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The Role of Information Technology in Sustainable Economic Development

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Abstract

While western corporate operating procedures were adequate in a world where resource consumption was dominated by a small segment of the population, their application on a global scale is not sustainable. At the same time, the inefficiencies inherent in industry in developing and lesser developed countries is also not an option as global consumption increases. New corporate operating procedures are needed that can leverage technology to support increased global consumption in a sustainable fashion. In this work, we analyze how several emerging technologies including gamification, crowd sourcing and virtual reality will impact economic development drivers such as supply chain efficiency and effectiveness and levels of entrepreneurship.

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1. Introduction

"Among the many ways that sustainability has been defined, the simplest and most fundamental is: 'the ability to sustain' or, put another way, 'the capacity to endure.' Today, it is by no means certain our society has the capacity to endure – at least in such a way that the nine billion people expected on Earth by 2050 will all be able to achieve a basic quality of life. The planet's ecosystems are deteriorating and the climate is changing. We are consuming so much, and so quickly, that we are already living far beyond the earth's capacity to support us"
From www.sustainability.com/sustainability

Advanced economies are characterized by well developed capital markets and liquid stock and bond markets (Stiglitz, 2000). The conception of the corporation as solely existing to increase shareholder value has led to short term corporate thinking, since corporate earnings are published quarterly (Allen, 1992). This problem of short term thinking is further exacerbated by the compensation schemes for top managers, which are often in the form of stock options that need to perform well in the short term (Barton, 2011). This problem translates to several corporate decisions that have benefit in the short term, but are negative for the long term prospects of the corporation. For example, outsourcing is often driven by short term cost reduction goals, as opposed to a critical analysis of what is in the long-term interests of the corporation (Florin, Bradford, & Pagach, 2005). Similarly, economic growth in western, developed economies has been characterized by a belief that technology will substitute for natural resources (Pearce & Turner, 1990), and has led to excessive resource consumption in order to deliver a continually escalating "delightful experience" for customers used to resources being expended on them(Rust & Oliver, 2000). Thus, vehicles in the USA have had historically low fuel efficiency standards, and overall there has been a high depletion rate of natural resources in developed economies (Korten, 2001). This model of resource consumption in the name of economic growth is sustainable if a small percentage of the globe's population can consume a disproportionate share of the globe's resources in the name of economic development. However, as more economies open up to growth, this model becomes increasingly unsustainable.

Less developed economies have hitherto been characterized by small unit packages, low margin per unit sold, high volume and high return on capital employed (Prahalad, 2009). The corporations servicing the populations at the "bottom of the pyramid" tend to be relatively less efficient because of lower capital expenses. They tend to have a lower environmental impact per customer because the overall consumption in monetary terms per customer is low. However, as consumption levels increase in less developed countries, corporate practices from advanced countries are usually introduced. Over the last two decades, there has been a major push of multinational investment in India and China, for example. Western style corporate practices for those seeking a fortune at the bottom of the pyramid can lead to serious economic impact (D. G. Arnold & Williams, 2012). For example, plastic bottle consumption in India and China has

risen manifold over the last decade, leading to greater availability of potable water but with serious environmental impact (E. Arnold & Larsen, 2006). Based on the above discussion it is clear that corporate practices in advanced economies that were suitable for a select few and led to disproportionately large natural resource consumption cannot be extrapolated to larger segments of the global population without unsustainable impact on natural resources.

A common eco-centric worldview in environmental economics is that market mechanisms and technological change can produce some substitutability for diminishing physical resources, with some exceptions such as fossil fuels that may need to be managed conservatively (Pearce & Turner, 1990). As worldwide consumption increases and natural resources come under increasing pressure, emerging technologies may lead to new corporate practices that are more sustainable.

Based on this view, the primary contribution of this work is an analysis of how emerging technologies will impact drivers of economic development. We examine technologies including gamification, crowd-sourcing and virtual reality. The economic drivers include supply chain performance, entrepreneurship levels and education. Our analysis yields important insights into how technologies can be used to enhance sustainable economic growth. The rest of this paper is organized as follows. In section 2, we describe the set of emerging technologies. Section 3 describes the economic drivers that will be impacted by the emerging technologies. Section 4 contains an analysis of the impact each of these technologies will potentially have on the economic drivers. We conclude with limitations and recommendations in section 5.

2. Set of Emerging Technologies

We describe seven emerging technologies: a) *gamification,* b) *ubiquitous recording,* c) *biometric identification and authentication,* d) *crowd sourcing,* e) *access to online knowledge and skills,* f) *robots/drones* and g) *virtual reality*. Next we describe each one in some detail.

Gamification is defined in (Deterding, Dixon, Khaled, & Nacke, 2011) as "the use of game design elements in non-game contexts". Typically in gamification, the overall task or project may be broken into sub-tasks, with points or badges earned as progress is made. Elements of competition may be introduced as well as the formation of communities. Gamification promotes feelings of engagement, instant feedback, feelings of accomplishment and the feeling of self efficacy when obstacles are overcome (Kapp, 2012).

Ubiquitous recording technologies allow the recording of audio, video and other multi-media data by a large number of people engaged in their daily life (Bell & Gemmell, 2007). The availability of smart phones wearable or remote-control devices with audio and video recording abilities, coupled with the ease of posting recorded content on platforms such as YouTube so that it is accessible and searchable on the world wide web (WWW), has made it possible to record activities that were previously secret (Boothroyd, 2011). This notion of

perpetual surveillance both by governments and our co-citizens has the potential to lead to several changes in the way our societies (Čas, 2011).

Biometrics is the science of identification using physical or behavioral attributes (Jain, Ross, & Nandakumar, 2014). Departing from the more traditional login/password approach biometric identification implies a unified identity that allows seamless transition when accessing multiple systems. Biometric authentication implies greater security against prevalent problems such as identity theft and the financial cyber-crime (Judson, Haas, & Lagu, 2014).

Crowdsourcing is defined in (Webster, 2014) as "the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers". Several typologies for crowdsourcing have been proposed, for example in (Howe, 2008). Crowdsourcing can broadly be divided into four areas: *mobile* (*e.g.*, uber.com), *fund raising* (*e.g.*, kickstarter.com), *prediction markets* (*e.g.*, www.hsx.com) and *policy experiments* where volunteers participate and self collect data in order to analyze the effects of existing policies on citizens.

Mobile crowdsourcing involves small transactions where common citizens take on the role of supplies of a service. Fundraising crowdsourcing implies large numbers of common citizens taking on the role of financial lenders for projects. In prediction markets, large numbers of players apply their knowledge and ability to predict events by buying or selling stocks that represent different events, such as the likelihood that a movie will gross over, say, $10 million in the opening weekend. Policy experiments can be used to improve government decisions and may include contests amongst citizens, use of a wiki, voting or social networking (Nam & Sayogo, 2011).

Access to online knowledge and skills has increased exponentially because of the availability of free content-hosting platforms such as YouTube, as well as the ability to record activities and lectures that visually demonstrate knowledge and skills that may have earlier been available only in a text book or through specialized education. For example, massive open online courses (MOOCs) allow access of course material to anyone with a WWW browser (Hew & Cheung, 2014). Several factors go into MOOC adoption such as curiosity or the need to learn a new topic on an existing knowledge base. Similarly, websites such as khanacademy.com provide access to thousands of short videos that visually explain short concepts in areas such as mathematics and science. YouTube hosts several videos on diverse skills such as woodworking, calligraphy, etc.

Robots and drones have been widely used in the military and manufacturing. They are becoming increasingly available to civilian businesses and hobbyists as described in (Ross, 2014). Intelligent agents are being imbued with emotional artificial intelligence (AI) that allows them to relate to humans better in situations including disaster relief (Belhaj, Kebair, & Said,

2014) and education (Pateromichelakis et al., 2014). As knowledge becomes increasingly codified and searchable on the WWW, drones and robots may perform several tasks in the future currently performed by humans (Blar, Idris, Jafar, & Ali, 2014).

Virtual reality (VR) consists of "interactive computer simulations that sense the participant's position and actions and replace or augment the feedback to one or more senses, giving the feeling of being mentally immersed or present in the simulation" (Sherman & Craig, 2002). VR has been used extensively in training for complex tasks such as flying airliners, handling military equipment, military and police training, and medical care ranging from administering first aid to surgery (Bowman & McMahan, 2007). From an entertainment standpoint, game playing has become extremely popular and has led to immersive experiences in a variety of games. Examples include the upcoming *hololens* released by Microsoft.com. As hardware and bandwidth become cheaper and faster, VR has the potential to permeate more aspects of our life and can be used to provide emotional reinforcement as well (Rothbaum, Hodges, Watson, Kessler, & Opdyke, 1996).

3. Economic Drivers

We look at five drivers of an economy: *supply chain efficiency and effectiveness*, *reliability of contracts*, *education quality and level*, *entrepreneurship levels* and the *overall culture of excellence*. Next we describe each of these in some detail.

The **supply chain** is the logistical cornerstone of most organizations. It usually consists of suppliers who supply goods or services to the organization in question and customers who purchase finished goods or services from the organization. While initial supply chains were purely in the realm of operations research and optimization, current supply chains are increasingly requiring collaboration and people management skills (Wisner, Tan, & Leong, 2015).

We define effectiveness in supply chains as the speed of movement and costs associated with moving goods and services from one point in the chain to another. We define efficiency of a supply chain as the costs involved in moving and holding inventory in the supply chain. These are usually referred to as agility and lean, respectively (Gligor, Esmark, & Holcomb, 2015).

The **reliability of contracts** deals with the level of trust that different participants have in the both the transactions at an individual or firm level, as well as in the institutions that allow redress for failed transactions, such as banks and courts (Bajaj & Leonard, 2004; Burns & Brady, 1996). While it is widely accepted that low-level corruption at the individual level is more rampant in lesser developed countries, the level of institutional corruption in developed versus lesser developed countries is still an open question (Khera, 2001). More reliable contracts lead to greater efficiencies as well as effectiveness of processes in an economy (Aidt, 2003).

The **level and quality of education** is important in the development of human capital beyond its innate abilities. Several studies, listed in (Blundell, Dearden, Meghir, & Sianesi, 1999) have shown a positive return on investments in education. We define the level of education as the degree to which schooling in marketable skills is available to the general populace. We define the quality of the education as the effectiveness at transferring knowledge or skill to the students. It is clear that our definition here has a wider scope than education offered only to minors or in educational institutions. *E.g.,* if a mid-career executive learns how to use a spreadsheet package, then this would qualify as education in our definition.

The **level of entrepreneurship** is a direct measure of small, grassroots level business activity in an economy. We define it as the percentage of the labor force engaged in self-employed activities. Developed countries can increase this level by providing incentives for startups and commercializing R&D technology, while lesser developed countries can increase it by offering higher levels of management education and fostering foreign direct investment (Wennekers, Van Wennekers, Thurik, & Reynolds, 2005).

Postmodernist management thought de-differentiates culture and economic development. This has led to the fostering of creative enclaves where excellence is encouraged in activities governing every aspect of people's lives (Willmott, 1992). An **overall culture of excellence** emanates from greater freedom to pursue activities that are of interest to individuals, and fosters both cultural and economic advancement.

Next we analyze the potential impact of emerging technologies on the economic drivers shown above.

4. Impact of Technologies on Economic Drivers

4.1 Supply Chain Efficiency and Effectiveness

As supply chain management problems have become increasingly collaborative and less structured, gamification has been used to find optimal solutions for complex problems. See http://supplychaincrunch.com/supply-chain-gamification/ for an example of how games can potentially be used to find cheap solutions for production schedules in the area of manufacturing.

Successful supply chains require the recording of large amounts of data to track goods and services, storage parameters, shipping parameters, etc. Ubiquitous recording capabilities allow for this data to be recorded using remote cameras, sensors (*e.g.,* for humidity or shock), leading to greater efficiencies and effectiveness. Biometric identification authentication allows for less restricted flow of goods and personnel, *e.g.,* radio-frequency identification allows for tracking of goods without removing them from pallets (Chow, Choy, Lee, & Lau, 2006).

Crowdsourcing can be applied to supply chains in several ways. New suppliers or distributors may be created using crowdsourced funding mechanisms. New features for

products may be identified using prediction markets populated by customers. Inefficiencies may be highlighted by prediction markets populated by suppliers. Finally, decisions to outsource, manufacture in-house or in-source existing products may be made on the basis of prediction markets populated by employees.

Access to online knowledge and skills can be helpful if suppliers or distributors need to be brought in to keep the supply chain running, and need quick training for the new product or service. Robots and drones can be useful in several ways. First, robots may be used to scan and move heavy inventory more efficiently and effectively. Second, drones may be used for just in time movement of some goods in the supply-chain. An example of this is the prime drone service being currently proposed by Amazon.com. Third, drones may be used to patrol supply lines, *e.g.*, oil or gas pipelines, and check for faults. Finally, drones may be used to monitor perishable material for spoilage with the use of sensors. Virtual reality may be used in the area of supply chains to create and test supply chains in virtual worlds such as in activeworlds.com, before implementing in the physical world.

4.2 Reliability of Contracts

Gamification can be used to create incentives for contract participants to be reliable. These incentives may include small rewards or the feeling of being part of a winning team in the game of reliable contracting. Ubiquitous recording technologies increase fear of being caught and prosecuted (Stephens, 1986). Further, if everyday corporate activities are being recorded and monitored, then there is less ability for a select few to manipulate the system hidden from whistleblowers.

Biometric identification and authentication reduces the risk of fraudulent transactions involving identity and credit card theft (Edwards, 2014). This is particularly useful in developing an economy where large numbers of small-scale anonymous transactions can occur safely. Crowdsourcing technologies such as prediction markets can be used to offer incentives to large crowds of employees or suppliers to report on suspicious, small scale fraudulent activity around them. Access to online knowledge and skills allows better crafting of contracts, thereby reducing disputes and fraud downstream in a business relationship. It also enables participants in the economy to navigate through multiple steps that may be required to create contracts (Al–Hujran, 2012).

As robots and drones begin to participate increasingly in activities constituting business processes, the reliability and predictability of these processes will increase. An example of this is the Amazon drone delivery service that may drive down costs and improve customer lead times (Prior, 2013). Virtual reality can be used to emotionally condition participants in order to improve the ethical perspectives when entering into contracts (Lavric, 2013).

4.3 Education Quality and Levels

Gamification has found several uses in education, where different learning styles can be accommodated, and student interest maintained using reward points and encouraging team play (Huang & Soman, 2013). An example of teaching computer programming using gamification techniques can be found at www.codeacademy.com. Ubiquitous recording technologies allow the creation of micro courses by virtually anyone with a skill or some knowledge to share, while platforms such as at www.google.com/edu and www.youtube.com providing inexpensive and robust hosting and searchability of these courses.

Biometric identification and authentication allow for easy sign-on and sign-off for students and teachers on hosting sites, and also allow for seamless availability of material on different devices including flexible screens and projection based systems. For example, an automobile mechanic can search for a micro course on how to trouble shoot the transmission of a car, and then view the remainder of the video on the garage floor, while working on the customer's car (Stanimirovic et al., 2014).

Crowdsourcing technologies can allow the creation of courses where each participant contributes a small portion, representing perhaps a unique skill or specialization. For example, it is straightforward to imagine a course on automobile transmission troubleshooting, where specialists in each car manufacturer's transmissions present 10 minute segments on how to trouble shoot their particular transmission. Access to online knowledge and skills has significantly impacted education, whereby courses offered on www.coursera.org, the open classroom created by the Massachusetts Institute of Technology, small videos on youtube, www.khanacademy.com, etc offer access of knowledge to ever increasing numbers of students across the world, most of it at no cost.

Robots can serve as inexpensive and patient teachers who can adapt to different learning styles and present material to students as well as offer adaptive testing (Serholt et al., 2014). These may be especially valuable in areas where qualified human teachers are hard to find and place. Virtual reality has been used in military and pilot training for decades, and is especially useful when context based learning that involves procedural activities needs to occur. Examples of this include surgery, machine repair, manufacturing, nursing, etc (Lee, 2012).

4.4 Level of Entrepreneurship

Gamification can be used to harness the competitive spirit and team-play in youth to come up with ideas for start-ups, Several examples of this exist today including hackathons and competitions hosted by technology companies promoting their technologies to create mobile apps. *E.g.*, The Watson platform offered by International Business Machines (IBM) has hosted competitions where college teams participate in building applications for cognitive computing (Ferrucci, 2012). These applications are then funded by venture capitalist panels who also act

as judges. Ubiquitous recording allows customer feedback on, and promotion of, an entrepreneurial product in unique ways, leading to quick feedback on current products. This highlights niches for new products.

Biometric identification and authentication allows for inexpensive and readily set-up point of sale systems. *E.g.,* squareup.com allows for easy setup of credit card readers. Apple pay allows for easy biometric authentication of payment via the iPhone using the user's fingerprint (Pogue, 2015). These are beneficial in reducing startup costs for new projects.

Crowdsourcing in the form of prediction markets allows for the identification of new product ideas as well as improvements on current products. Crowdfunding sites such as indiegogo.com or kickstarter.com allow for capital to be raised by new projects that may not be funded via the traditional venture capital route. Access to online knowledge and skills allows would-be entrepreneurs to acquire knowledge and skills that may be necessary to launching a project or product. For example, an entrepreneur may learn the art of making custom fountain pens, prior to launching their own enterprise that makes customized corporate gifts.

Robots and drones in the coming future may serve on startup costs by taking over jobs that humans need to perform at present. Virtual reality will allow new products to be marketed to and sampled by a global audience with very low costs.

4.5 Culture of Excellence

Gamification can enhance healthy competitiveness in a society, provide rewards for excellence and encourage collaboration. An example of this is open source code writing, where points may be awarded to productive coders for quality and quantity of code. Ubiquitous recording technologies allow for continuous feedback on an organization's products and employee activities. For example, if an employee is being recorded consistently at work, then the supervisor may be able to offer instant feedback for improvement, rather than letting errors build up.

Biometric identification and authentication mechanisms can enable tracking of all employee activities and conversations at work, and ensure that credit is given to responsible parties, which can lead to improved morale (Al-Masslawi, Lea, Fels, & Currie, 2014). In the area of crowdsourcing, prediction markets can pinpoint areas of improvement in an organization or society, such as with hsx.com (Singh, 2014).

Access to online knowledge and skills allows for the transfer of tacit knowledge via video, for example, which may lead to higher baseline knowledge levels in a society. For example, in the domain of website development, access to multiple resources such as w3cschools.com allows for an overall improvement in the design and creation of web pages.

Robots and drones can potentially take over more mundane and dreary tasks, thereby freeing up humans for more creative and open-ended tasks (Marsh & Miller, 2014). Finally, virtual

reality can lead to enhanced repetitive, context-based training or complex tasks such as surgery. It can also lead to positive reinforcement of values that can raise overall excellence in a society.

The above discussion is summarized in Table 1, where each row represents one of the emerging technologies and each column represents an economic driver. The table thus summarizes the technology impact framework presented in this work.

Table 1: Framework Summarizing Impact of Emerging Technologies on Economic Drivers

Economic Driver → Technology ↓	**Supply Chain**	**Reliability of Contracts**	**Level and Quality of Education**	**Level of Entrepreneurship**	**Overall Culture of Excellence**
Gamification	Collaborative games to find optimal solutions	Offer rewards and incentives to participants for being reliable	Competitive learning, reward points, team based learning	Increase customer participation with rewards and competitions.	Create competitiveness, rewards for excellence, encourage collaboration.
Ubiquitous Recording	Data entry via video, voice, sensors	Fear of being caught, less ability to game the system if everything is being monitored	Easy development and hosting of micro course modules	Get customer reviews in multimedia, showcase new product features quickly.	Constant feedback from customer allows for real adjustment and feedback in what we do.
Biometrics	Seamless flow of personnel and goods with universal IDs	Reduce risk of fraud	Easy sign-on and real-time availability of multimedia material when needed.	Get secure and quick micro payments for small value, high volume transactions.	Track who performed what activities and ensure people get proper credit.
Crowd Sourcing	Identify new suppliers and customers, use prediction markets to identify new products and decisions	Offer rewards and motivate employees to report ongoing fraudulent activities in organization	Create courses with multiple teachers contributing to micro modules.	Prediction markets for new product ideas, crowd funding for financing.	Prediction markets can help improve business processes and products.
Access to Online Knowledge and Skills	On the job training for workers who have to switch for a colleague	Access to legally applicable contracts and correct legal procedures	Access to educational content for everyone on the globe.	Develop skills and knowledge needed for entrepreneurs following their passion.	Enables everyone to have minimum baseline knowledge, provides transfer of tacit knowledge.
Robots and Drones	Delivery systems, watch supply lines, check for spoilage with sensors	Contracts with greater percentage of activities performed by robots or drones may be more reliable	Robots and software can be patient, cheap teachers that can adapt to individual students.	Start-up may need less people and have reduced costs.	Free up humans to focus on more creative tasks about which they are passionate.
Virtual Reality	Experiment with supply chain strategies in virtual world	Emotional conditioning to sensitize participants to ethics	Training of sophisticated procedural activities, such as surgery.	Allow trial of your product or service to a global audience, before purchase.	Enhanced repetitive training, realistic scenarios develop procedural knowledge.

5. Conclusion

Traditional, western corporate practices work well when resources are being consumed by a small segment of the world's population. However, they are not sustainable when developing

countries with large populations want to also increase their consumptions. In this work, we presented several emerging technologies that can potentially enhance the social and material well-being of developing countries with large populations in a sustainable fashion, by consuming fewer resources. We used a framework of five economic drivers: supply chain efficiency and effectiveness, reliability of contracts, education quality and level, entrepreneurship levels and the overall culture of excellence. We analyzed the impact of seven emerging technologies: gamification, ubiquitous recording, biometric identification and authentication, crowd sourcing, access to online knowledge and skills, robots/drones and virtual reality on each of these drivers.

Our framework can serve as a starting point for an analysis of which technologies may need to be encouraged in different societies, either through the relaxation of governmental regulation and/or increased public funding. For example, a drone program may be created in economies that are agriculture based, that can lead to more distributed storage and monitoring of the food supply chain, leading to less spoilage. Virtual reality conditioning may be incorporated into training of government administration officials in order to incorporate ethics in their behavior, thereby reducing corruption. State or federal governments may create self-organizing, online classrooms in remote villages, that bring educational content to people across the country. It is our hope that the judicious usage of the emerging technologies described here can lead to greater consumption while lowering the impact to non-renewable natural resources.

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