

# Economic Possibilities for our Children

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8/18/15

In 1930, the economist, John Maynard Keynes wrote, with both anticipation and dread, of *technological unemployment* [2]. He marveled at how “the great age of science and technical inventions” and the power of exponential growth was “solving mankind’s economic problem.” And, yet, he was deeply concerned about “the age of leisure and of abundance”:

“[W]e have been expressly evolved by nature—with all our impulses and deepest instincts—for the purpose of solving the economic problem. If the economic problem is solved, mankind will be deprived of its traditional purpose.” [2]

Keynes was writing in the midst of the Great Depression, but also as the results of the first two technology revolutions<sup>1</sup> were being felt throughout society. Today, we are in the midst of the Third Technology Revolution<sup>2</sup> (TR3), which will do more than just increase productivity. It is likely to reduce the labor component of the marginal cost of production towards zero: In other words, TR3 is likely to replace most human labor with a range of technology, made possible by further advances in computing, machine learning & big data, robotics, and other core TR3 technologies. For a large swath of humanity, this will lead to two existential problems: an economic problem—how to acquire the physical necessities for life—and a psychological problem—how to find meaning and dignity in life apart from one’s vocation. Addressing these issues will lead to many challenges and changes in our economic, educational, social welfare and maybe even monetary systems.

## 1 Technology Revolutions

The first two TRs involved a synergistic change in how we produced and used energy, how we manufactured goods, and how we processed information. TR1 (1760–1830) came with the creation of coal-powered steam engines, the centralized factory, and the steam-powered printing press. TR2 (1860–1910) harnessed electricity and the oil-powered internal combustion engine, the assembly line, and electromagnetic-based communication. Each technology revolution was disruptive and each encountered pockets of resistance such as the early 19th Century Luddite movement when handloom weavers burned mills and pieces of factory machinery for fear of being displaced by the new technologies for textile production.

But, in each case there was, after a sufficient time, a substantial improvement in economic welfare for every segment of society. There were two reasons for this. First, higher productivity led to lower costs of production and lower real prices. This, in turn, led to an induced increased demand for all the associated factors of production, including labor.<sup>3</sup> Second, the new technologies created new types of jobs that, while requiring more skills and training, were associated with a higher marginal product of labor and therefore a larger real wage.

Both of the above positive outcomes will fail to occur in TR3. As human employment is replaced by technology, the induced increase in demand is for technology, not for human labor. In essence, the amount of labor required for additional production (the *labor* component of the *marginal cost of production*, LMCP) diminishes, going in the limit towards zero. The additional labor demanded by the additional aggregate economic demand will not, as it did in TR1 and TR2, make up for the displaced labor.

Second, humans have a wide range of capabilities as factors of economic production—ranging from raw power, to physical dexterity, to a wide range of cognitive, social and emotional skills (often, in these latter cases, requiring substantial education and training). But, one of the defining features of TR3 is that technology will increasingly be able to outperform humans in cognitive and physical (and potentially into social and emotional) tasks which heretofore were the sole province of humans. This will pertain even for many jobs that appear to require creativity (already more and more newspaper stories are being written by computer), judgement in un-structured environments (e.g., driverless cars), or complex interaction with the environment (robotic surgeons). As such, the new types of jobs that are created in TR3 will, in large part, themselves go to technology.

<sup>1</sup>We prefer the term “technology revolution” (TR) to “industrial revolution” as they apply to more than just the industrial sector of society.

<sup>2</sup>TR3 begins, for us, with the most famous exponentially improving technology—integrated circuits and photolithography. However, there are other important exponentially-improving innovations in fields as diverse as synthetic biology, photovoltaics and solar energy, machine learning & big data, and demand-side economies of scale in network technologies.

<sup>3</sup>This is an example of one of the many interpretations of “Says’ Law.”

So, while TR3 will foster greater overall economic productivity, TR3's technology will be good enough to outperform most humans at most jobs more quickly, accurately, and cost-effectively. Neither TR1 nor TR2 changed the fundamental role of labor as a factor of production for a large fraction of the population; TR3 will. Unlike TR1 and TR2, the Luddites fears of technological change permanently destroying job opportunities for humans will be justified in TR3. Just as TR2 largely eliminated, for all time, the role of horses as a dominant factor of production, much of human labor may well be a similar victim of TR3.

Note that we do not assume that all job categories for humans will be eliminated or even that all humans will be eliminated from any particular job category. TR3 will likely be characterized by a relatively small cadre of humans who will earn great wealth through successful entrepreneurship, invention of intellectual property leading to important improvements of technology, creatively managing complex organization, and thriving at the very top tail of the distribution in the arts, athletics, and other winner-take-all endeavors.

In addition, there also will always be some areas where human labor will dominate because human empathy and direct engagement with other humans define the relevant interactions. Starbucks might decide that its lattes are generally made better by machine, but hire humans to provide the relationships that drive customers to return. However, such jobs are likely to be low paying. Important new job categories are likely to be developed that build on personal relationships, empathy, and art (in the broadest sense of the word). Still, most blue collar and white collar workers will experience continued pressure on wages or will be supplanted entirely. We can already see the initial effects on labor markets in the US and across the world as the last few decades have seen an unprecedented "hollowing out" [1] of the job market and no significant increases in median wages for over forty years.

Note also the significance of the fact that key TR3 technologies have and will continue to improve exponentially, unlike in TR1 and TR2. As such, even if increased education leads people to be to be equally cost-effective as technology for some given job at some given point in time, the technology will continue to improve, and at an exponential rate, soon overtaking humans. In this sense, TR3 may be thought of as "the last technology revolution" with regard to the role of the majority of people serving as a dominant factor of economic production. Someday, there will surely be a TR4, TR5, and so forth. But, once a factor of production has been dominated and displaced as a factor of production, it will not return. Just as TR2 eliminated horses as a broadly-used factor of production, TR3 will do the same for much of human labor, not only for this but also for all subsequent technology revolutions.

Finally, it is worth noting that the substitution of technology for most humans in most jobs and the resulting huge inequality of income and wealth is the most notable but not the only significant economic challenge to the smooth functioning of market-economies posed by TR3. As technology becomes more effective, as information becomes even more central to production of goods and services, as networks become primary distribution and communication channels, and as energy prices decline, the marginal cost of production will decline in many key industries, in some cases approaching zero. The result are natural monopolies becoming more and more prevalent. This will lead to a wide range of economic policy challenges, ranging from anti-trust and tax policy to price regulation.

## 2 Money and Reputation

TR3 should produce a society of plenty. But, without employment, how will people pay for goods and services (even if they are very inexpensive)? One policy-based solution is for the government to change and increase its current mechanisms for redistributing income and wealth through tax and welfare policy. This will be enormously challenging. Moreover, it is unlikely to satisfy human needs for dignity and meaning.

We suggest that there may be powerful market-based solutions based on formalizing a metric for reputation with the result that we move in part to a "reputation economy." A reputation economy could simultaneously address the two existential questions created for most of humanity—those disenfranchised from the labor market by TR3. First, it could redistribute income/wealth in a bottom-up manner. Second, it could enable the creation of activities, engagement, motivation, and satisfaction for those individuals who will no longer be employed in a "normal" job.

The basic notions behind a reputation economy are illustrated in small ways by what we already see in social media and on the web, e.g., the various forms of recognition used in social media today (followers, likes, up-votes, etc.) and the use of reputation on Stack Overflow [5]. We suggest that a more formal metric for reputation could lead to a new form of currency that would be the basis for a monetary system that would not require a centralized sovereign-backed fiat currency. One main reason for our current system is that a key aspect of money is the fact that everyone trusts that it will be accepted by everyone, i.e., that obligations between two parties can be safely transferred to a third party [3]. Through the aid of computation and the network there are many possible ways that a reputation-based currency could

emerge from a formalized reputation metric—a metric that allows money to carry along with it its associated risk of transferability.

### 3 On Being Human

Keynes' predicted eight-fold increase in GDP per capita from 1930 to 2030 is, assuming no catastrophes, likely to be surpassed. Yet at the same time the current technology revolution may well eliminate the need for most human labor. In such a society how do we deal with wealth inequality, and, more generally, how will we maintain human dignity when we are “deprived of [our] traditional purpose?” We have relatively scant experience as a species living at, let alone designing our economic systems, for the higher levels of Maslow's hierarchy [4].

There are deep and interesting computer science problems to be tackled to create an economic system based on a computer-mediated system of barter and reputation which will allow people to turn time spent on their avocation into a means of acquiring “money” to trade for goods and services. Doing so, however, may be one important way we can re-“purpose” our lives towards pursuing self-actualization instead of trying to meet our physiological needs.

Between now and then we face two other overwhelming needs: improved education and serious investment in modern day TR3-relevant infrastructure. Our educational goals were formed at the time of TR1 and TR2, when workers needed to become more literate and numerate and eventually secondary schooling became compulsory. However, the skills based approach to teaching leaves students unprepared for the ever-changing environment of TR3. As routine tasks are taken over by technology, humans will have to compete in terms of creativity, discovery, and synthesis—dealing in unstructured environments without rules—even statistically-derived ones. Furthermore, with the exponential growth inherent in TR3, we must be prepared to teach more post-graduate education. Delivering such an education to everyone will require much more efficient delivery systems—ironically replacing most of what we do today with technology. Luckily, TR3 will create the time for us to excel at what we do best—be truly innovative.

Just as rails were laid (for TR1) and electric wire strung (for TR2) we need to invest in infrastructure to enjoy the fruits of TR3. The distributed nature of TR3 requires less centralized control of our networks and more integration with sensors and actuators. Also needed are tools to support collaborative distributed communities over this network. The creation of trusted hardware which would authenticate all accesses to the network could also enable trust without having to constantly fight a war we can't win in attempting to provide security and privacy. Trust is essential if we expect our currency to carry with it a certificate of its risk. To support the kind of education and distributed manufacturing we need a network of maker spaces with associated advanced CAD tools.

### 4 CSD100

With necessary changes in how (and how much) we effect the redistribution of income and wealth, a proper investment in infrastructure, improved educational goals, and a computer-mediated reputation-based economy we will hopefully look back on Keynes' worry as overly concerned. Instead of the dystopia of unemployment we will be able to pursue our dreams. With high school students compiling designs for bacteria that grow into living sculptures and computer science professors looking forward to TR4 with a platform technology, predicated to arrive just in time for CSD125, of hard-AI.

### References

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