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NONLINEAR DRIVERS OF ENVIRONMENTAL SUSTAINABILITY IN ITALY: EVIDENCE FROM A QUANTILE-BASED FRAMEWORK

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Abstract – Ensuring environmental sustainability in advanced economies such as Italy is a prerequisite for achieving sustained economic development while preserving ecological balance and long-term environmental resilience. Consequently, policymakers and environmental stakeholders face a pressing need to identify new factors that can effectively enhance environmental sustainability, particularly in the context of rapid technological advancement, the expansion of green-oriented financial activities, and increasing geopolitical uncertainty. While previous studies have examined the linear relationship between environmental sustainability and its determinants, there remains a gap in the literature regarding nonlinear and asymmetric associations. The present study therefore explores the asymmetric effects of artificial intelligence innovation, energy technology development, green finance, and environmental governance on environmental sustainability in Italy, while controlling for economic growth, geopolitical risk, and natural resource rents. To accomplish this, we adopt innovative quantile-based econometric methodologies, including quantile cointegration techniques, to capture asymmetric long-run relationships across different states of environmental sustainability, by using time-series data for Italy. The results indicate that artificial intelligence, energy technology, green finance, economic growth, and geopolitical risk exhibit a strong asymmetric association with environmental sustainability, as measured by the Load Capacity Factor (LCF). In particular, excessive economic growth and heightened geopolitical risk tend to exacerbate environmental pressure when environmental sustainability is weak. Technological advancement and green financial development do not uniformly enhance environmental sustainability under conditions of severe ecological stress. By contrast, natural resource rents contribute to improving environmental sustainability by alleviating environmental pressure. Our findings corroborate that moderate advancement in artificial intelligence, energy technology, and green finance can help improve Italy's environmental sustainability without intensifying ecological degradation. Accordingly, Italian policymakers should place greater emphasis on mitigating the negative spillover effects arising from excessive economic expansion and geopolitical instability, while also accounting for other ancillary factors that interact closely with technological and financial development. Moreover, strengthening environmental governance before environmental pressure reaches critical levels is crucial for ensuring long-term ecological resilience and sustainable development in Italy.

Keywords – Artificial intelligence; environmental sustainability; green finance; Load Capacity Factor (LCF); quantile-based analysis

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