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Opinion

Jevons Paradox: Sustainable Development Goals and Energy Rebound in Complex Economic Systems

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Abstract: Jevons Paradox has fundamental implications on sustainable development and the UN Sustainable Development Goals (SDGs). The paradox states that technological improvements aiming to increase the energy efficiency risk causing a rebound effect, and an increase in demand, production, and resource exploitation. Third world countries undergoing early-stage technological development may be particularly vulnerable, but it is also relevant in complex economic systems, where policymaking on climate and energy building on insufficient knowledge and attention to rebound effects can impair the desired outcome in terms of climate change mitigation, resource use and sustainable development.

Keywords: SDGs; sustainability; energy efficiency; Jevons Paradox; energy rebound

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In the mid-19th century, the English economist William Stanley Jevons observed that, while technological development significantly increased the efficiency of steam engines, and thus enabled them to generate more work with lesser coal, consumption of coal did not decrease. On the contrary, it increased. In his 1865 book, *The Coal Question* [1], he expressed this apparent contradiction (chapter vi, p. 103): "It is wholly a confusion of ideas to suppose that the economical use of fuel is equivalent to a diminished consumption. The very contrary is the truth." This confusion of ideas is now known as Jevons Paradox. The paradox states that technological improvements aiming to increase the energy efficiency risk causing a rebound effect, and an increase in demand, production, and resource exploitation.

Jevons Paradox infers significant implications for sustainable development and the UN Sustainable Development Goals (SDGs) [2,3]. SDG7 on affordable and clean energy has a target, 7.3, aiming at doubling the rate of energy efficiency improvements by 2030. If valid, the paradox renders the target not only futile but also counterproductive if some, or the entire, energy savings are offset by a subsequent increase in energy consumption [3].

The existence of rebound effects is not controversial, but their magnitude is. Jevons observed early-stage technology development, and while the paradox might hold true for single-sector economic systems and early-stage technological development, there is a lack of empirical evidence to support the quantification of energy rebound effects in larger and more complex systems. Research reports diverse magnitudes of rebound effects, mainly due to disagreements on the definition, on economic assumption and system boundaries [3–5]. Moreover, difficulties in determining the counterfactual baseline—what would have happened absent efficiency improvements—introduce further uncertainties [5]. Knowledge of the indirect effects of improved energy efficiency operating across diverse hierarchical and temporal scales is hard to gain [2], which is why policies addressing energy efficiency risk being developed with insufficient attention to impacts on other sustainable development goals. Furthermore, rebound effects are not only influenced by the extent of thermodynamic efficiency improvements, but also by energy's substitutability with other inputs in production and the potential efficiency improvements [3,5,6] as well as consumer substitutability and behavioural responses [4,7,8].

Research suggests, however, that the rebound effect is stronger for developing countries and general-purpose technologies than in developed countries and niche technologies [3–5,8]. In line with the generic IPAT (Impact = Population × Affluence × Technology) concept, countries may experience declines in energy consumption not linked to rebound effects but to declining population or GDP [9]. Nordhaus [5] argues that rebound effects are key to improved human wellbeing, especially in developing countries, as energy efficiency can be a precondition for achieving other SDGs such as SDG 1 (no poverty), 3 (good health and well-being) and 8 (decent work and economic growth). At the same time, Nordhaus [5] and others [3,8] emphasise that due to rebound effects, energy efficiency policies will have limited impact, if any, in mitigating climate change (SDG13). If not assessed properly, rebound effects can counteract SDG7 and SDG13, because of unpredicted increases in energy consumption and hence insufficient renewable energy capacity. Further, increased renewable energy capacity can have trade-offs with other SDGs concerning environment and land use [10].

In Europe, the USA, and Australia, very few energy efficiency policies address rebound effects, although the number is increasing [4]. If included, policies tend to underestimate the actual effect [7]. Freeman et al. [11] highlight the lack of research on "intervention testing" to determine how policies can limit rebound. Estimating the rebound effect and its drivers is key to creating the right policy framework [6]. Economic instruments as taxation and cap-and-trade systems are potential ways to mitigate rebound effects, though success is dependent on design. For example, ensuring worldwide coverage is essential to avoid spill-over to other sectors or nations [4,8]. Furthermore, policy and cultural adjustments play an important role in determining the feedback loops which will result from technological improvements within any system. The work of Freeman et al. [11] on behavioural, economic, technological, and alternative interventions on fleet efficiency provides helpful insight and suggests that similarly focused research needs to be carried out in multi-scale systems to inform policymaking. Examples of more behavioural-focused strategies to mitigate rebound effects are information, labels and changing social norms, aiming to shift consumption to products that are less resource-intensive [4], or systemic changes, e.g., shifting to a steady-state economy or de-growth [8].

Conclusions

Energy efficiency improvements are key to sustainable development, but Jevons Paradox points to efficiency improvements as a double-edged sword. We find there is inadequate focus on Jevons Paradox and the risk of rebound effects at the current state of energy policy development and deployment. Developing economies undergoing early-stage technological development are particularly vulnerable, but also more complex economic systems. Policymaking on climate and energy building on insufficient knowledge and inadequate attention to rebound effects can impair the desired outcome in terms of climate change mitigation, resource use and sustainable development.

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