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TECHNOLOGY CREATES 21ST CENTURY WEALTH — PROCESSES, PROBLEMS, AND PROGNOSIS

TECHNOLOGY CREATES 21ST CENTURY WEALTH — PROCESSES, PROBLEMS, AND PROGNOSIS

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Summary

Science and technology are the driving forces increasing the global standards of living. The technology - wealth relationship is complex and not well understood presently but recent macro data tends to support Robert Solow's 1957 observation that societal, company, and individual wealth and increased standards of living is created by application of science and technology to socio-economic challenges. In 1987, Robert Solow received the Nobel Prize in Economics, for his insight that "seven-eighths" of the world's increase in world wealth is due to advances in science and technology. The challenges and costs of of wealth creation are identified. This paper explores wealth as defined by GDP/capita, and the current correlations between world/GDP per capita and R&D spending, the number of scientific and technical articles, and number of patents applications from 2000 to 2012/2013 with a forecast of world GDP/capita to 2025 of approximately $15,000 USD from today's $10,000 USD.

Keywords: wealth creation, technology, innovation, world GDP/capita, world R&D, patent applications, scientific articles, researchers worldwide

Inroduction

There are a number of ways to measure society's economic wealth. Wealth is commonly measured as Gross Domestic Product (GDP) at a country level, market valuation at a company level, and net worth at the individual level. The most commonly used national measure is Gross Domestic Product (GDP). Gross Domestic Product is an indicator of both a nation's economic wealth and its related standard of living.

In recent history, GDP/capita doubles approximately every 100 years (Madison 2007). For example, using Madison's estimates of GDP/capita converted to current USD by the US Bureau of Labor Statistics inflation index estimates that the world GDP/capita was approximately $1,288 USD in 1814. By 1914, the world GDP/capita increased to $2,762 in current US$ — an increase of $1,474 USD — a 114% increase over 100 years from 1814 to 1914. However, in 2014, the world GDP/capita is $10,743 USD — a $7,981 increase — a 388% jump from 1914 to 2014.

In the current 21st Century, the world's GDP/capita and related wealth is dramatically increasing. United Nations and World Bank Development data underscores that world GDP/capita jumped from $5,436 in 2000 to $10,743 in 2014 — a 98% increase in 14 years. The world's ability to generate new wealth seems to be accelerating.

The interesting question is why is world GDP/capita increases accelerating? Having analyzed data from 1909 to 1949, Robert Solow (1957) argued in the paper "Technical Change and the Aggregate Production Function" which earned him the 1987 Nobel Prize in Economics, that science and its application via technological innovation is responsible for approximately 87.5% of the world's increase in wealth and standard of living — not capital and labor as many economists previously thought. Solow (1957) concludes, "It is possible to argue that about one-eighth of the total increase is traceable to increased capital and man hours (labor), and remaining seven-eighths to technical change."

This is a logical observation since scientific knowledge and its related technology "build upon itself" — the more we know, the more we learn. The challenge is converting knowledge to new products, new services, and new ventures that create new wealth. Three distinct processes are involved: knowledge creation itself which may be measured by world R&D as percentage of the world economy; the dissemination of knowledge via scientific and technical journal publications, and lastly, patent applications which are surrogates for knowledge application aka technology.

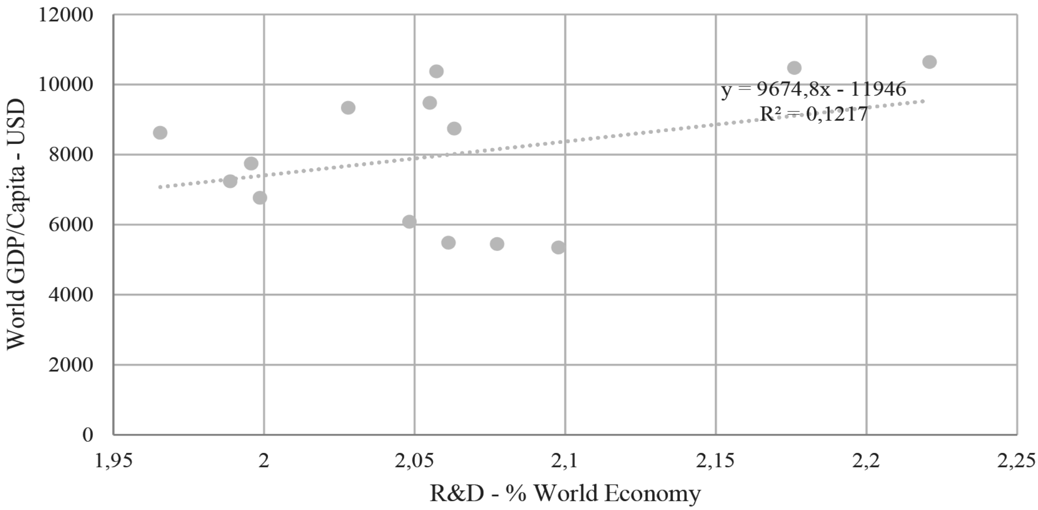
Global Scientific Innovation and Knowledge

As is with economics, there are a number of imperfect methodologies to measure scientific innovation. Each innovation indicator has some strengths and limitations. One method is to estimate the world expenditures on research and then simply count the number of individuals classified as researchers. Then, measure the researchers' productivity output by the number of papers published in scientific and technical journals as well as the number patents applied for as a gross indication of future economic value to society. Using the latest data available from the World Bank Economic Development series and year 2000 as a baseline, all scientific and economic indicators for world knowledge creation are not only positive but are accelerating.

For example, Worldwide R&D expenditures as a percent of the world economy have increased from 2.10% in 2000 to 2.18% in 2014 — a 40% increase in 14 years — 2.9% increase annually. Most of the R&D expenditures are in developed economies — but both China and India are dramatically increasing their funding of R&D as their economies grow.

The coefficient of determination (r^2 =.1217) is weak as is the correlation (r = .3448) between world GDP/capita and world R&D as a percent of the world economy for the years 2000 to 2013 — see Figure 1. This is logical since it takes time for R&D investment to impact world GDP/capita.

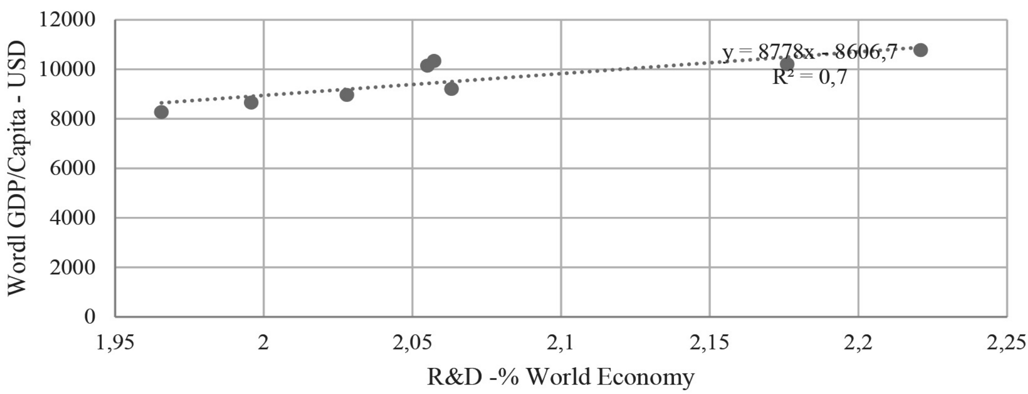
Figure 1. **World GDP/ Capita — R&D %World Economy**



Source: World Bank Development Data.

This observation is illustrated when comparing world GDP/capita and world R&D as a percent of the world economy with a 6-year time lag. The coefficient of determination (r^2 =.7000) and related correlation (r) increases to a strong .8035 when lagged. See Figure 2.

Figure 2. **World GDP/Capita — R&D % World Economy — 6-Year Time Lag**



Source: World Bank Development Data.

Many of the technologies embodied in products impacting us today such as satellites and cell phones can be traced back to the R&D associated with the American and Russian space programs in the 1960's — over 50 years ago. The Internet is only about 30 years old. It takes time from discovery to product development to deployment.

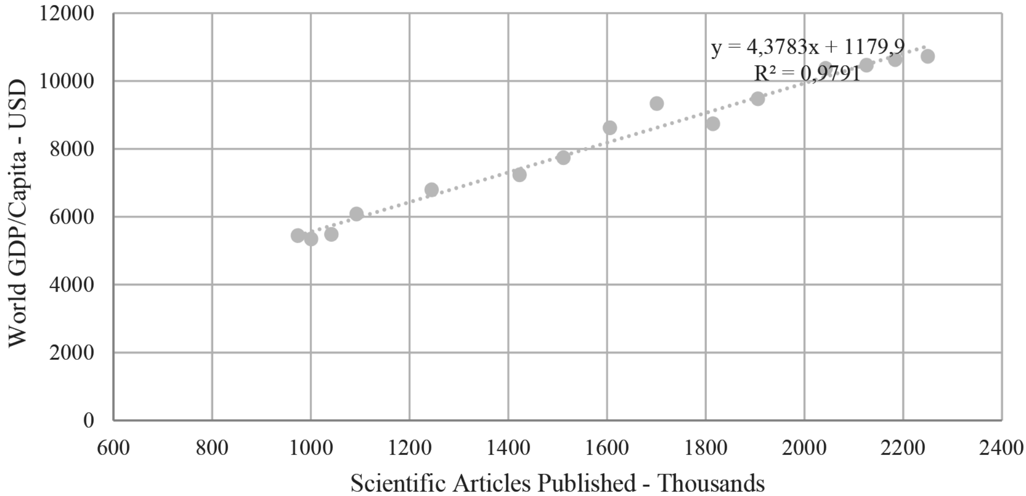
As R&D funding support by governmental and non-governmental organizations grew in the 21st Century, the number of researchers worldwide has increased from 1,082 researchers per million population in 2000 to 1,268 researchers per million populations in 2013 — a 17% increase in 13 years — a 1.3% increase annually. The more researchers, the more new knowledge generated for future wealth creation.

Scientific Articles and GDP/Capita

Scientific articles may be conceptualized as dissemination of scientific knowledge. The number of articles published in scientific and technical journals increased from 974,170 articles in 2000 to 2,183,993 articles in 2013 — a 124% expansion in 11 years — an 11.3% increase annually. The productivity of the researchers is increasing faster than the 2.9% annual increase in funding and faster than the increased number of researchers that is growing at 1.3% annually.

Figure 3's plot illustrates the relationship between world's GDP/capita and scientific articles published globally from 2000 to 2011. Note the coefficient of determination (r^2 =. 0.9791) is exceptionally strong as is the correlation coefficient (r = 0.9894), which is also a nearly "perfect" correlation. There is simply a strong positive correlation between science and technology advances as measured by scientific articles and global economic development even though the actual mechanism of the process is not well understood.

Figure 3. World GDP/Capita — Scientific Articles Published Worldwide — 2000 to 2013



Source: UN Data and World Bank Development Data. Retrieved on April 13, 2016, from http://unstats.un.org/unsd/snaama/dnllist.asp and http://data.worldbank.org/data-catalog/world-development-indicators

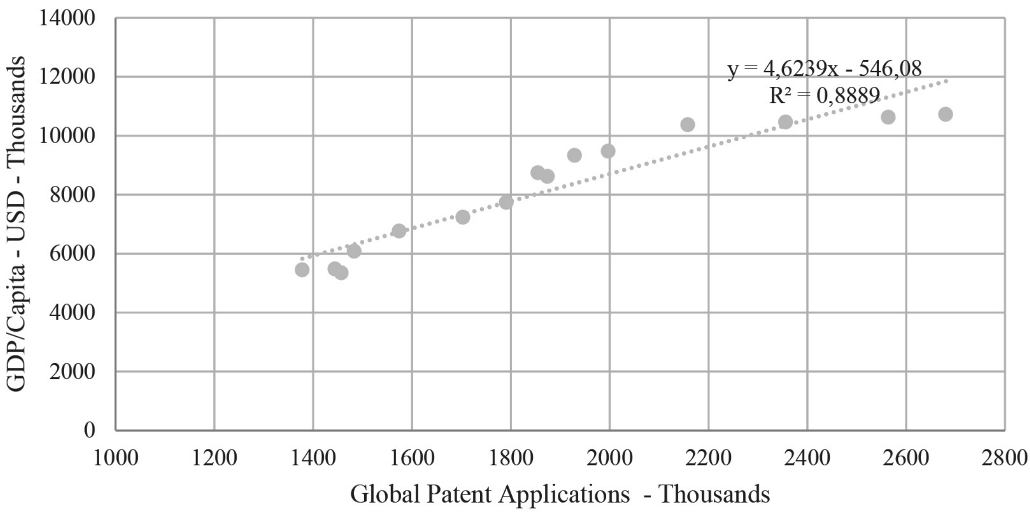
Patent Applications and GDP/Capita

Patents may be abstractly conceptualized as the translation of scientific knowledge into products. Patents are a path to monetize scientific and technological insights and discovery. Patents grant the owner a monopoly to use the concept for a limited time period. Patents represent potential future economic value. Global patent applications may represent the conversion of worldwide scientific and technological knowledge into new products and services. Patents may be representative of the conversion of knowledge to new products/services and may give a preliminary perspective on new ventures formation.

The number of world patent applications virtually doubled from 824,055 in 2000 to 1,624,969 in 2013 — a 97.2% increase in 13 years — a 7.5% increase annually.

Figure 4 shows the relationship between global patent applications and GDP/Capita from 2000 to 2014. Note the coefficient of determination (r^2 =. 0.8889) is strong as is the correlation coefficient (r = 0.9428), which is also a very strong relationship. This simply underscores that a strong positive correlative relationship exists between science and technology advances as measured by patents and global economic development.

Figure 4. **GDP/Capita and Global Patent Applications — 2000 to 2013**



Source: UN and World Intellectual Property Organizations' Data.

Not all patents are commercially valuable. A 1997 study of 300 patents by Stevens and Burley concluded only one patent out of the 300 had significant commercial value.

Our world is becoming increasing technologically complex as science and technology expand the world's knowledge database. Not only are the researchers creating more and more data but also it is being captured and transformed from knowledge to useful products and services. Technology is creating valuable brands, valuable companies, and wealthy individuals.

Wealth Creation — Brands, Companies, and Individuals

Three empirical surrogate measures of wealth are the economic value of global brands, global companies, and the net worth of individuals.

World's Most Valuable Brands

Annually, BrandFinance ranks orders the world's 100 most valuable brands. Table 1 presents the ten most valuable global brands for 2016. Eight of the world's top ten most valuable brands are based on technology. If we add Wal-Mart (retailing) and Wells Fargo (banking), which are built on deep technology foundations, then all ten of the top 10 of the world's most highly valued brands in 2016 are based on technology.

Table 1. **2016 World's Most Valuable Brands**

Rank	Brand	Brand ValueUSD Billions	Industry
1	Apple	145.9	Technology
2	Google	94.2	Technology
3	Samsung	83.2	Technology
4	Amazon	69.7	Technology
5	Microsoft	67.3	Technology
6	Verizon	63.1	Technology
7	AT&T	59.9	Technology
8	Wal-Mart	53.7	Retail Technology Base
9	China Mobile	49.8	Technology
10	Wells Fargo	44.2	Banking Technology Base

Source: Brandirectory. (brak datowania). Wartość 25 najbardziej wartościowych marek w lutym 2016. In Statista — The Statistics Portal. Uzyskane 1 kwietnia 2016 pod adresem: http://www.statista.com/statistics/264875/brand-value-of-the-25-most-valuable-brands

World's Most Valuable Companies

Statistica calculates daily the world's most valuable companies based on market valuation, which is price per share multiplied by the number of shares outstanding. It is interesting that technology underpins the world's ten most valuable companies. Without technology virtually each of the top 10 companies would not exist.

Table 2. **2016 World's 10 Most Valuable Companies**

Rank	Brand	Market Capitalization ValueUSD Billions	Industry
1	Apple	607.5	Technology
2	Alphabet/Google	516.6	Technology
3	Microsoft	435.4	Technology
4	Exxon Mobil	351.0	Oil — Technology
5	Berkshire Hathaway	349.9	Financial Services — Technology
6	Johnson & Johnson	300.7	Medical Technology
7	General Electric	297.0	Technology
8	Amazon	281.9	Technology
9	Wells Fargo	275.4	Banking — Technology
10	AT&T	242.2	Technology

Source: Najbardziej wartościowe firmy na świecie, według kapitalizacji rynkowej z 31 marca 2016, za: https://en.wikipedia.org/wiki/List_of_public_corporations_by_market_capitalization

Again, empirically the world's most valuable companies in terms of market capitalization are built on foundations of science and technology.

World's Wealthiest Individuals

Forbes Magazine estimates there are 1.810 billionaires in the world in 2016. With the exception of Warren Buffet, nine of the top ten wealthiest billionaires created their wealth by using technology to satisfy customer needs and eight of the top ten billionaires made their wealth themselves. The Koch brothers inherited a small company, which they built into a large diversified industrial empire.

At the age of 31 and the rank of 6 worldwide, Mark Zuckerberg is the world's youngest billionaire ($50.4 USD billion) on the *Forbes*' 2016 list. Mark Zuckerberg founded Facebook 11 years ago when he was twenty.

Table 3. 2016 World's Top 10 Wealthiest Individuals — Wealth USD Billions

Rank	Name	Wealth	Company	Sector	Source of Wealth
1	Bill Gates	$ 77.7	Microsoft	Software	Self-made
2	Amani Ortega	$ 72.2	Inditex/Zara	Retail	Self-made
3	Warren Buffet	$ 67.0	Berkshire Hathaway	Investment	Self-made
4	Carlos Slim Hela	$ 60.1	Telmex/Grupo Carso	Telecom / / mobile phones	Self-made
5	Jeff Bezos	$ 52.6	Amazon.com	Technology	Self-made
6	Mark Zuckerberg	$ 50.4	Facebook	Technology	Self-made
7	Larry Ellison	$ 49.9	Oracle	Software	Self-made
8	Michael Bloomberg	$ 43.5	Bloomberg	Technology	Self-made
9 tie	Charles Koch	$ 42.9	Koch Industries	Diversified	Self-made — Small to Large9
tie	David Koch	$ 42.9	Koch Industries	Diversified	Self-made — mall to Large9

Source: Kroll, L. i Dolan, K. (red.). The World's Billionaires: The Richest People on the Planet, 2016. W magazynie Forbes. Uzyskane 2 kwietnia 2016 pod adresem: http://www.forbes.com/billionaires/list/#version:static

Note that technology has created the fortunes of nine of the world's top ten wealthiest individuals.

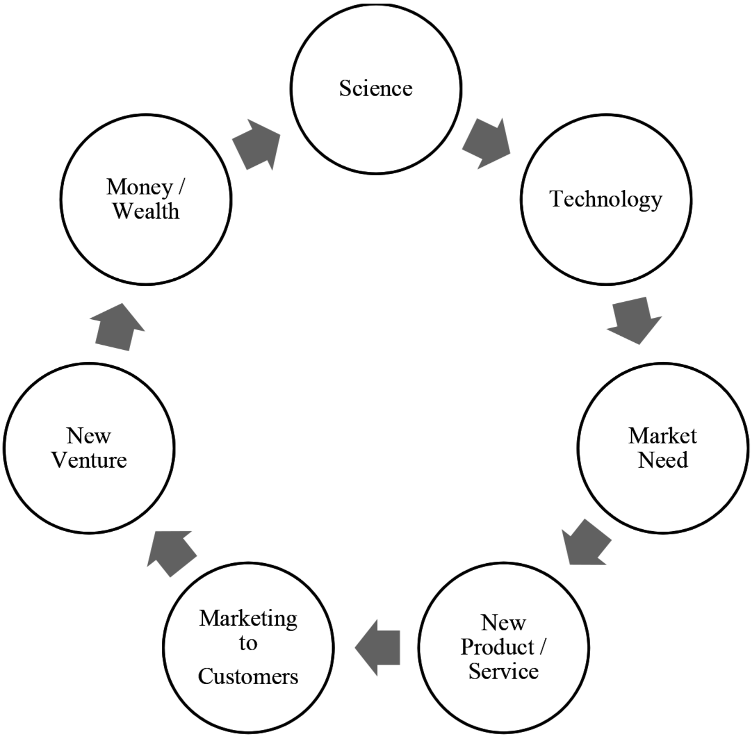
The Wealth Creation Process and Illustrative Example

The Process

There is a relationship between science and technology and the creation of wealth in the 21st century. The technology — wealth relationship is complex and not well understood presently but the macro data tends to support Robert Solow's observation that societal, company, and individual wealth and increased standards of living is created by application of science and technology to socio-economic challenges.

Dr. Dariusz Trzmielak and Dr. Brad Zehner (2011) hypothesized the following simplified wealth creation process cycle in Figure 5.

Figure 5. Wealth Creation Process Cycle



Societal, company, or individual wealth funds basic science; then, basic science is transformed into technology which can help address a specific market/customer need; the technology must be transformed into a new product or new service and marketed to potential customers to create economic value; the entrepreneur is the person who catalyzes and drives this process to create a profitable new venture which creates new societal, company, or individual wealth to repeat the cycle.

Bill McDermott, SAP's CEO writes "Every 18 months, the amount of data in the world had been more than doubling thanks for the proliferation of devices that collected it." Once the data has been captured, the Internet distributes it both rapidly and globally. Knowledge creation and distribution are rapidly creating innovative new products and services such as mobile phones, Facebook, Snap Chat which dramatically changes how we "live, work, and play".

The Internet and related global communications technology is accelerating this process on two distinctive levels. First, the time lag between the basic discovery — in the lab — and the delivery of a new product or service to the market place is declining. Product lives are shortening as knowledge builds on knowledge to create "better, faster, and cheaper" solutions to customer's needs.

A Historical Illustrative Example

The science — technology wealth creation process has been going on for hundreds of years. There are a number of significant challenges confronting entrepreneurs in converting science and technology into wealth. The challenge is to translate scientific knowledge into technology to produce goods and services desired by society. The process is generally expensive with low odds of success. These challenges are not new and have been faced by entrepreneurs for several millennia as the following story illustrates:

The information age began long ago. The earliest known printed book is the *Diamond Sutra* that was printed in China in 868 B.C. using clay type. In 1041, movable clay type was used throughout China. The movable clay type did not render clear impressions and wore out rapidly.

During the Middle Ages in Europe, books were produced for the Catholic Church using the process of woodcarving. Wood carving required the craftsman to carve away the background to create a raised image. The woodcarvings wore down quickly and did not allow many copies to be printed clearly.

In 1436 in Mainz, Germany, Johannes Gutenberg, a German goldsmith and inventor, realized that casting letters in metal would solve the problems of the wooden type. Additionally, the metal letters were easy to cast, lasted longer, and make clearer impressions on the paper. After a number of experiments with various metals, Gutenberg discovered the right proportions of lead (83%), antimony (12%), and tin (5%) so the metal letters did not shrink when cast. This formula is still used in casting letters today.

As do many current inventors, Johannes Gutenberg funded his venture via a business arrangement with Andreas Dritzehn, a German businessman. Dritzehn funded the building of the first prototype of a printing press in 1438, which proved the concept of metal moving type printing.

By 1440 Gutenberg completed his first commercial press that used metal moving type.

In 1450, Gutenberg entered into an agreement with Johannes Fust, a German businessman, to build a large Gutenberg press and to print the Bible. In 1452, Gutenberg began work printing the Bible which was completed in 1455 with the publication of 200 Bibles — the first book to be published in volume. However, Gutenberg failed to re pay his loans to Fust who foreclosed confiscating the press.

In 1455, Gutenberg was declared bankrupt. In 1468, Johannes Gutenberg "died penniless, living on a dole from one of his investors, a classic example of technological success and financial frustration (Drew 1996, 28)."

By 1476, William Canton set up a press in England. By 1499, printing was established in over 250 cities throughout Europe. Printing technology had diffused and was established "globally" less than fifty years after Gutenberg printed the initial Bibles.

Gutenberg's story is about the commercialization of science and technology. Gutenberg experimented to find the right alloy for the type (science) so he could translate his idea into a commercial product — the Bible (commercial product) via his press (technology).

Wealth Creation Challenges

There are multiple challenges in wealth creation based on scientific and technical knowledge ranging from long odds of success to expenses to organizational conflicts between the innovators and managers, as well as impacts on societies.

Long Odds of Success

New technology based products/service generally have a low probability of success in the market place. Hansen (1995) discovered that of 333 ideas only 29 were original. Of the 29 original ideas, 6 ideas were patentable, and of two ideas introduced to the marketplace only one idea succeed. A similar study by Stevens and Burley (1997) of 125 projects illustrated a similar pattern. Beginning with 3,000 raw ideas, organizations initiated 125 projects, which were reduced to nine major projects and further reduced to four significant projects to achieve one successful project in the marketplace. The odds of success are long.

New Product Development is Costly

Not only is the challenge to introduce a successful new product or service to the marketplace but also it is costly to do so. In his classic 1997 book, *Commercializing New Technologies: Getting from Mind to Market*, V.J. Jolly points out some interesting cost ratios, "If the cost of discovery is $1, developing it to a prototype costs $10, and getting a marketable product ready is $100. But this is how *cost* is distributed, not *value* (19)." Value — product/price ratio — is what the market perceives and pays to address customer needs. The difference between value and cost is profit, which tends to be high for technology-based companies as they are frequently the first to provide solutions to customers' needs.

Organizational Conflict between Technologists and Managers

As the product moves from the prototype "proof of concept" to the market introduction stage there is often a great deal of organizational conflict between the scientific — technical and commercial perspectives. The scientists perceive themselves as creator of the organization's wealth and the commercial function as obsessed with profit. Without commercial invest and related the risk, the technology simply languishes in the lab. The commercial function perceives the scientists as "dreamers." Dubinskas (1988) insightfully describes the intrinsic differences between the technologists and managers: "They, the complete adult realist managers, in their struggles with economic necessity, must contend with the immature scientists-dreamers; while from the other side of the table, the far sighted progressive scientists must protect their work — the basis of the firm's wealth from the myopic and developmentally retarded managers."

Impact on Society

Even when the entrepreneurship is successful in launching a new product, new service, or venture, the wealth creation process technology is simultaneously creating opportunities for new products and new services while simultaneously destroying the old technology and related projects. This is Joseph Schumpeter's creative destruction process. Think about pc computer storage media. From 1980 to 1995, the storage media was floppy disks. From 1995 to 2005, 5 1/4 blue disks replaced the floppy disks; from 2005 to 2015 the 5 1 blue disks were replaced by USB flash drives, which in turn are being replaced by the "cloud". Product life cycles are becoming shorter and shorter.

The underlying technology is shifting and frequently, the organizations that excel at one technology are unable to transition to the newest technology that may explain why the typical life of a company is between 12 to 20 years (de Geus 1997). It is difficult for successful companies to create an "encore" since organizationally companies tend to do what made them a success.

Relatively few organizations ask themselves Dr. Peter F. Drucker's (2008) penetrating questions: What is our mission today? Is it still the right mission? How has our mission/technology changed since our founding? And the tactical question, "If we were not in this (activity) already, would we now go into it? And if the answer is "no", the next question should be: "How do we get out and how fast?"

Despite the low odds of success, high costs involved, organizational issues, and shorter product lives, entrepreneurs are constantly addressing societal needs with new products and new success. When the entrepreneurs' are successful they create a great deal of wealth for all stakeholder involved in a brief time period, as did Mark Zuckerberg with Facebook in only 11 years.

Wealth Creation Prognosis

The recent past is normally the best indicator of the immediate future — especially for global trends. The two global trends are that positively project the future are the number of scientific and technical articles published and patent applications, which reflect the world's expanding base of scientific and technological knowledge base. Both patent applications and scientific papers published are conservative projections since they are linear.

An argument might be made that since knowledge compounds on itself, the projections should really be nonlinear.

Scientific Knowledge Projections

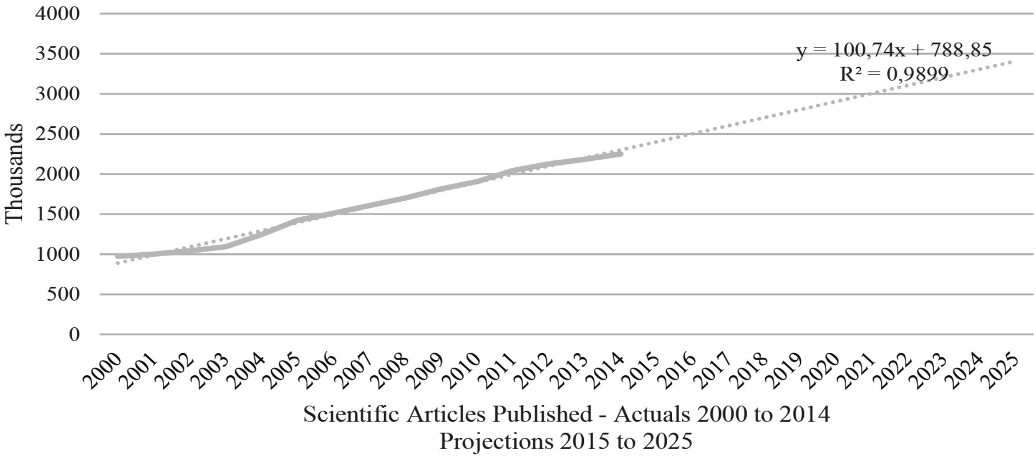
The number of scientific papers published annually is trending upward as illustrated by Figure 6. Scientific papers provide the foundational knowledge to develop new products, new services, new ventures, and ultimately new wealth. Figure 6 shows that the number of journal articles published will increase to about 3.5 million in 2025 from approximately 2.2 million in 2014 — a 60% increase.

Figure 7 projects the number of patent applications to be approximately 3.5 million in 2025 — up from approximately 2.6 million applications in 2014 — a 35% increase. As product applications increase, we can expect a number of new products and services to explode in the global marketplace creating new wealth.

Based on trends in scientific articles published, Figure 7 projects that world GDP/Capita is projected to increase from approximately $12,000 USD today to approximately $17,000 USD in 2025. This is logical since the knowledge involving patents is normally is applied and much closer to commercialization than is the knowledge reported in scientific journals.

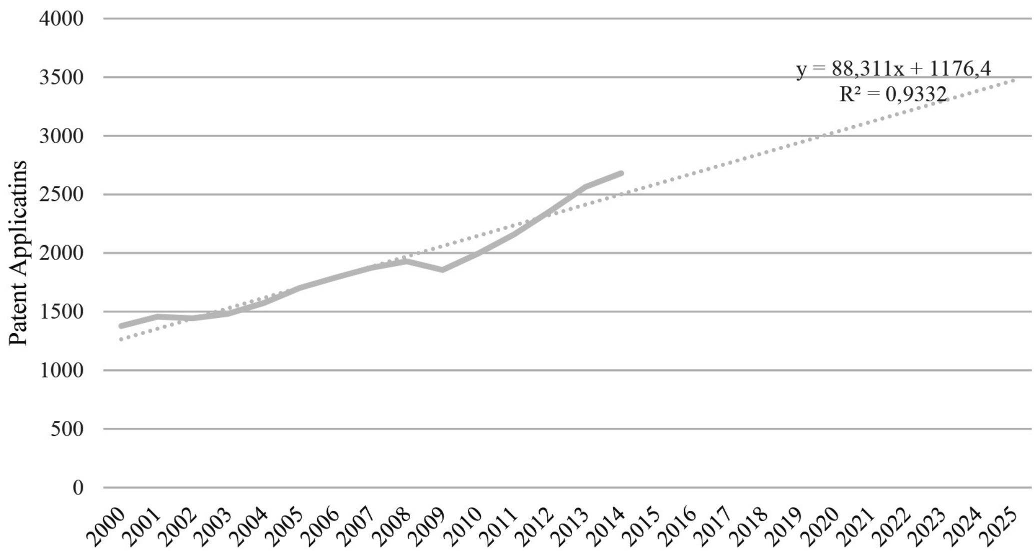
Using the data from 2000 to 2013/2014, time series regression forecasts for the number of scientific papers published world and patent applications worldwide were developed. For the variable paper published versus time, a correlation coefficient of .9947 and a R^2 of .9894 were produced. For the variable patent applications versus time, a correlation coefficient of .9660 and a R^2 of .9332 were produced.

Figure 6. **Scientific Articles Published and Projected — Thousands — 2000 to 2025**



Source: World Bank Development Data.

Figure 7. **Patent Applications Worldwide — Actual and Projected — 2000 to 2025**

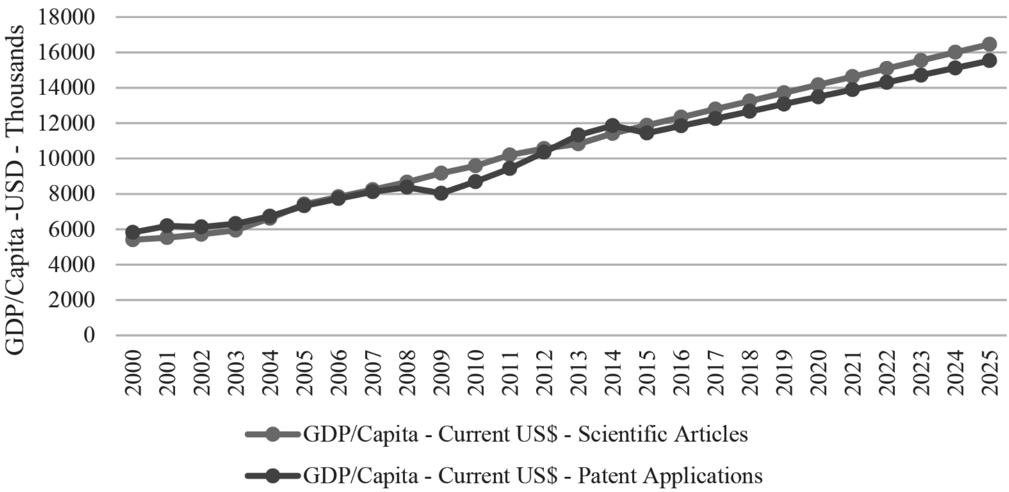


Source: World Bank and World Intellectual Property Organization Data.

The regression coefficients were then used to develop time series forecasts for the years 2013/2014 to 2025. The forecasted values for papers published and patent applications were then used to forecast GDP/Capita for the years 2013/2014 to 2025.

The forecast world GDP/capita to be approximately $17,000 current USD. See Figure 8. In 2000, the world GDP/capita was approximately $5,436, growing to $10,743 in 2014.

Figure 8. ŚWorld GDP/capita — Scientific Articles Published and Patent Applications



Discussion and Summary

Worldwide wealth as measured by GDP/capita is rapidly increasing creating increased standards of living. The distribution of the wealth is a significant issue which this paper fails to address. Using the relationships among scientific papers published and the number of global patent applications and world GDP/capita, the prognosis for progress is bright since the world GDP/capita may triple from approximately $5,000 USD in 2000 to over $15,000 USD by 2025.

The prima facie evidence capture by value of brands, companies, and individuals tends to indicate strong correlations between wealth and science and technology. However, much more research is required to deeply understand the relationship among the variables and the related processes. What we do know is that the entrepreneur who is brokering the relationship necessary to convert science into technology to create new products, new services, and new ventures faces exhilarating challenges. The odds of real success are long and the costs are high but for those individuals who succeed the rewards are great.

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