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Cattle, energy, and emissions: Dynamics of sustainability in Latin America

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Abstract

Increasing demand for animal-source products has positioned cattle ranching as a strategic driver of rural development in Latin America. However, the environmental footprint associated with its expansion, particularly greenhouse gas emissions, poses a critical sustainability challenge. In this context, improving energy-use efficiency emerges as a key lever for reducing the sector's environmental impact while sustaining productivity growth. This study investigates the dynamic relationships between cattle production, agricultural energy intensity, and environmental degradation – measured as cattle-related CO₂-eq emissions – across 12 Latin American countries over the period 2000–2018. Using Vector Autoregressive (VAR) and Panel VAR (PVAR) models, the analysis explores causal linkages among these variables and evaluates the extent to which energy efficiency can mitigate emissions. The empirical framework integrates sector-specific data on the gross value of cattle production, agricultural energy intensity, and emissions, capturing both regional trends and cross-country heterogeneity. The results reveal a clear unidirectional causal chain: increases in cattle production precede changes in agricultural energy intensity, which in turn drive CO₂-eq emissions. Additionally, cattle production directly influences emissions, reinforcing its role as the primary driver of environmental pressure in the sector. Impulse–response functions show that production shocks initially increase both energy use and emissions; however, over time, improvements in energy efficiency contribute to a gradual reduction in emissions, indicating partial decoupling between productivity and environmental impact. Descriptive and correlation analyses support these findings, showing a strong positive relationship between cattle production and emissions and a negative association between energy intensity and emissions. Forecasting results suggest that continued growth in cattle production may be accompanied by declining energy intensity and a modest stabilisation or reduction in emissions. However, efficiency gains alone may not fully offset the environmental effects of expanding production without broader systemic change. These findings highlight the importance of technological and management innovations in reconciling productivity and environmental objectives. Climate-smart agriculture practices, such as silvopastoral systems, improved forages, and renewable energy use, emerge as effective strategies for enhancing resource efficiency and reducing emission intensity. Scaling such interventions requires integrated policies combining technical assistance, financial incentives, and inclusive governance to accelerate sustainable intensification.

Keywords: Cattle production, climate-smart agriculture, energy efficiency, greenhouse gas emissions, panel VAR (PVAR), sustainable intensification, vector autoregressive models (VAR)

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