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Dynamic socio-economic disequilibrium catalyzed by the Internet of Things

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Letter from Academia

The technology based conceptualization of the internet of things (IoT) and the industrial internet may have started circa 1988 with the work of Mark Weiser of Xerox Palo Alto Research Center who suggested that computers may *"weave themselves into the fabric of everyday life"* and influence the future of business, as a consequence (*Scientific American, 1991*). The knowledge base Weiser was referring to is the discussion by Herbert Simon in his 1987 paper "*The Steam Engine and the Computer: What makes technology revolutionary*" where Herbert Simon frames his thoughts about the computer, "*you have to make friends with it, talk to it, let it talk to you.*"

Hence, contrary to the media hype, in progress, the vision of the Internet of Things (IoT) and its meaning did not germinate from a presentation (Ashton, 2009) at a retail product manufacturer. In 2000, the seminal paper entitled *THE NETWORKED PHYSICAL WORLD* (MIT-AUTOID-WH-001) gave birth to the concept of the IoT (Manyika et al., 2011; Sarma et al., 2000) and the evolution of the industrial internet. Facts about IoT as well as the name "internet of things" (The MIT Sloan CIO Symposium, 2013) was discussed at a recent symposium at the MIT Sloan School of Management.

Connecting physical world objects (made of atoms) with information (packaged as bits) may segue to another revolution, predicted by many, among them, Neil Gershenfeld. The current wave is often referred to as the third industrial revolution, in relation to the Information Age (second) and the first Industrial Revolution. In some quarters, the present trend is (also referred to as Industrie 4.0) the age of cyber-physical systems (CPS).

Revolutions are supposed to reshape things to come. The third wave will be no exception. It will generate friction, both social and economic. The clash of status quo with business not as usual. The collision between the imaginative versus those whose imagination is out of focus. The asphyxiation from old world ideas versus geographically-agnostic unbridled innovation unleashing the wizardry of technology to leak into our lives.

Pundits, market observers and industry players are divided over their belief regarding the transformational capabilities of technologies and the ubiquitous connectivity IoT necessitates. Social friction is erupting from erosion of privacy in its conventional format and the redefinition of privacy which challenges old world beliefs. There is justifiable concern about security yet there is measurable reluctance to give up the benefits associated with either. Financial friction is evident both in industrial nations

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and emerging economies whenever unskilled labor is a part of the workforce. Labor, in general, abhors automation, which shrinks the demand for unskilled labor and creates a negative impact on the economy and society, as a whole.

But these are not new observations, in fact these are centuries old and will be repeated over and over, again, albeit in different shades. According to economic historian Norman Poire, "the five centuries that span the years 1440 to 1939 were among the most dynamic in all of history. Many technological advances surfaced during that time, but three inventions stand above the rest as turning points in the direction of technology that led to decisive social change. The invention of the printing press by Johannes Gutenberg in 1440 spurred the arrival of the Information Revolution that spread the Renaissance throughout Europe. In 1609, Galileo Galilei's telescope ushered in the Scientific Revolution and the Age of Reason. The Industrial Revolution and Marxism arrived shortly after James Watt unveiled his steam engine in 1769. In 1939, a fourth technological revolution began. In that year, John Atanasoff and his graduate student Clifford Berry invented the electronic digital computer and unwittingly with it the Second Information Revolution." A little less than century later, we are on the cusp of yet another sea of change.

The Third Industrial Revolution may spur the grand convergence of the industrial revolution with the information revolution and other existing unknowns.

Erik Brynjolfsson and Andrew McAfee at the MIT Sloan School of Management (Center for Digital Business) talks about the frictions that may surface from the third revolution, namely, higher unemployment and rising inequality (*Race against the Machine* and *The Second Machine Age*). The incisive insight about inequality may be also found in the works of Joseph Stiglitz (*The Price of Inequality*) and Robert Reich (*Inequality for All*).

Brynjolfsson and McAfee revisit the discussion of higher unemployment which John Maynard Keynes described as "technological unemployment" in the 1930's. Robert Frank revisits the same topic as technology-catalyzed "winner takes all" labor markets in 1990's and also in his book *The Darwin Economy*. Brynjolfsson and McAfee expect "our world will prosper on the digital frontier" but what about the path to the frontier? The road ahead is fraught with feuding nations, malnutrition, dysfunctional sanitation, inadequate education and poverty of energy. Taken together, these factors are already fueling glaring socio-economic frictions which may be exacerbated by the attributes necessary for the global diffusion of IoT (internet of things).

The fruits of IoT will depend on our ability to interoperate between systems, objects and devices in different environments supporting different standards of operations, protocols and applications. It is impossible to expect that the world will strive to support one common standard. Hence, not standardization *per se* but the *interoperability* between major standards will be the key to diffusion of the products and services of the IoT and the industrial internet which reaches into the domain of all things mechanical. Industry leaders must enable open standards for interfaces (APIs) where products from SMEs can plug into a common global bus to access the connectivity and add their value added services, analytical engines or enhance niche applications. The *systemic* deployment of open connectivity backbone is central to data acquisition and the spread of IoT.

Ultimately, the ability to extract intelligence from data will drive the value proposition of the connectivity. Transaction cost economics (*The Nature of the Firm* by Ronald Coase, 1937) of connectivity will determine the return on investment which will influence business adoption.

The emphasis on low hanging fruits, short term return, prevalent in the business world, may impact the extent of acquisition of data. Inadequate investment may limit

the tools necessary to accumulate critical mass of data. However, without sufficient data, the analytical tools may stumble to unlock hidden patterns in the data. The latter is necessary if real time dynamic analytical engines (at the edge and core) may be one path to monetization of IoT. New sources of revenue may be created from micro-payments based on pay-per-analytics model of information arbitrage which will use intelligent predictive analytics to augment decision support for semi-autonomous activities.

One lesson in data acquisition and analysis may be cryptic in the classical experiment in quantum mechanics described as Young's double-slit experiment. A variation of the experiment was performed at HCRL (Hitachi Central Research Labs) by Dr Akira Tonomura (1942-2012) which revealed (HITACHI, 2015) the build-up of interference pattern from single electrons but it was not observed until sufficient electrons were allowed to pass through the slit. The lesson from this experiment for business is obvious – running pilots and experiments on small scale may not offer appropriate outcomes or provide wrong indications because you cannot construct an elephant using the mouse as a model. This work is insightful because it suggests large scale deployments may be the key to extracting the value and significance of the tools and technologies which, when combined and converged, may provide solutions.

One lesson may be found in the history of general process technologies, in particular, the strategies which enabled the spread of electricity (*The Economic Future in Historical Perspective* edited by P. A. David and M. Thomas, Oxford University Press, 2003). Clayton Christensen's (*The Innovators Dilemma*) 'disruptive' is a hype based on the original concept of general process technologies (GPT) introduced during the era of electrification to indicate systemic integration versus "slap-on" *ad hoc* usage. Christensen mis-used the word and mis-led the business world using poor data analysis to suggest everything is disruptive.

We have observed for the past 15 years the lack of systemic integration of RFID. As a consequence, we have not sufficiently profited from the ability of RFID tags to acquire sufficient high volume data from a systems approach. As a result, we may have failed to deliver adequate transparency within supply chains and the savings from the value chain remains far below what was anticipated. The lessons from the abandoned RFID initiative at WalMart (*Is RFID dead?* Florian Michahelles [2010] Auto-ID Labs St. Gallen, ETH Zurich) is not a failure of the technology but an inadequate use of data tools in the *context* of the business process.

IoT (internet of things) may learn from the history of electrification and RFID in order to find better ways to progressively penetrate our daily reality through systems integration, connectivity and applications. IoT must evolve from things to internet of systems (IoS). Connectivity between the ecosystems of systems may create the next tsunami of profitability. In turn, it will generate even more clamor for security, privacy, trust and ethics related issues on our social policy agendas. IoT connectivity and communications with objects and processes will change the way we interact and behave in our personal and professional lives in the IoS era.

The pursuit of autonomy in healthcare, transportation and manufacturing will create new solutions, old headaches and germinate new business models. The prediction of cancer at least a decade before it affects you, is not an illusion. The autonomous vehicle that parks itself and a freight truck that delivers cargo without humans in the loop is yesterday's news. The death of inventory and birth of distributed manufacturing on demand (dMOD) at the edge (dMODE) is the embryonic Manufacturing 5.0 catalyzed by 3D printing. From heart valves to nano-satellites and from NASA-guided soil moisture active passive (SMAP) guidance for precision farming and graphene-purified arsenic-free desalinated drinking water and everything euphoric in between (neurosynaptic web and neuromorphic chips), we have already begun the next 100-year journey.

According to Jeff Immelt of GE, "in the future one expects an open, global fabric of highly intelligent machines that connect, communicate and cooperate with us. The Industrial Internet is not about a world run by robots, it is about combining the world's best technologies to solve our biggest challenges. It is about economically and environmentally sustainable, energy, it is about curing the incurable diseases, and preparing our infrastructure and cities for the next 100 years."

Economic friction is evident from the loss of middle-income repetitive tasks which may be largely automated or can use online tools for completion. Bank tellers, store check-out clerks and even K-16 teachers will be eliminated from the workforce in favor of ATMs, self-check-out kiosks and MOOCs. This is not only due to IoS but the integration of computation with our daily lives, as predicted by Herbert Simon and Mark Weiser.

IoS connectivity with a greater cross-section of objects and processes in addition to exposure to greater degree of monitoring (for example, in healthcare) will induce changes in behavior with increasing diffusion of the internet of things. Whether ubiquitous connectivity modifies rational versus irrational activity remains to be observed and analyzed (*Thinking Fast and Slow* by Daniel Kahneman). The outcome of such analyses must be taken into account when designing future products and services, for example, the wireless hospital of the future or MRI machines in hydrogen refueling stops or portable x-rays in medical huts in the Amazon. The utility of these advances may depend on the socio-economic ethos of the society (*Scarcity* by Sendhil Mullainathan) and its stage in socio-economic development (*Development as Freedom* by Amartya Sen).

The prediction that connectivity will change behavior is rooted in the fundamental principles of particle physics. The observer effect, as it is called, refers to changes that the act of observation will have on a phenomenon being observed (not to be confused with the uncertainty principle proposed by Werner Heisenberg). The former may explain why one can sing in the shower but not in public.

It may be noted that combined behavior, especially, time-centricity of cyberphysical systems (hardware and software integrated with physical objects) changes, if any one of the components are changed, even if the components are almost near-identical. The tryst with time may be difficult at times.

In addition to slow changes in behavior, economic re-equilibration will be sluggish because massive changes in our education system are necessary to optimize social consumption of the fruits of technology. No amount of technology or online courses will deter the spread of the rupture in our financial fabric unless we retrofit public education, re-install respect for academia, re-focus on rigor, rejuvenate all aspects of scientific research, restore the dignity due to a teacher and re-ignite the passion expected from a teacher.

The emerging supply chain of talent must include an abundance of girls who excel in math, who can code and write cohesively. It is essential that women pursue higher level of science, engineering, mathematics, economics and philosophy. How can we accept that about 50% of the brain power is left out of the workforce?

Educated women will help educate boys who are respectful and girls who are dignified. Taken together, they will accelerate the massively parallel innovation from distant crevices of the world. The latter is already ushering tectonic shifts even in the most traditional businesses. The analysis-paralysis approach of the behemoths may lead to their extinction if they continue to remain oblivious of the fact that failure is the new road to success, failure is the new key to success and failure is the mantra for those who wish to succeed.

Distributed innovation demands an entrepreneurial approach and an assault on multiple levels, concurrently, rather than the mythical silver bullet solution

(*Innovation: The Attacker's Advantage* by Richard Foster). The taxi cab industry vs uber, the hospitality industry vs airbnb and temp agencies vs oDesk are bright examples. Explosion of engineering tools has dramatically reduced the cycle time necessary to introduce innovation by vastly compressing the time from conception (development supply chain) to realization (fulfillment supply chain). Industry giants must harness this explosion by giving away platforms in order to aggregate the intelligence that can run on open source platforms. The flow of micro-revenue from billions of pings on your product will be the differentiator and that value-added data-service will be related to intelligent analytics of data and delivery of actionable information to the point of use ***before*** the data perishes.

However, the dynamics of perishability of data changes when the accumulation of time series data is far more critical for predictive analytics (for example, healthcare) rather than data with short half-life (for example, mean time between failure (MTBF) metric for spare parts). Data transport and data storage are important in this business but consumers may be willing to pay only for real-time analytics. Consumers expect raw data to be free.

However, all advantages are temporary. The financial wisdom from micro-revenue earnings from leasing the platform is one reason why Apple opened up its "bus" for anyone to hop on (create applications). Apps pour in from all over the world. The app creator is a part of the economic avalanche by allowing Apple, as the channel master, to aggregate micro-payments using open innovation. *Small data* from millions is the reason why Apple is laughing all the way to the bank with the world's largest database of payments, to the tune of 99 cents at a time. PayPal's success fueled Tesla which may give away the car to sell swappable graphene based batteries and on-board services using software defined networking (SDN). The automobile may be the mobile electricity grid of the future substituting for the smart immobile grid for off-grid distribution of power. Free products with pay-per-use micro-revenue based services is indeed a proven business strategy (printers vs ink, mobile phones vs services, water coolers vs bottled water) to amplify micro-earnings, which will enjoy a long life and substantiate the value of long tails.

The spread of IoT and IoS is expected to give rise to new (Datta, 2015b) products and services. The consumption of such goods and improvements in efficiency may generate a magnitude of economic growth which is inducing CEOs to be euphoric. According to GE, Cisco and others, the IoT and the industrial internet (IIoT) may add about $14 trillion to $19 trillion to the global economy, over the next decade. An explosion of consumerism is necessary for such numbers to materialize. The billions who are writing on the wall or posting photographs to buoy the software market cap of the social media bubble are in an earnings group which cannot afford the talking car or the avatar to manage the morning bed-tea or robotic laparoscopy. The educated consumer is the best customer. The bubble of the twitter frenzied social media economy may be limited by the amount of "energy under the curve" and the irrational exuberance may fuel the next global recession which may be just around the corner (2020-2022). With 2008 as the year of the last recession, we expect the next one around 2022 if the "boom-bust cycle" has a 14 year periodicity according to Finn Kydland (Nobel Prize in Economics, 2004).

In the US, several initiatives throughout industry and academia are emerging to address the next generation of advances in the IoT space, industrial internet, internet of systems (IoS) and the exciting possibilities from research in cyber-physical systems (CPS). Several consortia were formed in 2014-2015 with backing from market-leading companies. Several academic groups are leading the way with new inventions and innovation. The EU has funded a massive multi-year program called Horizon 2020 to the tune of more than $100 billion to explore the growth of IoT and help harvest the associated economic windfall.

But, it will be an egregious error on the part of the global leadership to be blinded by the economic projections and continue to polish the chrome without paying attention to tune the engine of education. Is a smart city (Datta, 2015a) really smart without smart citizens?

Humanity needs dreamers (Datta, n.d.) and education (Datta, 2014) is the quintessential salt (*Salt* by Mark Kurlansky) which acts as the purveyor of inspiration, imagination, invention, innovation and drives implementation of ideas (Datta, 2015b). The education of a boy may change the fate of a man. The education of a girl may change the destiny of a nation.

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