

Unleashing the new Wealth Of Nations

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Letter from Academia

Abstract. Economic growth and wealth creation was once exclusively a product based operation, through sale of goods (cattle, cars, planes, trains, parts). Today, it is also based on services. Economic growth through services, naturally, started with financial services, circa 1300. In the 20th century, economic value from the use of “data as a service” was made possible by the creation of the Atanasoff-Berry computer in 1942. Geographic limits on the export of knowledge was rendered agnostic, when the internet was publicly released by the NSF, in 1995. In the 21st century, the information economy is still crawling, with 60% of the world not yet connected to the internet. Those who are connected may not have the necessary access. Expert knowledge arbitrage, combined with data as a service, are major economic drivers, which is far from its utilization potential, in the US. Therein, lies vast opportunities. Reasonable weather, low incidences of natural disasters, and basic infrastructure makes certain locations more attractive. Dynamic demographics, academic institutions and cultural liaison to large external markets, are other positive features, for the future of wealth creation.

Keywords. Global Economic Development; Systems as a Service; Supply Chain; Innovations.

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1 Introduction

Economic growth and wealth creation was once exclusively a product based operation, through sale of goods (cattle, cars, planes, trains, parts). Today, it is also based on services. Economic growth through services, naturally, started with financial services¹, circa 1300. In the 20th century, economic value from the use of “data as a service” was made possible by the creation of the Atanasoff-Berry computer² in 1942. Geographic limits on the export of knowledge was rendered agnostic, when the internet was publicly released by the NSF, in 1995. In the 21st century, the information economy is still crawling, with 60% of the world not yet connected³ to the internet. Those who are connected⁴ may not have the necessary⁵ access. Expert knowledge arbitrage, combined with data as a service, are major economic drivers, which is far from its utilization potential, in the US. Therein, lies vast opportunities. Reasonable weather, low incidences of natural disasters, and basic infrastructure makes certain locations more attractive. Dynamic demographics, academic institutions and cultural liaison to large external markets, are other positive features, for the future of wealth creation.

2 Information as a service evolves to systems as a service

Enterprise creation using advanced R&D generates jobs and economic growth. In the US and some OECD nations, we are eager to probe the bleeding edge. Hence, we aim to lead in robotics, aeronautics and astronautics, high value healthcare tools and similar high end, high margin, high profit, areas. This is welcome news but there is a lot of room left behind the edge!

Think about complementarity in business and strategy, ventures and entrepreneurship, innovation and necessity, systems and solutions. This suggestion is about massive economies of scale, where services are offered for low end, low margin, low R&D solutions, needed by 80% of the world, with the potential for sustained, long term, cumulative, mega profit, for providers.

This note is also about the evolution, from data and information as a service, suitable for OECD nations, to *systems as a service*, for the rest of the (80%) world. The latter demands answers, not numbers. Advanced tools and technologies are catalysts for advanced nations, where infrastructure and skilled resources exist, to *synthesize* the advances, generate solutions, and profit from outcomes. Developing economies (80% of the world) may lack the ability to deal with bleeding edge resources. Their solutions must be synthesized, seamless and integrated, to serve as functional systems. In other words, *outcomes* are preferred over gadgets, and widgets.

Hence, the advanced R&D paradigm, including data as a service (as a subset), is suitable for developed nations. But, immense business opportunities, revenue and “loads of money are left on the table” unless advanced strategies are complemented by parallel approaches. In this prong, solutions are synthesized to fit the *context of the demand*, economic feasibility and availability of infrastructure.

Systems as a service indicates that “data as a service” is insufficient and must integrate ecosystems, to generate “systems as a service” in order to provide the solution, or the desired outcome. Data and information are a *part* of the solution, and information arbitrage may *still* be a source of profit, but *systems as a service* will be the source of the revenue.

Mobility of information, due to the internet, *where available*, induces unlimited potential for innovation and creativity to shape the “systems as a service” business model, by distributing the tasks, and generating pay-per-use revenue, from *each instance* or event.

There are no 800-lb gorillas (or sharks⁶) as the sole player, in the digital economy. It is a distribution, albeit, often, uneven, skewed and heteroskedastic. Co-creators of systems shall seek to profit from sub-components or sub-sets of the system. Entrepreneurial innovation in systems integration may need access to the ecosystem of R&D, which, in turn, becomes a part of the solution, but, *within* the *systems as a service* paradigm.

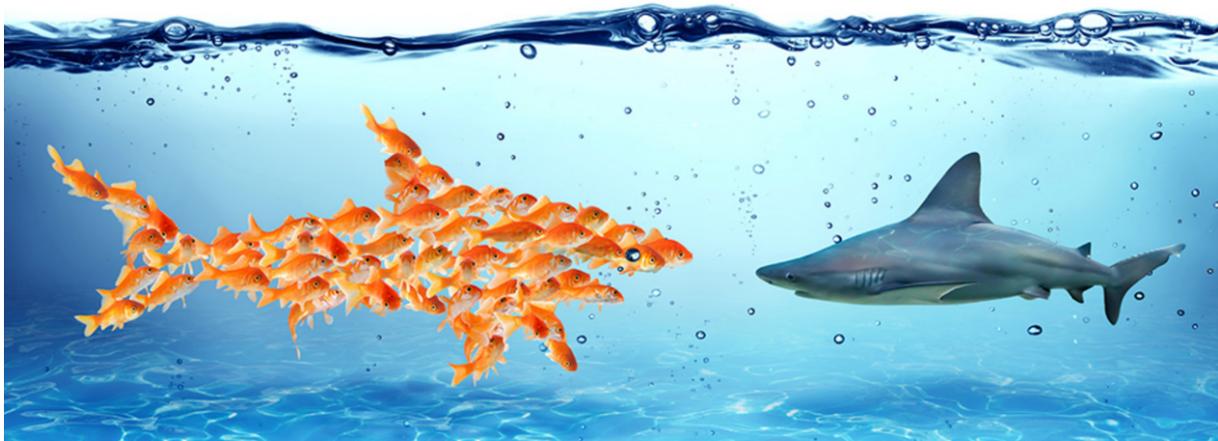


Fig. 1. Service SCM - Systems as a service - whole is greater than the sum of the parts ⁷

Advanced R&D at the bleeding edge may be sequestered by the upper crust of the supply chain. But, pragmatic innovation can re-shape the outcome to serve the rest of the world, where the mega markets exist – excluding US, EU and JP (which represents 10% of the population).

The distributed digital pay-per-use service economy is a virgin territory. The US-EU *entente* balks at low cost services. The digital economy, catalyzed by the global internet, is the mobile medium, where service businesses can profit, slowly, not only for the lifetime of the product, but for the *lifetime of the customer*. Lifecycle management evolves from product lifecycle (1-10 years) to the lifecycle of the consumer (10-50 years). Is it a significant change?

The digital economy makes it possible to transform the paradox of a product-less world to a new paradigm, where products are leased as services related to the products. The product sale is a fee, not a final event. The service is always “on” and each instance of use, of the product, is logged in as a service, which in turn, generates micro-revenue, one event at a **time**. Billions of instances of pay-per-use, per day, generates trillions in earnings, **over time**. To profit from this paradigm, the focus must be on the business need of the billions. Hence, the complete solutions, through convergence, are more useful than high tech advanced R&D at the bleeding edge, alone.

The time-dependency of digital dividends, may suggest that time series econometrics⁸ may be a potential tool for exploring the digital economy using time series (lagged ? values) data as input⁹ for artificial neural networks, illustrated below. The roots of this line of thinking is not new and can be traced back to the seminal contribution by Sir Clive W. J. Granger (reference

7).

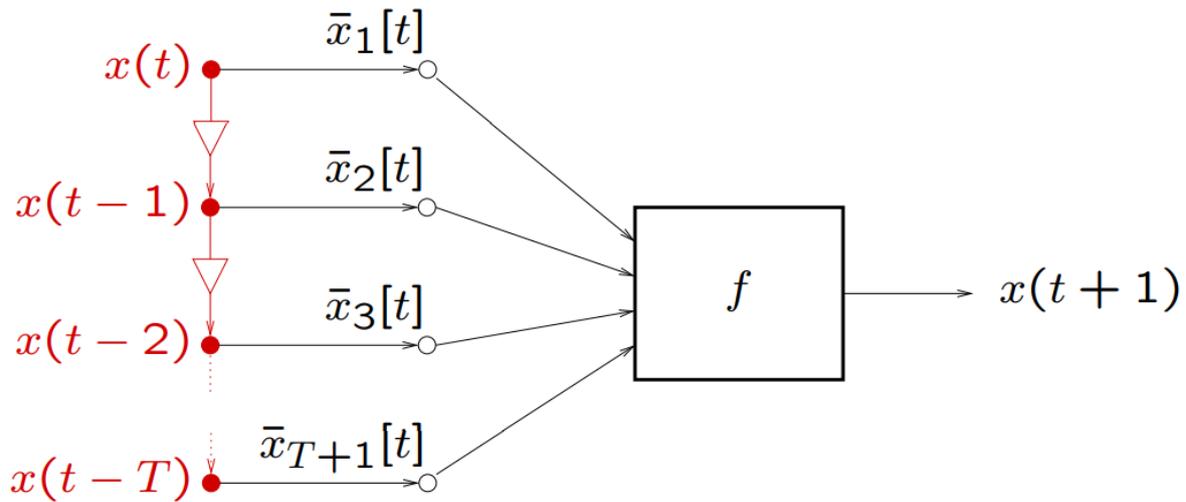


Fig. 2. Artificial neural networks & time series econometrics - digital SCM - convergence of tools⁸

Time dependent profitability, from micro-payments, is not a new business equation. It is the underpinning of the 99 cent hamburger, in the American parlance. The digital economy has introduced a dynamic stream of “push-pull” mix of product and services. In this paradigm shift, we have not removed the product, but we have enabled digital transformation of the **business model related** to the product. We have made the product, and the associated service, a part of the **systems as a service** solution pack, using digital threads to track and trace deliveries.

In this model, earnings must be traceable to its lowest common denominator, which is the *pay per each use of each unit of service*. We aim to replace one time purchase of a product, or a block purchase of service (warranty) or block payment from customer (leads to customer unhappiness, fractured loyalty, lowered credibility, tarnished brand image, poor penetration). The granular reach of pay-per-use model was not feasible prior to the medium of the internet. Digital transparency in the digital enterprise can provide secure tools, to document the process of consumption, and related services, in order to charge for what is used, nothing more.

The systems integration necessary for pay-per-use business model demands tools and infrastructure. The latter may be beyond the capacity of the developing economies. This is where the advanced economies and forward looking states, can sow creativity, to coalesce the *systems as a service* model. Harvesting revenue from each customer touch point, from billions of users, creates immense potential for ethical profitability. These models can also work through public-private partnerships, if the providers are interested in both, profit and service of public goods.

Vision, and the application of internet based business tools, when coupled with R&D for products, and access to global ecosystems, creates the critical mass of synergy, which is the foundation of the *systems as a service* approach. New sources of revenue can be realized through local, and global, public-private partnerships and academic-industry joint ventures.

The solution may *contain products* which may serve in the geography where it is needed, thousands of miles away from its provider. But, the *service* link to the product in use, that is – data and information – will be linked to the business. Hence, local job creation. Businesses will profit each time its products or service is used, as a part of the *systems as a service* solution package, agnostic of its location. The data and information related to the service offers value. The value is embedded in the *systems as a service network*. If shared, this is the source of continuous revenue, for entrepreneurs, businesses, citizens and public-private partnerships.

This is the digital supply chain of data, from network of devices, enabled by connectivity, globally integrated, to provide *systems as a service*, as a *seamless solution* for the customer. Using jargon, unleashed by MIT in 1999, this is a part of the connected world of IoT, **internet of things**. The networked physical world¹⁰ is about making decisions about the state of atoms.

Decisions, the good ones, profitable ones, can make a great difference. The ubiquity of decisions (what to eat, wear, drink) makes us oblivious that data is constantly converged, to make decisions. If the decision is incorrect due to error in data processing, the outcome may be trivial or catastrophic or somewhere in between. If the parameters and volume of data is too many, and too large, then, humans may choose to use data processing tools and technologies. Automation, machine learning, artificial intelligence, optimization, predictive analytics and risk estimation are a part of this process. Our increasing reliance on tools has created opportunities for “time spoofing” or “infecting” our decision tools. Cybersecurity risk mitigation strategies may call for humans to be involved in key decisions, including digital supply chain, for critical commands. Therein lies the importance and need for “cognitive” tools¹¹ to aid in the monitoring, supervision, and validation of *contextual* data, prior to execution of command(s) in a system.

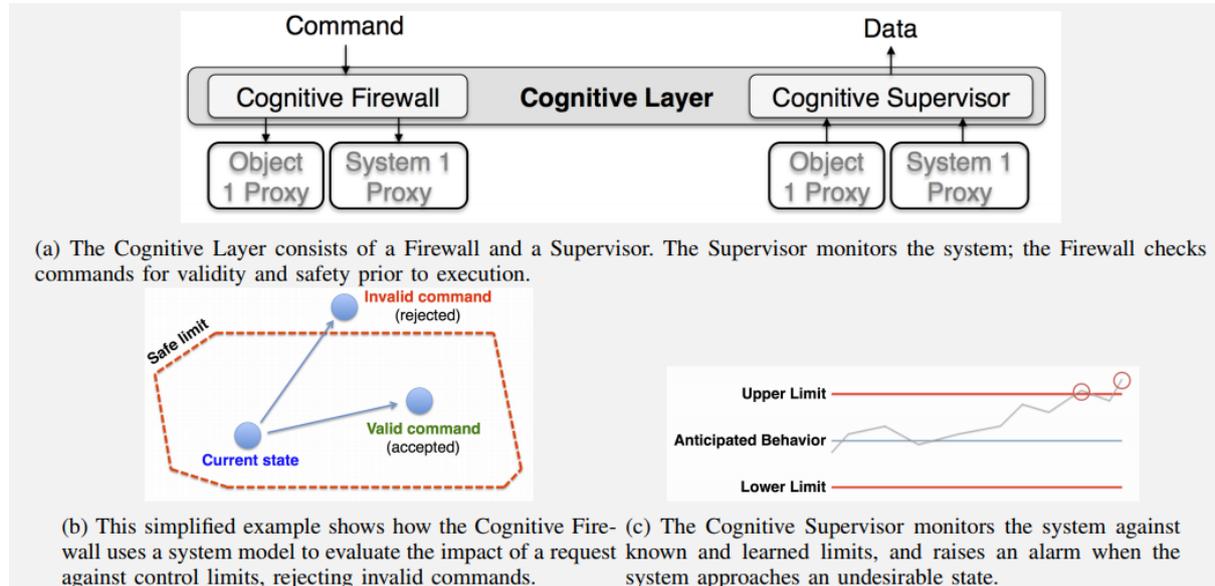


Fig. 3. The ‘cognitive layer’ in the digital copy¹⁰ of the physical world - cognitive digital twins?

The digital copy of the physical world (referred to as digital proxy or digital duplicates or digital twins¹²) may enable real-time visualization of data, metrics and analytics of machines

and systems. The sense and response functions in “intelligent” operations may need humans in the loop for mission critical activities. Introducing “cognition” is a prudent cybersecurity measure and risk mitigation strategy. Cognitive monitoring and supervision ensures the decision system is “behaving as expected” and commands do not cause harm. The Data Proxy model [10] applies context information for monitoring faults and validates incoming commands prior to execution.

In the context of the current discussion to aid in improving 80% of the world, one begs to ask if data analytical tools, such as, machine learning, artificial intelligence, neural networks, and cognitive digital twins, are germane to the effort. The answer depends on what (objects, things, products) is at the “edge” of the networked physical world, what decisions we are trying to improve and who or what is involved in that decision process. 80% of the world is in need of answers, not numbers. But, without numbers one may not be able to deliver the “good” answers.

3 The networked physical world

Data driven decision systems, if supplied with data, information and intelligent analytics, may make better decisions, perhaps more profitable decisions. But, these systems are not trivial, in terms of systems integration. It may need orchestrated performance from various ecosystems.

Whether it is a rice farmer in Saigon about to plant a rice seedling, or

a child about to drink water from a tap in Bogota, or

a house-husband in Dalian preparing to use electric appliances in the kitchen, or

a septuagenarian in Mysore using a sensor to estimate her blood glucose, or

a surgeon in Addis Ababa requesting a 3D-printed stent for coronary angioplasty,

it is all about decisions and data, which, when, and if, connected, is a *system*.

From Santa Clara, we can tell the farmer in Saigon if the conditions are optimum for planting the seedling. From Boston, we can warn the child in Bogota that the tap water contains more than permissible amounts of mercury. From Detroit, we can inform the house-husband in Dalian that it will be cheaper to use the electrical deep-fryer if he could cook the chicken after 630pm but before 8pm. From Miami, we can tell the patient in Mysore that her blood glucose of 140mg/dl is slightly elevated. From Atlanta, we can send the instruction set to the 3D printer in Addis Ababa for the surgeon to print the stent for the percutaneous coronary intervention (PCI).

Data and information from anywhere may serve local needs. Data can be transformed to information or products, globally. Mobility of the medium, the internet, enables *systems as a service* to offer solutions. If one provides a piece of this pie, one may earn a part of the revenue.

However small the profit may be, billions of pennies each day, can lift many boats. It is this piece of the global pie which can be harvested through the social business model. We need the network of tools, technologies, objects, processes and systems, as a part of our symphony.

Using your phone from Shropshire, UK you can call a cab to pick up your Mom from her home in Santiago, Chile. From Mumbai, India, you can order a pizza for a friend in Miami, FL.

This is the digital supply chain, made possible by reduction in *transaction costs*.

This is *systems as a service*. We connect atoms (things) to bits (data, information).

It may require bleeding edge R&D tools from research but must be connected to yield answers, which can penetrate any market, to provide actionable information and real solutions.

What are these systems or solutions most needed by 80% of the people in the world?

This is a business question and central to the global value network and supply chain.

It is not about drone taxi or robots flipping burgers or the pursuit of asteroid mining.

The quest for fundamental solutions needed by 80% of the world is focused and few.

It is a short FEWS:

F Food

E Energy

W Water

S Sanitation

I am inclined to make it FEWSH and add healthcare. FEWS may aid “prevention” and reduce the need for “correction” but, wear and tear of the human system, needs healthcare. This combination, FEWSH, of commodities, if served through the paradigm of *systems as a service*, presents new lines of business and scope of profitability, never imagined before. But, *systems as a service* is **not** a panacea for all solutions. Cumulative profitability from *systems as a service* is vast, one must remain vigilant about the norms of ethical profitability. To transform these ideas into reality, imagination, invention and entrepreneurial innovation must run in parallel with business creativity, to create global liaisons and penetrate markets where FEWSH is in demand.

There is no one clear approach to FEWSH. It will be a complex and dynamic ecosystem, where we must develop solutions in ***collaboration with the markets***¹³ where we intend to sell *systems as a service*. Markets must have some “skin in the game” because we need access, adoption and we must retrieve¹⁴ the data related to *accounting of use*, in order to profit from each granular event, and optimize the economies of scale. This is long term revenue planning.

This is uncharted territory. This is virgin space. This is the digital economy. The classical approach to advanced R&D works well for OECD but it is time to move out of the box. Tools and technologies are parts and components, awaiting integration, to generate a system, which will offer a function. The sum of the parts must be greater than the whole. When you want tea, you actually expect to receive a steaming cup of brewed hot tea. You don’t want an empty cup, a saucer, a spoon, an infuser, Darjeeling tea leaves, electric tea kettle, water, pot of milk, cradle of sugar, malted milk biscuits from Tesco or Fortnum and Mason.

The “whole” in this world, is about systems. Academia, industry and government, plays a critical role as the purveyor of knowledge and tools necessary to install the infrastructure, in order to provide the parts of the system. We profit from components but the ***function*** of the system, the ***outcome***, is a symphony of ***structures***, which is of value, if the product supply chain is seamlessly coordinated with the service supply chain, in a manner that the work flow is friendly for consumers, customers and end users. Hence, a ***seamless systems as a service***.

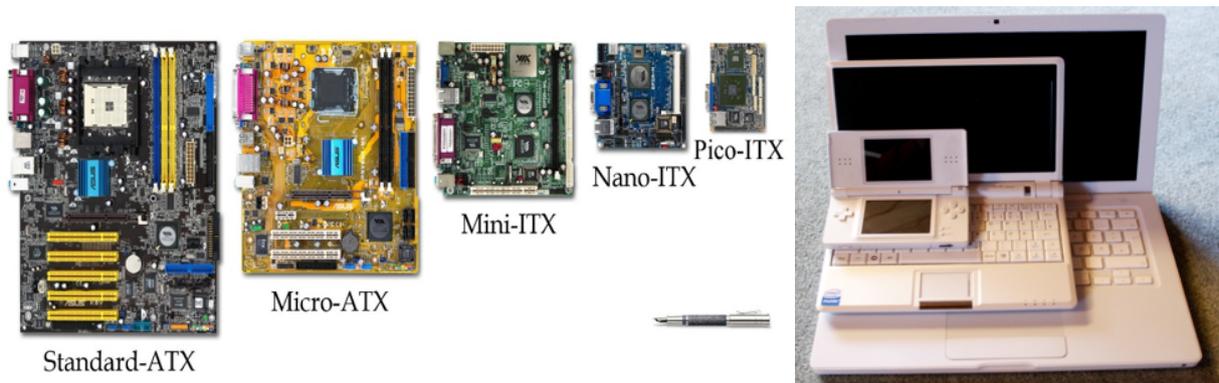


Fig. 4. Advanced R&D products and components (structures¹⁵) are essential but not sufficient to create user friendly solutions (functions). End users may only pay if the “function” offers value.

4 Information arbitrage

United States has exported knowledge at least since 1835, with the establishment¹⁶ of the American School for Girls, which is now the Lebanese American University in Beirut. The list of American Universities abroad has grown significantly.

How many foreign universities do we have in the USA? Very few¹⁷, if at all we can label them as universities. The lack of name recognition and the astronomical cost of creating a campus in the US are probably the main deterrents. Can we attempt to change that equation?

Can we offer “data, information and knowledge” as the catalyst to encourage FDI and foreign universities to establish US campuses? How about King Saud University in Maryland, University of Jordan in Michigan, Cairo University in Boston, Qatar University in Oregon?

Can a similar approach work with China, India, Brazil? An IIT in Tallahassee, FL?

Why am I emphasizing the Middle East and the BRIC nations? Because we want to create and sell services, and the gigantic markets are in the Middle East, Asia and Africa. By co-creating some of the services with campuses in the US, we create a direct sales channel for entrepreneurs, to reach these vast markets. Perhaps we may also hold half the IP rights.

Co-creation, collaboration and cooperation are catalytic to create, open, new markets. Can we change the equation, challenge *status quo*, think global systems. Can we combine?

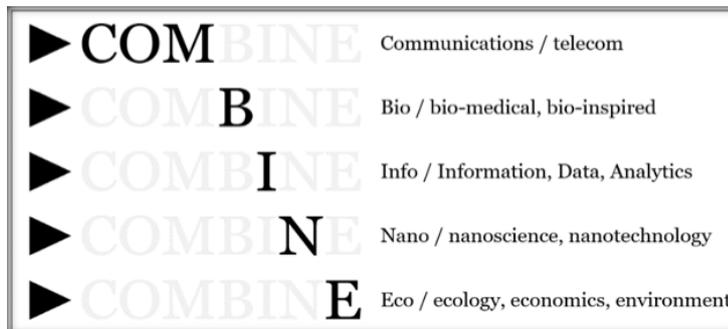


Fig. 5. Combine

5 A few uneasy words for academic departments defined by disciplines? Combine, complementarity, confluence, community, and convergence

Convergence is the inescapable truth for systems and the gospel of *systems as a service*. The mantra of convergence meets with a flourish of *lippenbekenntnis* (lip service) but the vision to practice convergence and complementarity, *at the level of departmental operations*, is quite limited, to a select few elite institutions in the US, and even fewer universities in OECD nations. Perhaps this is at the heart of a disconnect. Perhaps it is a reason why we see so few clusters of entrepreneurial excellence and almost all talent trying to flock to such nodes.

Departmental operations managed by “installed” “tenured” leaders (chairs, search committees) are still drinking the same “cool aid” – chemistry department is for chemists, engineering faculty must have a PhD in engineering, management professors must have a business degree. This rigid attempt to preserve disciplines in departments to pursue “pure” and “credible” research is highly laudable, quintessential to the pursuit of knowledge, and required for excellence in science and engineering. This is **not** the problem. We **must not** dilute rigor.

The problem lies in the failure of departments not to unleash a parallel channel and embrace the view, that, systems and solutions require multi-disciplinary approaches, to solve problems in the real world. Acknowledging this fact requires that departments recruit, at the same ranks, people with non-formal degrees and out-of-the-box experiences as full time faculty members. The pursuit of these faculty members will be unconventional, cannot be subjected to the “publish or perish” dogma¹⁸, they will venture out of the traditional set up, re-define the type of problems to be addressed. These faculty will liaise with other departments, break silos, cross pollinate with industry and reach out to end users, markets and the global ecosystem, at large. These activities may not bode well for departmental “object codes” and create discomfort for the traditionalists who are limited to papers, conferences and grant writing, as performance metrics.

The answer is **not** in this HBR article¹⁹ and certainly not about selling out to industry. The answer is far more complicated. It must balance workforce development and academic complementarity with industrial economic growth as well as the creation of new global markets. Cooperation, collaboration and community must share the grounds with economy, science and engineering. Basic research must be supported and the fruits, when possible, must serve soci-

ety. The erudite faculty dedicated to building “pillars” must find a way to find and accept the need for a breed of people, in traditional departments, who will be building bridges, based on pillars. We must enable some people to see further, even if it is by standing on the shoulders of giants²⁰.

Institutional lethargy to institute change and embrace convergence at the operational level, runs parallel to the resistance for change for local and state governments entrusted with economic and workforce development. City, county and state economic development offices are staffed with public relations and communications people, generally. Occasionally business experts are in the mix with lawyers occupying the leading roles. Academics, scientists and knowledge resources are few, if any. In the management of state and federal economic development, the old adage²¹ may still ring true, *scientists on tap*²² *but not on top*.

Hence, a chasm between knowledge (institutions) and workforce silos (economic development agencies) fails to catalyze the bridges essential for cultivation of symbiosis.

The hype about jobs of the future²³ and the traditional²⁴ view of the future²⁵ are, ultimately, somewhere²⁶ bounded²⁷ by demand, on one hand, and remuneration, on the other.

The task of economic development is to create a supply chain of talent, skills and training, to feed the expected demand for labor. SCM is not only about logistics and returns.

The task of the institutional machinery is to inculcate students, in the pre-college pool, with the foundation that the colleges can build upon, to feed the supply chain of talent necessary for economic growth. Supporting the gifted, identifying the outstanding, and the pursuit of excellence, is also the task of the university-research complex. Departments were created to undertake this task, but not be limited to that task. But, often, they are. Hence, the quagmire.

Building bridges is one solution to support excellence, while maintaining the ability to compete globally. The bridge between institutions and economic development agencies are crucial to our progress.

There must be “people” on both sides who can speak both “languages” and politically adept to navigate the bureaucracy, adroitly. In addition, these “people” must understand the broad spectrum of needs with respect to the community (demographics), economics of the business (industry needs) and disciplines (breadth of knowledge in science and engineering).

These are the “people” who are few and far between. Neither the departments nor the agencies are seeking these people – because they don’t belong in any one box which can be fitted to a “job” description. These people must be dedicated to the “mission” and not a job or a task. These people must do all that is necessary, break barriers, and help to lift many boats. These people must give credit to others, refrain from narcissism and believe in altruism. These people must be able to ‘connect the dots’ and convey their purpose with lucidity, dignity, and *humility*.

It is easy to list ideas, pontificate and hide behind platitudes. It is a difficult task to orchestrate knowledge systems, spur technical innovation, implement tools integration, stitch business models, and offer a “seamless systems as a service” to help people and serve society. I wish to provide an imperfect example. In a collaborative project, we published²⁸ a paper on how to construct ultra-low cost (3D printed) nano-dot sensors to detect mercury (Hg) in water, using a smartphone which runs an AI (artificial intelligence) based program. One key is the *ultra-low cost* of the sensors (which are also robust enough for metrics and measurements). This is a tiny

drop in the ocean. But, if we could execute our vision of the “seamless systems as a service” then these ultra-low cost sensors and the smartphone detection system may save lives. The system can detect contamination (mercury, Hg) in drinking water and alert the end users.

Embracing the mission to enable science to serve society is fraught with financial challenges. Thousands of life-saving sensors never escape the lab and their potential withers in publications. The description of “World Sensor Organization” in Commentary C is an idea²⁹ which few may grasp in terms of its immense global impact and even fewer may wish to support. Society may need new organizational structures to stitch the vision of connectivity, and service for citizens, in a manner that is economically prudent, sustainable and offers measureable value. Universities, public agencies, government and non-government organizations, are all important part of this ecosystem but none appear to be equipped or eager to lead this important charge.



Fig. 6. Bridges are built on pillars: Ponte di Rialto and Ponte Vecchio by Antonietta Brandeis³⁰

6 3D PRINTING – THE BLESSINGS OF DIMENSIONALITY (THERE IS NO CURSE³¹ HERE)

In our very small contribution (paper), the tool that enabled us to manufacture the low cost sensor was 3D printing. The technology is 40 years³² old, yet, its vast potential seems to be hovering around high end applications³³ or facetious³⁴ consumer toys. In a separate article, I have discussed³⁵ a few thoughts on 3D printing in entrepreneurial innovation (Commentary B).

3D printing may be compared to lenses. The ability to “see” was transformed by lenses³⁶ and in the 17th century³⁷ Anton van Leeuwenhoek (1632-1723) made his “microscope” using a lens. After 400+ years, in the 21st century, we may be going further and forward (?) to a new state of lenslessness³⁸ which promises even more wondrous insights. It is likely to foment a new form of a revolution, for good. 3D printing possess all the ingredients for a revolution, too.

Total knee arthroplasty was first performed nearly 50 years ago³⁹ and knee/hip joint replacements are a part of our modern vernacular. Vast advances in implants, joints, prostheses, are helping people, worldwide, albeit far more in the advanced economies (OECD). The hyper-inflated cost of material combined with ultra-precision manufacturing costs, may make it less affordable to about 80% of the world, who are not a part of the OECD nations.

Can 3D printing bridge this chasm between haves and have-nots, partially? What if 3D printers and materials (alloys, powders) were provided to hospitals or clinics, globally?

The business model may be a portfolio of tools in order to lower the barrier to entry into markets. What if there was a minimal set-up cost, as a down-payment, and then a “pay-per-use” *modus operandi* to charge for each unit of time the 3D printer was used?

The paradigm change is in the business of the product as a service, in this case the product is not only the stent or the hip joint but also the 3D printer. The hospital or clinical may not have to seek capex funds to afford the printer. Micro-payments may transform equipment installations from the capex (capital expenses) column to the opex (operating expenses) domain. The latter may better serve resource-constrained organizations, often held hostage by cash flow.

Are 3D printer manufacturers dictating surgical implants? Not at all. It is the reverse. Surgical implant manufacturers are going to evolve as 3D printer manufacturers, too. The old school investment / sand casting manufacturing of metal products (implants, etc) in a few locations (company manufacturing locations), may be partially replaced by 3D printing, by supplying 3D printers to hundreds of locations, globally distributed, on-demand manufacturing.

In the new business model, for old surgical implant manufacturers, *data will be the salt*.

Precision manufacturing, for material science, is not really precise for physiology or orthopedics or cardiology, it is an approximation to minimize discomfort. In many cases, it is a statistically “average fit” for implants, joints and prostheses. 3D printing may reduce the need for the “one-size-fits-all” approach necessary for mass manufacturing. 3D can deliver precision fit for every individual, when necessary, if feasible. In the new business model (for old surgical implant manufacturers), data from imaging will design the “fit” required for that individual.

The imaging data will be at the location of the patient (assumption - location is equipped with imaging equipment). Imaging data will be transmitted to the company (for example, Bio4D in Cambridge, MA). 3D design experts, orthopedic specialist, neurosurgeons, software experts and engineers can use the imaging data, to create, modify or change, the dimensions of the product (stent, joint, etc). The material specifications (alloys, powders) and the instruction file for the 3D printer, for 3D printing the personalized precision part, will be transmitted to the 3D printer, at the location of the patient. The part will be 3D printed and used by the medical team, attending the patient (assumption – printed part does not need any specialized or rate-limiting pre-processing step or cellular treatment which may be unavailable at the location of surgery).

The surgical parts business of Bio4D (for example), remains the same – still providing implants, joints. But, in this highly distributed manufacturing on-demand model, the company has extended its ecosystem and owns a new line of business which provides 3D printers, and perhaps also inks an IP agreement for the 3D printer alloy powder, with innovation labs in material science, and instrumentation for co-creating the specs for the alloy to be used for parts.

However, the ecosystem for Bio4D does not stop at printers and powders, it also holds the *data* from [1] patient imaging and [2] the algorithms and software necessary to turn that data into a precision fit for the required 3D printed part. The raw data from the patient may still belong to the patient or the hospital of origin. But Bio4D can own, or reserve the right to license, the *processed data* which is created by Bio4D, through convergence of imaging data with software

for 3D printing. The *data set* (instruction) for printing the part which is transmitted to the 3D printer (at a remote location), is a part of the business revenue for Bio4D in terms of the digital economy, or knowledge economy or health information (whatever jargon may apply).

The combination of these strands of revenue demands new business models. Traditional pay-for-product and pay-for-service schemes may not be the only tool. Pay-per-use and its variations, may be complementary mechanisms. Micro-payment strategies may stay in place for the life cycle of the user. The latter may be 10-50 years, depending on post-operative longevity.

If the cost of *implant-as-a-service* was priced at \$1 per day, as long as the person is alive, then for a 10 year life cycle, the service⁴⁰ will earn \$3,650 or if it a bigger part⁴¹ (for example, knee or hip joint), charging \$10 a day generates \$36,500 as gross earnings, per item, per patient, for a 10 year post-operative use. In addition to per part revenue, there will be revenue from use of 3D printers, per use, over the life cycle of the engagement with the hospital or clinic. By reducing the burden of upfront fees, one increases market penetration for services.

7 Going back to the bleeding edge

Vilfredo Pareto (1848-1923) published his first work, *Cours d'économie politique* (1896–97), where the 80/20 “rule” (Pareto Principle) was used⁴² to represent various distributions of land and wealth, in Italy. We have used this 80/20 rule to claim that untapped economic growth from the 80% of the world’s population, may not need all the accoutrements from bleeding edge R&D, in order to provide a plethora of services to improve the quality of life and living, globally.

The 20% of the affluent world, funds inventions and innovations. Polarization (Fig 6) of wealth is a gigantic problem yet some of these individuals are investors pushing forward the boundaries of science and technology. In our example of 3D printed parts, we discussed what may help 80% of the world. But, *much more* can happen in the context of 3D body parts. But, it will need massive investments, experiments and trials, before an approved development may become a *feasible* part of the future of 3D printed parts, for the less affluent global citizens.

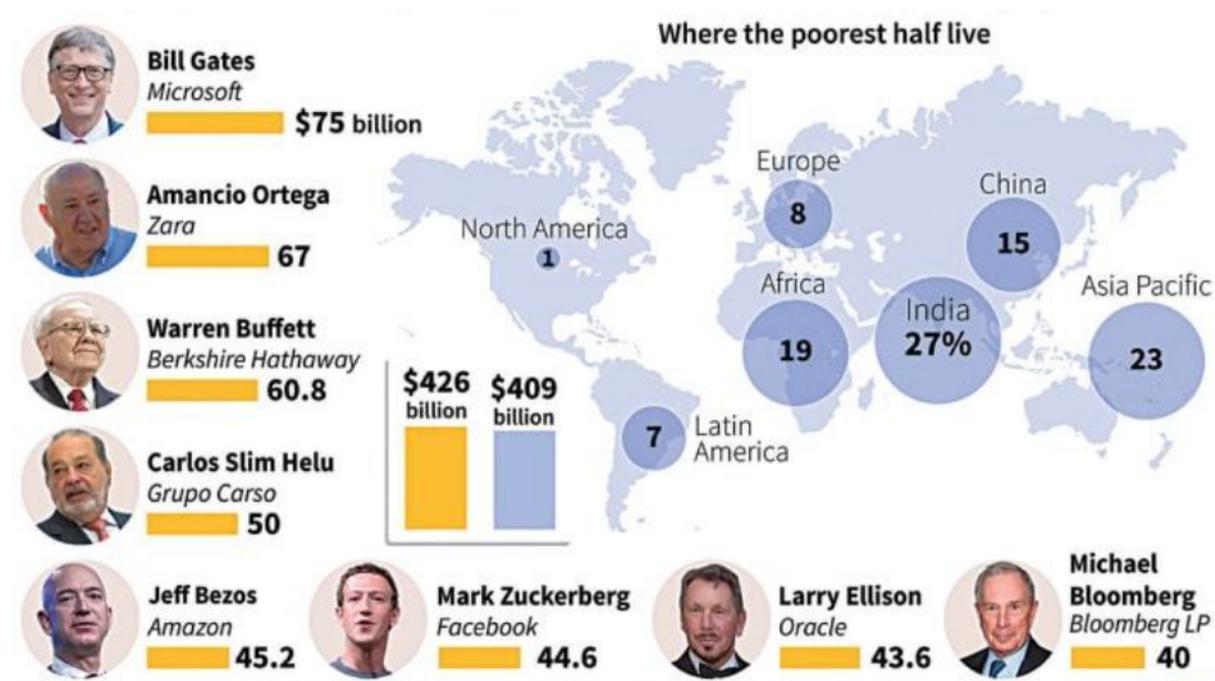


Fig. 7. Eight men, own more wealth than the poorest half of the world's population⁴³ according to (2018) calculations⁴⁴ from Oxfam based on a 2017 report⁴⁵ from Credit Suisse.

Flexibility and precision due to 3D printed body parts may enable the use of 3D printed implants to act as Trojan Horses⁴⁶. For example, stents filled with drugs⁴⁷ or stem cells or joints with internal sensors, printed polymer⁴⁸ electronics, tunable radiofrequency communications⁴⁹ and nanotube radios⁵⁰. Using data from implant-sensors, the delivery service of drugs, cells and analytes, *in vivo*, on demand, may be remotely controlled using RF communications network **in** the body, in partnership with analytics, systems and humans-in-the-loop, **outside** the body.

A perusal of references 43-46 (above), will reveal that these ideas, and papers, are more than a decade old (in some cases, 20 years old). The self-adjusting hip joint using a smartphone to “sense” gait (provide auto feedback to the hip joint to adjust) is not impossible to deliver, for 20% of the world, who can afford to invest in the R&D and pay for the services. When will that service become feasible for 80% of the world?

The answer depends on the investors (in that 20% group) who must fund the bleeding edge R&D necessary to transform this idea into reality. If adopted by users, in the 20% group, the cost of the service may start to decline, over time. At some point, it may become affordable even for the people in the developing economies.

Hence, the need for individuals in the 20% group, to catalyze certain forms of progress, which may lift the lives of people, referred to as the 80% of the world.

8 Comments

In this example of economic development from the digital economy, I have focused on a tiny sliver, that of, the impact of 3D printing on replacement of body parts. It is not at all a new technology. The suggestion is not about advanced technical R&D, but the *strategy* of its use, aimed to offer healthcare *solutions*, even for the developing economies (80% of the world).

What the 20% of the world can do, to further the R&D related to 3D printing, should not stop us from finding ways to deliver the help, we can, at this time. But, transformation is hard.

Transforming Bio4D, which mass manufactures surgical implants, to view the future of its business as “implant-as-a-service” is the business challenge. The ability to think outside the box, and “connect the dots” essential for the service ecosystem, is not an easy task. It requires vision, leadership and investment. Truth is, it also requires altruism, a dedication to the mission of improving lives, and a sense of the future, where credibility, égalité and dignity, are not just buzz words or platitudes but part of the corporate mission, which, of course, must also include profitability.

The global growth of new business offers immense potential for profit, albeit, over time, from micro-revenue. There may not be any instant financial gratification. There is an underlying need for establishing credibility through local and global partnerships. There will be a need to serve as a global ambassador for health and healthcare, to lift many boats, not just a few yachts.

9 Concluding opinion

Old world “industry” leaders chained to Wall Street may not “see” the future. Perhaps their imagination is out of focus, their vision may suffer from myopia or macular degeneration, and risk-averse strategists may insist that they keep within their well-defined comfort zones.

On the other hand, the “new” world is super-saturated with the high tech buzz, where creating an “app” can apparently escalate one to celebrity status on social media. Once on the pedestal of prosperity, the next step is to surround oneself with ultracrepidarian marketing staff. The reality of the bigger picture, pales, and fades, by comparison with the thrills from virtual reality (VR). High tech seems to be synonymous with high growth (Figure 7).

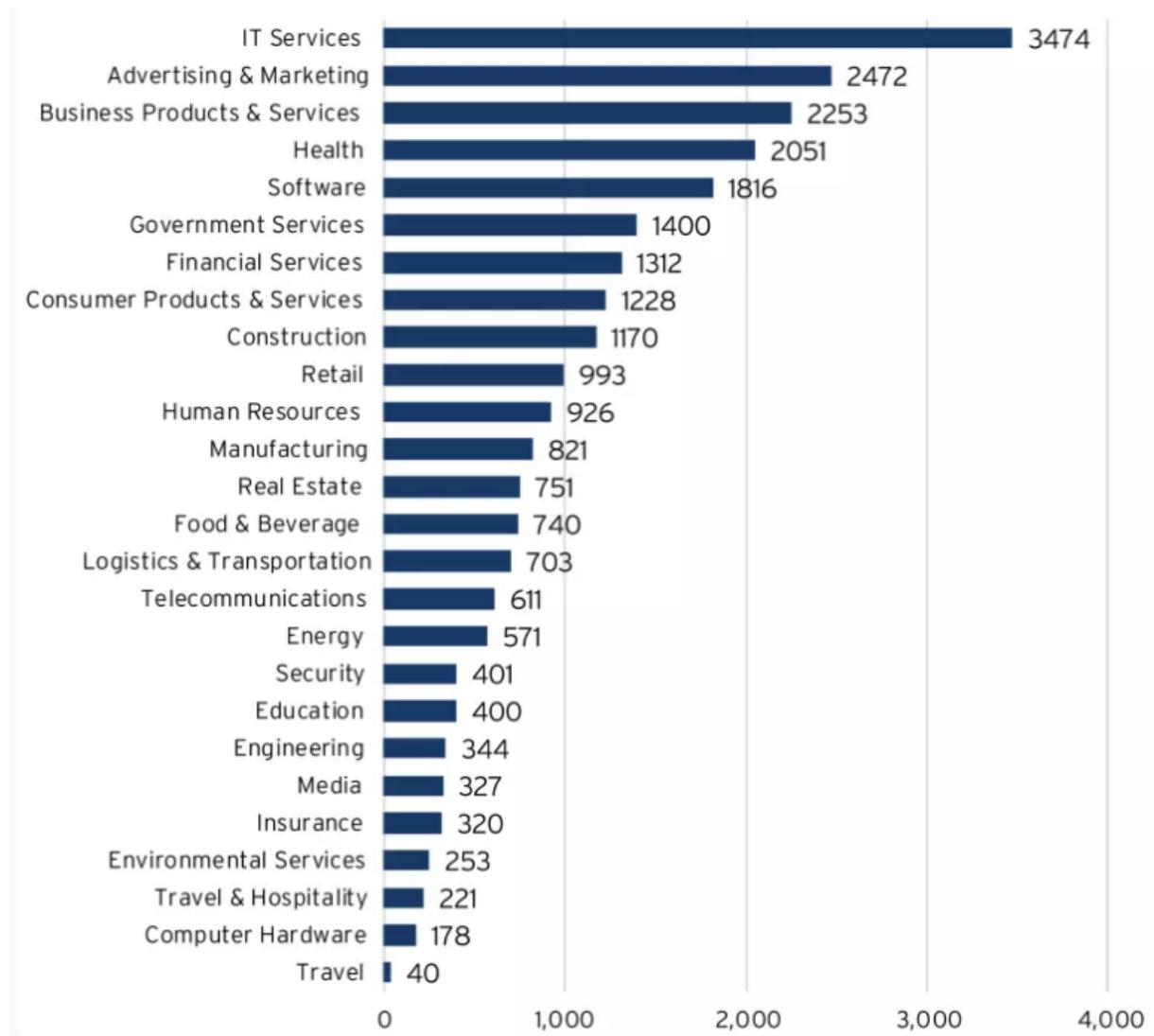


Fig. 8. High growth company industries⁵¹ in the US (2011-2017)

The suggestions in this simplified proposal can lead to global prosperity, albeit incremental in nature. It may be accomplished without any grand invention and vastly differs from the prediction of consulting pundits, according to the sales mantra shown in Figure 8. The need for safe drinking water, sewer systems, and managed sanitation services, does not even register on the “map” yet these are daily challenges⁵² for billions of people, in the 80% group.

- **2.1 billion people** lack access to managed drinking water services. (WHO/UNICEF 2017)
- **4.5 billion people** lack safely managed sanitation services. (WHO/UNICEF 2017)
- 340,000 children under five die every year from diarrhoeal diseases. (WHO/UNICEF 2015)
- Water scarcity already affects four out of every 10 people. (WHO)
- 80% of wastewater flows back into the ecosystem without being treated (UNESCO, 2017)

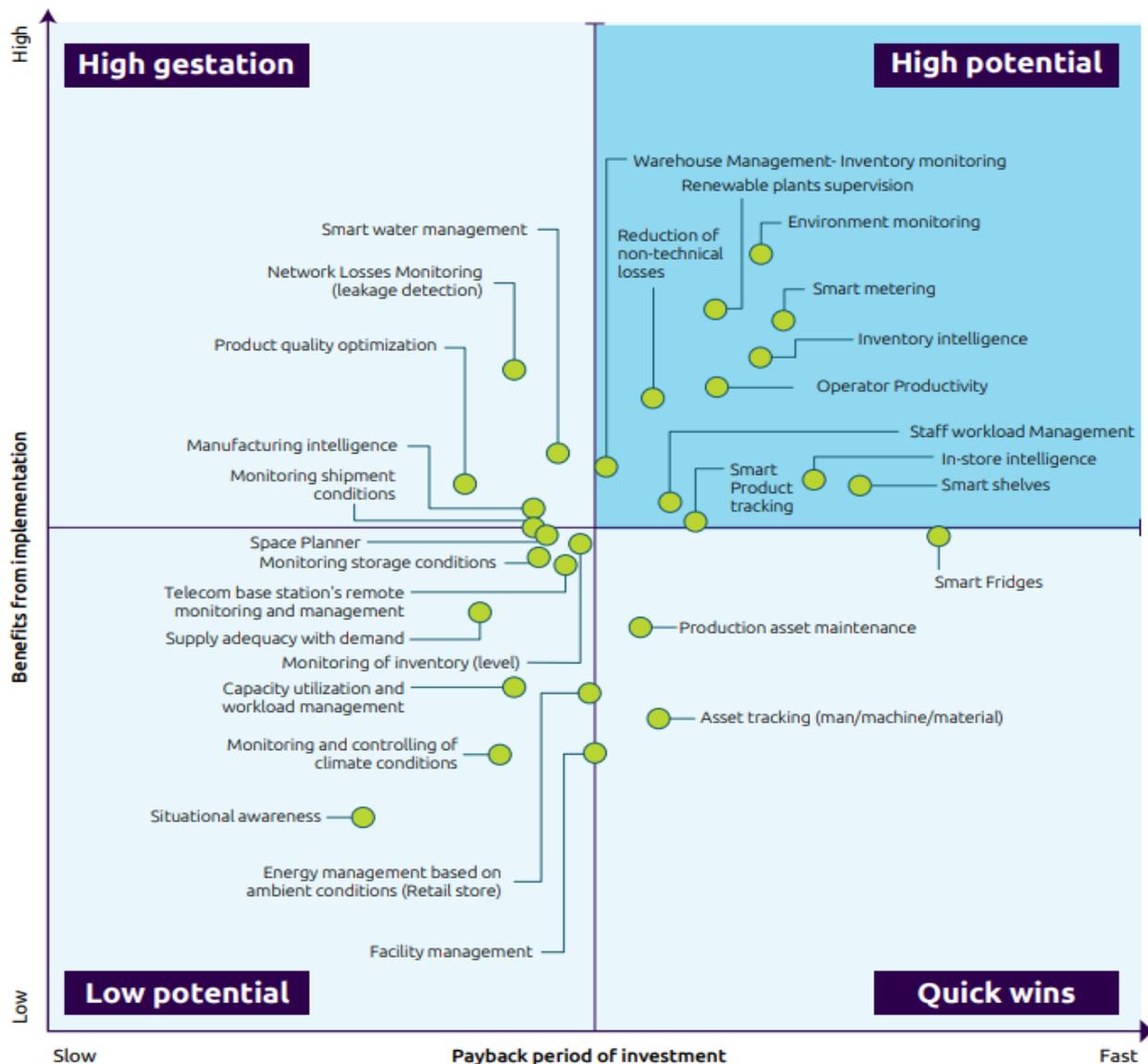


Fig. 9. Use cases peddled by US consulting⁵³ firms, indicates “smart fridges” as a quick win.

The (delusional?) choice of “smart fridges” by the consulting firm (Figure 8), points to a flawed vision: the failure to recognize efficiency as a function of the ecosystem. The “smartness” of a fridge is linked with identification of inventory in the fridge. The *retail supply chain of food* must offer tools for identification, recognition and communication of items, stored in the fridge. Slapping sensors or cameras inside the appliance is **not a systemic answer**. The *systems as service* approach to a smart fridge is much more complex. It needs convergence of multi-tiered supply chains. It harks back to incorrect steps made by proponents⁵⁴ of RFID. The history⁵⁵ of general purpose technologies reveals similar mistakes made during the 1920’s in course of electrification in the US. However, “smart fridges” may be relevant to use⁵⁶ in OECD nations

(20% group), but, even then, the business case remains extremely wobbly. The “smart” bubble is luring investments from developing countries (Fig 9). Is it mimicry or competition?

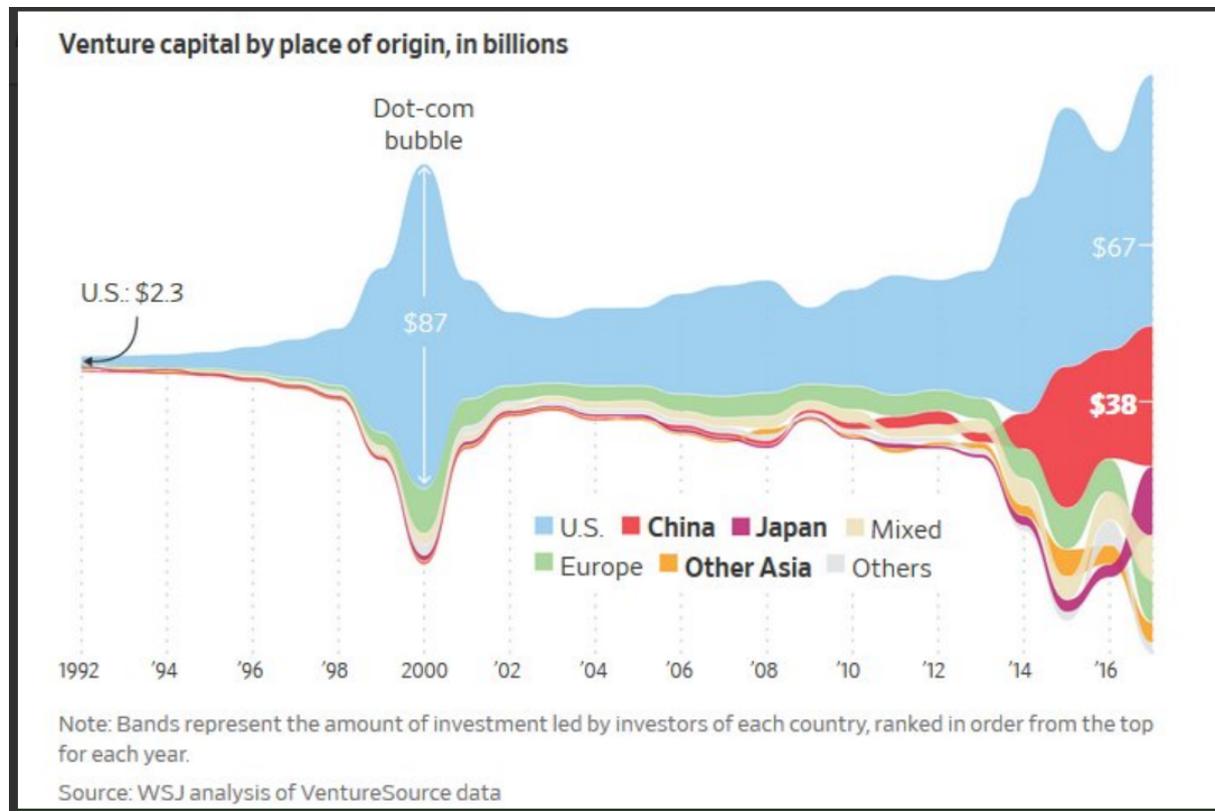


Fig. 10. Venture Capital Flow, US\$ Billions. Source: Wall Street Journal Venture Source Data

Entrepreneurial innovation is a word bandied around in business conferences. Here, in this essay, we present examples calling for distributed and global entrepreneurial innovation for the rest of the world. We echo the renewed wake-up call by Jim Kim, President of World Bank, who admits⁵⁷, *“it is imperative we find new paths to prosperity. The traditional route to economic growth and job creation through industrialization is rapidly closing.”*

The convergence of ecosystems outlined in this suggestion is greater than the sum of its parts. The magnitude of its potential cannot be unleashed in little steps, small advances or short term thinking. Long term ROI is inextricably linked to economies of scale, and services, which can penetrate any market. The “heart” of this model is not a lab project or a “small” pilot test bed or an isolated experiment. One may not be able to build an elephant using the mouse as a model.

10 Epilogue

After reading an earlier draft of my “mindless drivel” (this essay), a teenager from a developing nation in SE Asia (daughter of a friend of a friend), send me a message via WeChat. She wondered

if 80% of the world is just a “market” for the “systems as a service” businesses that 20% of the world may wish to develop (because “the 20%” have the R&D resources, human resources, and necessary investment, to stitch together the services and decision systems).

I have now added this epilogue to respond to her concerns. The first response to her question is that I really don’t know the dimensions and dynamics of how and who may create these systems as a service. Because, the *context of demand* is relevant to each market, hence, it is my naïve assumption that these “services” must be *partnerships* where part of the R&D, tools and technologies may be from OECD nations but the human resources required for systems integration, deployment, and maintenance, is likely to originate from developing economies. Knowledge transfer, skills training, and workforce development, are central to the “shared” notion. Online education⁵⁸ may be a platform to facilitate dissemination.

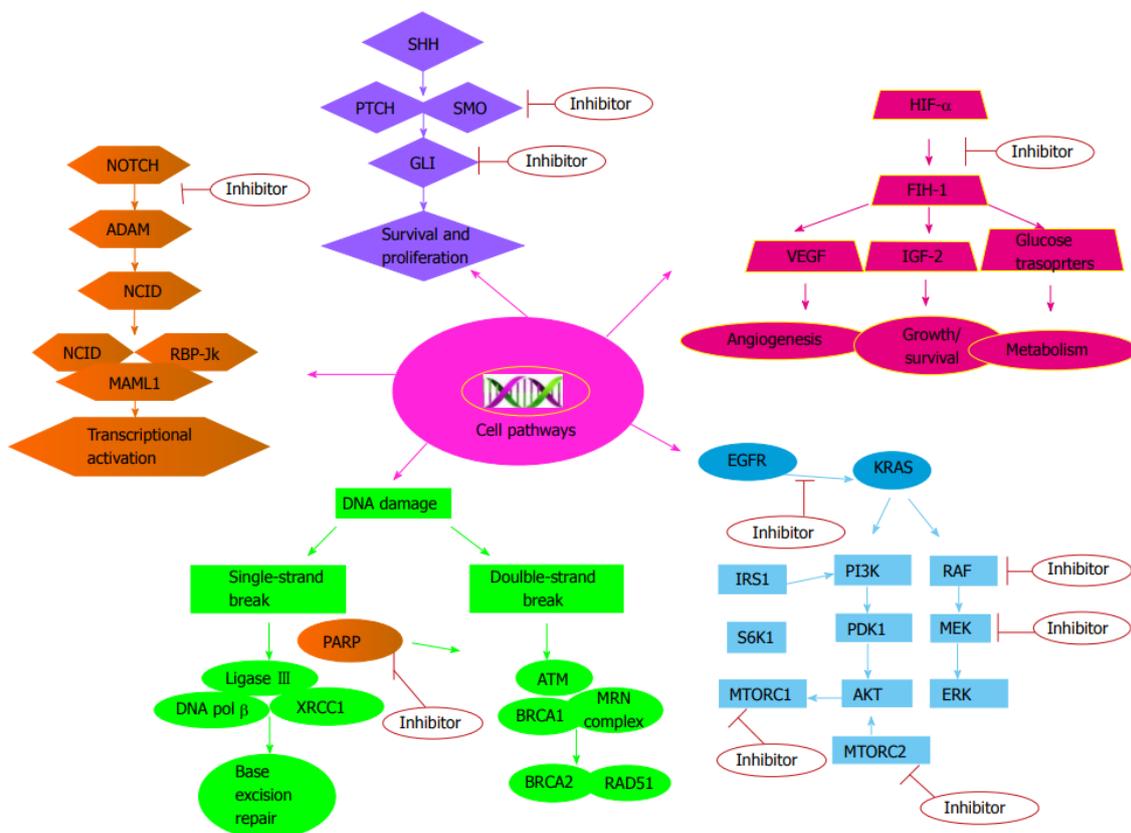


Fig. 11. Cell signaling pathways involved in pancreatic ductal adenocarcinoma carcinogenesis and actionable molecular targets⁵⁹. Imagine the research necessary to scratch the surface of one type of cancer *system*. Scientists in developing nations must also ask the hard questions, which require peace of mind, infinite patience, and a sense of purpose, to use science to serve society.

However, there may be a deeper question, which remains unvisited. Where should the developing economies invest in terms of research? I am unequivocally unqualified to answer that question.

But, the latter wouldn't stop me from making some suggestions, for example, malaria research (you do not have to agree with any suggestion, we can pre-agree to disagree).

The etiology of malarial diseases (which results in 2 million deaths per year) is a clear example of how parasites evade cellular immunity using antigenic variation⁶⁰ (*Plasmodium falciparum*, is responsible for about 90% of human mortality and morbidity, but over 200 species of *Plasmodium* are known to infect vertebrates). The almost exclusive occurrence of malaria within the 80% of the global population, mostly in non-OECD nations, makes it a target for eradication, by 80% of the world (rather than depending on initiatives from the 20%).

But, the 80% of the world cannot ignore the other afflictions, for example, cancer, diabetes, cardiovascular malfunctions and pulmonary diseases, to name a few. Which means, in the biomedical domain, the rest of the world must find ways to use therapeutic advances, for example, human induced adult pluripotent stem cells, plant based bio-pharmaceuticals, traditional biologics (monoclonal antibody producing autologous cells), metabolomic sensor networks (*in vivo* wireless communication networks monitoring analytes and transmitting data from inside the body), molecular robotics (ingested micro-machines removing intestinal polyps) and nano-machines⁶¹ to target apoptosis⁶², precision cell death⁶³ and time-based drug delivery.

Therapeutic *systems* have a long way to travel from the bench to the bedside. Business models focused on profit⁶⁴ and business school education, may be detrimental to the vision of convergence. Should we demolish⁶⁵ business schools? The business of translational medicine, as outlined in the above paragraph, may need a business model which values R&D partnerships.

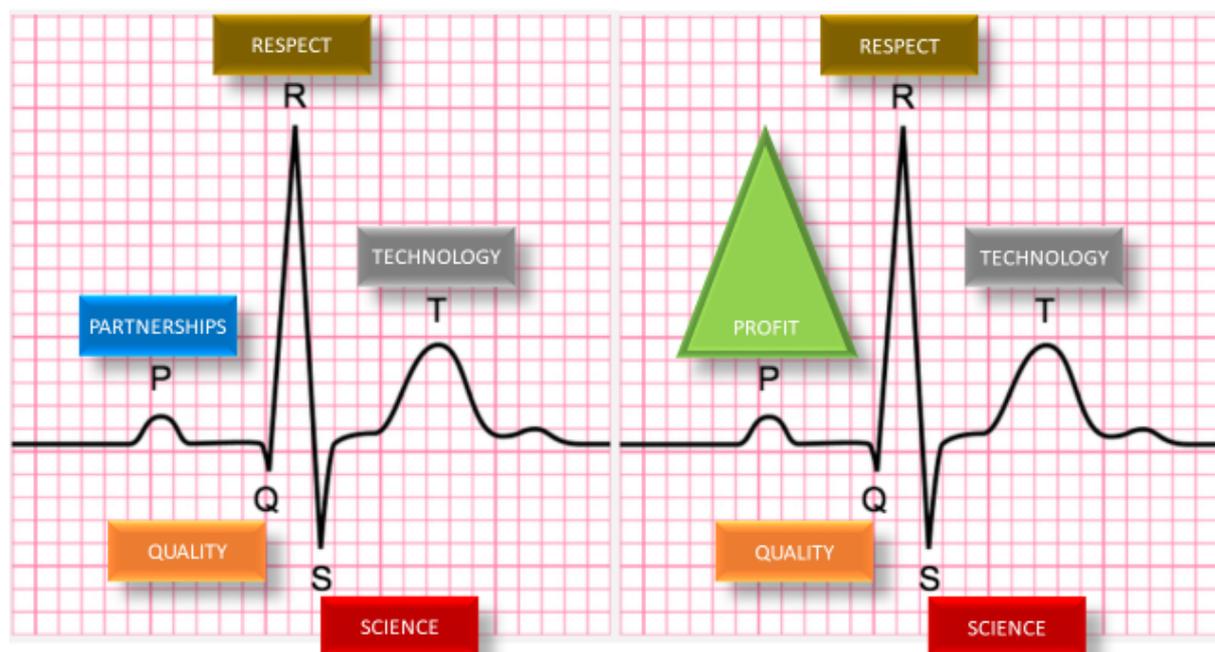


Fig. 12. Profit from business value of partnerships may exceed profit from profit-driven business

The heartbeat of business, illustrated in Figure 11, may benefit from a slightly different perspective. Consider the basic PQRST waveform⁶⁶ telemetry, displayed as electrocardiograph,

representing electrical impulses generated by the heart (transferred to electrodes on the skin, which in turn displays the waveform on a screen or prints out on a telemetry strip). PQRST may serve as a bio-inspired business guide, to draw attention to the push-pull dynamics between P for Profit (the business school mantra) and P for Partnerships (a sense of the future). The new path does not exclude profit. It maximizes profit. PQRST suggests the need for industry and businesses to structure partnerships, with other industries, academia, government agencies, and global organizations, to co-create, co invent, co-innovate in order to co-opt markets, grow goodwill and profit from delivering a higher quality of service for society.

These and other suggestions for business and society, aimed at improving the quality of life, and living, shares a common denominator, irrespective of the wealth of the nations. The supply chain of talent may be the underlying primary determinant and the purveyor of progress for civilization.

In this context, one observes that the US has built a Taj Mahal on top of a wobbly base of rickety twigs. One may arrive at this general observation based on the near-abysmal quality of US public education in 80% of K-12 schools vs the rigor, creativity, excellence, and brilliance, in about 20% of US entities of higher education (research universities, institutions). Even a cursory glance at Figure 12 drives home the fact that is far cheaper to be entertained⁶⁷.

In this essay, one may find ample evidence of “see-saw” between *service as a system* for the 80% of the world and occasional discussions about the bleeding edge of R&D advances. There is no doubt we need *service as a system* but the origin of talent is agnostic of nations. The limited budget in developing nations may be judiciously used to strengthen academic foundations, to contribute to the global supply chain of talent. But, the affinity for STEM must not induce a phobia for funding humanities, languages, arts and music.

In research, developing nations must not be afraid to ask the hard questions, with long term value. Biomedical research is an essential part of FEWSH, as well as materials science, nano-satellites, energy storage and mathematics. These are preferred over programming, networking certifications, and serving as robots, in call centers. However, there is also a place for vocational education and apprenticeships. Fact is, there will never be an optimum one shoe fits all solution. It is always going to be a question of balance and priorities in order to remain competitive in the global economy without sacrificing the plight for decent standards of living, for all, with dignity.

Leaders, to qualify to be referred to as leaders, must possess incisive foresight, vision, and imagination. Business leaders, social pundits, and academic gurus, must all understand that humans need to belong, to be appreciated, and to be valued. Leaders must understand, that at the heart of civilization, at its PQRST core, lies an incontrovertible truth. The education of a boy may change the fate of a man, but, the education of a girl, may change the destiny of a nation.

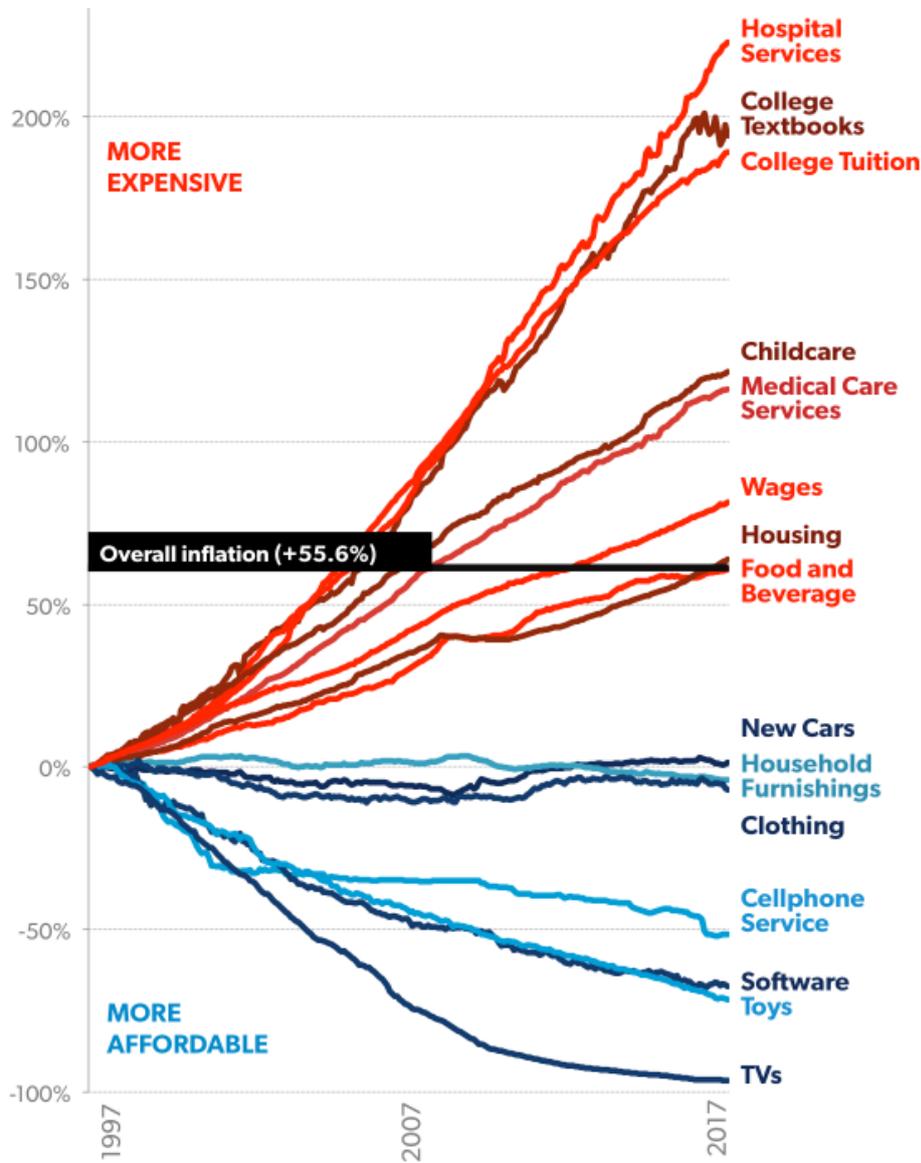


Fig. 13. Changes since January 1997 in the prices of selected consumer goods and services. There is no dearth of cheap entertainment even for the minimum wage masses in the US but cost of higher education, and healthcare, may pose insurmountable barriers, or bankruptcy.

Final Remark: Opinions in this essay are due to the author and do not represent the views of any institution.

Notes

¹In the 1300's, the Venetian traders were first to start trading securities from other governments. In 1531, the first 'stock exchange' in Antwerp dealt in promissory notes and bonds. In the 1600's, the Dutch, British, and French governments gave charters to companies with East India in their names. Amsterdam Stock Exchange was established in 1602 by the Dutch East India Company (Verenigde Oostindische Compagnie, VOC) and was the first to formally begin trading in securities. They issued stocks and offered dividends. Many "exchanges" occurred in coffee houses in London, for example, in Lloyd's Coffee House, opened by Edward Lloyd on Tower St in 1686 (which finally gave birth to the eponymous Lloyd's of London, the insurance company). The first stock exchange in London (formed 1773), was followed by the Philadelphia Stock Exchange (first US stock exchange) and then the New York Stock Exchange (1792).

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Biographies



Shoumen Palit Austin Datta. Dr Shoumen Palit Austin Datta is a Senior Member of the MIT Auto-ID Labs, Research Affiliate at the Department of Mechanical Engineering, School of Engineering, MIT (<http://autoid.mit.edu/people-2>) and Senior Scientist, MDPnP Lab, at the Massachusetts General Hospital, Harvard Medical School (<http://mdpnp.mgh.harvard.edu>). He is the former Co-Founder and Executive/ Research Director of the MIT Forum for Supply Chain Innovation (2001-2010) at the MIT School of Engineering. A former Member of the Auto ID Center at MIT (1999-2003), MIT Data Center (2004-2006) and MIT Energy Initiative (2008-2009). As a Research Scientist in the Engineering Systems Division, MIT School of Engineering, he explored technology innovation, RFID, IoT, supply chain, data analytics and confluence of solutions.

He has taught Supply Chain, Strategy and Management at the MIT Sloan School of Management. He has offered executive education courses at MIT and several other institutions in US, EU and APAC. He is the former founding Senior Vice President for the Industrial Internet Consortium (IIC) and Senior Vice President at the Object Management Group (OMG). His current engagement with the MDPnP Program at Massachusetts General Hospital, Harvard Medical School is aimed at convergence of medical device interoperability with security and emerging tools from medical CPS and medical IoT. He is interested in IoT/IoT as a design metaphor and promoting the vision of the internet of systems (IoS) which extends ubiquitous connectivity, including the industrial internet, to catalyze economic growth, in different and diverse dimensions, for example, food and robotics. For the latter, he is also affiliated with the University of Florida and Purdue University. He has authored books, papers and articles related to evolution of IoT and the industrial internet (2003), intelligent software agents (2001), framework for predictive analytics, general operations and supply chain management, sensors in public health and healthcare platforms, renewable energy and digital transformation. He has served as advisor for start-ups, corporations and governments including US Department of Defense, United Nations (UNDP), World Customs Organization (WCO), President's Science and Technology Advisory Group (PSTAG) for the President of Taiwan (ROC). Dr Datta attended the University of Pittsburgh and earned his PhD from Rutgers University School of Medicine in collaboration with Department of Molecular Biology at Princeton University. He was a Research Fellow in Medicine (Thyroid Lab, Neuro-Endocrine Lab, Molecular Oncology) at the Massachusetts General Hospital and Instructor in Medicine at Harvard Medical School. He was a Research Associate at the Whitehead Institute at MIT and member of the MIT Human Genome Project. He was a Research Scientist at University of California UCSF School of Medicine, San Francisco, California. Dr Datta has served the public sector to improve education and technology as Special Assistant to the City & County of San Francisco, California; Science Education Partnership at UCSF School of Medicine; Berkeley Pledge initiative at the University of California, Berkeley and Chair of the National Task Force on Education, Workforce and Technology sponsored by ITAA, US Department of Commerce and The White House Council of Economic Advisers. For more info <https://autoid.mit.edu/shoumen-datta> & <http://mdpnp.mgh.harvard.edu> MIT Library <http://bit.ly/MIT-SD> and various articles <https://dspace.mit.edu/handle/1721.1/111021> Also explore: https://scholar.google.com/citations?user=_xAnvDEAAAAJ&hl=en&oi=ao.