A NEGOTIATED SOLUTION FOR THE JORDAN BASIN

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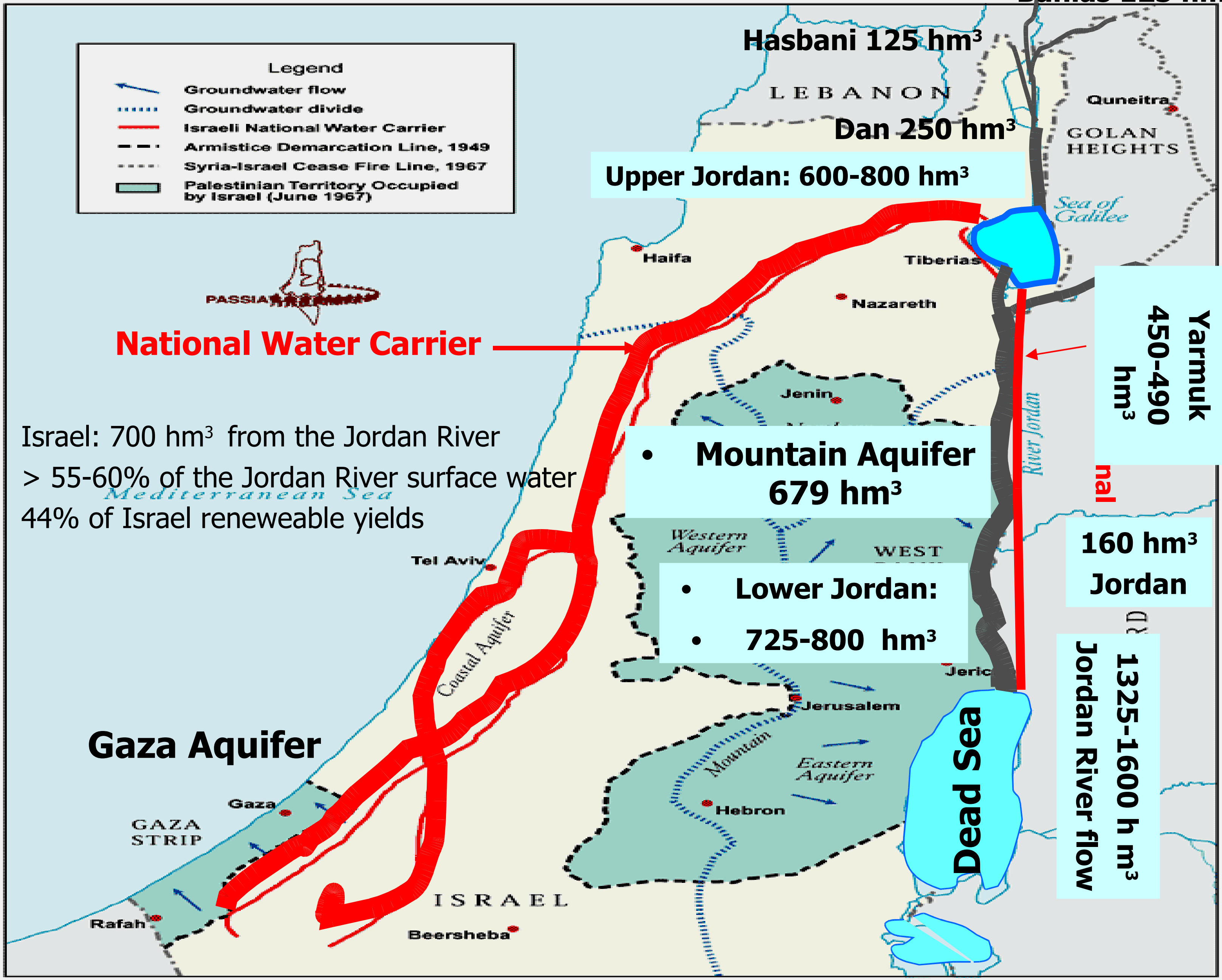
II. Objetives

- We propose a tentative model for water sharing in the Jordan Basin using a negotiation game with two players: Arabs and Israelis.
- We estimate a set of optimum Pareto allocations, as well as identifying a range of negotiated solutions:
    - Nash Bargaining Solution (regular and general)
    - Kalai-Smorodinsky
    - Johnston Plan (1953-1955)

0. Water Resources in the Jordan River Basin

Water Sources



Adapted from: 'Water and War in the Middle East' Info Paper no.5 , July 1996, Centre for Policy Analysis on Palestine/ The Jerusalem Fund, Washington D.C.

Palestinian Academic Society for the Study of International Affairs (PASSIA)

Current Water Alloctions in the Jordan Basin

Surface Water

The Jordan River: 1325-1600 hm^3
Israel: 800 hm^3 (55%)
Syria: 160-170 hm^3 (from the YarmouK)
Jordan: 300 hm^3
Lebanon: 10-20 hm^3
Palestine: 0 hm^3

Groundwater

Mountain Aquifer: 679 hm^3
Israel: 552 hm^3 (81.3 %)
Palestine: 121 hm^3 (17.8 %)

- Israel currently exploits practically all of the waters of the Upper Jordan, representing some 650-700 hm^3/year, which are diverted by the National Water Carrier (NWC).

In total, Israel uses 63% from the Jordan Basin

The Model: The Nash Bargaining Solution

- Bargaining Game Basic Elements and Assumptions
  - The negotiating parties (players): Israel and the Arabs
  - The Negotiation Issue (Problem): Water allocation of the Jordan River Basin
  - Negotiation or bargaining is a process to settle disputes and reach mutually beneficial agreements.
  - A typical situation of negotiation: the two players have common interests in cooperating but have conflicting interests in the way of doing so.

The Model: The Nash Bargaining Solution

- Two-person bargaining problem is usually defined as a pair (S, d) where:
  - S: **the feasible set**: Represents all the payoffs which can be obtained by acting together. It is a compact convex subset of **R^2** containing both d and a point that strictly dominates d.
  - $d = (d_1, d_2)$: **the disagreement or starting point** (conflict, disagreement): represents the utility of status quo, that is, d gives the utility level achieved by each player in the absence of any agreement. This is point can be interpreted as a pre-game asumption that the solution u^* cannot be worse than the starting point $u_i^*(u_1^*, u_2^*) >= d_i = (d_1, d_2)$.
  - As status quo point one often chooses the conservative value (the initial utilities of the players) of the game, but other choices are also possible.
  - **A bargaining solution** is a rule that assigns a feasible agreement to each bargaining problem.
  - **Nash proposed that a solution should satisfy certain axioms**:

  1) Pareto optimality (The Nash solution must be on the Pareto boundary),
  2) Symmetry,
  3) Invariant to affine linear transformations performed on the players' utilities,
  4) Independence of irrelevant alternatives,

.

- There exists exactly one Nash bargaining function which satisfies theses axioms

- The consequence of Nash's Theorem is that if the two players believe in the axioms of the Nash bargaining function, then there is a unique method to settle the conflict once the status quo pointis fixed.

- Under these conditions, rational agents will choose what is known as the *Nash bargaining solution*. Namely, they will seek to maximize:

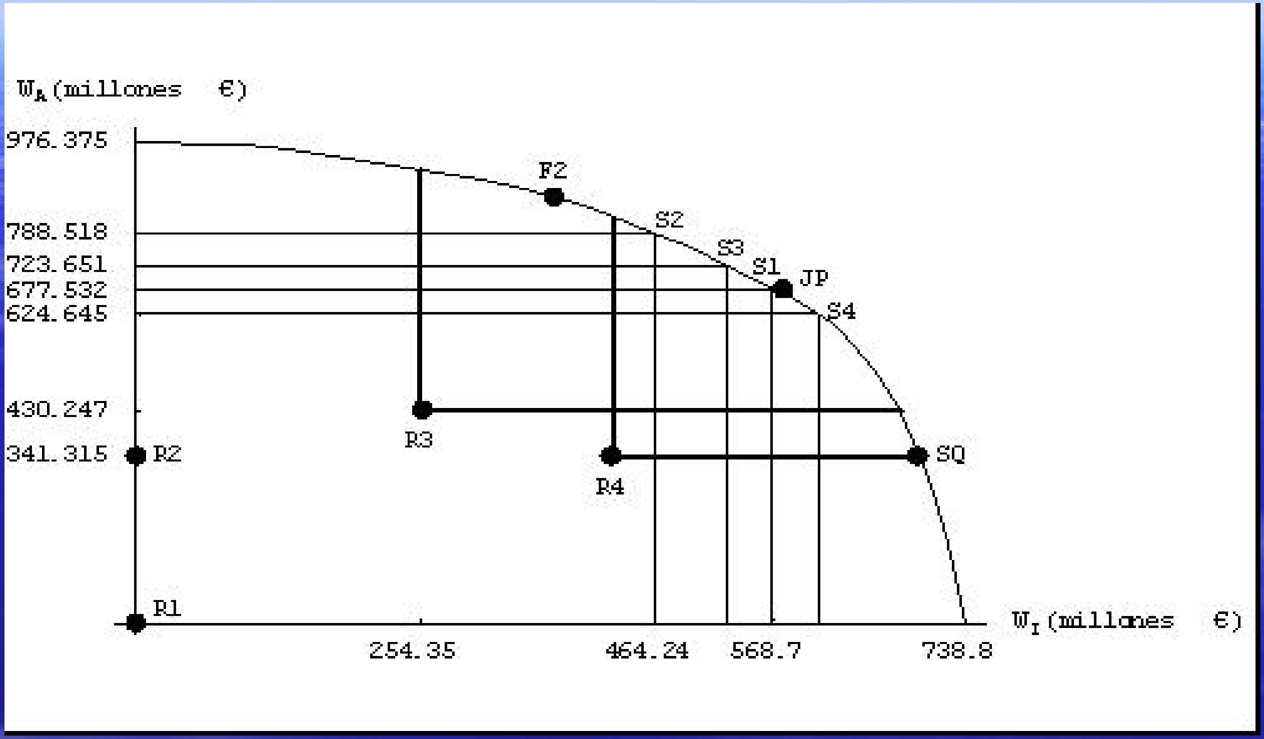
$$\max [u_1 - d_1)][u_2 - d_2],$$
such that u (u_1, u_2) >=d (d_1, d_2)

where d_1 and d_2, are the status quo utilities (i.e. the utiltity obtained if one decides not to bargain with the other player).

- The product of the two excess utilities is generally referred to as the ***Nash product.***

- **Other solution: Monotonicity condition**
- Independence of Irrelevant Alternatives can be substituted with an appropriate monotonicity condition, thus providing a different solution for the class of bargaining problems. This alternative solution has been introduced by E. Kalai and M. Smorodinsky.

Negotiating set and disagreements points



- $N = \{1,2\} \rightarrow$ Players (Israel, Arabs)
- $S \subseteq R^2 \rightarrow$ Set of feasible payoffs : is a convex compact set in the two dimensionl euclidean space (R^2) of the players' utilities
- $d = (d_1, d_2) \in S \rightarrow$ the disagreement point
- A solution (or a value) is a rule that associates to each bargaining problem a payoff in S
- $f : B \rightarrow R^2$ such that $f(S,d) \in S$ for every bargaining problem $(S,d) \in B$
- B : Is the set of all bargaining problems = set of all pairs (S,d)

$R_i = (\omega_I ; \omega_A) = (0;0)$ $S_i = (W_I^*, W_A^*) = (568{,}719; 677{,}532)$

The case of the Jordan Basin: Utility or payment functions for Arabs and Israelis

- In order to obtain and interpret the different solutions to the game, we need:

  - the utility functions for each player,
  - possible negotiating alternatives

- we shall use **agricultural returns** as the basis for the utility functions. Based on an analysis of both the crop patterns and water-use, and the revenues and costs generated by the different types of crops grown, we have estimated the **standard gross margin crop type per cubic meter of water used as**: revenues less direct costs: seeds, fertilizers, pesticides, water, machinery, energy, etc.

- The total volume of water used by Israel in irrigation is 994.663 hm^3, compared to 533.359 hm^3 for the Arabs.

Standard gross margins Curves: Economic revenues per cubic meter of water used

The empirical results for Israel are given in Figure 2, and those for the Arabs in Figure 3. Both reflect a clear downward and roughly hyperbolic trend:

Figure 2. Standard gross margins on irrigation and adjusted function for Israel

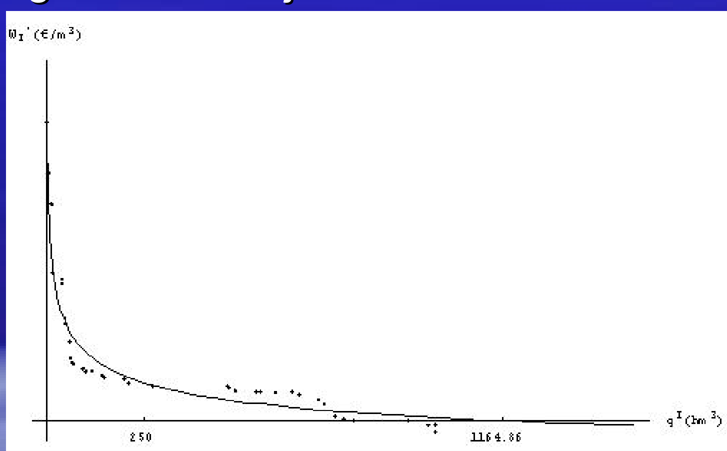
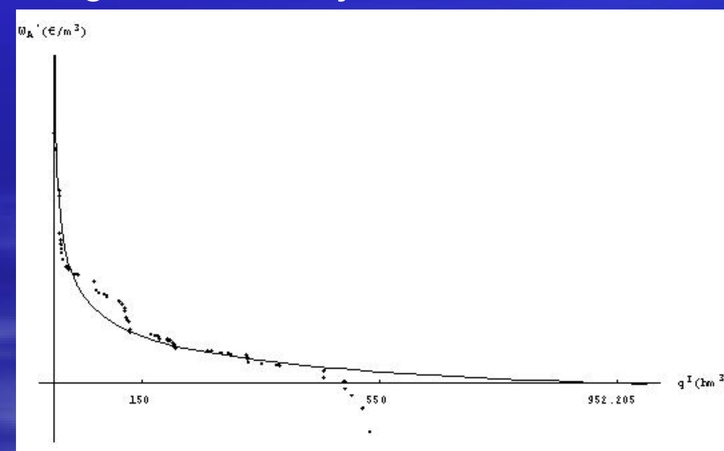


Figure 3. Standard gross margins on irrigation and adjusted function for Arabs



for ease of mathematical operation we have therefore opted to adjust the data using potential curves:

$$dW_I / dq^I = W_I' = \left(-1.73262 + \frac{10.744}{q^{0.258446}} \right)$$

$$dW_A / dq^A = W_A' = \left(-1.11024 + \frac{6.68398}{q^{0.261728}} \right)$$

Total irrigated water value curves for Israel and the Arabs in terms of transferred flows

Figure 4. Total irrigated water value curve for Israel in terms of transferred flows

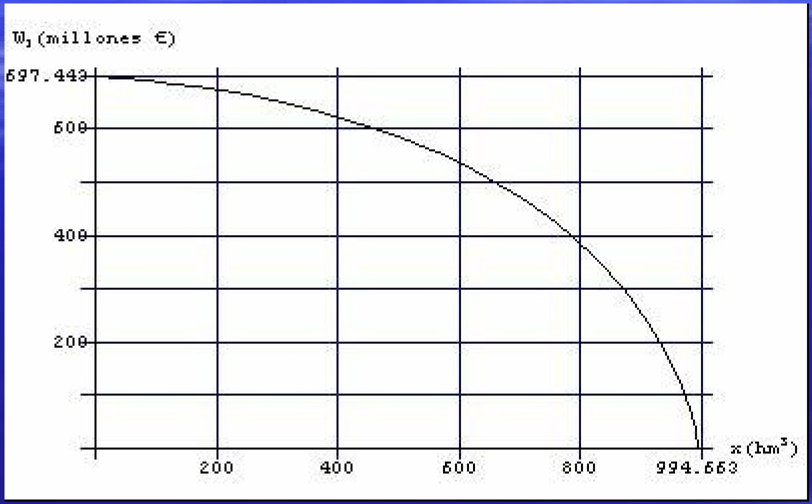
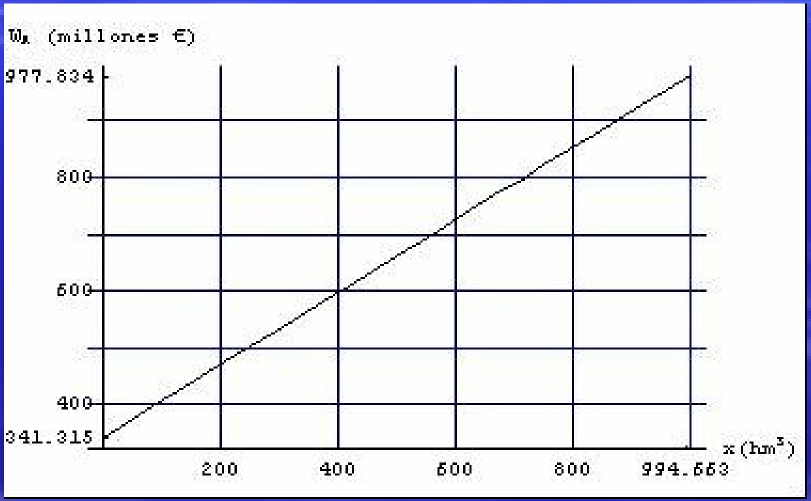


Figure 5. Total irrigated water value curve for for the Arabs in terms of transferred flows



$$W_I(q) = \int_0^q W_I' ds = \int_0^q \left(-1.73262 + \frac{10.744}{s^{0.258446}} \right) ds = 14.4885 q^{0.741554} - 1.73262 q$$

$$W_A(q) = \int_0^q W_A' ds = \int_0^q \left(-1.11024 + \frac{6.68398}{s^{0.261728}} \right) ds = 9.05355 q^{0.738272} - 1.11024 q$$

$q^I = q_{act}^I - x$ Such that q_{act}^I = 994.663 hm³

$$W_I(x) = 14.4885 \left(q_{act}^I - x \right)^{0.741554} - 1.73262 \left(q_{act}^I - x \right)$$

$q^A(x) = q_{act}^A + x$ Such that q_{act}^A = 533.359 hm³

$$W_A(x) = \left[9.05355 (q_{act}^A)^{0.738272} - 1.11024 q_{act}^A \right] \left(1 + \frac{x}{533.359} \right)$$

Negotiating Set: Players'utilities

The parties objective functions

- ***a) Negotiation set***

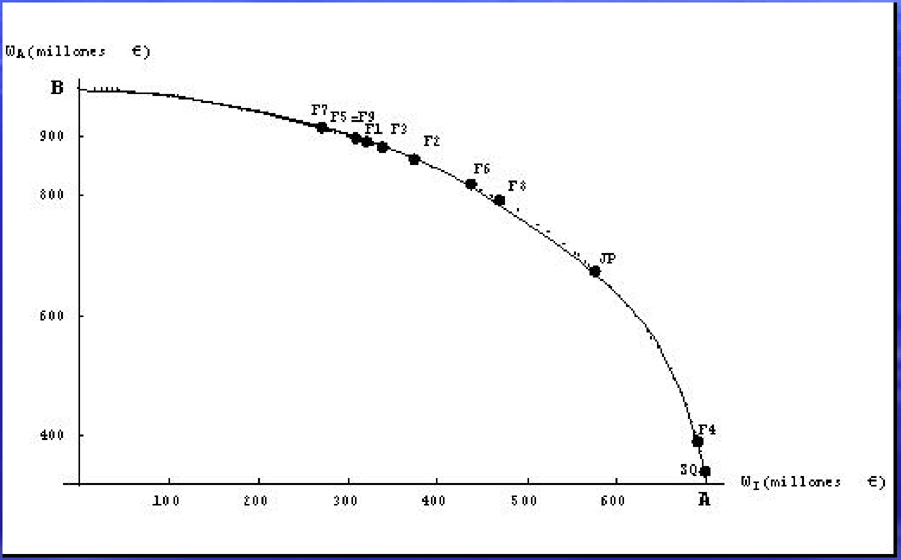
Israel:

$$W_I(x) = 14.4885\left(q_{act}^{I} - x\right)^{0.741554} - 1.73262\left(q_{act}^{I} - x\right)$$

Arabs

$$W_A(x) = \left[9.05355(q_{act}^{A})^{0.738272} - 1.11024 q_{act}^{A}\right]\left(1 + \frac{x}{533.359}\right)$$

$$W_A(W_I) = \left[9.05355(q_{act}^{A})^{0.738272} - 1.11024 q_{act}^{A}\right]\left(1 + \frac{f^{-1}(W_I(x))}{533.359}\right)$$



The following 7th order polynomial expression is an excellent approximation to the curve:

$$W_A(W_I) = 976.375 - 0.2484W_I + 0.00568023W_I^2 - 0.00006827693W_I^3 + 3.36779*10^{-7}W_I^4 - 8.34019*10^{-10}W_I^5 + 1.00573*10^{-13}W_I^6 - 4.71692*10^{-16}W_I^7$$

Johnston Plan (1953-1955)

- In 1953 the US President Dwight David Eisenhower asked Ambassador Eric Johnston to seek a solution that would be acceptable to both the Arabs and the Israelis.
- Approved by the technical committees of both parties, it was never actually ratified by either.
- The Plan estimated the flow of the Jordan at around 1.287 hm^3, 31% of which was allocated to Israel and the remaining 69% to the Arabs.
- If these proportions are applied to the flows in our game (1528.02 hm^3), the result obtained is the point in the negotiating set represented by the Johnston Plan, or point JP = (575.79; 674.71).
- This is surprisingly close, indeed practically identical, to solution S1 = (568.72; 677.53), proving the validity of the proposal made in the Johnston Plan, which 50 years on could still be rationally defended.

The Nash Bargaining Solution:

- Once we have specified the parties' objective functions, we proceed to write down the Nash solution which is the point that **maximizes the product of the two players' utility gains**:

$$MaxF\left[W_I, W_A\right] = \left[W_I - \omega_I\right]^{\alpha_1}\left[W_A - \omega_A\right]^{\alpha_2}$$

Where: α_1 and α_2 for Israel and the Arabs respectivelly

Assuming the same negotiating power: $\alpha_1 = \alpha_2 = 1$

ω_I y ω_A Disagreement point or starting point

FOUR SIGNIFICANT GAME SOLUTIONS BETWEEN ISRAEL AND THE ARABS

Disagreement Point at (0; 0) → Zero utility
(unavailability of Water)

- Two are Nash negotiating solutions (Nash, 1953) with and without lateral payments.
- The third is the Kalai-Smorodinsky solution,
- and the fourth is the proposal made in the Johnston Plan.

1) Regular Nash solution without lateral payments

- **break-off at (0;0)**
- **Both players have the same negotiating power**

$$Max\ W_I W_A$$

$$W_A(W_I) = \left[9.05355(q_{act}^A)^{0.738272} - 1.11024 q_{act}^A\right]\left(1 + \frac{f^{-1}(W_I(x))}{533.359}\right) \geq 0, W_I \geq 0$$

- S1 = (568.719; 677.532) ⟷ SQ = (697.444; 341.315)

  Comparing this to the current status quo:
- **Israel would lose around €130 million,**
- **The Arabs would increase their income by some €336 million, raising overall utility by 20%.**
- **The transfer of water to the Arabs would be in the region of 536.26 hm^3, but the water actually used would be the same**

2) Nash solution with lateral payments and break-off at (0;0)

- **Assuming, that both Israel and the Arabs, can make mutual transfers of income**
- **the negotiating set will differ from that considered in the preceding case.**
- **Only solutions in which both players receive non-negative amounts and that add up in total to the maximum obtainable income will be considered negotiable.**
- the efficient solutions are situated along a line running parallel to , where the joint utility at SQ is 1038.76.

$$Max\ W_I W_A$$

$$W_I + W_A = \underset{W_I \geq 0}{Max}\left(W_I + \left[9.05355(q^A_{act})^{0.738272} - 1.11024 q^A_{act}\right]\left(1 + \frac{f^{-1}(W_I(x))}{533.359}\right)\right);$$

$$W_I \geq 0; W_A \geq 0$$

- The maximum level of joint utility is obtained at point , which is a tangential to the aforementioned parallel line.
- The point in question is Smax = (480.628; 772.421). At this point, the joint utility obtained is €1253.05, which is greater than the €1246.251 obtained in the previous Nash solution. This point is not, however, the Nash solution.
- By symmetry alone, it can be seen that the Nash solution with lateral payments is S2 = (626.525; 626,525).

3) Kalai-Smorodinsky solution with break-off at (0;0)

- Solution: the intersection between the negotiating set and the line joining the break-off point and an ideal point K = $(W_{I\,max}; W_{A\,max})$ where $W_{I\,max}$ y $W_{A\,max}$ are the maximum utilities that can be achieved by the players within the negotiating set. In the present case, K = (738.8; 976.375).

$$W_A(W_I) = \left[9.05355(q_{act}^A)^{0.738272} - 1.11024 q_{act}^A\right]\left(1 + \frac{f^{-1}(W_I(x))}{533.359}\right) \geq 0, W_I \geq 0$$

$$W_A = \frac{976.4}{738.8} W_I$$

- which gives point KS = (538.56; 711.75), The joint income produced is €1250.313 million, which is close to the amount obtained at S1(€1246.25 million) and at S2 and Smax(€1253.05 million), and it results in a gain of approximately 20% in income for the Arabs compared to the initial status quo.

4) Johnston Plan (1953-1955)

- JP = (575.79 ; 674.71) is the point in the negotiating set represented by the Johnston Plan.

- This is surprisingly close, indeed practically identical, to solution S1 = (568.72; 677.53), proving the validity of the proposal made in the Johnston Plan, which 50 years on, could still be rationally defended.

Generalized Nash solutions for two-person Bargaining Game

Players have different levels of negotiating power
Greater negotiating power more gains be obteained

$$MaxF[W_I, W_A] = [W_I - \omega_I]^{\alpha_1}[W_A - \omega_A]^{\alpha_2}$$ Such that $\alpha_1 \neq \alpha_2$

Greating Arab Negotiating Power

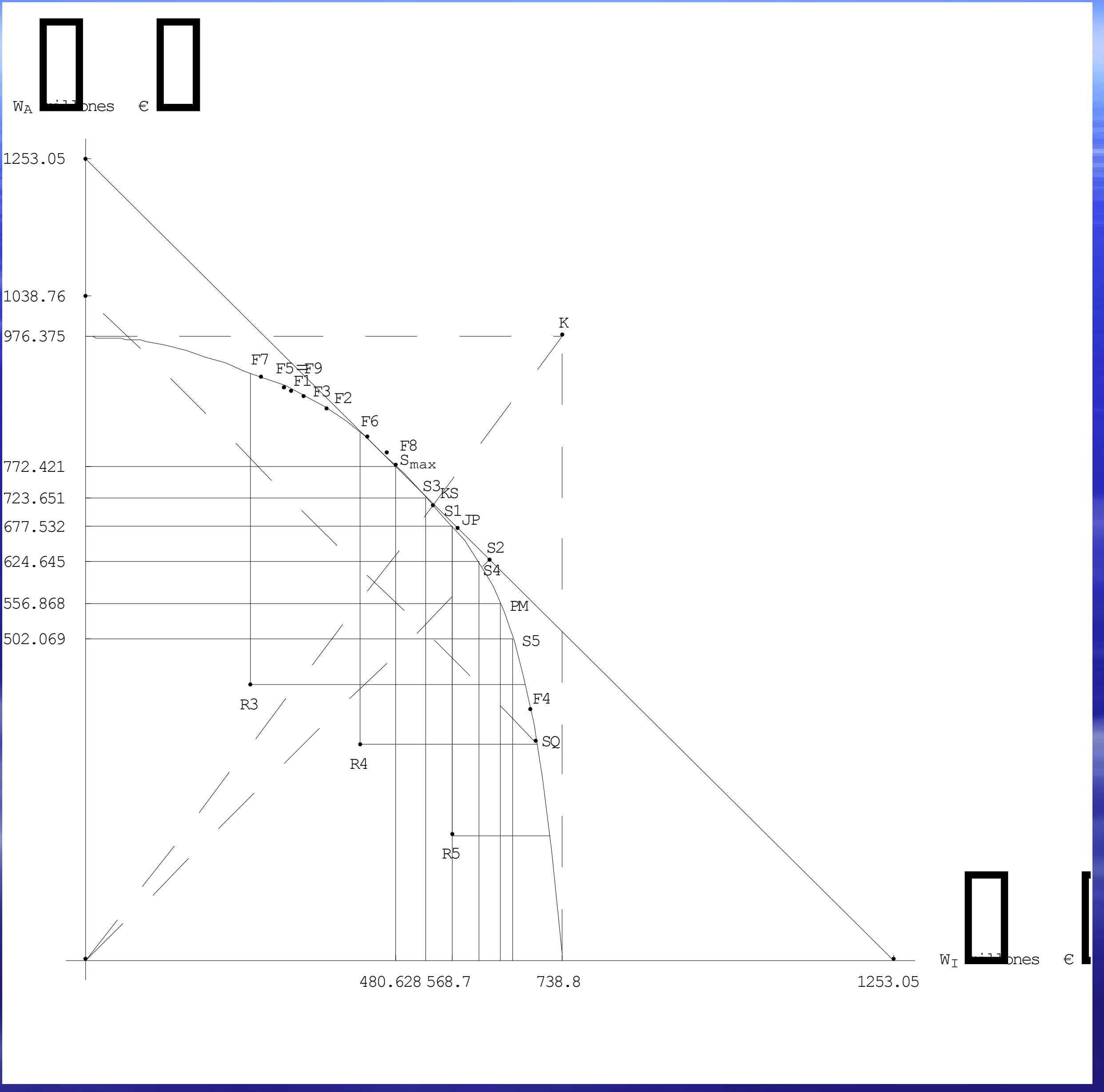
$\alpha_1 = 1$	$\alpha_2 = 1$	S1 =	$(W_I^*, W_A^*) = (568.72;677.53)$	
$\alpha_1 = 1$	$\alpha_2 = 2$	SA2 =	$(W_I^*, W_A^*) = (444.48;807.02)$	
$\alpha_1 = 1$	$\alpha_2 = 3$	SA3 =	$(W_I^*, W_A^*) = (392.90;849.20)$	
$\alpha_1 = 1$	$\alpha_2 = 4$	SA4 =	$(W_I^*, W_A^*) = (361.72;869.78)$	
$\alpha_1 = 1$	$\alpha_2 = 5$	SA5 =	$(W_I^*, W_A^*) = (338.40;882.86)$	≈ F3
$\alpha_1 = 1$	$\alpha_2 = 6$	SA6 =	$(W_I^*, W_A^*) = (318.90;892.47)$	≈ F1
$\alpha_1 = 1$	$\alpha_2 = 9$	SA9 =	$(W_I^*, W_A^*) = (268.30;913.50)$	≈ F7

Greating Israeli Negotiating Power

$\alpha_1 = 1$	$\alpha_2 = 1$	SI1 =	$(W_I^*, W_A^*) = (568.72;677.53)$	
$\alpha_1 = 2$	$\alpha_2 = 1$	SI2 =	$(W_I^*, W_A^*) = (625.14;595.15)$	
$\alpha_1 = 3$	$\alpha_2 = 1$	SI3 =	$(W_I^*, W_A^*) = (646.21;548.77)$	≈ S6
$\alpha_1 = 4$	$\alpha_2 = 1$	SI4 =	$(W_I^*, W_A^*) = (659.13;512.36)$	
$\alpha_1 = 5$	$\alpha_2 = 1$	SI5 =	$(W_I^*, W_A^*) = (668.31;481.64)$	

As might have been expected,
the players increase their gains where they have greater negotiating power.

Figure 4. Efficient points curve and solutions (millions of euros)



CONCLUSIONS AND FINAL REMARKS

- simplest Nash solution (regular with null break-off points): which is **S1 = (568.72; 677.53),** practically the same as the solution **JP = (575.79; 674.71)** for the Johnston Plan.
- The Nash solution obtained where compensation between the parties are assumed also presents very similar values and is located in the same area: **S2 (625.525; 625.525).** In this case, payment would be made by the Arabs to the Israelis, since the highest return on joint production is obtained at Smax and the Arabs should therefore compensate the Israelis in some way for the use of water. Let us note here that Arab income in this case is lower than in the S1 and JP solutions.
- The Kalai-Smorodinsky solution, **SK = (538.56; 711.75),** also falls in this area, giving the Arabs somewhat more than S1, S2 and JP.

CONCLUSIONS AND FINAL REMARKS

- Nevertheless, the overall utility of the four solutions is very similar, and all of them would result in an increase of approximately 20% compared to the current status quo.
- All of this suggests that the 1955 Johnston Plan could be revisited as a starting point for present-day negotiations. However, it would be required some adjustment to make room for modern approaches to integrated, sustainable management, but the Plan proposals appear to provide an acceptable combination of the possible, the technical and the socially desirable.