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# Blending Experimental Economics and Living Laboratories in Water Resource Management

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## Abstract

The increasing pressure on global water supplies from over-exploitation, drought, and pollution necessitates efficient and sustainable water management. Integrated Water Resource Management (IWRM) strategies have shown effectiveness in decision support, but a deeper integration of economic and participative methodologies is needed. This research reviews the core characteristics and directions of experimental economics and Living Labs (LLs) and it aims to address three research questions, namely, how the participatory, real-world environment of living laboratories can be incorporated into the controlled, hypothesis-driven nature of experimental economics; what is the significance of behavioural insights that are derived from experimental economics in the design and implementation of living labs; and how these two approaches can be merged under one framework. The focus of this paper is the improvement of water resource management through collaborative and stakeholder-driven innovation. Living Labs provide authentic environments for co-creation, allowing scientists and stakeholders to address water-related issues like supply, demand, and shortage. These environments connect controlled experimental conditions with real applications, providing comprehensive insights into behavioural reactions and policy formulation. LLs can enhance and be strengthened by economic methodologies, particularly in water valuation through integrated frameworks accounting for environmental externalities and opportunity costs. Finally, this paper shows that integrating behavioural insights and experimental approaches within LLs improves the external validity of experimental economics by putting interventions in real-world settings.



**Key words:** Behavioral Microeconomics, Field Experiments, Water Resource Management; Water Supply and Demand, Analysis of Collective Decision-Making

# 1. Introduction

With the ever-increasing strain placed on global water resources – over-exploitation, drought, pollution (Gerten et al. 2020; Jägermeyr et al. 2017; Loucks & van Beek 2017; Navarro-Ortega et al. 2015; Vanham & Leip 2020), effective and sustainable water resource management has become more crucial than ever. As water not only plays a central role in supporting life on earth, but also in meeting sanitation needs, energy generation, food production, supporting economic activity and many instances transportation, it functions as both a public and economic good (UN 2014). Thus, the sustainable water resource management aims to strike a delicate balance to achieve water security in the face of conflating stresses and competing and competing demands. Over the last few decades, Integrated Water Resource Management (IWRM) approaches have proven to be one of the most effective approaches available to managers in the water sector, as such approaches bring together a broad range of knowledge and methodological approaches from various disciplines in order to provide sound decision support for practitioners and policy-makers alike (Giupponi & Sgobbi 2008; Qi & Altinakar 2011). "Integrated water resources management is based on the equitable and efficient management and sustainable use of water and recognises that water is an integral part of the ecosystem, a natural resource, and a social and economic good, whose quantity and quality determine the nature of its utilisation" (GWP, 2020). That said, while current IWRM approaches have made great strides towards the integration of scientific input from the physical sciences, there is still room for closer integration of economic methods and critically participatory methods that seek to incorporate stakeholder input (Akinsete et al. 2022; Giupponi & Sgobbi 2013).

The greatest challenge in terms of water resource management is accounting for the human-factor. While nature runs its course through environmental cycles – precipitation, groundwater recharge, surface runoff etc, accounting for the impact of human activity, and more importantly the mechanisms of real-life human decision-making are central to inform effective, human-centric approaches to water resource management (Adams 2021). In particular, insight into the value that society places on its water resources are necessary to design robust water management measures and appropriate economic exchange mechanisms to support the allocation of water resources and the associated costs and benefits among stakeholders (Koundouri, 2002; Koundouri, 2004; Koundouri & Dávila, 2015; Koundouri & Pashardes, 2002).

Despite the importance of carefully considering the hydrological and environmental as well as the socio-econmic parameters of water resource management through integrated science-based policy and decision support tools, the uptake of such tools by policy and decision makers is limited due to the fact that such stakeholders are unlikely to use tools they are unfamiliar with and do not deem trustworthy (Adams 2021). In order for these integrated scitentific approaches to be effectively embedded in the descision-making process, it is important to incorporate methods which encourage stakeholder participation throughout the process. In other words, stakeholder participation through science-fed collaborative processes embeds co-determined inputs developed by scientists and stakeholders during periodic meetings(Adams 2021; Gupta H.V. DS Brookshire Tidwell V. Boyle D. 2011; Liu et al. 2008).

A tool to integrate stakeholders' input in the development of innovative solutions are the Living Labs. As defined by ENoLL (2024), Living Labs are open innovation ecosystems that are founded on a systematic user co-creation approach. This approach integrates research and innovation activities in communities and/or multi-stakeholder environments, positioning citizens and/or end-users at the center of the innovation process. They serve as real-life test and experimentation environments, encouraging open innovation and co-creation among the selected actors. Living Labs are both a research methodology and tool, bringing together key stakeholder including scientists, decision-makers, industry experts (e.g., water managers) and users in a co-creation and co-involved innovation processes which includes testing, experimentation, and evaluation within real-world contexts (Delina, 2020; Leminen et al., 2017; Schuurman et al., 2009). Living Labs (LLs) provide a space, where participants collaborate co-create, test, and refine solutions to complex societal challenges. Living laboratories, in contrast to conventional experimental environments, prioritize iterative processes, co-creation, and real-world complexity. Participants are not solely subjects; they are active participants in the innovation process.

The primary distinction between Living Labs and other types of experiments that involve stakeholders, such as Natural Experiments and Randomized Controlled Trials (RCTs), is that the objective of a Living Lab is not to assess the effectiveness or impact of a new program or policy. Rather, it is to enhance the decision support tools by enabling stakeholders to participate in the process, collaborate, and co-create an improved version of the tool that considers the human factor. Although LLs, RCTs and natural experiments can be conducted in real-world settings, their methodologies and objectives are significantly different. Both RCTs and natural experiments investigate causal relationships. RCTs are dedicated to conducting comprehensive statistical testing to determine "what works" by evaluating specific interventions under controlled conditions using a randomized design, such as testing the effectiveness of an incentive program and randomly assigning households to receive or not receive the incentives. Natural experiments, on the other hand, investigate causal relationships in settings where exogenous factors (e.g., policies, disasters) induce "as-if" randomization, such as evaluating the impact of an intervention in one location and using a control group a location where the intervention is not implemented.

In contrast, LLs focus is not restricted to causal analysis; it also includes systemic fit, acceptability, and usability by attempting to dynamically adapt and co-develop solutions, frequently incorporating feedback loops and diverse stakeholder perspectives. In LLs, stakeholders are carefully chosen and asked to work together to come up with, test, and improve solutions to problems facing society. For example, LLs could gather residents, local authorities, and researchers to collaborate and enhance a new decision support tool that a water management authority intends to implement in order to more effectively manage and allocate water resources. In an LL, stakeholders are carefully chosen to guarantee that they are not only "interested" in the process, but also significant in terms of the extent to which they are influencing or being influenced by the new tool. On the other hand, RCTs use random assignment of participants to eliminate selection bias and compare results, while natural experiments create control groups by considering natural events or policies being studied (*Table* 1). Click or tap here to enter text.LLs not only bridge the gap between scientists and stakeholders, but they also provide a means to elicit qualitative insights in on relevant water management issues such as supply (Hirshleifer et al. 1969), demand (Franks 2002) and scarcity (Olmstead 2010). Such areas of focus may then be further investigated utilizing experimental economic methods.

*Table 1 - Key differences between Living Labs, Randomized Controlled Trials and Natural Experiments*

| Feature | Living Labs | RCTs | Natural Experiments |
|---|---|---|---|
| Objective | Innovation, usability testing, and co-creation | Efficacy testing and causal analysis | Leveraging outside factors for causal analysis |
| Control | Limited; real-world complexity | High; tightly controlled | Moderate; depends on context |
| Randomization | Not always used | Essential | Mimicked by external factors |
| Stakeholder Role | Active participants in design and testing | Subjects in a controlled experiment | Observational subjects |
| Adaptability | Iterative and flexible | Fixed protocol | No direct intervention |
| Scope of Analysis | Broad (causal, behavioral, systemic) | Narrow (causal effects) | Narrow (causal effects) |

Experimental economics relies on an established methodological toolbox to provide evidence-based insights into individual and collective decision-making, as well as strategic interactions between individuals and groups. At heart of the method is creation of controlled settings, keeping potential confounding variables fixed between groups under consideration. Varying a single aspect of interest, one may attribute differences in participant's behavior to this aspect. This approach grants causal conclusions (internal validity; (Lonati et al. (2018)). Extensive control, however, comes at the cost of reduced external validity. The gap separating controlled designs and 'real life' likely explains systematic differences between lab settings and natural environments (Galizzi & Navarro-Martinez 2018) questioning whether lab studies may truly provide quantitative conclusions (Loewenstein 1999). However, the linchpin of empirical findings is their applicability in real-life, as economics aims to inform about the best course of action. Consequently, field experiments alleviate this issue by moving investigations from the lab to more realistic contexts (Harrison & List 2004). However, the distinction between lab and field is not necessarily synonymous with a trade-off between internal and external validity (Lonati et al. 2018) experimenters applying scientific rigour and careful designs may succeed to preserve both also in field settings (Harrison & List 2004).

When it comes to studies that concentrate on the environment in general and water resources in particular, there are three basic sorts of trials. The first category investigates the ways in which the specific behavioural characteristics of individuals might have an impact on the value that society places on resources and the environment. Extending environmental valuation models by incorporating the affective value of natural resources (López-Mosquera & Sánchez 2011; Welsch & Kühling 2009) and taking into account cognitive biases like myopic temporal discounting (Clot & Stanton 2014; Weber 2010), gain-loss discrepancies (Jang et al. 2020; Ölander & Thøgersen 2014) and suboptimal emotional forecasting (Nisbet & Zelenski 2011) are all potential ways to enhance environmental valuation models. Specifically with regard to water resources, such as the readiness to pay for the protection of water resources, as well as the role of use and non-use elements (Halkos & Matsiori 2014). Taking a look at the impact that institutions and incentives have on decisions and outcomes is the subject of the second category. Specifically, studies investigate many aspects of water market management, such as the management of water resources by markets García-Gallego et al. (2012) and the optimal characteristics of water market design (Garrido, 2007).According to Cardenas (2000), the third category investigates the social issues or externalities that are associated with public goods and resources that are taken from a common pool. This category has direct relation to the management of resources and the environment, particularly the management of shared resources. The purpose of these research is to get an understanding of the impact that individual activity has on the value of resources and the circumstances of the environment.

Scientists strive to reap the benefits of observing behaviour in the natural setting while maintaining some control over explanatory factors, which leads to more collaborative efforts with outside parties (Levitt & List 2009). LLs have the potential to facilitate this gap-bridging between lab and field. Examples of water-specific experimental economics studies supported by LLs include feedback on water use (enabled by smart meters) results that resulted in a long-term 8% reduction of volumetric water consumption among almost 50% of the households, with the effects persisting for over two years after the program's start, especially for the households receiving sub-daily smart meter information (Cominola et al. 2021). The quantitative results of the study raise further qualitative questions that could be addressed by the Living Labs – e.g. the reasons behind the remaining half of the households not showing any savings (such as the lack of engagement with the feedback or long-formed water consumption habits), the success factors of the saving households (such as social responsibility or money savings). Thereby, the LLs provide further insight into the results of the behavioural experiments via an iterative process and producing more robust outputs to support the establishment of appropriate economic arrangements, the success of which are largely determined by stakeholder engagement processes (World Bank 1999).

Despite approaches towards the integration of such economic and stakeholder engagement processes in the field of water management remaining in their infancy, the co-developmental nature of these approaches helps promote a closer and more transparent working relationship between the various actors in the water management sector. Furthermore, in the broader sense, facilitate a system-wide shift towards greater sustainability, social equity, and inclusive policy development within water management (Hermans et al. 2006; Hossain et al. 2019; McPhee et al. 2021; Voytenko et al. 2016). The paper is organized as follows: sections 2 and 3 present the primary attributes of the two methodologies and conduct a literature review of the most prevalent methodologies and trends that these approaches employ. Section 4 explores the interconnection between Experimental Economics and Living Labs and establishes a new framework that offers concrete examples of how these approaches could be interconnected.

## 2. Experimental Economics and water resource management

The following studies illuminate various factors that shape Willingness to Pay (WTP) for environmental goods such as water, alongside socio-economic issues like the undervaluation of natural resources in key industries, such as manufacturing. (Das et al. 2023) provide a comprehensive review of water valuation metrics in the manufacturing sector, arguing that traditional approaches—centered on the direct cost of water—substantially underestimate its broader economic and environmental value. They propose a more comprehensive valuation framework that incorporates opportunity costs, environmental externalities, and shadow pricing, which bears significant implications for resource management. This enriched valuation method offers a more accurate assessment of water's true worth, encouraging stakeholders across various sectors to adopt sustainable water management practices and invest in water-saving technologies.

In water resource management, behavioral insights drawn from experimental and behavioral economics can further explain water users' decision-making processes. For instance, loss aversion Kahneman & Tversky (1979) highlights that individuals are more sensitive to losses than to equivalent gains, which has profound implications for policy design. By emphasizing the losses linked to overconsumption—such as financial penalties or environmental degradation—policies may prove more effective than those centered on rewards for conservation. Similarly, status quo bias (Samuelson & Zeckhauser 1988) indicates that individuals often resist change, even when adopting new water-efficient technologies could yield significant benefits.

In the context of living labs, interventions could be designed to explore these biases by varying the framing of water-saving messages across different groups. For instance, one group could receive loss-framed messaging, such as the financial and environmental consequences of excessive water consumption, while another group receives gain-framed messaging emphasizing the benefits of conservation. Through careful experimentation, it is possible to identify which framing strategy elicits a stronger behavioral response, offering policymakers more refined tools for fostering sustainable practices (Thaler & Sunstein 2021).

Moreover, Costa & Alexandre Soares (2022) confirm the financial and environmental advantages of smart metering technologies. Their pilot project in Brasília demonstrated that individualized water consumption tracking, paired with leak detection systems, produced financial returns significantly exceeding the initial investment, highlighting the broader economic benefits of smart water technologies. Additional research, such as Fornarelli et al. (2022) underscores the community-level impacts of smart meters. Their study illustrates how the spatial and temporal precision provided by these technologies allows both utilities and consumers to better understand consumption patterns and implement targeted interventions that encourage water conservation. Integrating insights from Das et al. (2023)into such interventions could also pave the way for dynamic pricing mechanisms that better reflect the broader economic and environmental costs of water use. This would ensure that pricing structures are not only aligned with behavioral incentives but also more accurately capture water's true value, thereby improving both conservation efforts and long-term sustainability.

Recent technological advancements, especially the use of smart meters, have significantly enhanced water conservation efforts by enabling real-time feedback systems. (Cominola et al. 2021) illustrate how the long-term success of water conservation initiatives is driven by providing users with real-time feedback on their water usage. Their research demonstrates that personalized digital engagement through feedback mechanisms leads to sustained reductions in consumption. Such feedback systems could be effectively incorporated into living lab experiments, allowing researchers to evaluate the effectiveness of different water-saving incentives, thus equipping policymakers with more actionable data.

The feedback mechanisms discussed by Cominola et al. (2021) offer dynamic opportunities for experimentation, where user groups can receive customized messages about their consumption relative to set benchmarks. This real-time approach, supplemented with behavioral nudges, would enable a more precise evaluation of which feedback strategies—such as financial incentives or social comparisons—are most successful in fostering long-term water conservation behaviors.

## 3. Living Labs

The term 'living lab' was first used by (Knight 1749), but its emergence has been examined by two distinguished methods: the North American and the European approach. Some studies indicate that the living lab concept originated from Prof. William Mitchell of the Massachusetts Institute of Technology, who played a significant role in boosting early living lab activities in Europe. The concept gained scholarly attention in the 1990s when the EU began funding large-scale living lab projects. Both of the approaches share the concept of involving users in innovation activities in real environments, with the North American living labs being typically business-driven, technology-focused, and commercialization-oriented, with a concentration on corporate R&D and entrepreneurs. On the other side, European Living Labs emphasize policy integration, co-creation, and societal challenges, fostering a more collaborative approach that involves governments, citizens, and academia (Hossain et al. 2019). Although both models encourage innovation, Europe's approach is more broadly based and participatory, whereas North America's is more market-driven and product-oriented.

The characteristics of living labs are associated with two main paradigms: open innovation and user innovation (Hossain et al. 2019; Leminen & Westerlund 2016). Living labs are innovative spaces that involve a variety of expertise and are often linked to the open innovation paradigm. They are often considered a form of open innovation or open innovation networks, where different stakeholders collaborate and innovate jointly (Leminen et al., 2012). Living labs rely on external sources for innovation, facilitating collaboration and helping develop and validate new products and services. They follow the philosophy of open innovation, with some scholars arguing that living labs take a structured approach to open innovation (Nyström et al. 2014). However, others argue that living labs differ from open innovation, as they are often employed in a business-to-consumer setting with a clear focus on users, products, and services (Bergvall-Kåreborn et al. 2009a). Living labs are practical approaches for implementing open innovation and delivering prototypes to private organizations for commercialization. Open innovation, on the other hand, may be company-led or top-down. In conclusion, living labs emphasize public-private partnerships and the importance of users, while open innovation includes a more limited collaboration between companies (Hossain et al. 2019).

Other studies associate Living Labs as pioneering intermediary communities that adopt a user innovation methodology. They contrast with other innovation methodologies based on the dimensions of 'in situ' (in a use situation) and ‘ex situ’ (outside the use situation). User involvement, whether community-led or bottom-up, addresses the needs of users or user groups (Leminen, 2013). Living labs operate in real-world settings and regard people as co-creators (Almirall et al. 2012). Citizen and civil society participation is a fundamental component of living labs, serving as a source of innovation. User engagement varies according to the sort of living lab; but, at a minimum, users can contribute diverse content, including designs, words, images, audio, and video (Følstad 2008). Living labs facilitate the development of novel products and services by including users with diverse expertise, ideas, and experiences (Hielkema & Hongisto 2013). Both active and passive user roles are essential for user-driven innovation. User participation signifies a transition in innovation towards users, engaging in co-creation with them.

Living labs are upper-level research environments that focus on various topics. Key characteristics of living labs include context, users, activity, challenges, and innovative outcomes. Mulder & Kriens (2008) propose six elements: user involvement, service creation, infrastructure, governance, innovative outcomes, and methods and tools. Bergvall-Kåreborn, Holst, et al. (2009) highlight five key components: ICT and infrastructure, management, partners and users, research, and approaches. Leminen & Westerlund (2016) identify four key aspects in nine research avenues for living labs: (a) systems, (b) real life environments, (c) user and public involvement, and (d) the activity, project, or management tool. (Voytenko et al. 2016) list geographical embeddedness, experimentation, learning, participation, user involvement, leadership, ownership, evaluation, and refinement as key characteristics.

The existing literature comprises various research streams and suggests various characteristics for living labs. These characteristics are diverse, especially as each living lab has its own unique objectives, operation, finance, and actors. Moreover, living labs are described as an approach, method, context, environment, experimentation, network, business model, and intermediary. However, the usage and explanations of such terms in the previous literature are very inconsistent. Acknowledging this diversity, Hossain et al. (2019) conducted an extensive literature review aiming to map the essential characteristic elements of living labs. They showed that the eight key characteristics of living labs include: (i) real-life environments; (ii) stakeholders; (iii) activities; (iv) business models and networks; (v) methods, tools and approaches; (vi) innovation outcomes; (vii) challenges; and (viii) sustainability. We tried to enrich this mapping by providing condense descriptions, as presented in Table 2.

*Table 2 - Essential characteristic elements of living labs (adopted from Hossain et al. (2019))*

| Characteristics | Definition |
|---|---|
| Real-life environments (context) | These labs are innovation infrastructures shared by stakeholders and provide real-life environments for testing existing products, services, and systems. They are user-centric spaces that engage stakeholders in real-life contexts, creating sustainable value. Living lab methodologies are used to identify user needs and preferences, and the meaning of real-life environments is not well explored in the literature. |
| Stakeholders | Living labs involve multiple stakeholders, assuming a quadruple helix, involving academics, developers, industry representatives, citizens, and users. Living labs may also comprise four key actors: enablers, providers, users, and utilizers. Enablers support the activities, while providers provide knowledge and expertise. Users participate in various roles, while utilizers benefit from the outcomes. Living labs can be open or closed, with various roles for participants, including advocate, accessory provider, builder, contributor, coordinator, co-creator, facilitator, gatekeeper, informant, instigator, messenger, orchestrator, planner, producer, tester, and webber. |
| Activities | Living labs are a popular innovation approach that emphasizes collaboration, testing, validation, experimentation, and co-creation. They provide services around user experience, support users as entrepreneurs, and organize them in the innovation process. Activities focus on efficiency, implementation, execution, production, selection, choice, and refinement, with users being active participants. Living labs emphasize a shared infrastructure through management of participating user |

| | |
|---|---|
| | communities, controlled environments for product validation, and logical infrastructure for user innovation. |
| Business models and networks | Living labs are increasingly being studied from a business model perspective, focusing on the feasibility of complex solutions in real-life contexts. Living labs involve multiple stakeholders and are complex, requiring careful development of networks and their components. They can be networks of infrastructure, services, real people, and multiple actors. There are three types of network structures in living labs: distributed multiplex, distributed, and centralized. These structures can enhance the emergence of radical innovations, incremental innovations, and promote entrepreneurship. Living labs also show various types of business models and network structures. |
| Methods, tools and approaches | Living labs are increasingly used in organizations for innovation and development processes. These labs involve users as partners in the innovation process, measuring human behaviors and interactions. They provide an environment for co-creation and involve stakeholders in different phases. Living labs stress user involvement and use methods like ethnography and lead user innovation. They are used in the ICT sector to explore new applications and tackle innovation challenges faced by ICT service providers. Living labs require specific methods and tools to find relevant user data and are often used in coordination and participation approaches. |
| Challenges | Previous literature emphasizes the importance of close collaboration between stakeholders in living labs for successful innovation activities. However, challenges related to living lab methods and concepts include temporality, governance, unforeseen outcomes, efficiency, recruitment of user groups, and sustainability and scalability. Living labs often face challenges in managing stakeholders, ensuring long-term value, and transferring knowledge between different parties. Additionally, the success of living labs depends on transferring knowledge and overcoming conflicts. Research on living labs describes both passive and active user participants, with passive group recruitment being challenging due to personal traits. Living labs also require long-term funding to sustain and scale up their activities. |
| Outcomes | Living lab literature shows diverse results for innovation outcomes, with tangible outcomes including designs, products, prototypes, solutions, and systems, and intangible outcomes including concepts, ideas, intellectual property rights, knowledge, and services. The diversity of innovation suggests many outcomes, with most being incremental. Stakeholder roles are crucial in diverse incremental and radical innovations in real-life contexts. Most studies focus on incremental innovations, with few exploring radical innovations. |
| Sustainability | Living labs play a crucial role in sustainable development, focusing on sustainable products and services in urban settings like smart cities. They can address environmental, economic, and social issues through user engagement and collaboration. However, many living labs lack a sustainable business model due to project-based funding and face challenges in assessing products and services. Despite these challenges, living labs contribute to societal development by engaging relevant stakeholders. |

# 4. Discussion on the interconnection between experimental economics and living labs

As we have seen so far, the increasing strain on global water resources, including over-exploitation, drought, and pollution, necessitates effective and sustainable water resource management. Integrated Water Resource Management (IWRM) approaches have proven effective, integrating scientific input and economic methods. However, accounting for human-factors and real-life decision-making is crucial for effective water resource management. Living Labs (LLs) provide a co-creation space for periodic stakeholder engagement, bridging the gap between scientists and stakeholders. LLs enable co-determined inputs developed by scientists and stakeholders during periodic meetings, eliciting qualitative insights on water management issues such as supply, demand, and scarcity, which can be further investigated using experimental economic methods.

Experimental economics uses controlled settings to provide evidence-based insights into individual and collective decision-making and strategic interactions between individuals and groups. However, this approach can reduce external validity due to the gap between lab settings and real-life contexts. Field experiments can help bridge this gap by moving investigations from lab to more realistic contexts. Three major groups of experiments related to environment, particularly water resources, include studying how behavioral particularities affect society's value of resources and the environment, understanding how incentives and institutions affect decisions, and addressing group externalities and social dilemmas. When trying to understand the common ground between experimental economics and living labs, three key questions dominate the discussion.

a) *How can the participatory, real-world environment of living laboratories be incorporated into the controlled, hypothesis-driven nature of experimental economics?*
b) *In the design and implementation of living lab experiments, what is the significance of behavioural insights that are derived from experimental economics?*
c) *How can these two approaches be merged under one framework?*

## 4.1. Incorporating Living Labs into Experimental Economics

The incorporation of living laboratories into experimental economics unites two distinct yet complementary methodologies: the former concentrates on user-driven innovation in real-world settings, while the latter prioritises controlled environments to evaluate economic behaviour and theory. Although these two frameworks operate under distinct methodological assumptions, they can complement one another by establishing robust mechanisms for comprehending human behaviour and innovation processes in real-world applications.

Experimental economics is predicated on laboratory-based research that strictly regulates variables in order to identify causal relationships. Typically, experiments in this field are incentive-compatible, which means that participants are incentivised by genuine monetary rewards to guarantee truthful responses and realistic behaviour (Smith 2003). The controlled environment enables researchers to make precise inferences, which may not always be applicable to real-world behaviour as a result of external factors that are not considered in the laboratory. For examples, Carayannis & Dubina (2014) examined the amalgamation of innovative behaviour and policy through game theory and Living Lab simulations to tackle the intricate dynamics encountered by entrepreneurs and policymakers, particularly in uncertain contexts such as Russia. They analyse how policy might initiate and expedite innovation while considering socio-economic factors, proposing a hybrid strategy that incorporates both quantitative modelling (game theory) and experiential learning via living labs. Their research underscores a strategic, macro-level examination of economic systems, positioning innovation as a socio-political instrument for development.

In contrast, living labs are situated in intricate, real-world settings that involve a variety of stakeholders, including citizens, businesses, and governments. Their primary objectives are to facilitate co-creation, experimentation, and iteration. They are frequently designed to evaluate solutions to societal challenges and are highly participatory (Schuurman 2015). The complexity and unpredictability of external influences present a challenge in this context. The integration of the participatory, real-world nature of living laboratories with the experimental control of economics presents a potential synergy. For instance, experimental economists can develop field experiments or natural experiments within living laboratories to evaluate particular behavioural hypotheses. The rigour of experimental economics can be preserved while real-world participation is incorporated into these experiments. Living labs provide an opportunity to conduct randomized controlled trials (RCTs) to rigorously test interventions aimed at improving water resource management. RCTs, widely regarded as the gold standard for evaluating causal relationships, can be designed to examine the effectiveness of different water-saving policies in real-world environments. For example, one such trial might explore the impact of tiered pricing systems versus block pricing mechanisms on water consumption patterns (García-Gallego et al. 2012; Garrido 2007). In a tiered pricing model, households that consume more water would face higher marginal costs, while block pricing would increase costs progressively across consumption brackets.

Another RCT could focus on social comparison interventions (Allcott 2011), where households receive feedback about their water use compared to their neighbors. Such interventions might be tested in conjunction with financial incentives or social recognition strategies to determine which is more effective in promoting long-term behavioral change. The use of smart meters would facilitate the collection of granular, real-time data on household water consumption, enabling researchers to assess the impact of different treatments over time (Cominola et al. 2021).

### 4.2. Integrating the insights coming from experimental economics into the Living labs

The second question aims at comprehending how the insights obtained from behavioural experiments—including decision-making processes, incentives, and market dynamics—can inform the design of experiments in living laboratories that are designed to evaluate new technologies or policies in real-world environments. Experimental economics provides valuable behavioural insights, including the comprehension of bounded rationality, social preferences, and the impact of incentives, that are invaluable for the development of living lab interventions. For example, the manner in which collective action issues are dealt with in living laboratories, particularly in energy efficiency initiatives or urban planning, could be influenced by research on public goods games (Fehr & Gächter 2000).

Technological advancements, particularly the use of smart meters and Internet of Things (IoT) devices, provide new opportunities for integrating real-time feedback into water conservation experiments in living labs. These technologies can enable continuous monitoring and instant feedback, offering households real-time information on their water use relative to set benchmarks or previous usage.

For example, a randomized intervention could explore whether providing feedback on a daily basis, compared to weekly or monthly, leads to greater reductions in water consumption. Furthermore, time-of-use pricing models, where water rates fluctuate depending on peak demand hours, could be tested using IoT devices that monitor water consumption in real-time (Goette et al., 2019). By combining these technological innovations with the theoretical foundations of experimental economics, it becomes possible to test the efficacy of price-based and non-price-based interventions in naturalistic settings (Cominola et al., 2021).

The design of interventions can be enhanced by predicting how individuals will react to specific incentives or changes in their environment by incorporating such behavioural insights. A case study is the implementation of nudges (Thaler & Sunstein 2021) in living laboratories to promote pro-environmental behaviours, including the reduction of energy consumption. Living labs offer the real-world environment in which these nudges are deployed, while experimental economics provides the means to rigorously assess the efficacy of specific nudges in these contexts.

Indicatively, (Brohmer et al. 2023) tried to understand a common challenge in implementing a Living Lab regarding the recruitment of a sufficient number of participants for these types of studies: Participation may not be appealing to all individuals due to factors such as the necessity of proficiently managing smart technology or frequently exchanging information with researchers and other users, as well as the month-long study durations. Using two conjoint studies and one experimental study, they found that when considering promotion strategies and conducting comprehensive study planning, it is important to consider advertising a Living Lab with a shortened duration (less than a month), offering the option to participate from home, and—most importantly—offering financial incentives. Nevertheless, we address the potential for selection bias to affect individuals who are technologically adept and future-oriented.

### 4.3. A Framework for integration: The Experimental Economics-Living Lab loop

The inherent complexity of real-world environments in living labs presents methodological challenges, particularly related to the presence of confounding variables that could obscure causal relationships. While laboratory experiments in economics offer high internal validity, their external validity often suffers due to artificial settings (Galizzi & Navarro-Martinez 2018). This study suggests a new interdisciplinary approach to address these methodological challenges: the Experimental Economics-Living Lab loop, which seeks to combine the key characteristics of these two approaches to provide more valid insights.

This process involves a robust stakeholder mapping and identifying challenges, which helps researchers understand the barriers associated with topic of interest, such as the water management, from a wise perspective. Stakeholder mapping is a procedure that is typically implemented at the beginning of a research project. It is performed to identify groups, such as government agencies, researchers, businesses, and citizens, that are directly impacted by or have an impact on specific policies or other areas related to the research question(s). For example, Alamanos et al. (2022) employ the LLs approach to establish a shared and thorough comprehension of the challenges, evaluate the lessons learned from past failings, and collaborate to create a list of policy recommendations that are contextualized within the broader context of sustainable management of scarce water across vulnerable agricultural areas of the basin district of Thessaly, Greece's driest rural region. This process assists economists in the formulation of research questions that capture behavioral responses to policy interventions.

An additional critical component of integration is the adaptation of experimental economics' methodological tools to the real-world complexity of living laboratories. This entails the development of experiments that uphold scientific rigour while also acknowledging the participatory and iterative character of living laboratories. The results from these Living Lab interventions can be translated into experimental economics frameworks, where RCTs or other economic experiments are used to compare different incentive structures and develop pricing models that reflect consumer preferences (Banerjee & Duflo 2012). By embedding economic experiments in the Living Lab environment, researchers can collect both quantitative data (consumption patterns, energy use, and optimal pricing structures) and qualitative insights (stakeholder perceptions of fairness, social acceptance of dynamic pricing, and potential resistance factors gathered through surveys and focus groups).

For instance, aiming to study Integrated Water Resource Management (IWRM), the LL approach could involve multiple stakeholders, including government agencies, researchers, businesses, and citizens to test nature-based solutions for flood management and pollution control, using smart sensors, precision irrigation, organic fertilizers, and green infrastructure. The results (e.g., on water quality, nitrate runoff, and urban flood risks) could be then used as attributes for the development of an RCT or another economic experiment to compare the impact of different incentive structures (e.g., financial rewards versus social recognition) on consumer behaviour. Quasi-experimental approaches, such as difference-in-differences (DiD) and propensity score matching (PSM), allow for more rigorous control over confounding variables in non-randomized settings. For instance, DiD can be applied in water management experiments to compare consumption patterns across communities before and after a policy intervention, controlling for external factors that might otherwise distort the results. Similarly, PSM can be used to match communities or households based on key observable characteristics (e.g., socioeconomic status, baseline water consumption), thus reducing bias in the analysis (Levitt & List 2009).

The final stage of the Experimental Economics-Living Lab Loop ensures that findings translate into scalable policy solutions. This includes transforming results into policy briefs for decision-makers, collaborating with local governments to implement effective interventions, scaling successful treatments, and conducting follow-up experiments to refine and adapt policies based on long-term behavioral responses (Akinsete et al. 2022; Alamanos et al. 2022a). This iterative process ensures that economic theories and behavioral models are tested, validated, and applied in real-world settings where multiple variables influence decision-making. The Experimental Economics-Living Lab Loop represents an interdisciplinary approach that bridges the gap between controlled economic experiments and practical policy solutions. By integrating rigorous economic methodologies with stakeholder-driven innovation, this framework transforms water management into a data-driven, adaptive, and co-created process.

### 4.4. Obstacles and Prospects

An often-overlooked aspect of living labs is the unequal distribution of power among stakeholders, particularly in contexts involving large institutions such as governments or corporations, whose interests may not always align with those of local communities. Power asymmetries can lead to disproportionate influence by certain stakeholders, undermining the collaborative ideals of living labs (Hermans et al. 2006). One way to address these imbalances is through the design of common-pool resource (CPR) experiments within living labs, where different governance structures can be tested to assess their impact on water management. For instance, randomized trials could assign different governance mechanisms (e.g., top-down versus bottom-up) to various communities, measuring the effectiveness of each in terms of water conservation and resource allocation (Cardenas et al., 2000). By giving equal decision-making power to traditionally marginalized groups, such as smallholder farmers or low-income households, the experiments could provide valuable insights into the role of governance in achieving sustainable water management outcomes.

The integration of experimental economics into living laboratories presents inherent challenges. One obstacle is the loss of experimental control in a real-world environment, where a multitude of confounding variables may influence behaviour. Researchers must strike a balance between the chaos of real-world environments and the desire for rigorous causal inference. Nevertheless, this presents an opportunity to enhance economic models by incorporating these intricacies. Furthermore, the significance of ethical considerations is heightened when experiments are transferred from laboratory to real-world environments. The participatory nature of living laboratories necessitates that stakeholders remain involved in the process, and transparency regarding experimental objectives is essential for preserving trust. In addition, some studies argue that the evidence is not currently sufficient to justify the effectiveness of the LLs in terms of promotion of innovation (Paskaleva & Cooper 2021), which can be surpassed by those who provide funding for LLs to demand to evaluate their performance and assess their outcomes/impacts.

## Conclusions

Effective and sustainable water resource management is imperative due to the growing pressure on global water resources, which includes over-exploitation, desertification, and pollution. The efficacy of Integrated Water Resource Management (IWRM) approaches has been demonstrated through the integration of scientific input and economic methods. Nevertheless, it is essential to consider human factors and real-world decision-making in order to ensure the effective management of water resources. Living Labs (LLs) offer a co-creation venue for periodic stakeholder engagement, thereby bridging the divide between scientists and stakeholders. LLs facilitate the development of co-determined inputs by scientists and stakeholders during periodic meetings, which will provide qualitative insights on water management issues such as scarcity, demand, and supply. These insights can be further investigated using experimental economic methods.

Experimental economics employs controlled environments to offer evidence-based insights into the strategic interactions between individuals and groups and the decision-making processes of both individuals and groups. This method, however, may compromise external validity by failing to account for the disparity between laboratory environments and real-world scenarios. Field experiments can assist in bridging this divide by transitioning investigations from laboratory settings to more genuine environments. The study of how behavioural particularities affect society's value of resources and the environment, the understanding of how incentives and institutions affect decisions, and the resolution of group externalities and social dilemmas are three major groups of experiments related to the environment, particularly water resources.

This paper explores three main questions, the application of experimental economics in living laboratories, where stakeholders actively co-create solutions, the integration of experimental economics with living labs presents a potential synergy, allowing researchers to develop field experiments or natural experiments to evaluate specific behavioral hypotheses and the ways in which living laboratories can be interconnected with experimental economics seeking at testing theories in real-world contexts (Experimental Economics-Living Lab loop). Experimental economics is based on controlled environments to evaluate economic behavior and theory, while living labs focus on user-driven innovation in real-world settings. Living labs, situated in complex, real-world settings, involve stakeholders and are highly participatory. The Experimental Economics-Living Lab Loop is an interdisciplinary approach that combines the strengths of experimental economics and stakeholder mapping to provide more valid insights. This process involves identifying challenges and identifying groups directly impacted by a topic, such as water management. The results from these Living Lab workshops can be translated into experimental economics frameworks, comparing different incentive structures and developing pricing models that reflect consumer preferences. This allows for the collection of both quantitative data and qualitative insights. The final stage of this Loop ensures that findings translate into scalable policy solutions, including transforming results into policy briefs, collaborating with local governments, scaling successful interventions and conducting follow-up experiments to refine and adapt policies based on long-term behavioral responses. This iterative process ensures that economic theories and behavioral models are tested, validated, and applied in real-world settings where multiple variables influence decision-making.

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