Preface to the Fifteenth Volume of the *Annual Review of Resource Economics*

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INTRODUCTION

We are pleased to present Volume 15 of the *Annual Review of Resource Economics* (*ARRE*). When this Review was conceived, the proposal by Kenneth Arrow was to name it the *Annual Review of Agricultural Economics*. However, Gordon Rausser, our founding editor, recommended a broader scope, suggesting *Annual Review of Resource Economics*. Consequently, the journal encompasses the economics of agriculture, natural resources, the environment, development, and energy, adapting as these fields evolve.

Many conflicting trade-offs emerge for the broad set of problems that arises in resource economics, particularly between economic development and environmental preservation. This mirrors the discord between developed countries prioritizing sustainability—particularly conservation and safety—and developing countries aspiring to economic growth and resource expansion. Sustainable development represents a political compromise between these often divergent objectives (Bernstein 2001).

Partha Dasgupta, author of the prefatory article in this volume, launched the field of environmental and development economics, striving to harmonize these two domains and lay the groundwork for sustainable development. A notable achievement in this endeavor was the proposal to extend natural accounts to include natural resources and changes in human and natural capital (Dasgupta 2014). This journal has often reviewed these efforts (e.g., Hartwick 2011, Barbier 2016, Irwin et al. 2016, Bretschger 2017).

Sustainable development can be assessed from both aggregate and micro perspectives (Zilberman 2014). Micro-level strategies include the adoption of precision technologies to improve input use efficiency—for instance, advanced irrigation and chemical application technologies that optimize timing and reduce externalities. There is substantial evidence of benefits and challenges of adopting these technologies (Lin Lawell 2016, Finger et al. 2019, Miao & Khanna 2020), with increased input use efficiency significantly decreasing greenhouse gas emissions and enhancing the efficiency of the energy sector (Gillingham et al. 2009). Recycling is another crucial strategy. It reduces greenhouse gases and extraction costs for non-renewables. International trade

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sometimes drives recycling, especially in waste products, but its economic and environmental welfare impact often suffers from inadequate regulation and illegal activities (Kellenberg 2015). Waste product regulation and recycling relies on life cycle assessment. Rajagopal et al. (2017) reviewed the basis of life cycle analysis, its alignment with economic principles, and its potential to boost economic efficiency inclusive of environmental considerations.

Natural scientists endorse transitions to a circular economy. Fullerton et al. (2022) proposed that this approach needs economic adjustment, which is achievable through economic incentives. Evaluations of circular strategies should consider net economic welfare gain and the scientific pursuit of such strategies might yield innovative sustainable solutions.

Transitioning from non-renewable to renewable strategies has been key to sustainable development. We distinguish between physical renewables, such as solar and wind power, and living organisms. The journal covered the potential and challenges of solar energy (Baker et al. 2013) and wind power (van Kooten 2016), integration of variable renewable energy sources into the grid, the issue of storage (López Prol & Schill 2021), and the leapfrogging associated with implementing renewables in developing countries (Arndt et al. 2019).

The bioeconomy is becoming a more significant component of the transition to sustainable development. The bioeconomy includes agriculture, forestry, and emerging sectors using modern life science with living organisms to produce a range of goods and services. These include food, fuel, green chemicals, agri-tourism, and pharmaceuticals. Wesseler & von Braun (2017) reviewed methods of measuring the bioeconomy and the challenges associated with its regulation. Zilberman et al. (2013) drew a distinction between the traditional bioeconomy, which relies on agriculture for human nutrition and energy and used fermentation for products like bread and cheese, and the new bioeconomy. The latter harnesses advancements in life sciences and information technology to enhance food production and create fuel, chemicals, and pharmaceuticals.

As a cautionary tale, numerous reviews have shown that biotechnology regulation impedes the bioeconomy from realizing its full potential. Jensen (2016) reviewed the educational–industrial relationships that led to the emergence of modern biotechnology, and Pray & Fuglie (2015) underscored the private sector's crucial role in establishing the sector. Clancy & Moschini (2017) identified intellectual property challenges, while Qaim (2009) documented some of biotechnology's achievements and described regulations that have, in certain instances, prevented it from reaching its full potential. McCluskey et al. (2016) reviewed how consumer acceptance and the media affect biotechnology product demands, and Herring & Paarlberg (2016) analyzed political economy challenges that limit the expansion of biotechnology applications.

ARRE also provides analysis of economic and technological challenges that impact the evolution of different sectors of the bioeconomy. Rajagopal et al. (2009) reviewed technological challenges limiting the evolution of advanced biofuels, and Miao & Khanna (2020) assessed technological advances that enable welfare-improving food and fuel production. Of course, the bioeconomy extends well beyond crop-based ethanol. Hochman & Palatnik (2022) documented research on the potential of algae and duckweed for energy production, Masum et al. (2019) provided an overview of the wood-based bioenergy sector, and Rausser & Zilberman (2022) argued that the bioeconomy can play a vital role in addressing climate change challenges by producing more efficient food products, replacing non-renewables with renewables, and capturing and sequestering carbon.

Some reviews documented the impact of policies aimed at transitioning to a sustainable and green economy. Harrison et al. (2017) surveyed challenges for green industrial policy in developing countries. Van der Ploeg & Rezai (2020) emphasized the importance of developing policies that would allow a smooth transition to a green economy and limit the economic, financial, and political hurdles associated with the losses of carbon-intensive industries.

In sustainability, the role of public policy is critical, and many *ARRE* articles have emphasized policy design. Anderson et al. (2019), for example, described policies to regulate aquaculture, an important bioeconomy sector; Gillingham et al. (2009) reviewed an approach to enhance energy efficiency; and Carbone et al. (2022) highlighted the importance of appropriate scale in policy analysis and the use of partial and general equilibrium frameworks to assess public policy impacts.

Political-economic obstacles often arise when establishing policies to support the transition to sustainability that incorporate resiliency to unanticipated shocks (Rausser et al. 2011). To overcome such obstacles, policy frameworks must be structured to formally incorporate the political-economic forces by simultaneously implementing both growth and redistributive/social justice policies. Public policies must counter the rent-seeking obstructionists who pursue their self-interest to the detriment of the public interest. For example, in many countries, the standard economic prescription of taxing carbon emissions has yet to be implemented (Rausser 2022).

Climate change is one of the most wicked problems challenging sustainability (Foster et al. 2022). In this context, Rausser & Foster (2022) show that taking into account the political-economic landscape requires the simultaneous implementation of both growth-oriented policies [political economic resource transactions (PERTs)] and redistributive policies [political economic-seeking transfers (PESTs)]. PERTs are designed to expand the economic frontiers, while PESTs result in short-run deadweight losses, which can be controlled to foster sustainability if three conditions are satisfied: (*a*) credible sunsetting, (*b*) political and economic complementarities, and (*c*) asset diversification and mobility, which eliminate rent seeking. There are several potential carbon capture and sequestration technologies to address climate change that have yet to achieve scalability. Promising strategies include soils, plants, and microbial/fungus interactions that may remove carbon in the air and store it in the soil, and growing algae, which sequesters carbon and stores it in the ocean. Introducing carbon sequestration requirements may increase the price of food and energy, at least in the short run. PERT policies could allocate governmental resources to research and development (R&D) to identify and advance scalable solutions. These could be complemented by PEST policies, which provide incentives for widespread adoption and compensation for those low-income households that suffer from the higher cost of food so long as such policies satisfy the three conditions mentioned. We expect economic research to be part of multidisciplinary efforts to identify new, sustainable technological solutions to major global problems and the policy approaches that will lead to their upscaling and implementation.

OVERVIEW OF VOLUME 15

As always, the opening article is dedicated to celebrating the accomplishments of a distinguished scholar. Partha Dasgupta's research has been wide-ranging, covering welfare and development economics, game theory, economic happiness, and social capital. He was among the leading scholars in the evaluation of the environment in the context

of economic development. Yet it is his transformative work in ecological economics—particularly his focus on biodiversity economics—that has revolutionized our approach to evaluating the sustainability of economic programs. His groundbreaking report, the eponymous *The Economics of Biodiversity: The Dasgupta Review*, is a testament to his lasting impact in this field.

The content of *ARRE* has typically been grouped into four categories: agricultural economics, development economics, environmental economics, and resource economics. In this volume, we introduce two additional categories: health and nutrition economics and research and development.

Agricultural Economics

Krishna & Mkondiwa explore the economic factors driving utilization of crop residues, an often overlooked but significant aspect of agricultural practices. They cover the detrimental effects of unsustainable residue management and highlight the need to determine its economic, environmental, and health impacts.

Building on the theme of sustainability, Delgado et al. focus on the globally significant issue of food loss. Distinguishing food loss from food waste, they highlight the need for improved data collection and the importance of recognizing food loss as an integral part of agri-food systems. This article enhances our understanding of the systemic challenges in reducing food loss and improving sustainability.

Broadening the discussion on data accuracy, Abay et al. explore the repercussions of measurement errors in agricultural data generally. The article highlights the need for meticulous data handling to ensure sound policy and effective interpretation of behavior.

Giannakas & Yiannaka investigate the conditions enabling fraudulent activities in agri-food supply chains that affect economic efficiency and trustworthiness. A number of sources of fraud are described, including asymmetric information, imperfect certification processes, and weak monitoring and enforcement mechanisms. These findings again underscore the need for robust data management and efficient regulatory mechanisms.

Environmental Economics

Del Rossi et al. examine the economics of nutrient pollution from agriculture, focusing on the environmental degradation resulting from fertilizer use and livestock operations. They present compelling data on the upward trend in fertilizer application per acre in the United States and the connection between agricultural intensification and nutrient content in water bodies. Although considerable progress has been made on understanding the impact of nutrient pollution on physical ecosystems, challenges remain in quantifying economic damage from loss of ecosystem services. The authors spotlight the need for holistic cost estimates of pollution externalities and identify understudied areas such as health damages from nutrient pollution and the impact on drinking water sources.

A critical review of the market stability reserve (MSR) within the European Union Emissions Trading System (EU ETS), a key policy tool for reducing carbon emissions, is provided by Borghesi et al. The performance of the MSR is assessed from both conceptual and quantitative perspectives. The authors provide insight into how this tool has been adjusted to changing market outcomes and identify significant policy implications, unresolved issues, and a path for research that could enhance the effectiveness and stability of the EU ETS.

Koundouri et al. examine the intersection of behavioral economics and neuroeconomics with environmental values. Drawing from various levels of decision-making processes, ranging from individual resource valuation to institutional policies and impacts, they argue that understanding human decision-making processes is central to designing effective public policies. Technological and methodological advances coupled with behavioral and neuroeconomic insights can achieve this. They call for immediate action to integrate these scientifically grounded insights into policy making to optimize environmental resources for the benefit of current and future generations.

A comprehensive analysis of environmental regulation and labor demand is provided by Gray et al. They assess the effects of regulations on employment across various sectors and communities, drawing upon a neoclassical microeconomic framework and various equilibrium models. Their exploration provides an understanding of the implications of environmental regulations on both labor demand and supply.

The intersection of competition policy and environmental sustainability is tackled by Inderst & Thomas. Highlighting recent moves to integrate sustainability considerations into competition law and practice, they illustrate the rich research opportunities at the convergence of industrial organization theory and environmental economics.

Lai et al. examine the effects of temperature on labor productivity. Drawing upon scientific and economic studies they describe the physiological and cognitive impacts of temperature shocks, from micro-level productivity and macro-level impacts. This analysis sheds light on the inconsistent effectiveness of adaptation strategies at regional and micro levels. The authors call for further research to understand the distributional effects of temperature and its long-term impacts on individuals exposed to extreme temperatures in early life.

The impacts of climate change–associated risks on financial markets are examined by Zhou et al., covering a broad spectrum that includes insurance, banking, stock markets, bond markets, and international financial flows. They explore the ways in which climate change risks and natural disasters influence these sectors and advocate for forward-looking computational modeling.

Development Economics

Understanding the nonobserved or shadow economy is essential to measuring the economy as a whole. Schneider compares six distinct approaches that assess the shadow economy, covering both macro and micro approaches, highlighting the differences, correlations, and variations generated. The analysis adds a new layer of understanding of this elusive economic phenomenon.

Smith & Gregory tackle the alarming issue of food insecurity in the United States, embedding policy analysis within a wider socioeconomic context. Starting with the establishment of the Food Security Module, they present a framework that connects food insecurity to quality-quantity trade-offs and use consumption patterns in food-insecure households to assess the efficacy of federal food assistance programs, including the impacts on food insecurity and nutritional quality.

Correa et al. examine the intersection of social protection and rural transformation in Africa using a conceptual framework that ties noncontributory social protection to agricultural growth. Their assessment of access to social protection programs, increased asset holdings of rural people, and improved inputs and farm practices makes a persuasive

case for the integration of social protection programs in broader rural and agricultural development strategies.

Resource Economics

There is a considerable gap between the calculated necessary investments and the resources currently being devoted to ecosystem restoration. With a keen focus on policy implementation and efficacy, Mirzabaev & Wuepper use theory-informed insights to illuminate the challenges and underscore the need for further research.

Ewert et al. explore how agroecology could be mainstreamed to create more sustainable and resilient systems. This multiscale systems approach offers a comprehensive solution to the challenges of the agri-food system. The authors assess the economic viability of agroecology for various food system actors and explore the impact that new technologies could have, concluding with a framework to support large-scale adoption.

Mathematical programming of climate change impacts on agriculture and natural resources is the subject taken up by Fei & McCarl. It provides the means to analyze economic aspects of adaptation strategies and mitigation alternatives under previously unobserved conditions. The article presents an overview of this analytical approach and reviews studies that have been applied to explore climate change impacts, offering a fresh perspective on an urgent global issue.

Health and Nutrition Economics

This new category of articles explores the junction of public health and economics. Three key areas are examined in this volume: the taxation of sugar-sweetened beverages (SSBs), the effects of obesity on life expectancy, and the impacts of air pollution on health. Together, these pieces offer an in-depth exploration of the intersection between health and nutritional economics, illuminating the effects of specific policy measures and providing a broader understanding of public health issues from an economic perspective.

Kiesel et al. scrutinize SSB taxes at a time of mounting global concern over chronic non-communicable diseases associated with obesity. Evaluating the burgeoning body of literature through the lens of current food markets and consumer behavior, the authors question the efficacy of SSB taxes in inducing significant changes in consumption patterns and spurring the purchase of healthier alternatives, contributing to the discourse on policy approaches to combat the obesity epidemic.

Bansal & Jin identify the sociodemographics, contributing factors, socioeconomic consequences, health effects, and public policies linked to obesity in both developed and developing countries. By examining the associations between obesity and life expectancy at individual and population levels, they shed light on the heterogeneous effects of obesity across countries and genders. The analysis underscores the importance of tailoring policy solutions to address these variations and enhance health well-being in diverse settings.

Finally, Brewer et al. examine the intersection of air pollution and health outcomes. Using the economics literature on the subject, they detail common approaches to measuring and modeling air pollution exposures and scrutinize the epidemiological and biological information that informs air quality regulations. The authors highlight the importance of the causal inference framework used in economics, noting how it addresses potential estimation biases in epidemiological approaches, and offer research designs to estimate concentration-response functions.

Research and Development

In this new section, the nuances of R&D in agriculture and other industries are explored, from the slow, transformative impact of research to the revolution in standards of evidence for assessment of its impact. Together, the articles provide an overview of temporal and methodological considerations for agricultural R&D and expose the unique challenges and changes in this vital field of inquiry.

Alston et al. examine R&D lag models, aptly referring to the impact of R&D as "slow magic" and highlighting the dichotomy between conventional assumptions about industrial R&D and the practical manifestations of agricultural R&D. The maturation and diffusion of new technologies in agriculture require extended incubation periods that impact economic comprehension and policy formulation. The authors conclude that a reassessment of methodologies to measure and understand the temporal and directional trajectories from investment to tangible impact is required.

Recent advances in methodologies for assessing the impacts of international agricultural research are reviewed by Stevenson et al. A "rigor revolution" has taken place since the mid-2000s, with heightened standards for evidence hinging on the principles of causal inference, valid measurement, and statistical representativeness. By detailing these advances and their implications, emphasizing the importance of concrete empirical evidence, portfolios of innovations, and the bundling of these innovations, the article underscores the need for robust, replicable research designs to accurately evaluate the impacts of agricultural R&D on a global scale.

We hope you find this issue of *ARRE* valuable and enjoyable. Our thanks to all of the authors for their insights, ingenuity, and responsiveness. We hope these articles will catalyze discussions among readers, authors, and the editors. We welcome your input.

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