

Some Ideas About Growth and Quality in Technology

JOHN H. LIENHARD

ABSTRACT

The assumptions behind the exponential theory for the rate of improvement of the "quality" of technologies are studied. It is shown that the conformity of a measure of quality to the exponential law reveals that the technology is "motivated" and only "ingenuity-limited." It is shown that exponential growth suggests that quality is driven from within and resistant to the influences of such external factors as economics and politics. During the last century and a half, the exponential growth rate of a technology has increased with its inception date. This suggests means for analyzing the evolution of hybrid technologies.

A Preliminary Personal Prejudice

I am less interested in measuring technology than I am in taking pleasure in it. There is quality and beauty in technology, and there is a kind of innocent animal inexorability to it. It evolves at a pace that is quite independent of the people who seem to be responsible for making it happen.

We look at our technological product and it seems wonderful and remarkable—even inspired. Yet humankind has very little power to influence it. The human race is defined by its compulsive tool-making—its *technology*. Anthropologists do not decide whether or not a particular ancestor of ours was human, based on its physiognomy. They make the judgement on the basis of whether or not they can show that it made tools in any serious and methodical way.

Several French anthropologists (Andre Leroi-Gourhan and Maurice Daumier, for example [4]) have convincingly argued that tool making precedes human intellectual evolution—that the expansion of our intellect actually *follows* the development of tools, that the erect walk which freed the hand and the opposed thumb which made serious tool manipulation possible were causes of a great intellectual leap forward, not its results. I

JOHN H. LIENHARD is Professor of Mechanical Engineering at the University of Houston, Houston, Texas.

Address reprint requests to Dr. John H. Lienhard, Heat Transfer/Phase Change Laboratory, Department of Mechanical Engineering, University of Houston, Houston, Texas 77004.

have seen what the computer has done for—or to—my students and my children. It has altered them. It has permitted them to see things that I could not see when I was a student or a child.

When I look at the growth or the improvement of technology, what I see is not *man-driven*, but rather *man-driving*. This state of affairs is even pointed out in Genesis. We are told that we will be compelled to pursue our technology, and the fruit of our knowledge, whether we want to or not. It seems fairly clear that the real expulsion from Eden has only begun. The change from a symbiosis of man-and-garden to a situation where we must totally control any garden that we occupy is well underway, but it is far from complete.

General Description of the Method

SCOPE

We propose a method for predicting the rate of improvement of the quality of a technology. Of course we cannot predict quality until we form some sort of a definition of it. The very act of defining will preshape the prediction.

We thus form a definition which, when analyzed, yields a simple exponential growth law.¹ Exponential growth laws are not new,² but our focus is on the logic underlying such laws; it goes like this:

1. we define quality;
2. a prediction based on this definition says that the quality improves at an exponential rate;
3. the predicted growth law is subject to restrictions that are inherent in the definition;
4. a comparison of the prediction with data is successful, insofar as the data represent qualities that are consistent with the definition;
5. the data that fail to conform therefore sharpen and clarify the definition;
6. we thus achieve a quantifiable and predictable (though not all-encompassing) definition of quality. This improves our understanding of how technical change has taken place.

The motivation for this work is, in fact, not to make predictions, but rather to improve our understanding of the history of technology with the help of quantitative prediction.

DEFINITION AND ASSUMPTIONS

We first consider the rate of improvement of the quality of a technology.

Technologies are only included in these considerations if they are sufficiently complex that they cannot be brought to completion with a few inventions. We are interested in steam power plants and digital computers, but not in ball point pens or mousetraps.

Quality is a term we use to describe those improvements that are motivated, quantifiable, and ingenuity-limited. The quality of a technology will stop improving when it

¹This method was originally detailed by Lienhard [5] in 1979.

²Starr and Rudman made an interesting formulation of such a law in 1973 [11]. Another proponent of exponential growth laws has been Marchetti. (See, e.g., [6, 7]).

