordan to build dams up-stream from its water supplies. Even the cash strapped Gaza Strip has studied the possibility of building a desalination plant. To all parties in the region, the issue of who *owns* the water is a more primary concern than who *uses* it due to the problem of non-binding commitments to water transfers.

4.1 Background to the Proposed Nile Water Project

After the October War in 1973 and the withdrawal of the Israeli Defense Forces from the Sinai Peninsula, the Egyptian government announced a plan to convey water from the Nile Delta, along the Mediterranean coast to the town of El Arish in the Sinai (see map following the bibliography). The Egyptians were so enthusiastic about the project's potential that they foresaw water being pumped all the way to Jerusalem. This project has lost favor among analysts of the region because of disputes over riparian rights to water particularly among Egypt, the Sudan, and Ethiopia. Also, the surplus of water from the Nile river is now estimated to be smaller than originally thought. This proposed project can still be used to demonstrate the problem of commitment as discussed above.

It has been proposed that the most affordable and economically beneficial project for supplying a new water resource to Israel and the Palestinians would be the transportation of water from the Egyptian Nile Delta to the Gaza Strip and Israeli Negev desert. The West Bank would gain additional resources through trade with Israel, only made possible by the proposed project. Kally (1993) has analyzed the economic and hydrological feasibility of the project's extension from El Arish. He shows that given the marginal value of a cubic meter of water to the agricultural sectors in Israel, the West Bank, and Gaza Strip, the costs of the project per cubic meter are affordable. According to Kally (1989) and other authors, it would be economically feasible for Egypt to enter trade with Israel, the West Bank, and Gaza Strip as a seller of water.[35] All parties involved, including Egypt, would benefit financially.

This solution would involve conveying water from the Nile Delta by conduit or canals. The Nile, which the proponents say runs a surplus of water because of the construction of the Aswan dam, would contribute a small fraction of its capacity to the Gaza Strip and Negev Desert, just one half of a percent of what Egypt consumes.[36] Essentially, Egypt would be exporting water for a profit.

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[35] Kally, 1989, p. 309.

[36] There are several sources that cite this surplus including Kally (1989 and 1993), Zeitouni, et al (1994), Becker, et al (1996) and others.

Much of the infrastructure from the Duyami side of the Nile Delta is already in place or is under construction. Canals will deliver water through the Egyptian Sinai up to El Arish, an Egyptian town three quarters of the way from the Nile Delta to the Gaza Strip. The capacity of the canal begins with 2,800 million cubic meters (mcm) per year and reaches El Arish with a capacity of about 1,400 mcm per year. If the project was extended to sell water to the Gaza Strip and Israeli Negev, economic gains for Egypt are estimated at $10 million (1984 US$) a year.[37] This covers capital costs, maintenance, pumping of water and the marginal value of a cubic meter at the source. The necessary costs of infrastructure would be $158 million but could be expanded to increase capacity at a lower cost per meter but at a higher cost of infrastructure.[38]

This project would literally solve the Gaza Strip's water shortage problem. The quantity of water may even go so far as to replenish the coastal aquifer, currently the sole source of water to the Gaza Strip, by absorbing surpluses during the winter rains. The coastal aquifer is currently being salinated from the Mediterranean Sea because of overdraft. However, the economic benefits in this analysis are measured as a difference between economic gains under the "safe yield" amount of water, 70 mcm per year, and the addition of water provided from the Nile, 100 mcm per year. Current draft from the coastal aquifer is estimated between 120 and 130 mcm per year.

The shadow prices per cubic meter of water in the Gaza Strip are higher than the cost per cubic meter under the two versions of this project. Kally (1989) estimated the

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[37] Kally (1989), p. 305.

[38] This is taken from Kally (1993) estimates of project costs. Kally (1993) will become a benchmark for all numbers generated here. Estimates of other values were gathered with the intention of associating them to the project as it is specified by Kally(1993).

cost per cubic meter under the smaller, less expensive proposed infrastructure at $0.214 (1984 US$) compared to the current shadow price for water in the Gaza Strip of $0.30 to $0.46 per cubic meter.[39] This includes the cost of water at the source, capital costs, maintenance, water treatment and the cost of power to pump the water to its destination. Other estimates put the cost of water per cubic meter from such a project at $0.17. Shadow prices suggest that this project would be financially beneficial and the expansion to the Israeli Negev desert would make it even more beneficial.

If Israel joins the cooperative project, the canal would be expanded from a capacity of 100 mcm to 500 mcm per year. The cost of the project per cubic meter would drop from $0.214 to $0.198.[40] Israel currently pumps water from the Sea of Galilee in the north of Israel to the Negev desert. Energy costs for pumping alone is $0.17 per cubic meter. This is economically feasible because the Israeli government subsidizes the costs of water to the agricultural sector amounting to $250 million each year. The Israeli agricultural sector uses 64.4% of all water consumed in Israel, the West Bank, and the Gaza Strip combined but as a percentage of their national supply this is not markedly different from the world average.[41] If water is supplied from the Nile, then Israel would no longer have to pump water from the Sea of Galilee. Its agricultural sector in the Negev would be allowed to expand and become more profitable.

Furthermore, the water currently diverted from the West Bank aquifers could be used in the West Bank if the cooperative project included Israel, the West Bank, and Gaza Strip. Water from the Nile would not be conveyed to the West Bank, but as a trade off,

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[39] Shadow prices are taken from Zeitouni, et al (1994) p. 312.

[40] Kally (1993), p. 68

[41] Berck and Lipow (1994), p. 289.

Israel would reduce water extraction from the West Bank mountain aquifers and leave it for Palestinian use. The Israelis would have to be paid for the water.

There may be cultural and political reasons for the Egyptians to resist a project to provide water to the Israeli Negev desert. This has been the case over recent years since the project was first mentioned. After the Camp David Peace Accord was signed between Egypt and Israel, President Anwar Sadat was reported to have offered Israeli Prime Minister Menachem Begin 365 mcm per year in exchange for agreement on the Palestinian dilemma and the Israeli withdrawal from East Jerusalem.[42] This did not go over well with nationalist Israelis *or* Arabs. On the other hand, Egypt is relatively connected and committed to the Gaza Strip, most recently by its administration of the Gaza Strip from 1949 to 1967. There may be a greater willingness for involvement on these grounds.

A distribution of benefits must be found that is reflective of these political realities in order for the project to be successfully implemented. The political power held by Egypt is not reflected in the straight distribution of economic benefits from the cooperative game. Egypt's gains are small as will be explored below. Israel will profit the most from such a project mainly because of the size of its agricultural sector. Palestinian gains are also large relative to their acute water shortage. The asymmetry in benefit and economic risk associated with the project would leave opportunity for ideological opposition to the project in Egypt. The Egyptians control the tap to the source and the relatively small economic gains do not inhibit radical action on their part. For whatever reason pleases them, the Egyptians could simply stop or divert the flow of water at El Arish and cause devastating shock to the Palestinian and Israeli economic

[42] Dinar and Wolf (1994), p. 58.

sectors reliant upon the new water resource. There would be some loss of irreversible investment in infrastructure in Egypt. The discrepancy between economic gains and the marginal importance of players to the cooperative project raises issues of alternative allocations of profit, possibly in the form of side payments.

First, in order to demonstrate the problem, many assumptions need to be made and values estimated. Challenging the assumptions about values estimated does not, however, make the general conclusion of the analysis invalid. The analysis may be challenged on the grounds that if the solution does not hold for a noncooperative game, why should it hold for a cooperative game? The Shapley values may not be the best, stable, or even reasonable allocation of the benefits from the project but they do raise and make apparent the real problem of unsymmetrical power in the coalition.

4.2 A Cooperative Game and the Shapley Value Allocation

The players in the game are Egypt, Israel, the West Bank and Gaza Strip. Assume that the water rights are well defined according to the criteria discussed in Section 2.1, meaning they are completely specified and enforceable, they are exclusive, and they are comprehensive.

The value of the marginal productivity of water in agriculture in Israel, the West Bank, and Gaza Strip is estimated to be \$0.30 per cubic meter.[43] This value for the next unit of water to agriculture is interpreted as the shadow price or real value of water. Their being equal is justified by the fact that in a cooperative situation, the marginal

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[43] This is gathered from Zeitouni (1994) estimates of aggregated agricultural statistics which use Israeli Agricultural Statistical Quarterly (1992). Estimates for the West Bank and Gaza Strip are similar and are taken from Zeitouni (1994), Kally (1993), Dinar and Wolf (1994).

productivity of water for each agricultural sector should be equal. Technology, information, domestic and export markets should all be the same due to free trade and open access. $0.30 per cubic meter will be used as an upper limit for the willingness-to-pay for water in these three areas. There are other estimates of shadow prices that reach $0.46 per cubic meter for the West Bank and Gaza Strip. They reflect greater scarcity in the Occupied Territories under status quo property rights. The shadow prices will change as the availability of water in the Occupied Territories changes. For simplicity, the value chosen is a static $0.30 per cubic meter.

The demand for water, now or in the future, is not satisfied throughout the region except in Egypt. The Gaza Strip has a high level of excess demand that is certain to continue at current population growth rates.[44] The 1990 population of the Gaza Strip is 636,000 and may reach as much as 850,000 by 2010. Some water market allocations suggest that the Gaza Strip will be willing to purchase up to 200 mcm of water per year in 2020. This analysis will use the average produced by Kally (1993) and Abu Eisheh (1994) of 100 mcm for demand for water in the Gaza Strip.[45] This is done mostly for the convenience of being able to use the Kally (1993) project evaluation but it is not wholly inconsistent with other estimates.

Excess demand also exists in the West Bank. The excess demand in this area could be claimed as artificial. Palestinians argue that water is pumped illegally from the West Bank by Israel at a rate between 400 and 500 mcm per year. Current political power structures suggest that the deficit they do face will continue and the water they will gain from Israel will have to be bought. This analysis assumes the political status quo

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[44] Abu Eisheh (1994), p. 20.

[45] Kally (1993), 70; Abu Eisheh (1994), p. 20.

regarding property rights in the West Bank. At current rates of population growth, the demand for water will result in a 60 mcm deficit in the year 2020. [46]

Demand for water in Israel in the year 2020, given its current resources, will have a deficit between 231 mcm per year and 449 mcm per year depending on the rate of immigration. For this analysis we will use a constant additional demand of 400 mcm per year. Again, this is the estimate consistent with the Kally (1993) evaluation.

The objective function is similar to the model developed by Dinar and Wolf (1994b).[47] For player *i*, the objective function is

$$MAX_{\mathbf{p}}\ B_i = F_i(w_i) + \Sigma_j\, p_{ji}w_{ji} - \Sigma_j\, p_{ij}w_{ij} \quad i \neq j$$

subject to

1) $p_i \geq mc_i + vmp_i$

2) $p_i \leq vmp_i$

3) $w_i \leq w^* - \Sigma_j\, w_{ji} + \Sigma_j\, w_{ij} \quad \forall\ i \neq j$

The objective function for player *i* is maximized with respect to the price of water bought and sold. $F_i(w_i)$ is a welfare function for water for player (or country) *i*. A country's welfare is increasing in water. It is estimated here by using its shadow price, or willingness to pay for a unit of water, multiplied by the total number of units consumed. The estimated gains in welfare, $F_i(w_i)$, are measured by the increased productivity to agriculture as a result of lower shadow prices for water. $p_{ji}w_{ji}$ is the water sold by player *j* to player *i* multiplied by the price per cubic meter. $p_{ij}w_{ij}$ is the water bought by player *j* from player *i* multiplied by the price per cubic meter.

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[46] Kally (1993), p. 69.

[47] Dinar and Wolf (1994), p. 48.

This is not a competitive market but an allocation of water that maximizes the Nash product (or Nash solution) for the players on a cooperative basis. The payoffs are transferable and are expressed in monetary values. The solution is the point which maximizes the product of utilities or benefits ($B_i \times B_j \times \ldots \times B_z$) of the members of the cooperating coalition. When the equations are solved, the equilibrium prices are the median price between the minimum selling price for a player *i* [($p_i \leq mc_i + vmp_i$) where *mc* is the marginal cost of transporting a cubic meter of water and *vmp* is the value of the marginal productivity of a cubic meter of water] and the maximum buying price for player *j* ($p_i \leq vmp_i$).[48] The Nash solution is appealing because it is independent of the origins of the benefits gained, it is a Pareto improvement from the point of empty coalitions, and it is symmetric in price setting.

The third constraint states that through the exchange of water, player *i* does not use more water than their endowment (w*) less the water they sold ($\Sigma_j\ w_{ji}$) plus the water they bought ($\Sigma_j\ w_{ij}$).

For comparative purposes, the payoff for any player going alone is zero. Each coalition has an actual function for economic gains which is constrained by the costs of supplying the water and the value of the marginal productivity of water in each area. Many coalitions have zero value. All relationships are calculated as static here for convenience.

The first productive partial coalition is Egypt and the Gaza Strip. The canal carries 100 mcm at the total cost of $0.214 per cubic meter. The marginal value of

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[48] For a full explanation of the Nash solution, see Mas-Collel, Whinston, and Green (1995), p. 842-3.

productivity of water at the source is $0.006 and the marginal value of productivity of water in the Gaza Strip is $0.30.

Gains in Egypt are created simply by the sale of water, $B^{E \in \{E,G\}} = p_{eg}w_{eg}$. Gains in the Gaza Strip are created by increases in welfare due to a lower shadow price for water less the cost paid to Egypt, $B^{G \in \{E,G\}} = F_i(w_i) - p_{ge}w_{ge}$. The prices are found by maximizing the Nash product, the product of the benefits to Egypt and Gaza.

$$MAX_{\mathbf{p}}\ B^{E \in \{E,G\}} + B^{G \in \{E,G\}} = (100 \quad 10^6)(p_{ji} - .22) + (100 \quad 10^6)(.30 - p_{ij})$$

The economic gains of $8 million in this coalition are split because of symmetry in the Nash product. The price paid for water is $0.26 per cubic meter. The solution is the same when adding the West Bank to the coalition. The West Bank contributes nothing without the inclusion of Israel. This process is repeated for each coalition below.

The second productive partial coalition is Egypt and Israel. The canal carries 400 mcm per year to the Negev desert. The cost per cubic meter was extrapolated from Kally's proposed projects and found to be $0.2108 plus the marginal productivity of water at the source. Israel no longer needs to pump water from the Sea of Galilee, creating a savings of $0.17 per cubic meter.

$$MAX_{\mathbf{p}}\ B^{E \in \{E,I\}} + B^{I \in \{E,I\}} = (400 \cdot 10^6)(p_{ji} - .2168) + (400 \cdot 10^6)(.30 - p_{ij}) + .17 \cdot (400 \cdot 10^6)$$

The economic gains for Israel are $16.64 million plus $68 million and the economic gains for Egypt are $16.64 million. The price paid to Egypt for a cubic meter of water is $0.2584.

No other two party coalition receives positive payoffs. The coalition that includes Egypt, the Gaza Strip and Israel involves conveying 500 mcm of water per year. The total cost of the project per cubic meter is \$0.198 plus the marginal productivity of water at the source.

$$MAX_{\mathbf{p}}\; B^{E\in\{E,G,I\}} + B^{G\in\{E,G,I\}} + B^{I\in\{E,I\}} = (500 \cdot 10^6)(p_{ji} - .204) + (100 \cdot 10^6)(.30 - p_{ij}) + (400 \cdot 10^6)(.30 - p_{ij}) + .17 \cdot (400 \cdot 10^6)$$

Benefits rise per cubic meter for all three parties. Egypt receives \$24 million, Israel \$87.2 million, and the Gaza Strip \$4.8 million. The price paid to Egypt by both Israel and the Gaza Strip for a cubic meter of water is \$0.252.

The unlikely coalition of Egypt, Israel, and the West Bank should also be considered. The conveyance of Nile water to the Israeli Negev may leave some water surplus in the north of Israel, enough to cover the West Bank's 60 mcm deficit, artificial or not. The cost of infrastructure and of pumping of water from the Israeli system into the West Bank is \$0.14 per cubic meter.

$$MAX_{\mathbf{p}}\; B^{E\in\{E,I,W\}} + B^{I\in\{E,I,W\}} + B^{W\in\{E,I,W\}} = (400 \cdot 10^6)(p_{ji} - .2168) + (400 \cdot 10^6)(.30 - p_{ij}) + .17 \cdot (400 \cdot 10^6) + (60 \cdot 10^6)(p_{ik} - .14) + (60 \cdot 10^6)(.30 - p_{ki})$$

The economic benefits from this partial coalition are \$16.64 million for Egypt, \$89.44 million for Israel, and \$4.8 million for the West Bank. The price paid to Egypt for its water remains \$0.2584 and the price paid to Israel by the West Bank is \$0.22.

The grand coalition involves the same scenario for trade between Israel and the West Bank and the same prices from the three member coalition of Egypt, Israel, and the Gaza Strip.

$$MAX_{\mathbf{p}}\ B^{E \in \{E,I,W,G\}} + B^{I \in \{E,I,W,G\}} + B^{G \in \{E,I,W,G\}} + B^{W \in \{E,I,W,G\}} = (500 \cdot 10^6)(p_{ji} - .204) + (400 \cdot 10^6)(.30 - p_{ij}) + .17\ (400 \cdot 10^6) + (60 \cdot 10^6)(p_{ik} - .14) + (60 \cdot 10^6)(.30 - p_{ki}) + (100 \cdot 10^6)(.30 - p_{ij})$$

The economic benefits from this coalition are \$24 million for Egypt, \$92 million for Israel, \$4.8 million for the West Bank and \$4.8 million for the Gaza Strip. The price paid to Egypt by both the Israel and the Gaza Strip for a cubic meter of water is \$0.252 and the price paid to Israel by the West Bank is still \$0.22. The results are summarized in Table 4.1.

Table 4.1 Incremental Economic Gains for All Possible Coalitions (millions of $)

	Player:	Egypt	Gaza Strip	Israel	West Bank	Total
Coalitions						
{E}		0	-	-	-	0
{G}		-	0	-	-	0
{I}		-	-	0	-	0
{W}		-	-	-	0	0
{E,G}		4.00	4.00	-	-	8.00
{E,I}		16.64	-	84.64	-	101.28
{E,W}		0	-	-	0	0
{G,W}		-	0	-	0	0
{I,W}		-	-	0	0	0
{I,G}		-	0	0	-	0
{E,G,I}		24.00	4.80	87.20	-	116.00
{E,G,W}		4.00	4.00	-	0	8.00
{E,I,W}		16.64	-	89.44	4.80	110.88
{G,I,W}		-	0	0	0	0
{E,G,I,W}		**24.00**	**4.80**	**92.00**	**4.80**	**125.60**

If the Gaza Strip and the West Bank are considered a single entity under the Palestinian National Authority, then the economic gains from cooperation can be summed for these two areas (Table 4.2).

Table 4. 2 Incremental Payoffs for Egypt, the Palestinian Authority and Israel (millions of $)

	Egypt	Palestinian Authority	Israel	Total
{E}	0	-	-	0
{PA}	-	0	-	0
{I}	-	-	0	0
{E,PA}	4.00	4.00	-	8.00
{E,I}	16.64	-	84.64	101.28
{I,PA}	-	0	0	0
{E,PA,I}	**24.00**	**9.60**	**92.00**	**125.60**

What is immediately clear from this is that Israel gains the most in nominal economic terms. The Gaza Strip gains greatly in regards to their acute water shortage problem as it more than doubles its current water supply. The West Bank covers its water deficit and Egypt is paid $24 million each year.

The Shapley value σ_j allocates the economic benefits in an alternative fashion to represent each player's marginal contribution to each coalition. The marginal contribution of a player is the change in a coalition's gains as a result of the addition of that player to the coalition. The Shapley value takes the average of player *i* contributions to every coalition over all permutations of how the coalitions are formed.

$$\sigma_j = \sum_{0 \le s \le n} \frac{(s-1)!(s-n)!}{n!} \sum_{s \subset N} (v(s \cup \{j\}) - v(s))$$

The properties of the Shapley values are consistent with the allocation developed by the Nash product.[49]

1) *Pareto Efficiency.* $\Sigma_i \sigma_i (T, v) = v(T)$. The sum of the Shapley values equals the value of the characteristic function for the grand coalition. In this case, the property of Pareto efficiency requires that there be no wasted water or wasted utility from water.

2) *Symmetry or Anonymity.* The permutation of roles of players does not alter the Shapley values. Only the position in the game and characteristic function determine the outcome expressed by the Shapley value and not the label of the player. In this application, this simple property may be challenged as unrealistic. The Shapley value calculates, in part, the probability of a player being absent from a coalition. For example, the probability of Israel being absent from the coalition {Egypt, Israel, Gaza Strip} must be equal to the probability of the Gaza Strip being absent from the same coalition. Given the historical, political, cultural and geographical proximity of the Gaza Strip to Egypt, the probability of Israel's being absent from the same coalition could be quite different.

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[49] Mas-Collel, Whinston, Green (1995), p. 682.

This property of the Shapley value could be dropped to derive a Generalized Shapley Value but it is not done so here.

Dropping the property of symmetry for the Shapley value throws its interpretation further into question. Dinar and Wolf (1994a) discuss Generalized Shapley Values in order to incorporate political aspects into the cooperative game. Probabilities for coalitions are calculated based on the Political Accounting System discussed in Section 3 which states how countries would rank their appeal to the project, in its various forms, on a scale from -3 to +3. This is a subjective and speculative approach not taken here but an alternative method of incorporating political considerations is introduced. It is also unnecessary in demonstrating the power of the seller in the coalition.

3) *Linearity*. The Shapley values as determined by the equation above are a linear function of the probability of a player being absent from a coalition and the contribution of that player to the coalition. The economic benefits calculated here are linear and the Shapley values are as well.

4) *Dummy axiom or null players*. If the marginal contribution of a player to any coalition is zero, then the Shapley value derived for that player is also zero. Such a player is a null player. In this case, all players make a contribution to the economic benefits of the region by joining certain water coalitions.

The Shapley values display a disparity between the marginal contributions of the players and the economic gains that result from the forming of water market coalitions. They are 60.08 for Egypt, 56.08 for Israel, 6.24 for the Gaza Strip, and 3.20 for the West Bank. The Shapley values show the importance of Egypt to the coalition. Without Egypt, all gains are zero.

Table 4.3 The Shapley Value Allocation

		Economic Gains		Shapley Value
Egypt		24.00 (19.0%)		60.08 (48.0%)
Israel		92.00 (73.5%)		56.08 (44.5%)
Gaza Strip		4.80 (3.8%)		6.24 (5.0%)
West Bank		4.80 (3.8%)		3.20 (2.5%)
Egypt		24.00 (19.0%)		60.08 (48.0%)
Israel		92.00 (73.5%)		56.08 (44.5%)
Palestinian Authority		9.60 (7.5%)		9.44 (7.5%)

The Shapley allocation shows the discrepancy between the allocation of economic gains without side-payments and the power structure associated with the project for conveying water east to the Gaza Strip and Negev desert. It does not provide a solution or prescribed method for determining the allocation of economic gains. It simply raises the question in a way that can be approached so as to strengthen the likelihood of the project being started and strengthen the stability of the project once it has been established. All parties to the project should be interested in establishing as stable a regime as possible for allocating benefits for this project.

Mechanisms for determining the distribution of economic gains within this limited set of players should attempt to reflect the power in the region. If the mechanisms selected do reflect the power balance, the result will be a more stable arrangement over water and in turn a reinforcement of peaceful coexistence in the region. If nothing else, the Shapley values shed light on the need to explore mechanisms and incentives to be applied to this project and other international water projects in the Middle East. Mechanisms should seek to approach or reflect the Shapley values associated with these international projects.

Regardless of the distribution of economic benefits from a project, the agreement to trade water may remain unstable because of political changes in the region. In this cooperative game theoretic approach the political gains or costs, as discussed in Section 2, have not been explicitly considered. It has been implicitly assumed that the players find the arrangement to be politically beneficial or at least feasible. This would require some degree of peaceful coexistence. Indeed, all the existing literature on the international trade of water in the Western Middle East specifies that it could only take place under peaceful coexistence in an unspecified time frame.

4.3 A General Noncooperative Approach

> "I would hate to be in a situation in which the Egyptians could close our taps whenever they wished." -- Ariel Sharon, former Israeli Minister of Defense, former Minister of Agriculture and current Minister of Infrastructure.

In Section 2 above, six criteria for a desirable allocation process were discussed. Three of these criteria were ***certainty*** in the water supply, ***predictability*** in the allocation, and perceived ***fairness*** by the public. In the cooperative game above, the supply of water is assumed to be static, the allocation process was calculated for a single year in the life of the project and the public perception of fairness was dealt with in the distribution of economic benefits. A noncooperative game approach sheds new light on these issues.

Consider a game with only two players, one is a seller and the other a buyer of water. The seller and buyer could be any two players involved in either a bilateral transaction for water or in a multilateral transaction as was described above.

The payoffs to the players are composed of many things, not only financial gains or losses. The payoffs are ranked by the players according to their own preferences. Whereas the utility gained or lost was cardinal and transferable in the cooperative section above, it can be viewed as ordinal and nontransferable here. The economic costs and benefits have already been discussed at length. The political costs and benefits can be understood and interpreted in many ways. Political gains for selling water could be prestige or leverage in either a bilateral or multilateral relationship. Selling water could be seen simply as an act of good will among nations and used to build a leading role for the seller in regional affairs. Some analysts argue that water trade could foster peaceful coexistence because of the mutual trust gained through these relations.[50]

It has been argued here that the opportunity costs involved in water trade are largely political while the economic costs, given a monetary value, are relatively manageable. It is difficult to give political costs and risks a numerical value and so the values chosen here are ordinal, not cardinal. Only the players, and perhaps not even they, know how they would order their preferences for different political outcomes. The political costs for selling water could be caused by domestic strife. Selling water to other nations may be perceived as unfair in the agricultural sectors at home. The population in the selling country may consider the sale of water unethical or otherwise offensive under certain social and political conditions. The political costs in terms of buying water may be considered in terms of lost autonomy in water supply as is captured in the quotation above. Their preferences can be roughly estimated and the decisions they face can be expressed in a game tree format.

The game tree in Figure 4.1 represents a two period game with two players. In the first period, the two players must decide if they want to enter into a contract (*in*) to transfer water or pursue alternative options on their own (*out*). This stage of the game is played sequentially, with the seller making an offer or not making an offer and the seller responding. The infrastructure to convey water from one entity to another is expensive

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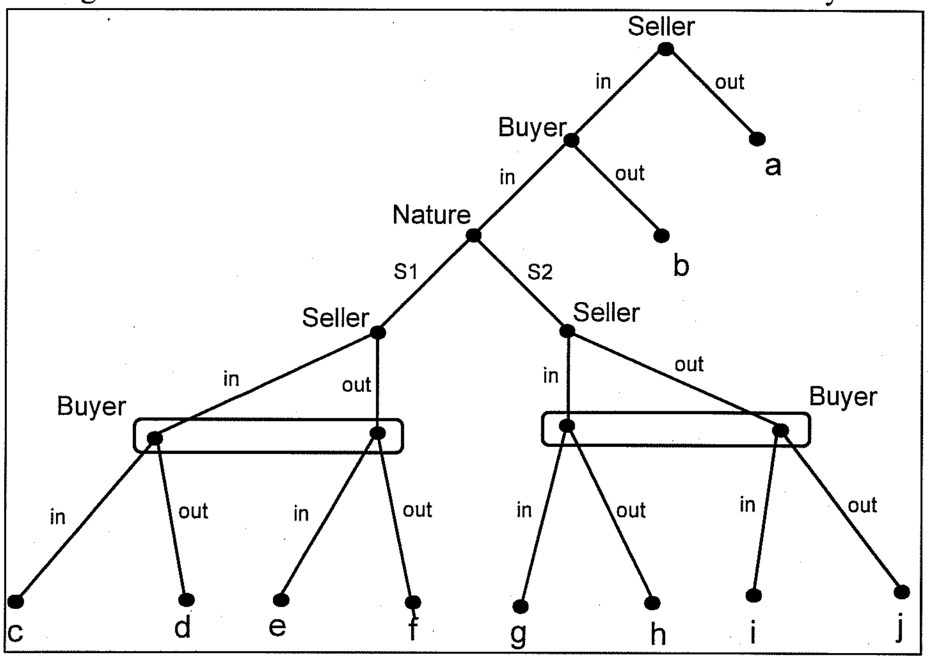
[50] Wolf and Dinar (1994), p. 69. Others agree that water trade, like any other type of trade, fosters good relations between nations.

and the project will only be economically viable if it is operational over some minimum period of time.

Figure 4.1 Game Tree for a Two Period Game with Two Players



S_1 and S_2 describe two different states of the world. Let us assume that during the first period, the state of the world in and among nations is favorable for international water trade, meaning there is peaceful coexistence and trade between nations and internal domestic politics are favorable, etc. After the players enter into a contract to transfer water, the state of the world may remain the same throughout the life of the project or it may change at some point during the life of the project. Let S_1 represent a state of the world similar to the state of the world in the first period, a state of the world that is favorable for international water transfers. Let S_2 represent a second state of the world less favorable or unfavorable for international water trade. The second stage of the game is simultaneous, as both players can choose to honor or break the contract reached in the first period. This explains the information sets in the second period, where each player knows in which state of the world they are, but does not know what the other player will decide to do.

Any number of factors can change in the state of the world to make it unfavorable for international water transfers. The contract to trade water is signed by two nations, represented by their governments. The governments may change; that does not mean that the players have changed. The players are nations, not governments, and therefore it is important for the allocation to satisfy the desirable characteristic of perceived fairness by the public and not only the government's perceptions. A change in government is one possible result from a change in the state of the world. A deterioration in public support, as a result of some change in the state of the world, can change the political gains or costs of a water transfer. Other possible factors may be an unforeseen decrease in water availability in the seller country by either changes in demand or supply. Changes involving outside players may also create an environment unfavorable for international water trade. For example, riparian nations other than the seller may try to prevent the sale of water in the second period. War may spark between one of the players and an outside country. The possible reasons for reconsidering a contract as a result of changes in the state of the world are endless and sovereign nations can renege on commitments in response to small changes in the state of the world. What may be a rational choice for the players in one state of the world may not be a rational choice for them in the second state. Players are well aware of this.

The usual procedure for dealing with choice under uncertainty in classical economic theory is in the expected utility form. This would require a probability distribution for possible states of the world and a probability distribution for possible actions taken by the other player(s). The usual expected utility approach cannot be expected to develop a satisfactory model to aid in finding or predicting an outcome of the game.

Another way to consider problems created by introducing a uncertainty in the second period is in terms of “bounded rationality”. The principle of bounded rationality is defined by its author, Herbert A. Simon:

> *The capacity of the human mind for formulating and solving complex problems is very small compared with the size of the problems whose solution is required for objectively rational behavior in the world -- or even for a reasonable approximation to such objective rationality.*[51]

The principle of bounded rationality does not imply irrationality or non rational factors introduced by human behavior. The players have limited information about the environment in which future water trade is to take place. The assumptions of full rationality and omniscience with regards to future water trade postulated in the cooperative approach and in the literature discussed in Section 3 could be augmented by this principle of bounded rationality. It is too strong an assumption to believe that the players will calculate their decisions based on fully objective alternatives with assumed outcomes. On the contrary, the players will more likely make subjective decisions based on safe guesses and prejudiced beliefs about their potential trading partners. Players may simplify their decision process by replacing the goal of maximization with what Simon calls "satisficing" or pursuing an outcome that is "good enough".[52] It is possible to use a game tree to aid in determining which outcome the players might find "good enough".

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[51] Simon (1957), p. 196.

[52] Ibid., p. 205.

The outcomes ***a*** through ***j*** in the game tree in Figure 4.1 represent two vectors of payoffs for the two players. The payoffs are not only economic but also political. The players have rational preference relations regarding the ten outcomes of the game. The outcomes are all different from each other with the possible exception of ***a*** and ***b*** where the outcome has been chosen through costless communication. Outcomes ***d*** and ***f*** are different in that under outcome ***d***, the seller has unilaterally broken the contract or chosen not to renew the contract to sell water. This may be considered more costly for the buyer than under outcome ***f*** where both players have gone "out" and so the buyer has not "lost face" at the very least.

When the contract is broken or not renewed, the irreversible investment cost has been lost. If the payoffs were solely economic with defined numerical values and an acceptable probability distribution were found which outlined the future, the expected payoffs could be calculated using some probability of the contract being broken. This would have to be done in terms of the life of the project, the irreversible investment costs, and the year to year economic return on the project. For example, if the contract is broken in the nineteenth year of a twenty year project, then it may still be profitable. If it is broken earlier, then the project may not break even. The payoffs of the game would need to be derived in a much more rigorous manner but the very simple and general approach below is satisfactory for demonstrating the problems in commitment to a long term project.

4.4 A Noncooperative Approach to Water Transfers from Egypt to Israel

A game which utilizes potential partners in Middle East water trade makes apparent how two players may resolve themselves to accept a "good enough" solution over possible maximizing solutions. To this date, potential partners in Middle East water trade have chosen not to pursue international water transfers as a high priority despite the possibilities for increases in efficiency in water usage. The following noncooperative game may explain this hesitancy.

Consider the proposed project to convey water from the Nile river to Israel and the Gaza Strip. In the game tree illustrated in Figure 4.1, Egypt is the seller and Israel is the buyer of water. The preferences of the two players may be ordinally ranked in the following (admittedly very subjective) manner to represent the cooperative game solution above involving the players Egypt and Israel.

Israel: $c > b \geq a > d \geq f \geq e > g \geq h \geq j \geq i$

Egypt: $c > a \geq b \geq e \geq f \geq d > i \geq j > g \geq h$

This is assuming that Egypt (simply for illustrative purposes) does not prefer to transfer water in unfavorable states of the world described by S_2. For illustrative purposes, suppose that both players prefer all outcomes in the state of the world S_1 to the outcomes in S_2. This may or may not be the case, but what can be said with confidence is that both players prefer transferring water under the favorable state S_1, to no project being started, which is preferred to all other outcomes.

These preference relations listed above simply state that Israel prefers to buy water under the favorable state of the world S_1 (***c***), to the choice of no project beginning (***a***,***b***), which is preferred to the other outcomes in the S_1 state of the world. Let us assume that all S_1 outcomes are preferred by Israel to S_2 outcomes. Buying water under the unfavorable state of the world S_2 (***g***) is preferred to, or is indifferent to, the other outcomes in the S_2 state of the world. The other preferences are differentiated by the issue of "saving face".

The ordinal ranking for Egypt can be described in a similar manner with preference in the S_2 state of the world being ***i*** or ***j***. Perhaps the rankings of the outcomes are different than what has been described. For example, perhaps the some of the outcomes in the S_2 and S_1 states of the world are mixed in their ranking by one of the players, alternating back and forth.

Figure 4.2 Two Sub-Game Equilibrium

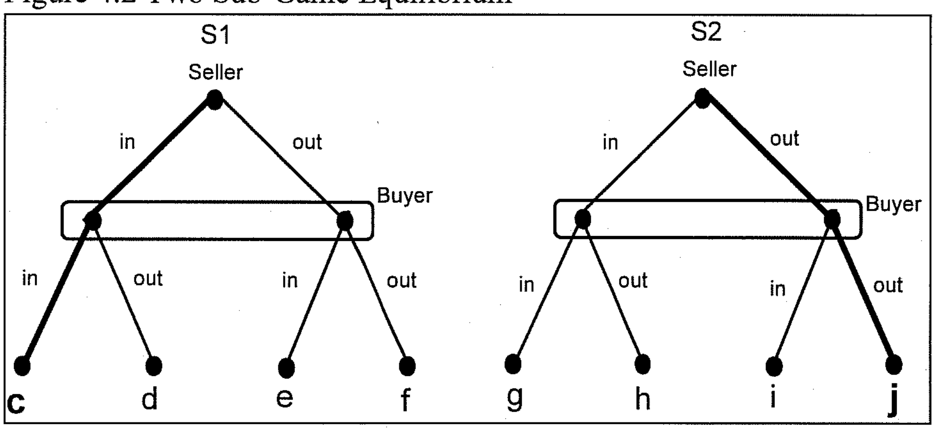

Figure 4.2 represents the same game in reduced form. By representing the game in this simultaneous move form, it is apparent that the players' decisions are based heavily on their expectations about the future, be them objective and calculated or subjective and based on conjecture. There are two subgame equilibria for this game and its assumed

states of the world: *c* in S_1 and *j* in S_2, assuming Israel values "saving face". The players must then weigh the expected payoffs for entering into the project for transferring water against the certain payoffs from not entering into the coalition. Certainly, Israel will be risk averse in its water supply. Egypt may be risk averse in its political payoff, more willing to err on the conservative side than take risks with its water and a trading partner considered untrustworthy. Given some probability of S_2 occurring, both Israel and Egypt would choose not to enter into a contract to begin the project for transferring water from the Nile east to Israel.

If all political, social or otherwise non-financial outcomes were dropped from the payoffs, it may be possible to be formulate a von Neumann-Morgenstern utility function. Using only cardinal utility, one could calculate the critical probabilities for the contract being broken given all the other necessary data regarding the costs of the project and the size of the surplus resulting from water trade. International water trade requires large, expensive infrastructure projects cooperatively built. For such a project to be profitable, it requires long term commitment and if such commitment cannot be guaranteed, such projects may never be built by risk averse nations. It is unlikely that such an expected utility function could provide a model of much assistance to decision makers in the Egyptian and Israeli governments.

Arguments for international transfers of water in the Western Middle East are qualified by their appeal to peaceful coexistence in the region. But peaceful coexistence is not the reality today. Nor does the coming of peaceful coexistence mean that it will continue. Peace is not introduced and taken away like opening and closing a door. It is a very vague, abstract idea that comes slowly and may disappear very quickly. The field of international relations is complex and so the parties to a cooperative project to transfer water around the region have difficult choices to make and must consider the possibility of the contracts being broken.

5. Conclusion

Based on this analysis, it is difficult to see any type of market for water developing in the Middle East in the foreseeable future. The parties are interested primarily in property rights for reasons of security.

If trade takes place, it is unlikely that it will be a flexible allocation process. It may be made a predictable allocation with some degree of certainty in supplies through bilateral and multilateral negotiations. The opportunity costs associated with trading water will be largely political and public perception of the process will be extremely important. The prices for traded water will also be determined at the negotiating table and not solely by supply and demand. The market is too thin to function properly while the political risks, costs, and benefits greatly outweigh more conventional pricing considerations. The participants will face numerous technical and operational difficulties due to the hydrological nature of water and all of its special social and economic characteristics. Any reallocation of water away from the initial property rights should be geared toward relieving water shortages which will also provide a lever in conflict resolution. This process will largely take place at a negotiating table and can be considered a game involving several players with broad agendas and preferences.

The game theoretic models presented show how the seller, be it Egypt, Turkey, Lebanon, Israel or any other nation, has the ability to determine whether or not the transfer takes place and how the economic surplus from trade will be distributed. The two weaknesses of the model are the poor quality of the data and the fact that it is static. It does give indications of potential gains made by trade in a world where there are trade relations and general good will among nations.

Given the ease at which sovereign nations can break contracts, potentially hostile nations may never enter into a cooperative project to sell water. This noncooperative model could be further developed but it may never become more useful than simply demonstrating the problem of commitment to the long term project. The weakness of this model is its subjective, ordinal rankings which make it unappealing to any kind of application. On the other hand, the general ordinal payoffs allow for the incorporation of economic and political factors into the same model, something previously untried in the literature.

Appendix: Definitions and Solution Concepts

Individual (and group) rationality. Rationality, in this game context, is defined by its payoffs. Each individual or group has complete and transitive preference relations between the payoffs from each coalition and non-coalition.

Coalition. A coalition is a non-empty set of players who have agreed upon a course of action in the game, i.e.: they are going to cooperate.

Grand Coalition. The grand coalition includes all the players in the game cooperating on a course of action.

The Core. The core describes a set of feasible solutions formed by competing coalitions where no coalition of players could improve the payoffs to all its members by leaving the larger coalition.

The Nash Product and The Shapley Value. The Nash Product and the Shapley Value are solution concepts with a single values. Their properties and formulae are described in Section 4.2 of this paper.

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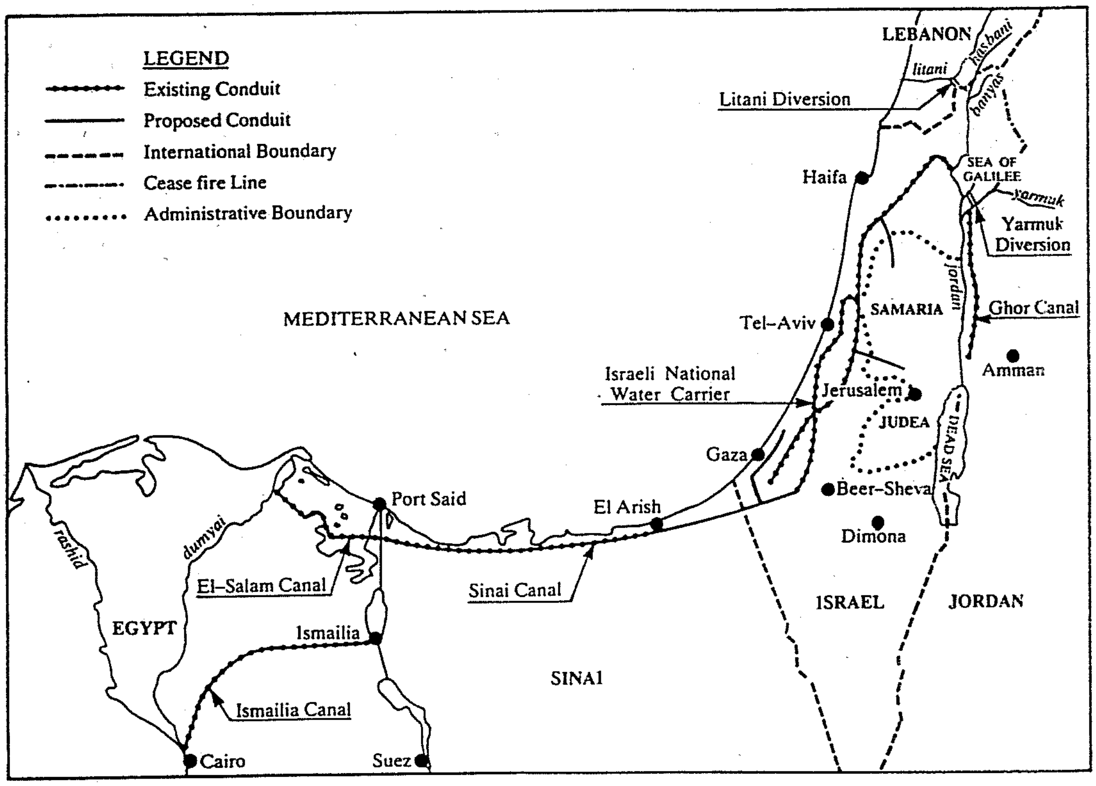
MAP 16.2: SINAI CANAL AND MAIN REGIONAL CONDUITS



Source: E. Kally, The Armand Hammer Fund for Economic Cooperation in the Middle East, A MIDDLE EAST WATER PLAN UNDER PEACE, Tel-Aviv University, March 1986.