How the rebound effect impacts the reconciliation of sustainable irrigation water management and agricultural export development in Tunisia

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Motivation

Tunisia is among the **20 most water–stressed countries** globally (Aqueduct 4.0, 2023)

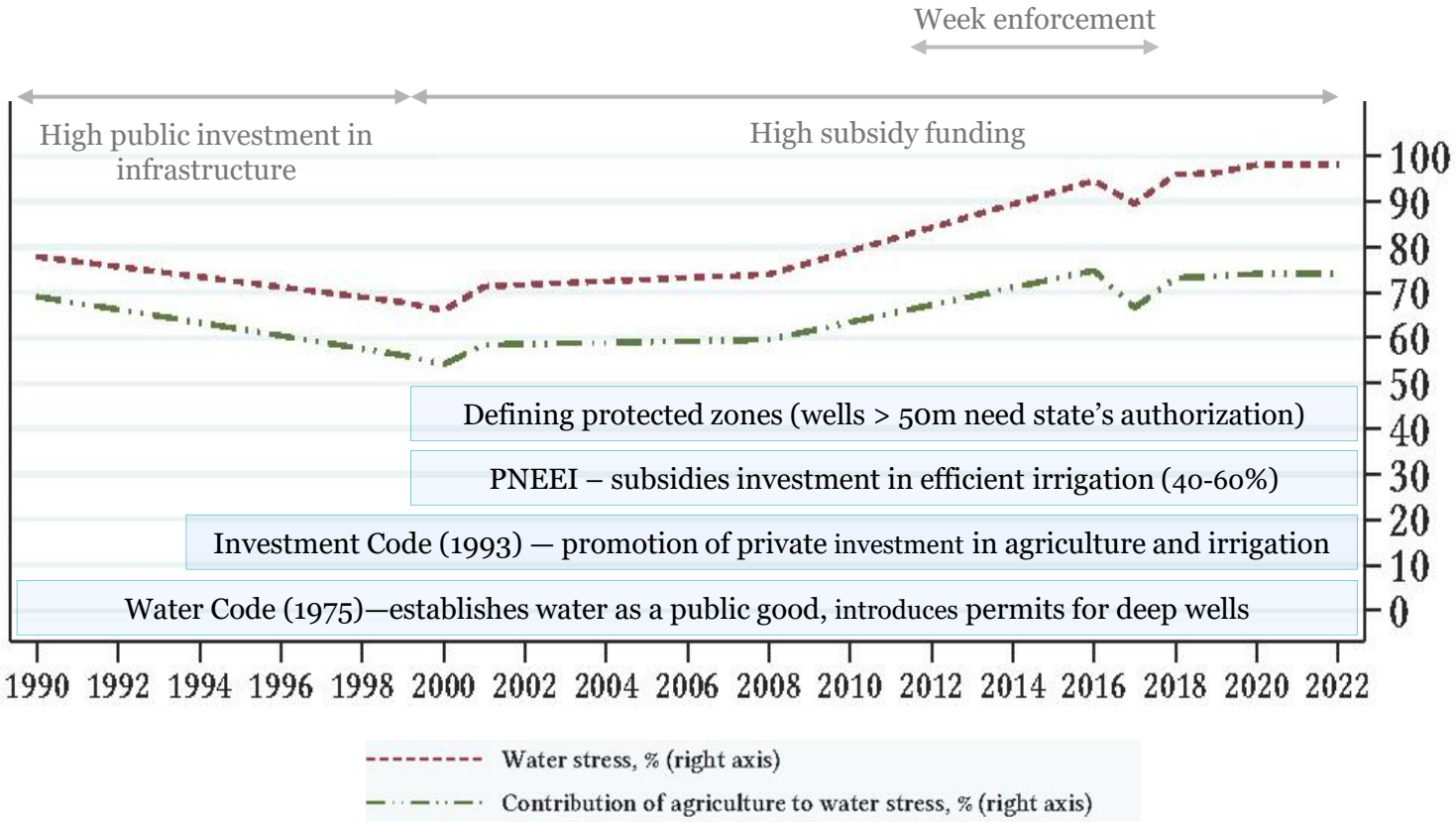
An economically **important agricultural sector** (10% of GDP) that **heavily relies on irrigation** (80% of water supply) (Aqueduct 4.0, 2023)

Trade and agriculture policies incentivize the **export of high–added–value crops** (Kuper, 2023)

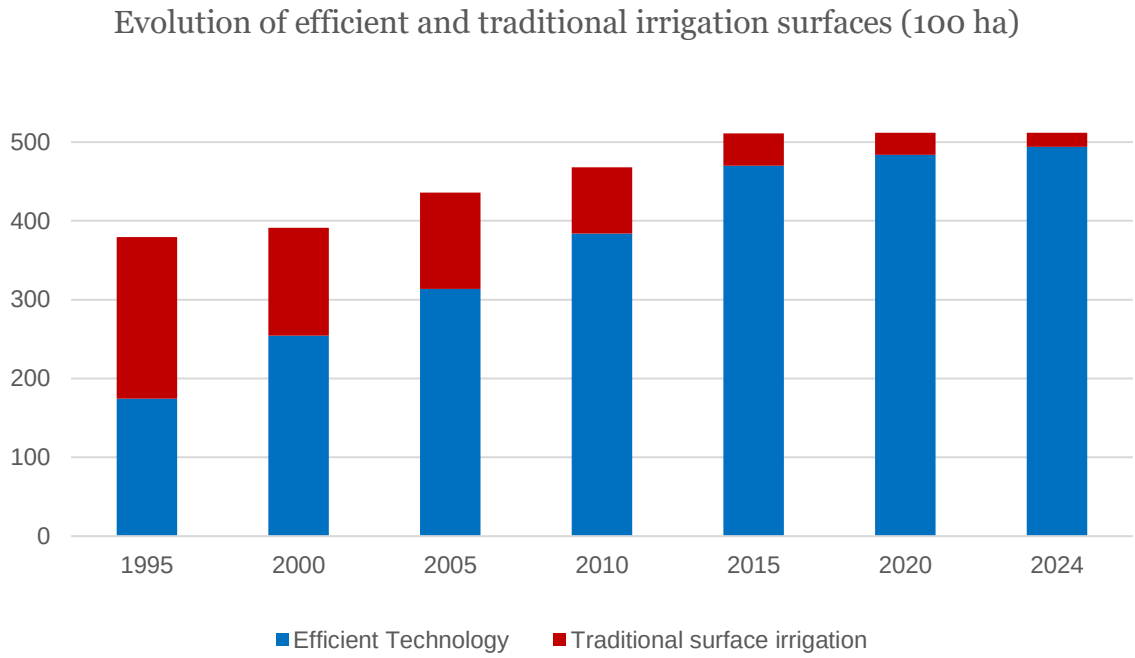
On average, every year 43% of blue water footprint is used to produce **exported** crops (mainly dates and olives) (Kekli et al, 2025)

→ Paradox ?

Motivation


Week enforcement
High public investment in infrastructure
High subsidy funding
Defining protected zones (wells > 50m need state's authorization)
PNEEI – subsidies investment in efficient irrigation (40-60%)
Investment Code (1993) — promotion of private investment in agriculture and irrigation
Water Code (1975)—establishes water as a public good, introduces permits for deep wells
100
90
80
70
60
50
40
30
20
10
0
1990 1992 1994 1996 1998 2000 2002 2004 2006 2008 2010 2012 2014 2016 2018 2020 2022
Water stress, % (right axis)
Contribution of agriculture to water stress, % (right axis)

Motivation



Evolution of irrigated land and efficient irrigation adoption from 1995 to 2024

Source: Authors' elaboration based on data from FAO STAT, Blinda (2009) and BPEH (2021, 2023)

Motivation

Authors (Bachta & Elloumi, 2005; Frija, 2009) argue that:

These subsidies have **not reduced** overall irrigation water demand—in fact, they have often produced the **opposite effect**.

They attribute this outcome to several **plausible factors**:

→ improper use of the technologies by farmers (Kuper, 2023)

→ poor maintenance leading to leaks in irrigation systems (Ferchichi et al, 2018)

→ very low water tariffs (Elloumi, 2016)

→ subsidy not coupled with restrictions on irrigated land expansion (Elloumi, 2016)

In the economic literature, failure of efficiency gains is often explained by :

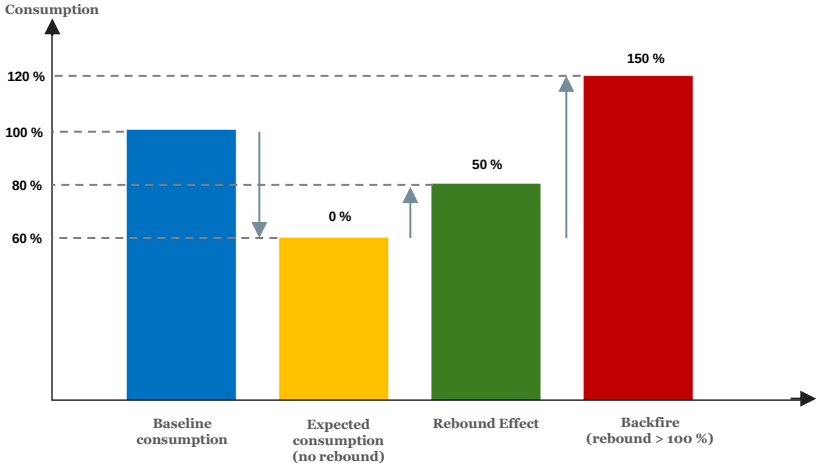
Rebound effect: The behavioral and market response to an improvement in resource efficiency that reduces—or even offsets—the expected resource savings that would have occurred if behavior had remained constant (Gillingham, 2014).

Literature review : The (Water) Rebound Effect

The rebound effect is measured against the savings we would expect from an efficiency improvement (Gillingham, 2014).

If irrigation technology becomes 10% more efficient → we might expect water use to fall by exactly 10%.

The rebound effect is the share of those savings that is lost because of change in behavior (Gillingham, 2014).



We call **backfire** (or **Jevons Paradox**) when resource use (irrigation) efficiency leads to a higher overall consumption.

China (Hetao district): irrigation efficiency rose from 20% → 53%, but water withdrawals rose sharply. WRE averaged 344%, a clear backfire (**Xu & Song, 2022**).

Australia (Murray-Darling Basin): farmers receiving irrigation subsidies extracted 21–28% more water than those without. Drivers: expansion of irrigated land, crop changes, and fuller use of rights (**Wheeler et al., 2020**).

This Paper

1. Introduces the rebound effect to the Tunisian irrigation context

- First attempt (to our knowledge) to apply rebound theory to Tunisia or North Africa.
- Moves beyond descriptive claims ("more efficient irrigation → more irrigated area") to analyze the underlying economic logic.

2. Applies microeconomic theory to farmer behavior

- Apply consumer theory (substitution + income effects) to farmer decisions.
- Show how efficiency gains can reduce the effective cost of irrigation and trigger behavioral adjustments.

3. Connects micro behavior to the broader system

- Connect farmer responses to regional irrigation expansion and changes in cropping patterns.
- Relate rebound effects to Tunisia's specialization in high-value, export-oriented irrigated crops (dates, olive oil, vegetables).

Research Question & Hypotheses

To what extent has the adoption of efficient irrigation technologies—supported by public subsidies—led to a rebound effect in Tunisia's agricultural water use, through expansions in irrigated area or increases in cropping intensity?

Hypotheses

Where is the rebound effect most likely?

In regions where efficient irrigation was a "game changer"

→ Lower irrigation cost

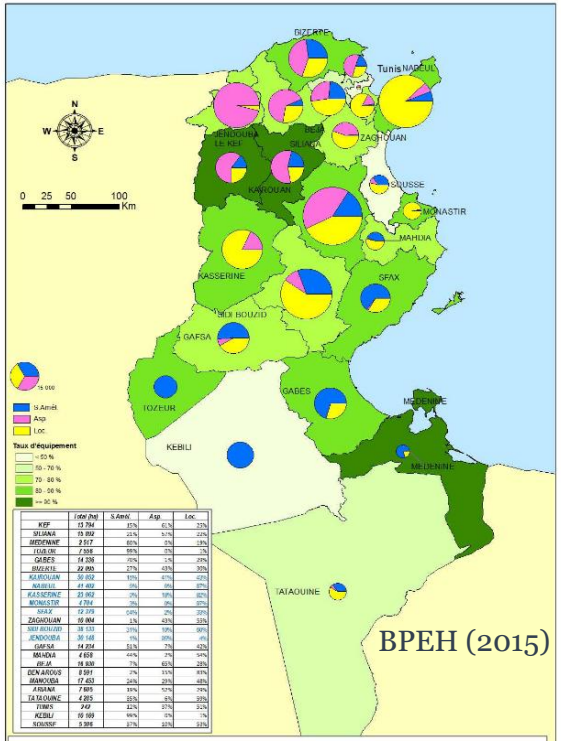
→ New high-value / water-intensive crops become viable

→ Expansion of irrigated land becomes profitable

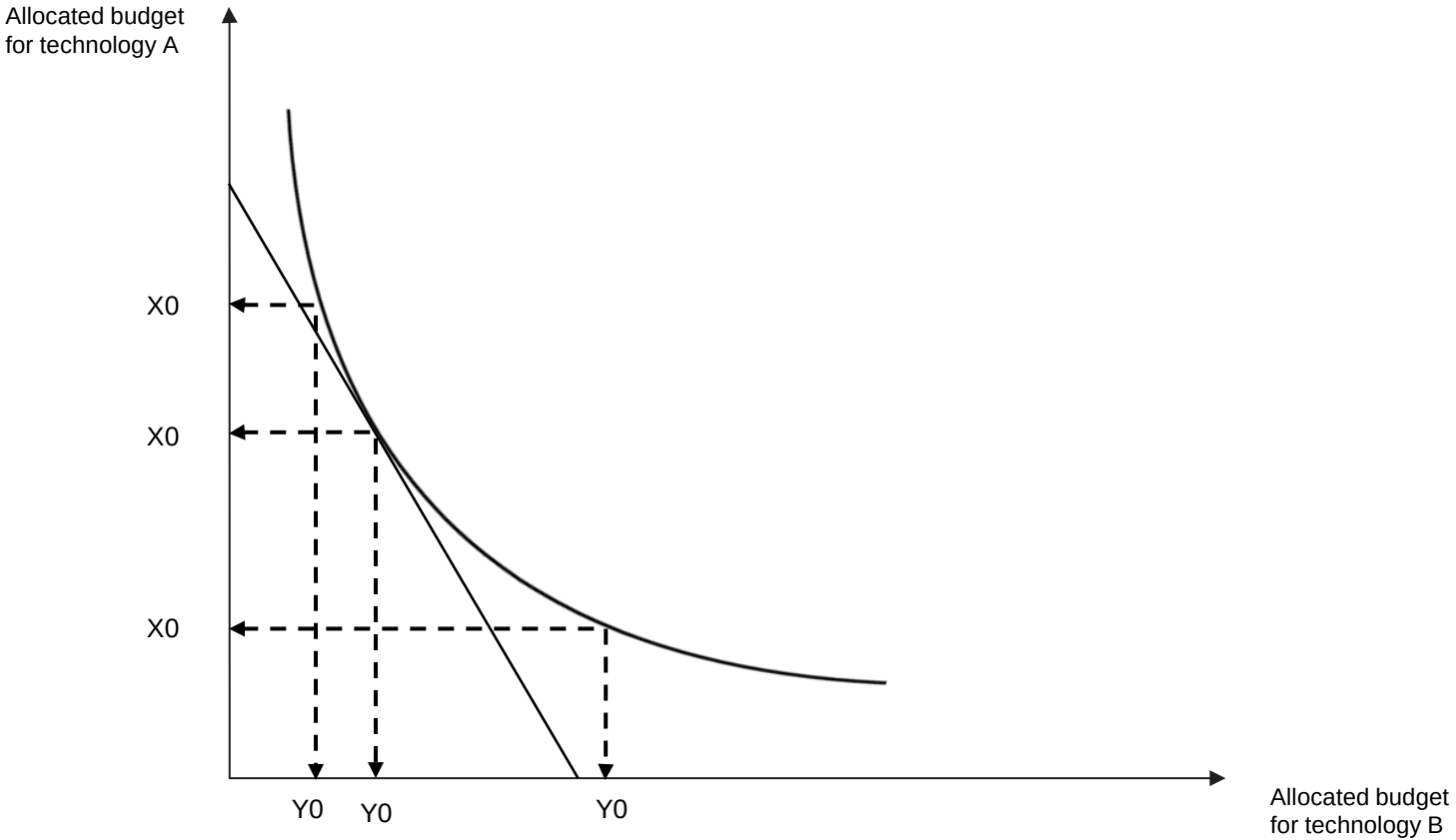
Where is rebound unlikely?

→ Mainly in the South, where irrigation expansion is (most likely) driven by deep wells, not by efficiency gains

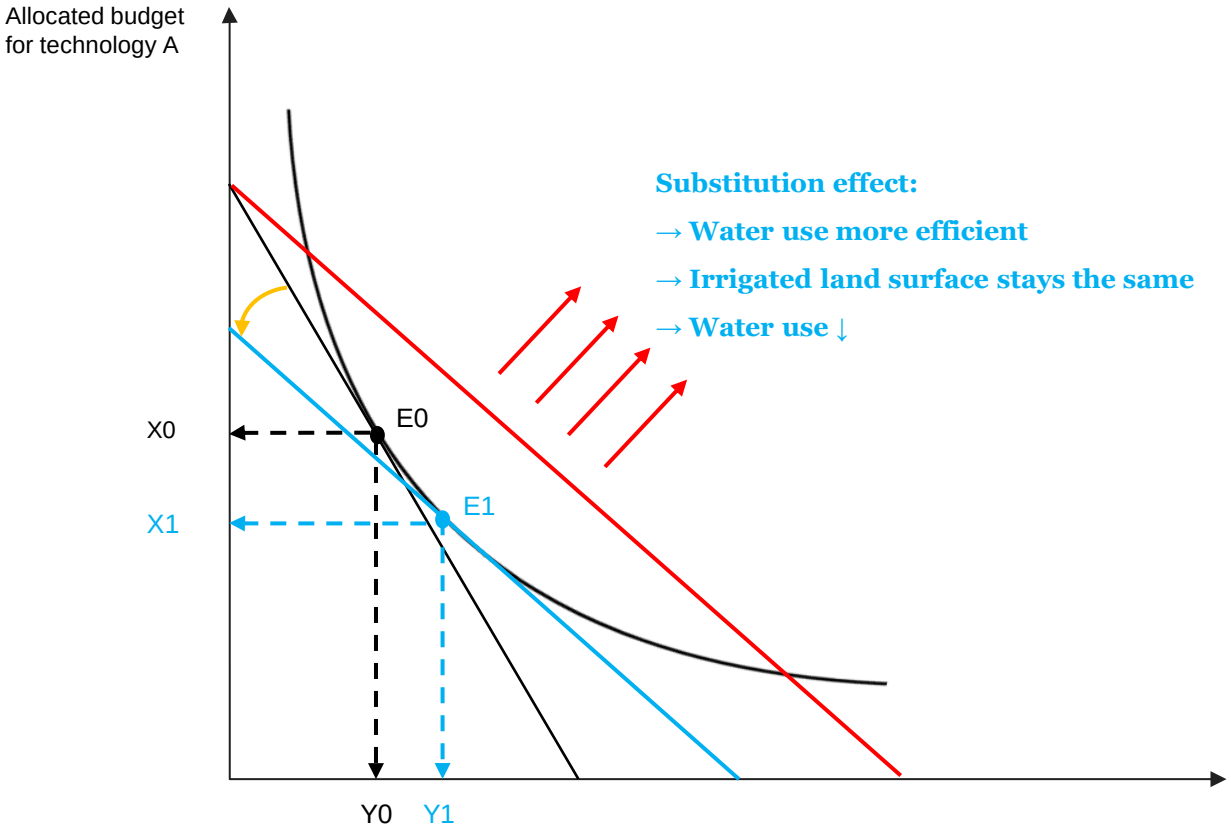
→ Here, water availability (not technology) explains expansion



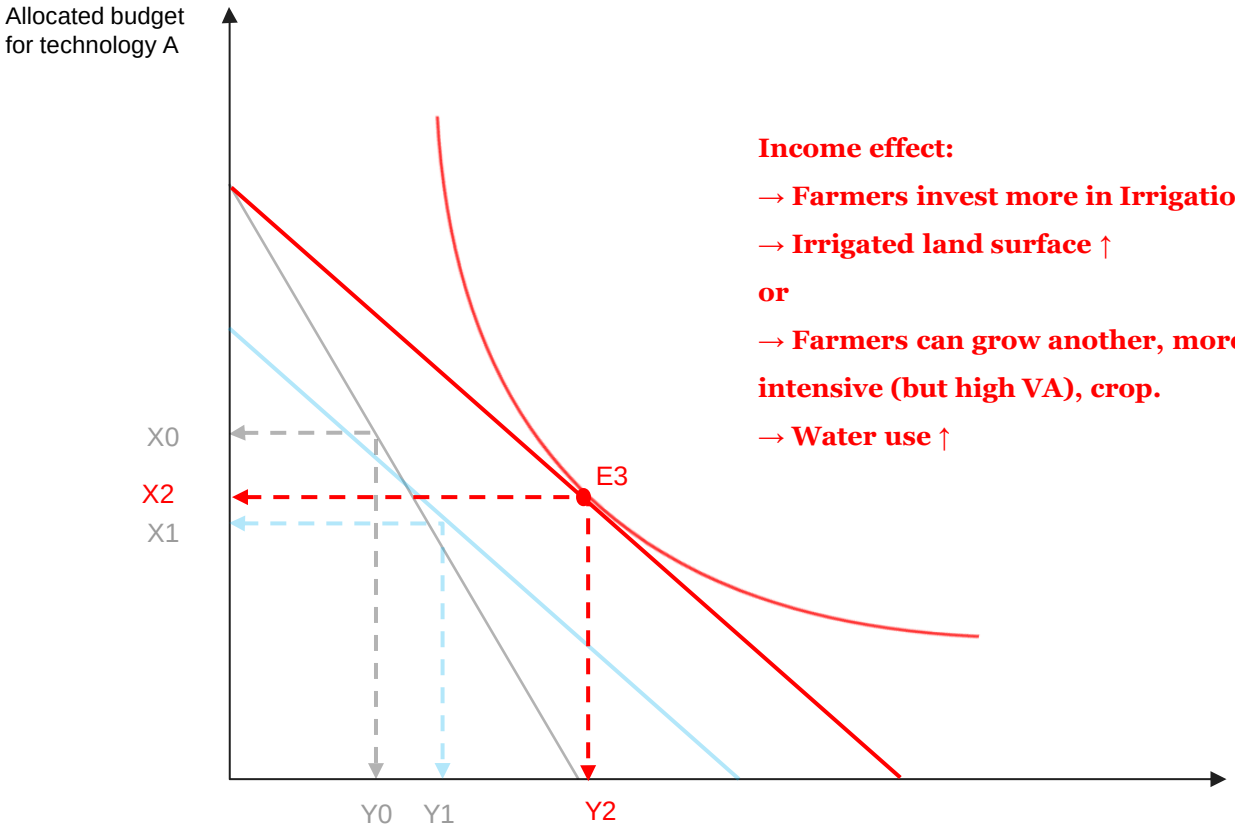
Conceptuel Framework



Conceptual framework



Conceptuel Framework



Income effect:

→ Farmers invest more in Irrigation

→ Irrigated land surface ↑

or

→ Farmers can grow another, more water intensive (but high VA), crop.

→ Water use ↑

How This Literature Review Supports My Research

→ **Defines the conceptual tools**

→ **Guides fieldwork design**: Identifies regions, crops, and mechanisms to investigate micro-level farmer behavior and irrigation decisions.

→ **Links micro dynamics to policy**: Helps evaluate how governments" interventions (subsidies, investments in irrigation) may influence irrigation expansion.

→ **Prepares the macro/trade analysis**: Provides the foundations to later model how agricultural specialisation and trade interact with irrigation water demand.

Questions ?

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