
Economics and
Operations Research in
Climate Change
Xiaowei Hu
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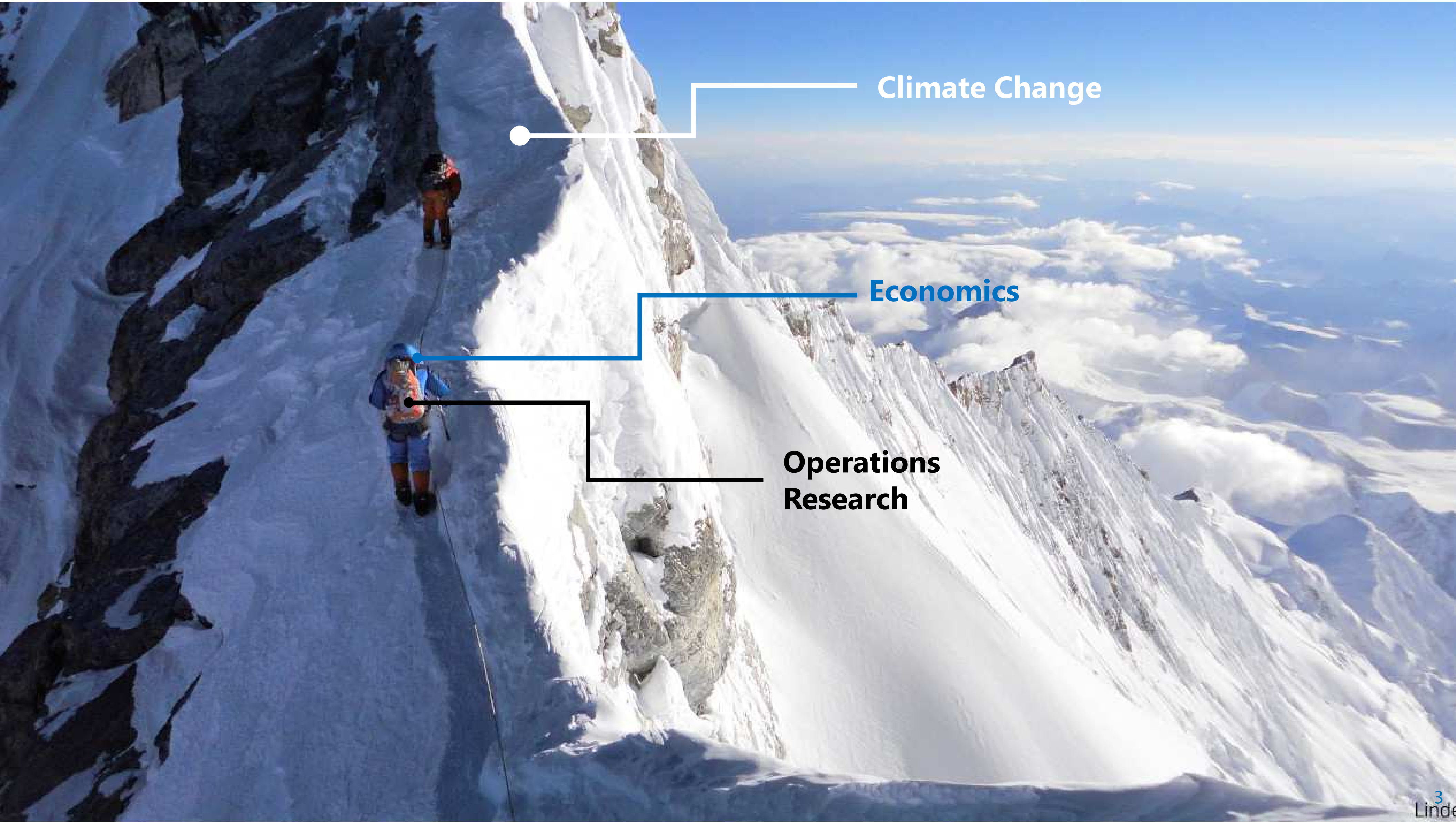
Maximize: $f(x)$

Subject to: $x \in S$


Climate Change
Economics
Operations Research

UNIVERSITY of WISCONSIN UWMILWAUKEE

INTERNATIONAL JOURNAL OF ENERGY RESEARCH

RESEARCH ARTICLE

A biofuel supply chain equilibrium analysis with subsidy consideration

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Summary

We consider a biofuel supply chain problem in which a farmer supplies two downstream refineries with nonidentical crops (corn and energy crop). The problem has been modeled as a multi leader single follower game to derive the farmer's decisions on land use as well as refineries' proposed prices to the farmer. We consider subsidizing the farmer and the refinery that uses the energy crop to study whether a subsidy plan can enhance the advanced biofuel production and meet the mandate of the Environmental Protection Agency (EPA). This mandate requires the production of 36 billion gallons of biofuel, out of which 21 billion gallons should be noncorn-based biofuel. We solve the problem under four cases based on the willingness of the farmer to sell corn to the food market as well as the availability of land expansion for her. The Nash equilibrium is derived for all cases, and parametric analyses are used to study the effect of subsidies on the profit of the players and the total social welfare of the supply chain. We observe that a government's expenditure can be offset by the increase of the social welfare under certain circumstances. We find the minimum budget requirement to meet the EPA's mandate and show that a specific budget can be distributed in different ways while obtaining the same results.

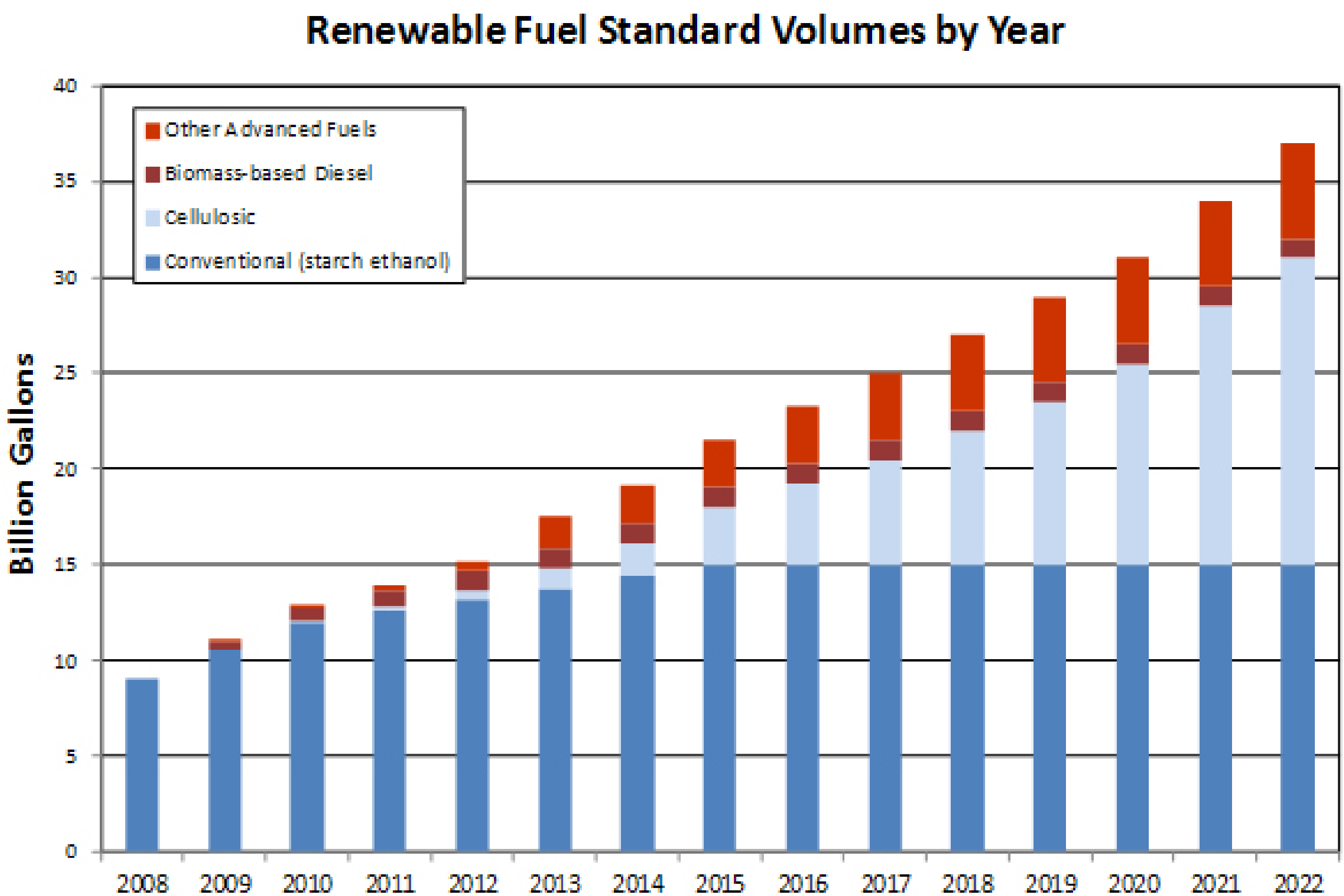
Energy Independence and Security Act of 2007

"Reduce gasoline consumption by 20% in 10 years."

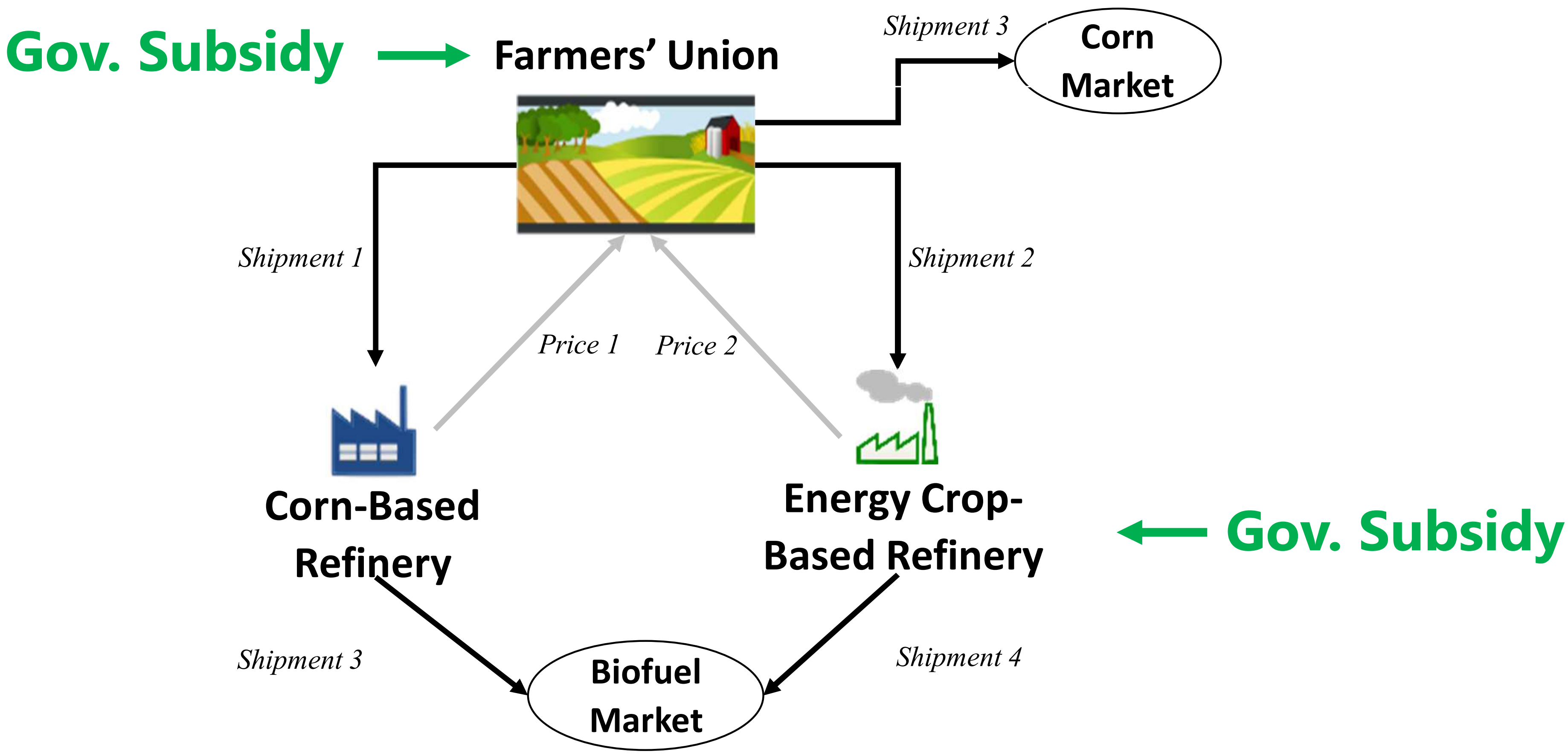
Title II - A: The Renewable Fuel Standard (RFS)

- Production objectives of biofuel
- 32 billion gallons by 2022

Title II - A: The Renewable Fuel Standard (RFS)

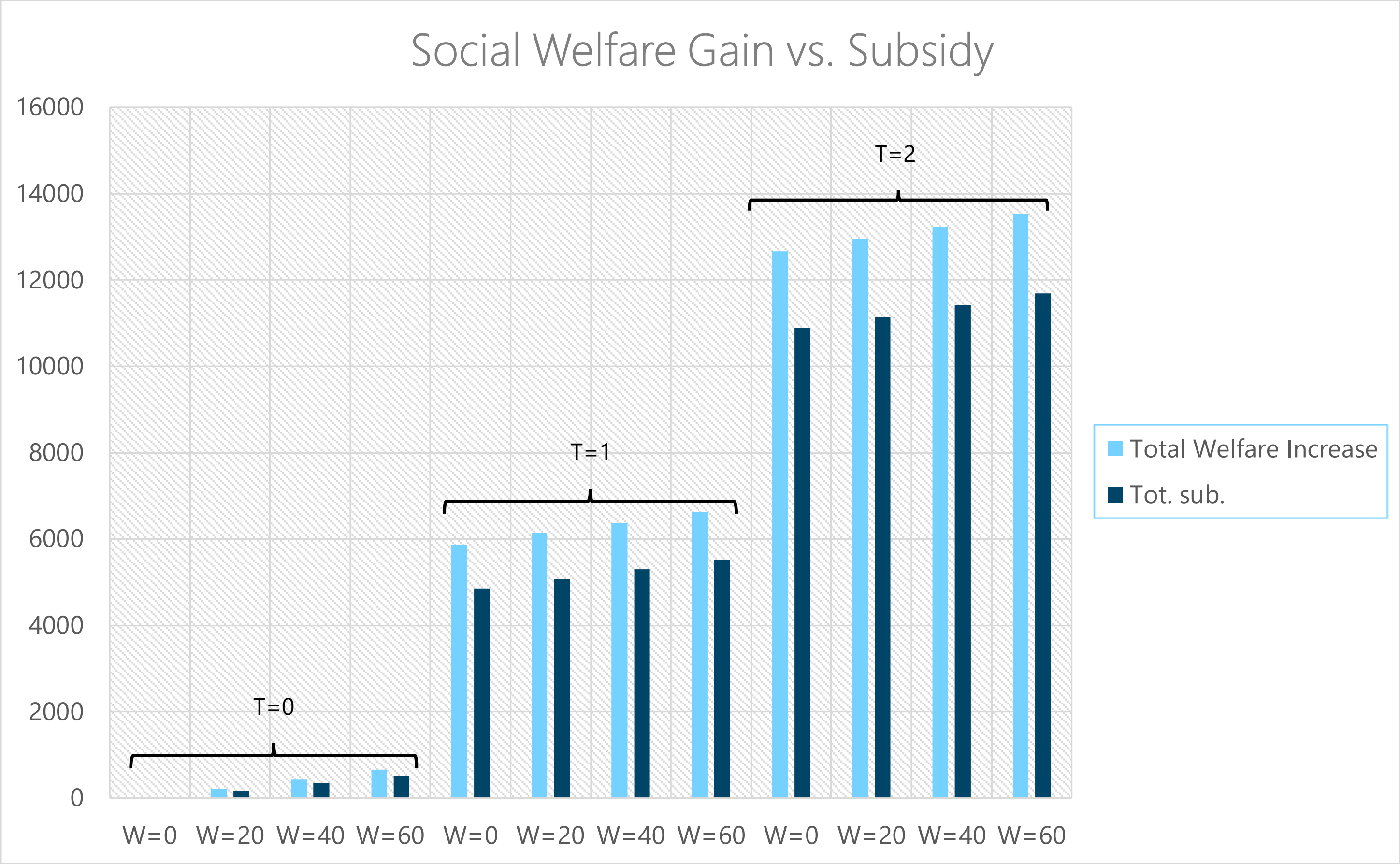


The Model



Gov. Subsidy
Farmers' Union
Shipment 3
Corn Market
Shipment 1
Shipment 2
Price 1
Price 2
Corn-Based Refinery
Energy Crop-Based Refinery
Gov. Subsidy
Shipment 3
Shipment 4
Biofuel Market

Selected Results



Paper Looks Like This

R1 and R2 announce their quote for corn and energy crop, respectively, at the same time to the farme to maximize their profit functions:

$$\max_{p_1} \pi_{R1} = P_2(\beta_1 q_1 + \beta_2 q_2)\beta_1 q_1 - p_1 q_1 - c_{R1} q_1 \quad (1)$$

$$\max_{p_2} \pi_{R2} = P_2(\beta_1 q_1 + \beta_2 q_2)\beta_2 q_2 - p_2 q_2 - c_{R2} q_2 + T\beta_2 q_2 \quad (2)$$

The farmer decides the amount of land for the food market and refineries, q_0, q_1, and q_2 to maximize her profit:

$$\max_{q_1, q_2} \pi_f = p_1 q_1 + p_2 q_2 - g_1(q_0, q_1) - g_2(q_2) + W q_2 + P_1(q_0) q_0 \quad (3)$$

$$\max_{q_1, q_2} \pi_F = (p_1 - c_c) q_1 + (p_2 - c_e + W) q_2$$

$$q_1 + q_2 \le Q$$
$$q_1, q_2 \ge 0$$

Domain	$(\lambda_1, \lambda_2, \lambda_3)$	Conditions	Farmer's BR	λ_i
1	(0, 0, 0)	$p_2 - c_e + W + p_1 - c < 2cQ$	$q_1^* = \frac{p_1^* - c_c}{2c}$ $q_2^* = \frac{p_2^* - c_e + W}{2C}$	$\lambda_1 = 0$ $\lambda_2 = 0$ $\lambda_3 = 0$
2	$(+, 0, +)$	$p_2 - c_e + W - p_1 + c_c > 2cQ$	$q_1^* = 0$ $q_2^* = Q$	$\lambda_2 = 0$ $\lambda_1 = \lambda_3 - p_1'$ $\lambda_3 = p_2' - 2cQ$
3	$(0, +, +)$	$p_1 - c_c - p_2 + c_e - W > 2cQ$	$q_1^* = Q$ $q_2^* = 0$	$\lambda_1 = 0$ $\lambda_2 = \lambda_3 - p_2'$ $\lambda_3 = p_1' - 2cQ$
4	$(0, 0, +)$	$p_2 - c_e + W + p_1 - c \ge 2cQ$ $p_2 - c_e + W - p_1 + c \le 2cQ$ $p_1 - c - p_2 + c_e - W \le 2cQ$	$q_1^* = \frac{p_1 - c_c - \lambda_3}{2c}$ $q_2^* = \frac{p_2 - c_e + W - \lambda_3}{2c}$	$\lambda_1 = \lambda_2 = 0$ $\lambda_3 = \frac{p_1' + p_2' - 2cQ}{2}$

Proposition 2.1 *In the absence of food market and with constant marginal cost structure, the NE are*

i) if $p_1^{\max} - c_c > p_2^{\max} - c_e + W$, $p_1^* = p_2^{\max} - c_e + W + c_c + \varepsilon$, $p_2^* = p_2^{\max}$

$$q_1^* = Q,\ q_2^* = 0$$

ii) if $p_1^{\max} - c_c < p_2^{\max} - c_e + W$, $p_2^* = p_1^{\max} - c_c + c_e - W_c + \varepsilon$, $p_1^* = p_1^{\max}$

$$q_1^* = 0,\ q_2^* = Q$$

iii) if $p_1^{\max} - c_c = p_2^{\max} - c_e + W$, $p_1^* = p_1^{\max}$, $p_2^* = p_2^{\max}$

$$q_1^* = q_2^* = \frac{Q}{2}$$

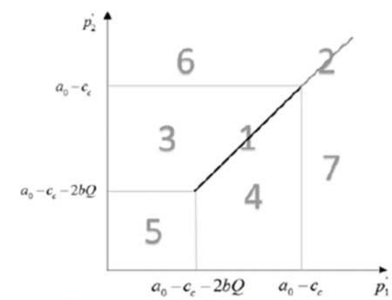


Figure 2.7 Domains of the price offers' space (p_1', p_2') in Case 3

$$\max\ \pi = (a - b\sum_{i\in I}\beta_i q_i)(\sum_{i\in I}\beta_i q_i) - \sum_{i\in I}(c_i^1 + c_i^2 + c_i^R) q_i + (a_0 - b_0 q_0) q_0 - c^{e1}(\sum_{j\in J} q_j + x)^2 - c^{e2}(\sum_{k\in K} q_k)^2 + \sum_{i\in I} W_i q_i - \sum_{i\in I} c_i^f q_i - c_i^f q_0$$

$$+\sum_{i\in I} T_i \beta_i q_i + b(\sum_{i\in I}\beta_i q_i)^2 / 2 + b_0 q_0^2 / 2$$

s.t. Linear version of EPEC (53)

“

All models are wrong. Some models are useful.

- George E. P. Box (Professor of Statistics, UW-Madison)

Critiques of This Study

- Focuses on stakeholders' decisions
- Connects the stakeholders' interventions
- Captures the large socio-economic features

- Narrow variety of interventions
- Lack of details
- Cannot be used for prediction

Critiques of Economic Models

- Normative bias
- Assumptions of rationality
- Equilibrium theory
- Incomplete

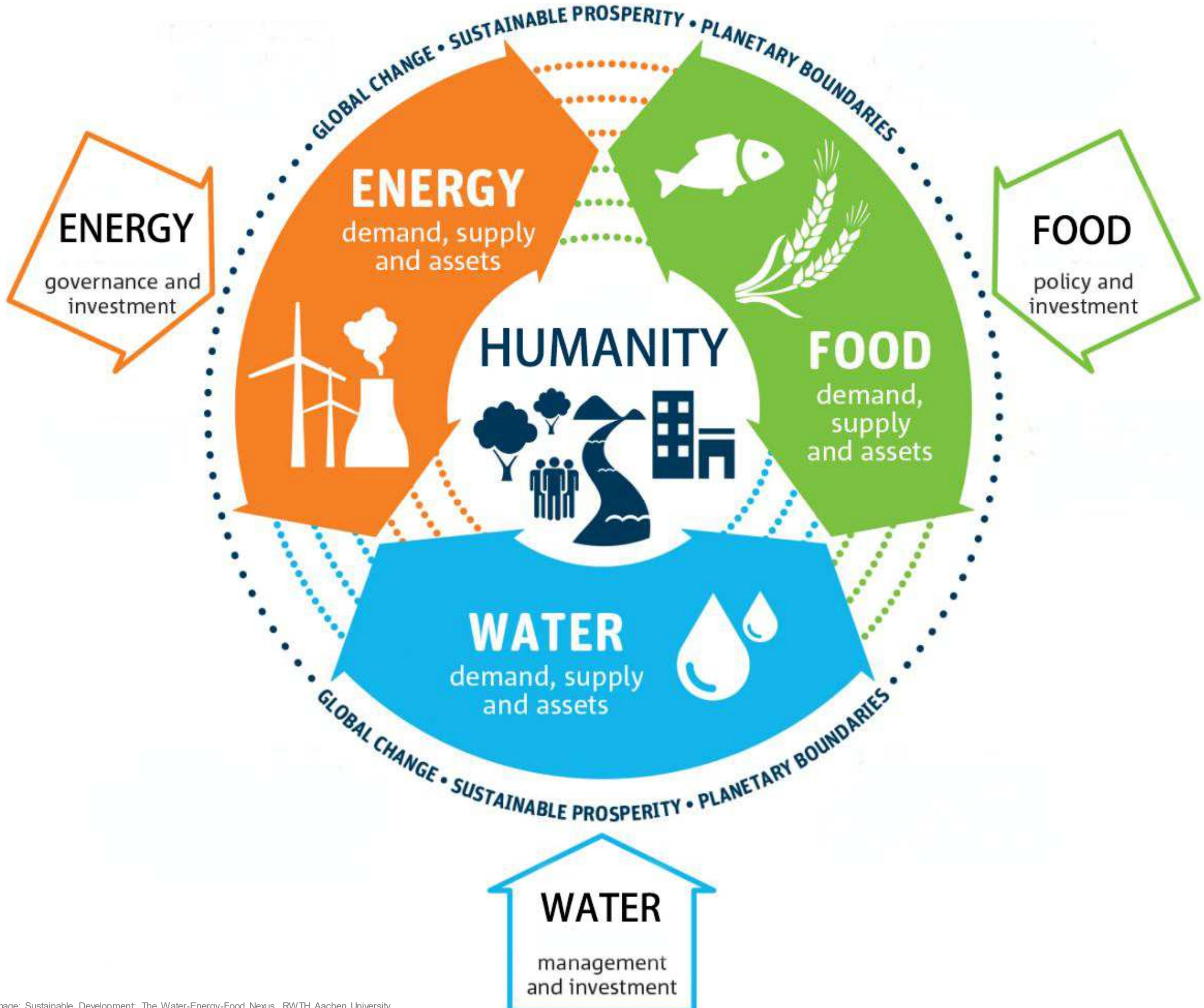
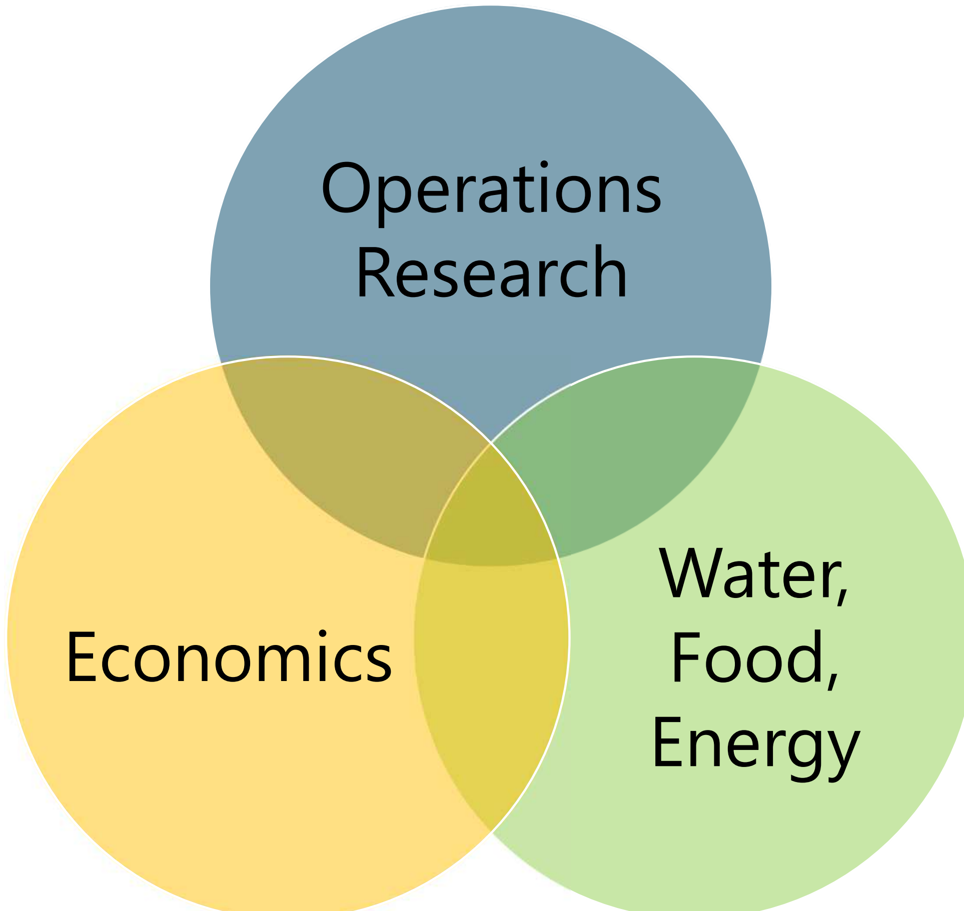


Image: Sustainable Development: The Water-Energy-Food Nexus. RWTH Aachen University.
http://www.iwa-network.org/learn/sustainable-development-the-water-energy-food-nexus/

Appendix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Water, Food, Energy

Four Generations of Biofuel