= Jevons paradox =

In economics , the Jevons paradox (/ ?d??v?nz / ; sometimes Jevons effect) occurs when technological progress increases the efficiency with which a resource is used (reducing the amount necessary for any one use) , but the rate of consumption of that resource rises because of increasing demand . The Jevons paradox is perhaps the most widely known paradox in environmental economics . However , governments and environmentalists generally assume that efficiency gains will lower resource consumption , ignoring the possibility of the paradox arising .

In 1865 , the English economist William Stanley Jevons observed that technological improvements that increased the efficiency of coal @-@ use led to the increased consumption of coal in a wide range of industries . He argued that , contrary to common intuition , technological progress could not be relied upon to reduce fuel consumption .

The issue has been re @-@ examined by modern economists studying consumption rebound effects from improved energy efficiency . In addition to reducing the amount needed for a given use , improved efficiency also lowers the relative cost of using a resource , which increases the quantity demanded . This counteracts (to some extent) the reduction in use from improved efficiency . Additionally , improved efficiency accelerates economic growth , further increasing the demand for resources . The Jevons paradox occurs when the effect from increased demand predominates , and better efficiency leads to more resources being used .

Considerable debate exists about the size of the rebound in energy efficiency and the relevance of Jevons paradox to energy conservation . Some dismiss the paradox , while others worry that it may be self @-@ defeating to pursue sustainability by increasing energy efficiency . Environmental economists have proposed that efficiency gains be coupled with conservation policies that keep the cost of use the same (or higher) to avoid the Jevons paradox . Conservation policies (such as cap and trade) do not display the paradox , and can be used to control the rebound effect .

= = History = =

The Jevons paradox was first described by the English economist William Stanley Jevons in his 1865 book The Coal Question . Jevons observed that England 's consumption of coal soared after James Watt introduced the Watt steam engine , which greatly improved the efficiency of the coal @-@ fired steam engine from Thomas Newcomen 's earlier design . Watt 's innovations made coal a more cost @-@ effective power source , leading to the increased use of the steam engine in a wide range of industries . This in turn increased total coal consumption , even as the amount of coal required for any particular application fell . Jevons argued that improvements in fuel efficiency tend to increase (rather than decrease) fuel use , writing : " 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 . "

At that time , many in Britain worried that coal reserves were rapidly dwindling , but some experts opined that improving technology would reduce coal consumption . Jevons argued that this view was incorrect , as further increases in efficiency would tend to increase the use of coal . Hence , improving technology would tend to increase the rate at which England 's coal deposits were being depleted , and could not be relied upon to solve the problem .

Although Jevons originally focused on the issue of coal , the concept has since been extended to the use of any resource , including , for example , water usage . It is perhaps the most widely known paradox in environmental economics .

= = Cause = =

Economists have observed that consumers tend to travel more when their cars are more fuel efficient , causing a ' rebound ' in the demand for fuel . An increase in the efficiency with which a resource (e.g. fuel) is used , causes a decrease in the cost of using that resource when measured in terms of what it can achieve (e.g. travel) . Generally speaking , a decrease in the cost (or price) of a good or service will increase the quantity demanded (the law of demand) . With a lower cost

for travel , consumers will travel more , increasing the demand for fuel . This increase in demand is known as the rebound effect , and it may or may not be large enough to offset the original drop in demand from the increased efficiency . The Jevons paradox occurs when the rebound effect is greater than 100 % , exceeding the original efficiency gains .

The size of the rebound effect is determined by the price elasticity of demand for the good . In a perfectly competitive market where fuel is the sole input used , if the price of fuel remains constant but efficiency is doubled , the effective price of travel would be halved (twice as much travel can be purchased) . If in response , the amount of travel purchased more than doubles (i.e. demand is price elastic) , then fuel consumption would increase , and the Jevons paradox would occur . If demand is price inelastic , the amount of travel purchased would less than double , and fuel consumption would decrease . However , goods and services generally use more than one type of input (e.g. fuel , labour , machinery) , and other factors besides input cost may also affect price . These factors tend to reduce the rebound effect , making the Jevons paradox less likely to occur .

= = Khazzoom ? Brookes postulate = =

In the 1980s , economists Daniel Khazzoom and Leonard Brookes revisited the Jevons paradox for the case of society 's energy use . Brookes , then chief economist at the UK Atomic Energy Authority , argued that attempts to reduce energy consumption by increasing energy efficiency would simply raise demand for energy in the economy as a whole . Khazzoom focused on the narrower point that the potential for rebound was ignored in mandatory performance standards for domestic appliances being set by the California Energy Commission .

In 1992 , the economist Harry Saunders dubbed the hypothesis that improvements in energy efficiency work to increase (rather than decrease) energy consumption the Khazzoom ? Brookes postulate , and argued that the hypothesis is broadly supported by neoclassical growth theory (the mainstream economic theory of capital accumulation , technological progress and long @-@ run economic growth) . Saunders showed that the Khazzoom ? Brookes postulate occurs in the neoclassical growth model under a wide range of assumptions .

According to Saunders , increased energy efficiency tends to increase energy consumption by two means . First , increased energy efficiency makes the use of energy relatively cheaper , thus encouraging increased use (the direct rebound effect) . Second , increased energy efficiency leads to increased economic growth , which pulls up energy use for the whole economy . At the microeconomic level (looking at an individual market) , even with the rebound effect , improvements in energy efficiency usually result in reduced energy consumption . That is , the rebound effect is usually less than 100 % . However , at the macroeconomic level , more efficient (and hence comparatively cheaper) energy leads to faster economic growth , which increases energy use throughout the economy . Saunders argued that , taking into account both microeconomic and macroeconomic effects , technological progress that improves energy efficiency will tend to increase overall energy use .

= = Energy conservation policy = =

Jevons warned that fuel efficiency gains can lead to an increase in the use of fuel , which cancels out any efficiency gains . But this does not imply that improved fuel efficiency is worthless ; higher fuel efficiency enables greater production and a higher material quality of life . For example , a more efficient steam engine allowed the cheaper transportation of both goods and people who contributed to the Industrial Revolution . However , if the Khazzoom ? Brookes postulate is correct , increased fuel efficiency , by itself , will not reduce the rate of depletion of fossil fuels .

There is considerable debate about whether the Khazzoom @-@ Brookes Postulate is correct , and of the relevance of Jevons paradox to energy conservation policy . Most governments , environmentalists and NGOs pursue policies that improve efficiency , holding that it will lower resource consumption and reduce environmental problems . Others , including many environmental economists , doubt this ' efficiency strategy ' towards sustainability , and worry that efficiency gains

may in fact lead to higher production and consumption . They hold that for resource use to fall , efficiency gains should be coupled with other policies that limit resource use .

The Jevons paradox is sometimes used to argue that energy conservation efforts are futile , for example , that more efficient use of oil will lead to increased demand , and will not slow the arrival or the effects of peak oil . This argument is usually presented as a reason not to enact environmental policies or pursue fuel efficiency (e.g. if cars are more efficient , it will simply lead to more driving) . Several points have been raised against this argument . First , in the context of a mature market such as for oil in developed countries , the direct rebound effect is usually small , and so increased fuel efficiency usually reduces resource use , other conditions remaining constant . Second , even if increased efficiency does not reduce the total amount of fuel used , there remain other benefits associated with improved efficiency . For example , increased fuel efficiency may mitigate the price increases , shortages and disruptions in the global economy associated with peak oil . Third , environmental economists have pointed out that fuel use will unambiguously decrease if increased efficiency is coupled with an intervention (e.g. a fuel tax) that keeps the cost of fuel use the same or higher .

The Jevons paradox indicates that increased efficiency by itself may not reduce fuel use , and that sustainable energy policy must rely on other types of government interventions . As the Jevons paradox applies only to technological improvements that increase fuel efficiency , the imposition of conservation standards or other government interventions that increase costs do not display the paradox and can be used to control the rebound effect . To ensure that efficiency @-@ enhancing technological improvements reduce fuel use , efficiency gains can be paired with government intervention that reduces demand (e.g. green taxes , cap and trade , or higher emissions standards) . The ecological economists Mathis Wackernagel and William Rees have suggested that any cost savings from efficiency gains be " taxed away or otherwise removed from further economic circulation . Preferably they should be captured for reinvestment in natural capital rehabilitation . " By mitigating the economic effects of government interventions designed to promote ecologically sustainable activities , efficiency @-@ improving technological progress may make the imposition of these interventions more palatable , and more likely to be implemented .