Environmental Adjustments to Agricultural Total Factor Productivity

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Agricultural productivity has long been one of the most important indicators of the sector's performance, measuring our capacity to produce more food with limited land, labour, water and capital. But as climate change and environmental degradation increasingly shape agricultural production, the way we measure productivity must also evolve. Productivity growth has underpinned global food security for decades. Yet agriculture both depends on and affects the natural environment. Climate change, water availability, soil quality and greenhouse gas (GHG) emissions increasingly influence agricultural production, while farming itself shapes environmental outcomes. As governments place greater emphasis on sustainability, an important policy question emerges: are current measures of agricultural productivity capturing the full picture?

Traditional measures of agricultural total factor productivity (TFP) compare the growth of all agricultural outputs with the growth of all inputs, providing a comprehensive measure of productive performance. Unlike partial indicators such as labour productivity, TFP captures the efficiency with which all production resources are used and has become the standard benchmark for evaluating agricultural performance at farm, regional and national levels. However, conventional TFP measures generally exclude environmental assets and externalities. Consequently, productivity growth may be overstated when higher output is achieved through greater natural resource depletion, increased pollution, or unusually favourable climatic conditions. Conversely, it may be understated when producers invest in pollution abatement, ecosystem restoration, or adapt to increasingly adverse climates. Recent evidence illustrates both effects. Ortiz-Bobea et al. (2021) identify climate change as an important contributor to the recent slowdown in global agricultural TFP growth, while Chancellor et al. (2021) show that adjusting Australian productivity measures for climate effects changes estimated TFP growth across most agricultural industries.

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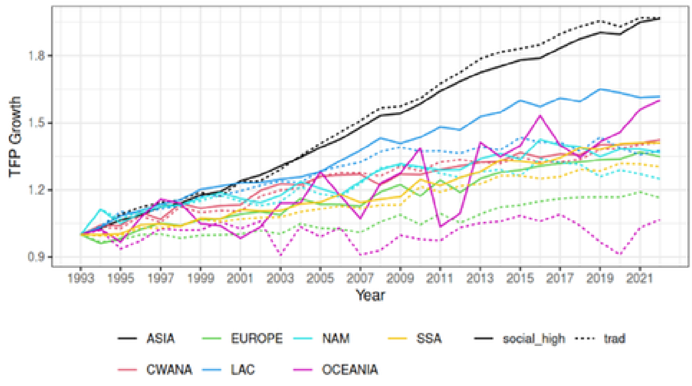

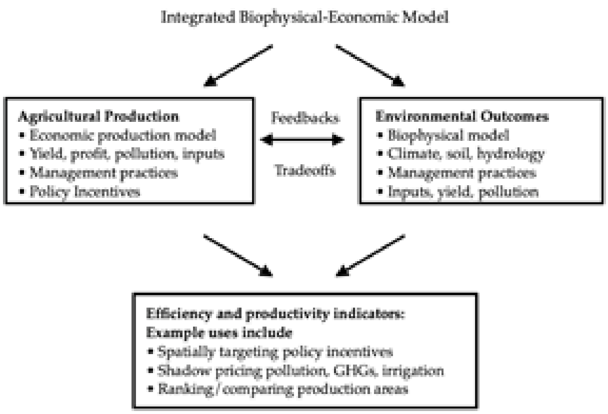

These challenges have prompted important international efforts to incorporate environmental information into agricultural productivity measurement. The OECD Network on Agricultural TFP and the Environment is developing best-practice approaches for environmental accounting, while the UN Common International Classification of Ecosystem Services (CICES) contributes to the broader System of Environmental-Economic Accounting (SEEA). Similarly, the USDA ERS International Agricultural Productivity (IAP) Dataset continues to expand the international evidence base. Together, these initiatives reflect growing consensus that future productivity measurement should recognise both economic and environmental performance.

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Two complementary methodological approaches provide practical pathways for environmentally adjusted TFP. The first builds on economic index theory, where changes in aggregate outputs are compared with aggregate inputs using price-weighted indexes such as the Fisher and Tornqvist indexes, both recognised as superlative indexes (Diewert, 1976). This framework can incorporate natural resources and environmental outcomes by assigning implicit economic values to non-marketed inputs and outputs (O'Donnell, 2012), making it particularly attractive for extending existing national productivity accounts. The second draws on production theory, representing agricultural technology through distance functions—including the radial formulations of Farrell (1957) and Shephard (1970), and the directional approach of Luenberger (1995) and Chambers (1996). As Wang and Chambers (2026) emphasise, these methods provide economically meaningful measures of performance while allowing productivity growth to be decomposed into efficiency change and technological change. Rather than competing approaches, they offer complementary perspectives for measuring environmentally adjusted productivity.

Recent research demonstrates that these approaches are no longer purely conceptual. Barnhart et al. (2023) applied a production-theoretical framework using directional distance functions to measure agricultural productivity in the Mississippi River Basin while explicitly accounting for nutrient runoff and changing climatic conditions. Henningsen et al. (2026), in contrast, used an index-number framework to adjust global agricultural TFP for greenhouse gas emissions. Together, these studies illustrate that environmental adjustment can be implemented using established economic methods rather than requiring entirely new measurement frameworks.

The policy challenge now is implementation. Initial efforts should focus on environmental variables that are increasingly observable and internationally comparable, particularly land, water, climate and GHG emissions. Advances in remote sensing, integrated biophysical-economic modelling and computational methods are rapidly improving the feasibility of these adjustments, while pilot studies can help refine methodologies before broader adoption.

Agricultural productivity has always been about producing more with less inputs. In the twenty-first century, however, "less inputs" must include not only conventional production inputs but also the environmental resources upon which agriculture ultimately depends. Environmentally adjusted TFP offers an opportunity to align productivity measurement with sustainable development objectives while remaining grounded in well-established principles of economic index and production theory. Improving these measures will provide policymakers with stronger evidence to support agricultural innovation, environmental stewardship and long-term food security.

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