Moore meets Malthus in multiples

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On the surface, the perspectives of Intel cofounder Gordon Moore and economist Thomas Malthus appear to be worlds apart. On closer inspection, however, there are many surprising parallels between them.

In 1803, Malthus published the second and expanded edition of his divisive "Essay on the Principle of Population." The first edition had received extensive criticism, so Malthus felt it necessary to revise and update his core thesis. His persistence earned him a place in intellectual history.

Malthus described a grim benchmark for the human condition: Subsistence is the norm of life unless strife and pestilence strike down enough of the population to enrich the few survivors. Indeed, people labeled economics "the dismal science" because of Malthus' vision. On the 200-year anniversary of Malthus' second edition, it is appropriate to consider why the world is not so bleak.

In 1965, Moore unwittingly provided one cornerstone to the answer. This occurred when Moore published his observation—which eventually became known as Moore's law—in an article in *Electronics* titled "Cramming More Components onto Integrated Circuits" (*Electronics*, vol. 38, no. 8, Apr. 1965, pp. 114-117).

Moore did not set out to contradict Malthus. His purpose was more modest. In fact, Moore's first forecast was rather timid, projecting growth out to 1975. Yet, it provides insight into why a majority of human beings in some countries in some time periods manage to rise well above abject poverty.

It will take a few steps to get there. Stay with me for a minute.

Malthus' dilemma

Malthus begins with the premise that, in his own words, "population increases in a geometric ratio, while the means of subsistence increases in an arithmetic ratio."

This is obtuse by vernacular standards. To oversimplify for purposes of illustration, and to appreciate why so many find Malthus' views objectionable, consider the "fruit fly" version of this thesis. That is, compare the human condition to fruit flies in a jar with nutrients supplied at a constant rate per day.

What happens? When there are few fruit flies, there is an overabundance of food. The flies are wealthy and happy. So they do what fruit flies do so well: They multiply. And multiply. And multiply even more. Eventually, the population of fruit flies increases to the limits of the resources, leaving all fruit flies in an inevitable state of mere subsistence.

Malthus further argued that other events could shock this type of system back from subsistence into a temporary state of wealth. In particular, war, pestilence, and other grim occurrences could reduce population levels dramatically but leave resources untouched. The survivors would, once again, be comparatively wealthy.

The total vision is dismal. Humankind faces either massive death or constrained reproduction. The former temporarily makes the survivors wealthy and happy at the expense of those killed (by a plague, say), while the latter eventually results in mere subsistence for the offspring. In the Malthusian world, resource abundance is inevitably temporary.

Despite its inherently unpleasant conclusion, the Malthusian tradition of analysis has survived in modified form for two centuries. It seems to provide insight about a slice of life in the worst parts of the globe, such as in villages in sub-Saharan Africa and rural Asia.

This tradition has also been thoroughly discredited elsewhere. It has little connection to the conditions found in modern Manhattan, Chicago, Tokyo, or London, not to mention Santa Clara, to name just a few places.

For those locations, you must start from a very different premise: that innovation holds the potential to help humans accumulate wealth. To be fair, Malthus wrote just as the industrial revolution began to take off in his home country of England, so it's understandable why he was silent on the topic.

Enter Gordon Moore

Moore's law is this era's central experience with innovative improvement. Indeed, there are three versions of Moore's law. I will use mostly his third version.

As noted, Moore issued his first version in 1965. By 1975, enough time had passed to test it. This resulted in the second

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version. As with the first, Moore was actually rather timid (in retrospect). He foresaw only a doubling of circuits per chip every two years. In fact, microprocessors and DRAMs have been doubling in capabilities every 18 months over the last three decades. By some accounting, it has been even faster than that since 1995.

The variability of Moore's actual predictions leads to a less pedantic version of Moore's law, which is the third and most popular version. In short, chips are becoming better rather quickly. It is enough to know this fact.

More broadly, in popular discussion, Moore's law stands for something bigger than just chips. All of electronic manufacturing—such as disk drives, display screens, routing equipment, data transmission capacity, and on and on—have undergone sustained improvement.

To compare this popular version with Malthus, one little, often unnoticed, assumption needs highlighting. Moore's law assumes something about the state of resources—in particular, that manufacturing costs would not increase proportionately faster than the rise in capability.

In other words, an economist's restatement of Moore's law would be "capabilities increase in a geometric ratio, while the cost of the means of production increases in an arithmetic ratio."

When capabilities expand at a faster rate than costs, human beings can either do the same thing at lower cost, or get more capabilities for the same money. In either case, if the total labor expenses devoted to production do not rise as fast as the increase in capabilities, then output per worker also rises.

Rising output per worker makes it possible for society to accumulate gains. The key word here is "possible." The portfolio of innovative activity has to be just right. Also, fertility must not increase in response to a general rise in wealth.

To be sure, the fertility behavior of modern societies is out of my domain. It is also too big a story for one column. Leaving it aside for now, let's turn our attention to the composition of the portfolio of innovation.

Intelligent advance

Incomes do not necessarily rise every time output per worker expands. That takes just the right portfolio of innovative activity. To illustrate, consider how innovative economies vacillate between two extreme outcomes. One of them is great and one of them is grim. Call one intelligent value creation and the other irrelevant advance.

The canonical example of intelligent value creation occurred between the time of Moore's first paper and his second. Moore's rivals at Texas Instruments created the first calculator. This group was motivated by a desire to replace the slide rule, allowing engineers to bring precise electronic calculation with them into remote locations. In other words, the goal was to allow engineers to multiply. And multiply. And multiply even more.

As we now know, we have more than just engineers multiplying away from electrical outlets. Three decades later, calculators are so pervasive that it has changed daily life. Nowadays, these calculators are cheap and common. Every child takes such a device to school.

More generally, these advances have gone further than anybody could have imagined. It has changed the quality of the life in less than a generation. The camcorders available at the local retailer possess capabilities in excess of anything available to Walter Cronkite in his prime. The cell phone in my pocket is close to achieving the fictional functionality of a prop from the original Star Trek.

It even affects toys. For example, to my disbelief, recently my four-year-old daughter gleefully chose a "calculator Barbie" as a reward/bribe for her bravery at the dentist. It adds, subtracts, multiplies, and divides; but, best of all, Barbie speaks. An upbeat voice starts every session with "Hi, I'm Barbie. Let's do math!" The doll announces every number entered. It seems like something out of a science fiction parody. My four-year-old thinks this is fun.

More significantly for economy-wide productivity, these changes have also found their way back into agricultural, housing, and clothing production. The latest global-positioning-system locators follow trucks and tractors with extraordinary precision, raising soybean and corn output everywhere. The latest architecture software improves a building's design, so it uses energy more efficiently during extreme weather. The latest fabrics are more durable, synthesized by a biochemist after simulating multiple potential chemicals by computer; the list goes on.

Before we become smug about this generation's accomplishments, however, consider the opposite outcome: irrelevant advance.

Not so fast

The canonical example of irrelevant advance occurred in spades during the dot-com boom, particularly—though not uniquely—in sectors affiliated with building the next generation of optic networks for data transmission. Companies invested—and wasted—tens of billions of dollars.

Years of engineering and scientific talent went into stretching the technical frontier for switches and lines. Indeed, this collection of clever people succeeded in making possible an enormous expansion of the US data network's carrying capacity.

There is one major problem, however. The newest capabilities overshot demand. There are not enough buyers for this stuff. To put the most positive spin on it, these new capabilities are ahead of their time.

This sector's future looks rather grim. Many of the firms that developed these products are now for sale or bankrupt. Employees must pay their mortgages, but the paychecks will stop coming soon, if they have not already. Kids must have clothes, but the income is not there for anything lavish. Massive layoffs have already happened and more are on the way.

More to the point, this sector involves some of America's best and brightest designers, most talented technicians, and most energetic entrepreneurial managers. When this group goes in the right direction, new capabilities emerge at an exponential rate. In this case, unfortunately, they were pointed in a direction with little market value.

Advance without value creation is painful. It wastes effort. In such cases, incomes do not rise. In other words, technological frontiers advance but not for any general benefit.

Caught between two outcomes

It is no surprise that Moore did not forecast this future. Who could have foreseen the emergence of pervasive economic value from packing more chips on an IC? It is surprising that more irrelevant advance has not yet emerged.

Malthus also did not forecast this future. How could he have foreseen a world where one generation of innovators builds a portfolio of new capabilities, then passes it on, and, if the previous generation guessed intelligently, the next generation makes the advances pervasive? It is not the most obvious way to make progress against poverty or to elevate the human condition over that of a fruit fly.

More to the point, it is such an unpredictable system. Only a small amount of good judgment separates intelligent value creation from irrelevant advance.

In that light, innovation is an unnervingly fragile engine for dodging the dismal dilemma. It makes the economic record of the last few decades look all the more remarkable, and that of the last two centuries even more so, many more times so.

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