

letters

the only way in which a better world—indeed the survival of this world—is possible.

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Spurious correlations

I would like to offer an observation about John Gilman's interesting comments on inventions and corporate size (October, page 9). Most of his conclusions are drawn from a plot of $\ln(P/S)$ versus $\ln S$ and from a comparison of P/S and R/S . Here P , S and R are respectively the patent activity, sales, and research expenditures for selected US corporations in 1977. In both instances, Gilman makes statistical comparisons of quantities which are functions of the same variable (S). Such procedures are known to introduce "spurious" correlations which may in turn lead to unjustified, and perhaps erroneous, conclusions about the relations of the other variables. This effect was, I believe, first discussed by Karl Pearson in 1897 (*Proc. Royal Soc. of London* 60, 489-502).

The point can be simply illustrated by the following example. Suppose that P and S are independent random variables and that P has a much more sharply peaked distribution than S . Then $\ln P$ is to a first approximation constant and a plot of $\ln(P/S)$ versus $\ln S$ will show a slope and a correlation coefficient both near -1 . The large correlation coefficient is called spurious because it suggests a relation between P and S when there is none. This effect persists even when the variability of $\ln P$ is comparable with that of $\ln S$. If both quantities have the same coefficient of variation (ratio of standard deviation to mean), the correlation coefficient is typically about -0.7 . (For Gilman's data, the coefficients of variation of $\ln P$ and $\ln S$ are respectively 0.14 and 1.30.) For similar reasons, a comparison of P/S and R/S may be expected to show a rather large positive correlation even if P , R and S are all completely uncorrelated.

Thus the results exhibited in Gilman's figure and his table 2 do not appear to be greatly different from what we would expect if the three basic variables were completely independent. Although his tentative conclusion that "the production of inventions becomes less important relative to other factors as an industrial corporation grows in size" and his inferences about the relation between R and S may well be correct, I do not believe that the data presented in the figure and the table

provide any substantial support for his arguments.

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Electric cars

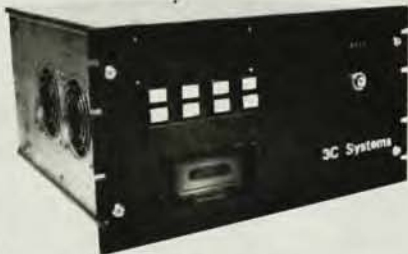
I feel it might be useful to respond to the electric car remarks of Richard Raymond and William Walsh (October 1980, page 100) and the earlier fine article by Walsh on batteries for electric propulsion (June 1980, page 34). As a person interested in environmental physics for the last 8 years or more, it is sometimes surprising to me how long it is taking for people to realize that the battery electric car is no such thing. It is a coal or nuclear car utilizing battery energy storage. As is painfully clear by now, batteries are costly, heavy and inefficient. In addition, were the society to replace cars going 1000 miles/month at some 33 miles/gallon efficiency with electric vehicles as defined above a monthly usage increase of about 10^3 kwh per such replacement would occur. The capital costs required to provide for such a doubling (or more) of electrical usage would be vast indeed. The point is that the sensible electric car uses presently available light, well-understood, easily repaired engines and runs them off electrically produced synthetic methane, LPG or gasoline-liquids. (LPG is the choice that I think will occur). Supposing one has the extra installed electrical generation capacity to do it, such a replacement of natural hydrocarbon fuel is technologically easy to imagine.

The "coal-fired, battery storage" car, as we might call it, can certainly find a restricted place for itself within a national transportation picture, but that place does not account for much of the whole system's energy or pollution total. I suspect it is a technology on a par with the dirigible or the carbon-arc street light. The appearance of internal combustion cars with LPG tanks and clean-burning synthetic fuel will be an easy technical change once we have (maybe Tokamak-produced) extra electrical power to spare for the job. Until that time, it is not clear to me that we don't do better running our cars and trucks off ancient solar energy stored (in a sense also electrically) with much greater efficiency in chemical heats of formation.

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