BOOK REVIEW PERSPECTIVES

John Polimeni, Kozo Mayumi, Mario Giampietro & Blake Alcott, 
*The Jevons Paradox and the Myth of Resource Efficiency Improvements*


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Our current global energy production and consumption patterns are unsustainable, whether one is concerned primarily about climate change, international security, or peak oil. Because today’s economy and society are dependent on energy production and consumption, addressing our global energy issues will require a complex set of actions. We would be wise to draw on an understanding of the multi-scale synergies and feedback loops among global consumers, producers, and policy makers—as well as the roles of technology research and infrastructure investment—to inform these actions.

Many of us, however, would like to believe that there are easy answers. We environmentalists are often on the lookout for “win-win” opportunities where we can save energy (and therefore protect the environment) and also save money without worrying about broader systems behavior. The Jevons Paradox and the Myth of Resource Efficiency Improvements, by John Polineni, Kozo Mayumi, Mario Giampietro, & Blake Alcott, challenges the implicit assumptions behind our embrace of the win-win. The authors point out flaws in the expectation that, if we as individuals make decisions to conserve energy, a collective sustainability will automatically emerge.

The Jevons Paradox was first introduced by William Stanley Jevons in 1865. He developed the idea to describe a phenomenon in the growing coal sector. According to the Paradox, the invention of equipment requiring less coal consumption led to greater overall consumption of coal as the cheaper-to-operate equipment became valuable for many more uses. In other words, the “rebound effect” can, in some cases, actually be greater than one, rather than close to zero as suggested by some researchers. As Polineni and coauthors correctly point out, many of us have inconsistent reasoning regarding the systems implications of increased efficiency. We expect labor efficiency and productivity increases to further economic growth, leading to more jobs overall. However, we do not expect the economic growth stimulated by our localized energy efficiency to lead to increases in energy consumption overall.

The book explores in some detail how to navigate the various mechanisms by which the Jevons Paradox may or may not operate within complex adaptive multi-scale systems. Key is the potential disconnect between policies, designs, and decisions aimed at solving a current local problem (such as adding lanes to address highway congestion) and the tendencies of the larger system to adapt to the change and/or evolve over time (more uncongested lanes lead to more cars). The larger message for the systems analyst is to strive for integrated analysis across dimensions and scales; for the citizen, that sustainability requires a “willingness to change yourself in order to be able to co-evolve with other humans and the environment.”

Chapter 1 is an introduction which poses that the global economy cannot grow infinitely in a resource-constrained world. It briefly lays out two societal options for addressing this situation. Option 1 is to look for alternate patterns of development no longer based on gross domestic product (GDP) maximization. Option 2 is to continue to assume that markets will self-correct and find substitutes for scarce resources. These options do not sufficiently draw on the insight offered by Paul Hawken, Amory Lovins, & L. Hunter Lovins (1999) in *Natural Capitalism*: “For all their power and vitality, markets are only tools. They make a good servant but a bad master and a worse religion.” Neither option explicitly focuses on the imperative raised by this book—leveraging the power of the market to address global energy and climate issues at sufficient scale.

Chapter 2 presents a history of the Jevons Paradox and related economic theory. This early observation of the Paradox constitutes one of the first recognitions of a rebound effect. The chapter stresses the difference between local, direct rebound and indirect, economy-wide rebound. The indirect effect is im-
important because money saved from energy efficiency is generally spent somewhere else, likely leading to additional energy consumption. There is a discussion of “backfire,” which is a rebound effect of more than 100%. To fully understand and to be able to quantify the rebound effect, it is important to quantify efficiency. The chapter correctly highlights confusion about the appropriate normalization factor for energy efficiency. Should we use physical units (tons of product or waste), monetary units (GDP), or welfare units (energy “services” in, say, person-kilometers)?

Chapter 3 shifts gears from the history of economic theory to complex systems and the challenges associated with bridging scales in analysis. The energy consumption per person or per unit of economic product may be the most straightforward way to assess energy efficiency. However, when economies reduce their energy consumption per unit of GDP, this is not necessarily ecologically meaningful. Global economy-wide total energy consumption is the ecologically meaningful measure. Returning to the micro-scale, the book discusses the evolution of trends in automotive engine-energy efficiency (and corresponding trends in features—air conditioning, powerful engines—boosting overall energy consumption) since the 1940s. This chapter extends far beyond economics and energy efficiency, spending some time on the ambiguity of the north, south, east, or west orientation of the coast of Maine and the relationship and shifting causality between sizes of predator and prey populations. This broad discussion eventually feeds back into a more abstract focus on the interplay between efficiency and adaptation. The chapter returns to touch on efficiency as it relates to material standard of living and environmental loading, pointing out that the financial gains from local efficiencies may best be fed back into the larger-scale economy if the rebound effect of the Jevons Paradox is to be avoided. However, the policy-oriented reader anxious to avoid the Paradox yearns for a more detailed concrete examples.

Chapter 4 presents regression analyses of empirical national-scale energy intensity, GDP, population, and other data for the United States, Brazil, and several countries in Europe and Asia from 1960 to the present. These data suggest that the Jevons Paradox is present in these regions. The significance of these analyses could have been presented a bit more clearly, and the discussion could have more effectively built on previous chapters. For example, the multi-scale perspective so extensively discussed in Chapter 3 seems absent. It also would have been interesting to explore the relative magnitude of the effect of the Jevons Paradox in different countries or regions (such as a comparison of planned versus free-market economies) at different time periods (for example, during the 1970s energy crisis). As Joseph Tainter asks in his wonderful forward, “When does [the Jevons Paradox] not apply?”

Chapter 5 is a very brief conclusion that highlights the exponential nature of our current global economic and consumption trends. It emphasizes the importance of “reflexivity” in addressing our global energy situation, stressing that we cannot simply rely on our economic system to stimulate silver bullet technological innovation. After the authors had worked hard to convince readers that we should think through our energy situation carefully at multiple scales, it was a bit disappointing to see the absence of constructive, specific, thoughtful suggestions for global economic energy policy informed by study of the Jevons Paradox. Specifically, how can we develop synergies between local and global scales so that innovations in energy efficiency and/or energy decarbonization can be effectively scaled up?

The book focuses extensively on the interplay between the economic system and technology innovation. However, it is written exclusively from an economist’s perspective. Having one chapter from an engineer or technologist would have been a valuable addition. The technological component of any solution to our energy challenges must include more efficient energy use. The central point raised by the book is not that technological energy-efficiency innovations are counterproductive, but rather that relying on an unadjusted economic system to scale them up is.

The Jevons Paradox discusses an interesting array of issues from various perspectives relating to energy efficiency, technological innovation, and the behavior of economic systems. It describes at some length the difficulties of relating production and consumption at the local scale to broader globally desired outcomes. Though a strong case is made for energy policies informed by a sophisticated understanding of economic system dynamics, the authors offer limited guidance for moving forward.

Author’s Note
Although this article was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

About the Author
Diana Bauer was one of the principal authors of EPA’s research strategy for sustainability. At EPA she has developed and managed the Collaborative Science and Technology Network for Sustainability (CNS), a research grant program, which supports regional projects using multidisciplinary science in sustainability-related decision making. She participates in government and academic societies developing research agendas for sustainability; green mate-
materials, manufacturing, and building; transportation; and alternative energy. Dr. Bauer received her Ph.D. in Mechanical Engineering from the University of California at Berkeley and her BSE from Princeton University. Before joining EPA, she served as a visiting researcher in Japan, a technical editor in Taiwan, and an English teacher in China. Dr. Bauer was also an engineer at two firms in Waltham, Massachusetts.

References

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In reading The Jevons Paradox and the Myth of Resource Efficiency Improvements, Box’s maxim is usefully recalled early on: “all models are wrong, but some are useful.” Box goes on to note, “not only does the selected model have to be pertinent in relation to the chosen narrative, but the selected narrative must also carry relevance for those using the results of the analysis.”

The narrative of carbon-fueled economic growth was changed irrevocably with the formal and global acceptance of the phenomenon of climate change, as laid out in the findings of the Nobel Prize-winning International Panel on Climate Change. For centuries, largely because of its ability to perform against a nineteenth-century narrative, neoclassical economics, with its three enabling technologies of electrical power, the internal combustion engine, and modern communication systems for coordination and control, has been the preferred method for managing national economies. Neoclassical economics solidified nations’ identities and dominance by documenting extraordinary production and growth of goods, but without registering either the free use of many natural resources and systems or unprecedented population growth.

Under this paradigm, today’s developed world has achieved levels of sustained growth unrivaled even by the greatest past civilizations: Romans, Mayans, ancient Mesopotamia and Egypt, and some dynasties of China. However, the driving forces behind these latter civilizations were largely renewable biological systems (i.e., crops and people) with few dire long-term consequences. Today’s economic growth and the current specter of climate change are both derived from common carbon-fuel sources, a fact commanding attention to all potential solutions, including the assumption that resource efficiency reduces consumption, which the Jevons Paradox reveals as a myth.

This book’s new integrated exploration plays an important role in realigning an outdated narrative. William Stanley Jevons first formulated the paradox in 1865, arguing that “it is a confusion of ideas to suppose that the economical use of fuel is equivalent to diminished consumption. The very contrary is the truth.” The implication is that the focus on attaining efficient use of carbon fuel and petroleum-derived products will not sustain high levels of growth while curtailing consumption. Heightened technological adaptability without reduced resource consumption will not provide the carbon-fuel reduction necessary to diminish climate impacts.

Given the new narrative reality that the Jevons Paradox rests against, we should now consider it an important principle to be integrated into current economic analysis and policy formation. For example, in January, 2008 Tata Motors launched the Nano in India with a price tag of just US$2,500. A tiny four-seater, it is an efficient use of materials and promises mobility to thousands of Indian families with the expectation of hundreds of thousands more to follow throughout the developing world. The vehicle embodies the global trend of producing more for less and enhances the determination to manufacture millions. But, with its unprecedented resource efficiency in production, the Nano is not very fuel efficient. A perfect example of the Jevons Paradox, as noted in a long conversation on an Indian news website (Vail, 2008). Where else have resource efficiencies become paramount? A recent McKinsey report, a prime informant to the corporate community, shows Robert Socolow’s wedge of efficiency providing more than enough expense reduction to afford technological improvements that reduce corporate carbon emissions. Advice is available everywhere on reducing one’s carbon footprint, mostly through efficiency measures (masquerading as reduction?). And, finally, there is talk among humanity’s more daring of “going-off-grid” (i.e., becoming energy independent) (while remaining plugged-in).

All of this argues for a closer look at and change to the way we calculate gross domestic product (GDP), the prime national economic measure. If our calculation of GDP does not report the full effects of approaching peak oil by unmasking the chimera of technological efficiency, we will both fail to sustain a progressively equitable global economic system and

1 See Crets et al. (2007).
2 See, for example, Socolow et al. (2004).
The authors, John Polemini, Kozo Mayumi, Mario Giampietro, & Blake Alcott, have made the book challenging to read and authoritative in their areas of expertise. Beginning and ending with jointly written chapters, the book layers history, complex adaptive systems, and empirical evidence in between.

The Jevons Paradox begins with a historical overview that constitutes just under half of the main text. The overview is thorough, yet fails to succinctly indicate missed opportunities where the lessons of the Jevons Paradox could have been integrated into mainstream economic theory. The authors thus put us all at risk of continuing on a false path littered with arguing economists. As with most mature disciplines, changes often come incrementally, but conversely, watching recent financial markets create new instruments and algorithms to globally connect and communicate key variables, one wonders whether the field of energy economics might show a more aggressively inventive spirit.

Giampietro & Mayumi’s section on complex adaptive systems is well presented and explained in ways that are accessible to readers unfamiliar with the discovery of quantum mechanics during the 1920s. Regrettably, the chapter fails to transform the fundamentals of another discipline (i.e., economics), a phenomenon that has already occurred in similar attempts with linguistics, ecology, and psychology. Perhaps new operational platforms for organizing whole groups of data and connecting them in ways that transcend the notion of holons3 and hierarchies will emerge to enable synthesis. In the chapter’s conclusion, titled “Practical Lessons for the Analyst,” two recommendations seem prudent: to attempt to change the narrative and using numbers to check quality and to apply integrated analysis across dimensions and scales. It may be much more difficult to achieve the remaining two propositions: to keep the observer in mind while completing the analysis and to remain motivated and convincing while engaging the caveat that any analytical outcomes are only approximate.

The use of examples from national economies animates Polimeni’s section on empirical evidence. This chapter examines the United States, Europe, Asia, and Brazil. Simply put, “technological improvements may not be the universal remedy that policymakers have been counting on.” The Jevons Paradox appears widespread, especially as illustrated in the case of Japan from 1971–2001. Over the long term, Japan’s energy-efficient adaptations have led to a rise in energy consumption, even in this tightly controlled and closely managed country.

Who should read The Jevons Paradox? The book is most appropriate for those in the fields of economics and financial market analysis, engineering, ecological economics, materials and information sciences, and biotechnology. The book’s insights are also highly relevant for people heading up business schools, departments of environmental and biological studies, and information-technology companies. In light of the many permutations of the Jevons Paradox, the book provides a route for entrepreneurs to take with abandon. Some general readers may find an interest, but to sustain it through the course of the book will take considerable persistent effort. It is not a light-hearted romp.

What next? The authors need to move their argument to multiple scales and to broaden it to include possible applications outside of carbon-fuel energy such as soil fertility, water use, and biological resource use and preservation. It would be instructive to address how genomics and nanotechnologies play into the equation. And the courses of developed and developing countries will take radically different roads in the very near future. As the writer on the Nano car noted, India may not have a middle-class like that of America or Germany, but it will have its own middle-class. This development implies increased overall consumption that will look very different from that of consumerist America. Finally, will increasing use and rapid growth of consumer electronics worldwide absorb the efficiencies at a fast pace, or not at all?

It would be intriguing and important to extend this concept for exploration by economists and market analysts, ecologists, engineers, software developers, and materials scientists at smaller scales than the nation. If GDP is to be redefined against the tidal wave of current global usage, then a new path will most likely come from the integrated efforts of non-state (open source) players. Even global financial markets can be drivers for change. These actors are now in the very active process of redefining themselves and the financial instruments that both mitigate risk and create fluid capital.

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3 Coined by Arthur Koestler, a halon is something that is simultaneously a whole and a part.
About the Author

Kathryn Papp began her professional life in the private sector and for the past eighteen years has developed and launched programs and campaigns as disparate as: building a business constituency to support establishment of a new federal environmental research agency; initiating a research program integrating the ecology, economy, and human usage of three major trans-boundary watersheds; convening an expert panel to report to the Congressional Oceans Caucus on fisheries, energy, and marine diseases; and creating a national conference focused on gardens as a way to teach science and environmental studies for elementary teachers. Ms. Papp holds an MBA from the Thunderbird School of Global Management, and a bachelor’s degree from the Honors College of the University of Toledo where she created a cross-disciplinary readings course in Asian studies. She reads extensively in the sciences, composes poetry, and enjoys music. A United States citizen and resident of Alexandria, Virginia. Mr. Papp’s carbon footprint is 6.7 compared to an average of 27 for the country overall.

References


Rejoinder from the authors

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First, heartfelt thanks to the journal for these reviews of our book. And also, of course, for the opportunity to respond to them—an intellectually fruitful arrangement that should be more widely applied. We even welcome responses to our responses to the reviews, if you will! The comments are appreciated and will help further our future research on the important and timely topic of the Jevons Paradox.

Diana Bauer, in our view, captures the Jevons Paradox accurately and concisely, including recognition of the problem of how to define energy efficiency’s numerator, in some sense the social “product,” with energy inputs in the denominator. She confirms as well our conviction that judging efficiency cannot be done without examining larger scales than particular products or economic sectors or even national economies—i.e., without extending the system boundaries under investigation. And the study of the Jevons Paradox, or “rebound,” has led us to share Bauer’s skepticism toward “win-win” technical solutions said to save the environment and save us money both! Bauer also mentions the irony that when labor instead of energy inputs is considered, analysts universally expect that productivity increases will increase employment, not “save” it.

We find Bauer’s critiques largely accurate; indeed we debated most of them among ourselves while writing the book. First, it is true, as she says, that we do not provide “constructive, specific, thoughtful suggestions for global economic energy policy informed by study of the Jevons Paradox.” In our view, a book whose goal is to explore the predicament associated with sustainability must contain at least three types of analysis: historical, theoretical and empirical. In our volume these appear in that order and we believe diagnosis must precede any prescriptions for a cure. The result of our critical (but hopefully not “destructive”) analyses is thus not a general policy recommendation.

We thus agree with Bauer that “we cannot simply rely on our economic system to stimulate silver bullet technological innovation” or any one-size-fits-all solution. Energy policy should not repeat development theory’s mistake of seeking a solution set valid for all countries. The energy security of a society depends on its ability to match two flows of useful energy: (i) that required by the society, which depends on its socioeconomic identity (population structure, level of services, diversity of activities outside the paid-work sector) and (ii) that supplied by the energy sector, which depends on that society’s biophysical-technical identity (the mix of energy sources, technology and know-how, energy carriers, and end uses).

These two identities—of the socioeconomic system and of the energy sector—affect each other. At times the material standard of living has to be adjusted because of biophysical constraints (the identity of the energy sector affects the identity of the whole society), and at times technical innovations remove some of the biophysical restrictions. What is more, neither socioeconomic system nor energy sector are
static over time but are “becoming,” subjecting policy formulation to uncertainties bordering on genuine ignorance, especially regarding the goals of the socioeconomic system and the technical option space in, say, 25 years’ time.

To return to Bauer’s call for “global” policy suggestions, given international markets and free-rider problems perhaps such will be necessary—but because the energetic metabolism of societies changes, and there are many dozens of societies, even suggesting plausible overall solutions is extremely difficult. While the Kyoto path is promising, because it goes directly at the culprit, so to speak, how can global policies be formulated in light of diversity and uncertainty? Put another way, what flanking policies would be necessary for diverse societies to agree to Kyoto-like restrictions? Thus, indeed, perhaps our only “guidance for moving forward” is to recognize that, strictly regarding resource conservation and emissions reduction, the technological efficiency path deserves severe skepticism. Whether it is “counterproductive” or not depends on which goal is meant; energy innovations are useful for affluence and poverty reduction, but probably not for lowering energy-consumption rates. We welcome keeping both material-welfare and environmental goals in focus, but believe they are too often conflated.

We therefore see some ambiguity in Bauer’s position that “the technological component of any solution to our energy challenges must include more efficient energy use.” Likewise, when she writes that “the imperative raised by this book [is] leveraging the power of the market to address global energy and climate issues at sufficient scale” we are not sure whether she is suggesting global energy taxes. Of course, while the “market” usually reacts to higher energy prices with increased efficiency, the technological efficiency solution challenged by the Jevons Paradox explicitly does not assume higher (tax-induced) energy prices.

The charge that “having one chapter from an engineer or technologist would have been a valuable addition” to the book is debatable. In today’s policy climate where the engineering, technical “silver bullet” approach of energy efficiency is praised by economists, prime ministers, and presidents, one feels: Stop, let us assume that efficiency increases are technically possible. So let us focus exclusively on the economic, society-wide, even anthropological or psychological question of what to do when we realize that a higher output-input ratio almost always means more output instead of less input. Concerning Bauer’s call for “synergies between local and global scales,” we are again unsure exactly what these would look like, and what the mix of private and government measures might be. But the Jevons Paradox at least draws attention to how small-scale changes affect large-scale results, a feature usually ignored in engineering approaches and universally ignored in evaluations of efficiency policy, where rebound is simply set at zero!

Concerning the book’s regression analyses showing significant correlation between energy efficiency and energy consumption, we intended to start from a point different from the vast majority of, if not all, studies on the Jevons Paradox which have been on a micro-level. We do briefly summarize around twenty of these examples, relating their estimates of overall rebound based usually on microeconomic methodology. As with most general energy economics studies, we decided to use a simplifying macro-level model to obtain some understanding of the factors that cause the Paradox. Thus, it is true that this chapter was not able to relate the macro-level data and results to more local scales, and we welcome the suggestion that the results could in the future be correlated with different economic institutions, time periods prior to 1980, and perhaps energy prices.

Bauer wishes, moreover, that our chapter of statistical macro-level studies had been “built on previous chapters.” If, however, the rebound literature shows us one thing, it is that while some “direct” rebounds have been reasonably accurately measured (if only for a single country), measurement of the environmentally relevant “total” or “economy-wide” rebound has been somewhere between elusive and impossible. But yes, the search for smaller-scale explanations of the Jevons Paradox, relating technology and consumption behavior, must go on.

To Kathryn Papp’s suggestion that we broaden our study “to include possible applications outside of carbon-fuel energy such as soil fertility, water use, and biological resource use and preservation” we respond in the affirmative. A further example might be in space or regional planning: If space use for residences becomes more “efficient,” for instance through building higher or denser, what are the consequences on the next wider scale? The answers could be somewhat different than for energy. We focused specifically on energy policy as a very timely area where technological efficiency is touted as the solution. To get into other areas would have given the book a more diffuse focus, whereas we had a very specific point, perfectly illustrated by the Jevons Energy Paradox. In addition, contributing to the energy debate with its intimate connections to other areas contributes by default to the discussion of other resources, including those that Papp mentions.

We agree with Papp’s characterization of the dominant neoclassical paradigm as neglecting “the free use of many natural resources and systems or unprecedented population growth.” Again, study of

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the Jevons Paradox is a start toward better understanding of the relations between the triad of resource prices, resource efficiency, and resource consumption. And some of us have specifically studied the effects on population growth of increased efficiency, particularly in agriculture. We also welcome Papp’s mentioning that “advice is available everywhere on reducing one’s carbon footprint, mostly through efficiency measures.” Because many of these recommended measures involve consumer “sufficiency” and non-carbon-based energy sources, this point nicely opens up the policy discussion.

If Papp’s example of the cheap, efficiently produced Nano automobile is invoked to show how its very cheapness should enable its sale to “hundreds of thousands more [people] throughout the developing world,” this indeed demonstrates one of the main mechanisms for the Jevons Paradox—one moreover explicitly named by Jevons. She writes, correctly in our view, that “Socolow’s wedge of efficiency provides more than enough expense reduction” to finance “technological improvements that reduce corporate carbon emissions.” However, assuming producer competition, this same efficiency provides the consumer with price reductions that increase the number of units sold; while the corporation may thus reduce emissions per unit, its overall emissions may rise. This is the general point of our systems analysis: The level or scale of corporate emissions has no necessary causal influence on the environmentally relevant society or world scale. We are, however, not sure of the status of her statement that “the Nano is not very fuel efficient.” Again, how is efficiency here measured? And if this is true, the Jevons Paradox could not be tested on this example.

Papp’s criticism that our pre-Jevons (1865) chapter “fails to succinctly indicate missed opportunities where the lessons of the Jevons Paradox could have been integrated into mainstream economic theory” is certainly true. This task, however, would have been not only beyond our present ability, but beyond the space available. One way to compensate for this deficiency is that, since neoclassical economics includes only capital and labor as “factors of production,” it cannot address the efficiency problem pertaining to natural inputs. Furthermore, since the “backfire” of labor-productivity increases—increasing population and employment over several centuries—was seen as positive, perhaps both classical and neoclassical thinkers felt no need to investigate it. To be sure, classical economists from Ricardo and Sismondi and the Owenites and Luddites through Say and Mill to Marx hotly debated the question of whether greater production efficiency would throw millions out of work.

Thus, regarding labor inputs backfire is both uncontroverted and seen as good, while regarding energy inputs it is, from an environmental viewpoint, contested and perceived, correctly, as harmful. Jevons’ main message seems to be that whenever any input is freed from former purposes, new purposes and/or new economic actors appear to employ the idle inputs. Were we to completely convert efficiency benefits into less production and consumption, rebound would indeed be zero. But the facts of poverty and human desire for comfort and prestige mean that, while, to prevent environmental catastrophe, input consumption must not rise, it in fact does. Therefore efficiency policy is not conservation policy.