Ecological Paradoxes: William Stanley Jevons and the Paperless Office

Richard York

Assistant Professor
Department of Sociology
University of Oregon
Eugene, OR 97403-1291[1]

Abstract

Here I draw attention to two socio-ecological paradoxes. The Jevons Paradox is based on the observation that an improvement in the efficiency with which a natural resource is used is often associated with an increase in the consumption of that resource. Similarly, the Paperless Office Paradox is based on the observation that the development of substitutes for a natural resource is not always associated with a decline in consumption of that resource, and in fact may occasionally lead to an increase in the consumption of that resource. These two paradoxes call into question whether technological advances alone will necessarily lead to conservation of natural resources.

Keywords: *Jevons paradox, paperless office, eco-efficiency*

Introduction

At the core of the broad program aimed at achieving environmental sustainability is a concern with how the dynamics of economic systems can be brought into harmony with ecosystems. One major challenge for this program is to understand the dynamics of market economies with respect to natural resource consumption. In particular, it is important for environmental social scientists to assess whether some modern economies are dematerializing — i.e., reducing the absolute quantity of natural resources they consume[2] — and, if so, why. Here I discuss two ecological paradoxes in economics that together call into question whether the dematerialization of economies can be achieved through either of two routes which are commonly suggested: (1) improvements in the efficiency of resource use in the production process and (2) the development of substitutes for some types of natural resources.[3] The first paradox I discuss is a classical one, the Jevons Paradox, which suggests that improvements in efficiency do not necessarily lead to a reduction in resource consumption; in fact they may lead to an *increase* in resource consumption. The second paradox I discuss is one that to my knowledge has not previously been explicitly identified as a paradox, the Paperless Office Paradox, which suggests that the development of substitutes for some resources may not lead to a reduction in consumption of those resources and in some cases may actually lead to an increase in consumption.

The Jevons Paradox

William Stanley Jevons (2001 [1865]), one of the foundational writers in ecological economics, in his famous book *The Coal Question* identified what is perhaps the most widely known paradox in ecological economics, a paradox which has subsequently become known as the Jevons Paradox (Clark and Foster 2001). Jevons observed that as the efficiency of coal use by industry improved, thereby allowing for the production of more goods per unit of coal, total coal consumption *increased*. At least two potentially complementary explanations for this paradox stand out. First, following classical economic reasoning, as the efficiency of coal use increases, the cost of coal per unit of goods produced decreases. This reduction in cost makes coal more desirable to producers as an energy source, thus leading producers to invest in technologies that utilize coal. Second, following political-economic reasoning, the drive to increase profits inherent in capitalist modes of production leads producers to try to both reduce costs by reducing resource inputs per unit of production (i.e., improving efficiency) and increase revenues by expanding the quantity of goods and services produced and sold, thus necessitating the expansion of resource consumption (Foster 2002, 92-103; Schnaiberg and Gould 1994, 45-67). The political-economic explanation of the Jevons Paradox suggests that the association between efficiency and total consumption is primarily due to a third factor that drives both, i.e., profit seeking behavior by capitalists, although it recognizes a potentially direct link in that profits stemming from improvements in efficiency can be invested in expanding production. The classical economic explanation sees efficiency and total consumption as causally linked through the cost of coal per unit of production. Of course, both processes are potentially complementary and may operate together or alternately in different historical moments, and other processes may well be at work too.

Determining the extent to which the Jevons Paradox does indeed exist and how generally applicable it is — how commonly is rising efficiency in the use of a resource associated with an escalation of consumption of that resource? — is an important task for environmental social scientists, since arguments that more efficient production technologies will help solve environmental crises are a staple in public policy discussions in most developed nations and are at least implicit, and frequently explicit, in various research programs, including industrial ecology (Graedel and Allenby 1995), ecological modernization (Mol and Spaargaren 2000), Factor X (Reijnders 1998), and the environmental Kuznets curve (Dinda 2004). Environmental social scientists can provide a great service by assessing the contexts in which there exists a paradoxical association between the efficiency of use and the total consumption of natural resources, and the reasons for this association (Alcott 2005).[4] Although Jevons focused on the association at a specific level (industry) between a specific type of efficiency (output per unit of resource use) and a specific natural resource (coal), it is important to establish how generalized the association between efficiency and total resource consumption is. After all, if rising efficiency is frequently associated with escalating resource consumption, then a focus on improving efficiency may be both misguided and misleading. I present two examples that suggest that the Jevons Paradox, as a factual proposition about the association between efficiency of production and the consumption of resources, may have broad applicability and characterize a variety of situations and types of efficiency.

Eco-efficiency of National Economies

Bunker (1996) found that over a long stretch of recent history, the world economy as a whole showed substantial improvements in resource efficiency (economic output per unit of natural resource), but that the total resource consumption of the global economy continually escalated. Similarly, York et al. (2004) have shown that at the national level, high levels of affluence are, counter-intuitively, associated with both greater eco-efficiency (GDP output per unit of "ecological footprint") of the economy as a whole and with higher per capita ecological footprint, suggesting that empirical conditions characteristic of the Jevons Paradox often may be applicable to the generalized aggregate level. In fact, this type of pattern appears to be quite common. York et al. (2003) explain how statistical analyses using elasticity models of the effect of economic development (GDP per capita) on environmental impacts, such as carbon dioxide emissions, can shed light on the relationship between efficiency and total environmental impact. With such a model, an elasticity coefficient for GDP per capita (which indicates the percentage increase in the environmental impact of nations for a 1% increase in GDP per capita) of between 0 and 1 (indicating a positive inelastic relationship) implies a condition where the aggregate eco-efficiency of the economy improves with development, but the expansion of the economy exceeds improvements in efficiency, leading to a net increase in environmental impact. Rosa et al. (2004) have found that several types of environmental impacts have an inelastic relationship with GDP per capita. This type of research does not establish a causal link between efficiency and total environmental impact or resource consumption, but it does empirically demonstrate that an association between rising efficiency and rising environmental impacts may be common, at least at the national level.[5] These findings also suggest that improving eco-efficiency in a nation is not necessarily, or even typically, indicative of a decline in resource consumption (York and Rosa 2003).[6]

Fuel Efficiency of Automobiles

The fuel efficiency of automobiles is obviously an issue of substantial importance, since motor vehicles consume a large share of the world's oil. It would seem reasonable to expect that improvements in the efficiency of engines and refinements in the aerodynamics of automobiles would help to curb motor fuel consumption. However, an examination of recent trends in the fuel consumption of motor vehicles suggests a paradoxical situation where improvements in efficiency are associated with increases in fuel consumption. For example, in the United States an examination of a reasonable indicator of fuel efficiency of automobiles stemming from overall engineering techniques, pound-miles per gallon (or kilogram-kilometers per liter) of fuel, supports the contention that the efficiency of the light duty fleet (which includes passenger cars and light trucks) improved substantially between 1984 and 2001 (the earliest and latest years respectively for which complete data are available), while the total and average fuel consumption of the fleet *increased*.

For the purposes of calculating CAFE (corporate average fuel economy) performance of the nation's automobile fleet, the light duty fleet is divided into two categories, passenger cars and light trucks (which includes sports utility vehicles [SUVs]), each of which has a different legally enforced CAFE standard[7]. In 1984 the total light truck fleet CAFE miles per gallon (MPG) was 20.6 (~8.8 kilometers per liter [KPL]) and the average equivalent test weight was 3804 pounds (~1725 kilograms), indicating that the average pound-miles per gallon was 78,364 (20.6 • 3804) (~15,100 kilogram-KPL). By 2001, the total light truck fleet CAFE MPG had improved slightly to 21.0 (~8.9 KPL), while the average vehicle weight had increased substantially, to 4501 pounds (~2040 kilograms). Therefore the pound-miles per gallon had increased to 94,521 (21.0 • 4501) (~18,200 kilogram-KPL), a 20.6% improvement in efficiency from 1984. A similar trend happened in passenger cars over this same period. In 1984 the total passenger car fleet CAFE was 26.9 MPG (~11.4 KPL) and the average equivalent test weight was 3170 pounds (~1440 kilograms), indicating that the pound-miles per gallon was 85,273 (26.9 • 3170) (~16,400 kilogram-KPL). By 2001, the total passenger car fleet CAFE MPG had improved to 28.7 (~12.2 KPL) while the average vehicle weight had increased to 3446 pounds (~1560 kilograms), making the average fleet pound-miles per gallon 98,900 (28.7 • 3446) (~19,070 kilogram-KPL) — a 16.0% improvement since 1984.

Clearly engineering advances had substantially improved the efficiency of both light trucks and passenger cars in terms of pound-miles per gallon (or kilogram-kilometers per liter) between 1984 and 2001. The observation of this fact in isolation might lead one to expect that these improvements in efficiency were associated with a reduction in the fuel consumption of the total light duty fleet. However, this is not what happened. Over this period, light trucks, which on average are heavier and consume more fuel than passenger cars, grew from 24.4% of the light duty fleet to 46.6%. Because of this shift in composition, the CAFE MPG for the combined light duty fleet declined from 25.0 to 24.5 (from ~10.6 to ~10.4 KPL), a 2% decrease. Clearly, engineering advances had improved the efficiency of engines and other aspects of automobiles, but this did not lead to a less fuel-thirsty fleet since the size of vehicles increased substantially, particularly due to a shift from passenger cars to light trucks among a large segment of drivers.[8] It is worth noting that even if the total fleet MPG had improved, a reduction in fuel consumption would have been unlikely to follow, since over this period the distance traveled by drivers per year increased from little more than 15,000 km (~9300 miles) per car, on average, to over 19,000 km (~11,800 miles) (Smil 2003, 326). And, finally, an increase in the number of drivers and cars on the road drove up fuel consumption even further. For example, between 1990 and 1999, the number of motor vehicles in the U.S. increased from 189 million to 217 million due to both population growth and a 2.8% increase in the number of motor vehicles per 1000 people (from 758 to 779) (World Bank 2005).

It appears that technological advances that improved the engineering of cars were in large part put, at least in the U.S., into expanding the size of vehicles, rather than reducing the fuel the average vehicle consumed. The causal explanations for this are likely complex, but the fact that, despite engineering improvements, the U.S. light duty fleet increased its total and average fuel consumption over the past two decades does suggest that technological refinements are unlikely in and of themselves to lead to the conservation of natural resources. Furthermore, it is possible that improvements in efficiency may actually contribute to the expansion of resource consumption, since it is at least plausible that a success at improving the MPG/KPL of a nation's automobile fleet may encourage drivers to travel more frequently by car, due to the reduction in fuel consumption per mile/kilometer — a situation directly analogous to the one Jevons observed regarding coal use by industry.

The Paperless Office Paradox

Paper, of course, is typically made from wood fiber, so paper consumption puts substantial pressure on the world's forest ecosystems. It would seem on the face of it that the rise of the computer and the capacity for the storage of documents in electronic form would lead to a decline in paper consumption and, eventually, the emergence of the "paperless office"; which would be decidedly good news for forests. This, however, has not been the case, as Sellen and Harper (2002) clearly document in their aptly titled book *The Myth of the Paperless Office*. Contrary to the expectations of some, computers, e-mail, and the World Wide Web, are associated with an *increase* in paper consumption. For example, consumption of the most common type of office paper (uncoated free-sheet) increased by 14.7% in the U.S. between the years 1995 and 2000 (Sellen and Harper 2002, 11), embarrassing those who predicted the emergence of the paperless office. Sellen and Harper (2002, 13) also point to research indicating that "the introduction of e-mail into an organization caused, on average, a 40% increase in paper consumption."[9] This observation suggests that there may be a direct causal link between the rise of electronic mediums of data storage and paper consumption, although further research is necessary to firmly establish the validity of this possible causal link.

The failure of computers and electronic storage mediums to bring about the paperless office points to an interesting paradox, which I label the Paperless Office Paradox: the development of a substitute for a natural resource is sometimes associated with an increase in consumption of that resource. This paradox has potentially profound implications for efforts to conserve natural resources. One prominent method advocated for reducing consumption of a particular resource is to develop substitutes for it. For example, the development of renewable energy resources, such as wind and solar power, are commonly identified as a way to reduce dependence on fossil fuel, based on the assumption that the development of alternative sources of energy will displace, at least to some extent, fossil fuel consumption. However, just as the Jevons Paradox points to the fact that efficiency may not lead to a reduction in resource consumption, the Paperless Office Paradox points to the fact that the development of substitutes may not lead to a reduction in resource consumption.

The reasons that computers led to a rise in paper consumption are not particularly surprising. Although computers allow for the electronic storage of documents, they also allow for ready access to innumerable documents that can be easily printed using increasingly ubiquitous printers, which explains in large part the reason for escalating office paper consumption (Sellen and Harper 2002). Due to the particularistic reasons for the association between electronic storage mediums and paper consumption, the Paperless Office Paradox may not represent a generality about the development of substitutes and resource consumption. However, this paradox does emphasize the point that one should not assume that the development of substitutes for a natural resource will lead to a reduction in consumption of that resource.

For example, over the past two centuries we have seen the rise of fossil fuel technologies and the development of nuclear power, so that, whereas in the 18th century biomass was the principal source of energy in the world, biomass now only provides a small proportion of global energy production. However, it is worth noting that even though substitutes for biomass — e.g., fossil fuel and nuclear power — have expanded dramatically, the *absolute* quantity of biomass consumed for energy in the world has *increased* since the 19th century (Smil 1994). This is likely due, at least in part, to the fact that the new energy sources fostered economic and population growth, which in turn expanded the demand for energy sources of all types, including biomass. This observation raises the prospect that the expansion of renewable energy production technologies, such as wind turbines and photovoltaic cells, may not displace fossil fuel or other energy sources, but merely add a new source on top of them, and potentially foster conditions that expand the demand for energy. Clearly, further theoretical development and empirical research aimed at assessing the extent to which substitutes actually lead to reductions in resource consumption is called for, and faith that technological developments will solve our natural resource challenges should at least be called into question.

Conclusion

Here, I have drawn attention to two ecological paradoxes in economics, the Jevons Paradox and the Paperless Office Paradox. The Jevons Paradox is a classical one, based on Jevons observation that rising efficiency in the utilization of coal led to an *escalation* of coal consumption. I presented two examples, which suggest that the Jevons Paradox may have general applicability to a variety of circumstances. The Paperless Office Paradox is a new one, which I identified here, that draws attention to the fact that the development of computers and electronic storage mediums has not led to a decline in paper consumption, as some predicted, but rather to *more* paper consumption. It is important to note that these are *empirically* established paradoxes — they point to the correlation between efficiency or substitutes and resource consumption. Each paradox may actually house phenomena that have a diversity of theoretical explanations. Therefore, underlying these two paradoxes may be many forces that need to be theorized.

Together, these paradoxes suggest that improvements in the efficiency of use of a natural resource and the development of substitutes for a natural resource may not lead to reductions in consumption of that resource — in fact, at least in some circumstances, they may even lead to an escalation of consumption of that resource. Although, obviously, improvements in efficiency and utilization of substitutes will reduce consumption of a resource *all else being equal* (i.e., if the scale of production remains constant), economies are complex and dynamic systems with innumerable interactions among factors.

Changes in the type and efficiency of resource utilization will likely influence many other conditions, thus ensuring that all else will rarely be equal. Relying on technological advances alone to solve our environmental problems may have disastrous consequences. The two paradoxes I present here suggest that social and economic systems may need to be modified if technological advances are to be translated into natural resource conservation.

Endnotes

1. Author to whom correspondence should be directed:
E-mail: rfyork@uoregon.edu
2. Here I am referring to *absolute* dematerialization. Some scholars focus on *relative* dematerialization — i.e., the reduction in resource consumption per unit of production. It is possible to have relative dematerialization, while total material consumption increases because the scale of production increases faster than efficiency of material use improves.
3. Typically this entails substituting one type of natural resource for another, such as plastic for steel or wood; or in the specific example used here, the resources embedded in computer hardware and electronic storage mediums for those used in hardcopy storage mediums (e.g., paper).
4. Alcott (2005) provides a review of research on the Jevons Paradox. Khazzoom (1980) raises similar issues to those discussed here. A special issue of the journal *Energy Policy* 28(6-7) contains several articles relevant to the present discussion.
5. It is possible that, at least in some instances, total resource consumption expands *in spite of* rather than because of improvements in effi-

ciency. Establishing the nature of causal processes is, of course, a difficult task in non-experimental sciences. Determining the extent to which the link between efficiency and total resource consumption is causal, and which direction the causality flows, will require both further empirical work and nuanced theoretical development.

6. Of course, factors like population growth also contribute to driving the expansion of resource consumption. My focus here is on the extent to which a connection between efficiency and the dynamics of economies can lead to escalation of resource consumption independently of other forces.
7. All data for these calculations are from NHTSA (2005).
8. This increase in light trucks did not happen by chance. It was strongly pushed by the auto-industry to circumvent CAFE standards (Bradsher 2002).
9. For a counter-example, see Hoogeveen and Reijnders's (2002) analysis of the effects of a Dutch electronic retailer's application of e-commerce on paper and energy consumption.

Acknowledgements

I thank Brett Clark and the *HER* anonymous reviewers for their helpful comments.

References

Alcott, B. 2005. Jevons' Paradox. *Ecological Economics* 54, 9-21.

Bradsher, K. 2002. *High and Mighty: SUVs — The World's Most Dangerous Vehicles and How They Got That Way.* New York: Public Affairs.

Bunker, S.G. 1996. Raw material and the global economy: Oversights and distortions in industrial ecology. *Society and Natural Resources* 9, 419-429.

Clark, B. and J.B. Foster. 2001. William Stanley Jevons and the coal question: An introduction to Jevons's 'Of the Economy of Fuel.' *Organization & Environment* 14(1), 93-98.

Dinda, S. 2004. Environmental Kuznets Curve Hypothesis: A survey. *Ecological Economics* 49, 431-455.

Foster, J. 2002. *Ecology Against Capitalism*. New York: Monthly Review Press.

Graedel, T. and B. Allenby. 1995. *Industrial Ecology*. Englewood Cliffs, NJ: Prentice Hall.

Hoogeveen, M.J. and L. Reijnders. 2002. E-commerce, paper and energy use: A case study concerning a Dutch electronic computer retailer. *International Journal of Global Energy Issues* 18(2/3/4), 294-301.

Jevons, W.S. 2001 [1865]. Of the economy of fuel [excerpt from *The Coal Question*]. *Organization & Environment* 14(1), 99-104.

Khazzoom, D.J. 1980. Economic implications of mandated efficiency in standards for household appliances. *Energy Journal* 1(4), 21-39.

Mol, A.P.J. and G. Spaargaren. 2000. Ecological modernization theory in debate: A review. *Environmental Politics* 9(1), 17-49.

NTHSA [National Traffic Highway Safety Administration]. 2005. Website: http://www.nhtsa.dot.gov/cars/rules/cafe/index.htm. Last accessed January 10, 2006.

Reijnders, L. 1998. The factor 'x' debate: Setting targets for eco-efficiency. *Journal of Industrial Ecology* 2(1), 13-22.

Rosa, E.A., R. York, and T. Dietz. 2004. Tracking the anthropogenic drivers of ecological impacts. *Ambio* 33(8), 509-512.

Schnaiberg, A. and K.A. Gould. 1994. *Environment and Society: The Enduring Conflict*. New York: St. Martin's Press.

Sellen, A.J. and R.H.R. Harper. 2002. *The Myth of the Paperless Office*. Cambridge, MA: MIT Press.

Smil, V. 1994. *Energy in World History*. Boulder, CO: Westview Press.

Smil, V. 2003. *Energy at the Crossroads: Global Perspectives and Uncertainties*. Cambridge, MA: MIT Press.

World Bank. 2005. *World Development Indicators*. CD-ROM.

York, R. and E.A. Rosa. 2003. Key challenges to ecological modernization theory: Institutional efficacy, case study evidence, units of analysis, and the pace of eco-efficiency. *Organization & Environment* 16(3), 273-288.

York, R., E.A. Rosa, and T. Dietz. 2003. STIRPAT, IPAT, and ImPACT: Analytic tools for unpacking the driving forces of environmental impacts. *Ecological Economics* 46(3), 351-365.

York, R., E.A. Rosa, and T. Dietz. 2004. The ecological footprint intensity of national economies. *Journal of Industrial Ecology* 8(4), 139-154.