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Technology, capital substitution and labor dynamics: global workforce disruption in the 21st century?

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ABSTRACT

Advanced agriculture, mining and construction are trimming their workforces, manufacturing has been 'hollowed out', and the service sector is increasingly capital-intensive. Rapid economic and technological transformation influences company investment and can affect labor demand and wage relativities. From a deductive introduction oriented to the societal scope of innovations, this inquiry proceeds empirically, for the first time analyzing *seven* interacting drivers of capital / labor substitution or labor displacement. Three time-phased response scenarios are related to levels of technological impact. Thereafter, inductive theorising probes workforce futures for both developed and developing countries, arguing that not only are immediate relations of capital and labor in flux but, more widely, so are industrial and market organisation, the global geo-economic order, and the human trajectory itself.

1. Introduction

Whereas macroeconomists record regularities among phenomena, build mathematical models and then evaluate their congruence with foregoing observations, this inquiry into the possibility of global workforce disruption in the 21st century adopts an alternative methodology common in strategic management. The backdrop is the factor mix in the production of goods and services. The approach relies upon a situation audit and analysis of commercial and labor market trends. It involves several elements: four levels of technological impact; related to seven drivers of factor change; acting within two time phases; and generating three scenarios of the future of work.

After initial contextualisation, empirical evidence is collected to advance inductive theorizing of the impact of technological change. An account is provided among different industries of work and innovation which introduces the drivers in the substitution of capital, management and labor. The resultant platform enables scenario building of labor dynamics, reinforced with reflections about the future of work, economic progress and the human trajectory in the later 21st century.

2. Technology and factor substitution

2.1. Gauging technological innovation

Technology is best understood as a way of doing things (Macdonald, 1983). As people devise more proficient/efficient solutions to existing and novel tasks, the stock of technology increases (Black, 1962). To create producer and consumer goods and services,

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economies 'do things' by substituting the factor inputs of capital and management for land and labor. Characterizing human evolution, such 'investment' has intensified since the Industrial Revolution to deliver 'economic development', with the psychic comforts of global participation and 'progress.'

Via deepening, capital per worker grows over time. The capital share of production rises, and output should respond. However, under fixed technology, strong investment in physical and human assets can soften returns to capital because, via investment theory, the most lucrative projects are selected first. Under a constant production function, output per worker and the wage rate eventually stagnate. Thus, as we replicate factories using existing methods of production, our standard of living plateaus.

Overcoming this impasse, quality change in factor inputs can elevate the aggregate production function as innovation occurs in processes and products. Favourable movements can benefit the purchase price of items, their expected life, capacities for different types of work, and running costs over time (Cocks, 1964). In these ways, capital deepening and technological growth together lift the marginal product of labor, workplace productivity and living standards (Samuelson & Nordhaus, 2001) – but not always consistently. Gordon (2014) maintains that the 'second industrial revolution' (1879–1929), an era around wireless, electricity and the internal combustion engine, was 'multidimensional', delivering the United States average annual productivity gains of 2.36 per cent from 1891−1972. The third, post-1975, information and communications technology (ICT) revolution has been uni dimensional. Yearly American productivity growth from 1972 to 2012 averaged only 1.59 per cent. Now, a fourth revolution is not only consolidating mature, postwar developments, but fusing technologies of automation and digitization with scale, scope and complexity not previously seen (Turner, 2017). This convergence, reinforcing the place of capital in the factor mix, demands interpretation and analysis. According to the World Economic Forum's Klaus Schwab (2015), the speed of breakthroughs lacks historical precedent. The current coalescence will underpin and stamp human progress for the next 30 years and extend further into the 21st century.

Whereas, via a long retrospective view, the path of technology might exhibit recognisable cycles or waves (Kondrat'ev, 1944), its progression over one or two decades can be marked by competitive jostling and turbulence. Addressing the decisive market outcomes of success and failure, Peter Dicken (2015: 76) nominates four levels of impact to rank the socioeconomic significance (aka disruptive ability) of innovation:

1 incremental: small scale modification of existing processes and products
2 radical: discontinuous events which abruptly change existing processes and products and can amplify their effect by occurring in clusters;
3 upgrades to the technological system which impact several parts of the economy and can create entirely new sectors; and
4 changes in the techno-economic paradigm: large-scale, revolutionary developments embodying new systems.

2.2. Factor substitution

The uptake of capital and labor will depend, first, upon marginal costs, since substitution reflects their input price ratio (O'Sullivan, 2007: 128). Equally important is the respective product of the two inputs (Mallick, 2012). Unlike fixed capital, labor is essentially[1] a variable factor and, barring scaled-up production, its total, average and marginal returns follow the law of diminishing returns. The business task is to compare the fixed cost and quantum of output of often lumpy plant and machinery, and/or the sunk costs of acquiring intellectual property (IP), with the value of production resulting from a flexible wage rate applied to a fluctuating count of workers. Neoclassical orthodoxy holds that the objective governing factor relationships and the quality and quantity of output is to optimize profit, the difference between total revenue and costs.

Accordingly, and following prior endeavors (Braverman, 1974; Collins, 2013; Granter, 2009; Rifkin, 1995), this analysis explores seven contemporary drivers of capital / labor substitution and ongoing labor displacement[2]. They are arranged intuitively from micro to macro, according to their probable technological impact as shown in Dicken's (2015) classification (Table 1). Their duration is interpreted in two phases. 'Short term' denotes influence within the next 30 years (roughly to 2050), while the 'longer-term' refers to the second half of the 21st century.

3. Seven drivers of change in the factor mix

3.1. Shadow work

The profit margin on sales in certain industries (e.g. supermarkets) can be as low as one or two per cent (Bean-Mellinger, 2018). To boost efficiency, roles can be outsourced via the 'shadow work' identified by Austrian philosopher, Ivan Illich (1981) in his eponymous book[3]. Shadow work is not a gift, as in volunteering, but the unpaid tasks undertaken by consumers for businesses and organizations (Lambert, 2015). The earliest grocery self-service concept has since encompassed automatic teller machines, self-pump gasoline stations, phone payments and banking, online booking and accounts management, do-it-yourself store checkouts and trolley return, landside airline baggage deposit and many more types of disintermediation. Lambert identifies four enablers:

[1] Variable in quantity but still attracting certain overheads (e.g. sick leave, pension contributions etc.).
[2] There are, of course, many other drivers of general socio-economic change including genetics, fusion and environmental pressure but the focus here is upon those involving marked capital / labor substitution
[3] See also Gershuny (1978).

Table 1
Drivers of capital / labor substitution (or labor displacement), their technological impact and time phase.

Driver	Technological Impact	Time Phase(s)
Shadow work	(Labor displacement)	Short term
The 'zero marginal cost' society	Limited incremental	Short term
Casualization and contracting	(Labor displacement)	Short term
Onshoring and offshoring of labor	(Labor displacement)	Short term
Ongoing product and service development	Incremental / radical	Short and longer term
Scale economies in production and corporate organization	Widespread incremental	Short and longer term
Advanced information and communications technology (ICT) development	Systemic	Short term
	Possibly paradigmatic	Longer term

Source: Elaborating Dicken (2015: 76).

- Technology, robotization and artificial intelligence as facets of ICT
- Democratization of expertise via publicly available information
- Business' 'information dragnet', which forces consumers to provide ever more personal information and then manage it online to a corporation's benefit
- Evolving social norms which allow people to accept these unrequited obligations

Besides their active shadow contributions, people will contribute passively by providing live data to be mined by component, appliance, and service suppliers. To Lambert, shadow work offers individuals autonomy, while paradoxically controlling more of their lives. This externalization of business functions is likely to be pursued until operational limits to practice are reached: for example, a lack of cost-effective, technologically- or materially-feasible opportunities to enlist customers and patrons via ICT; consumer disdain for shadow measures; and cyber criminality. Some of these manifestations have already emerged in sharing economy enterprizes (Carville, 2021).

3.2. *The 'zero marginal cost' society*

Given that diminishing returns influence the production function, the marginal cost (that of an extra unit output of a good or service) should initially decline, level, and then rise. If fixed costs are excluded, this venerable economic model can be recast as zero marginal cost is accessed. In other words, additional units can be produced essentially free to the supplier (Rifkin, 2014: 4–5; Spence, 2014).

Zero social and marginal cost economics are a recent and radical (Dickensian) technological influence likely to prevail over the short term. They are presently confined to industries involving IP and digital media, such as publishing (self-authorships, e-books etc.), publicity, entertainment, education (MOOCs – massive open online courses) and renewable energy (e.g. rooftop solar photo-voltaics)[4]. Marginal costs have similarly been lowered due to reconfigurable, three-dimensional printing ('digital fabrication'), which could stimulate mini-factories with custom outputs. Discussion is of 'prosumers', who both produce and consume in monopolistically-competitive markets in which productivity has risen to 'extreme' levels (Rifkin, 2014: 16).

3.3. *Casualization and contracting*

As distinct from foreign-recruited or regular domestic employees, the 'contingent workforce' describes those who work non-permanently and often from ICT-enabled platforms as freelancers, independent professionals, temporary workers, independent contractors, or consultants. Through both choice and necessity and in technologically 'incremental' ways, they displace in-house labor in firms. While different from permanent part-timers, participants are seldom called 'day laborers' engaged in 'piece-work', as known in the developing world. They have their own business registration and indemnities, accepting diverse assignments. Given the automation of routine tasks, higher-level, non-programmed and project-based human work complements this agile approach[5]. At its best, the external workforce can be its own boss and enjoy liberties eluding permanents and payroll 'casuals.' The converse is the loss of legal status as an employee and, perhaps, a regular cash flow, thus admitting fragility and precarity. Continued engagement and income can falter, unsettling lines of credit or a mortgage, and potentially impeding the macroeconomic flow of income between households and firms.

Casualization is enabled by web platforms and ICT but does not rank in Dicken's (2015) categorization of technological impact. However, the shift from full- to part-time jobs and then to outsourcing can impact real wage levels elsewhere in an economy (Das, 2015: 260). Surplus contractors could foster a 'race to the bottom', since whatever can be digitized can be globalized (Bonner & Wiggin, 2006). An early enabler was the German website jobdumping.de, offering work to the lowest bidder. Now the publicly-listed airtasker.com asks would-be employers to nominate 'a fair price,' whilst fiverr.com fractions digital work to the $5 nano-level. According to Investopedia (2020), 'gig economy' workers offer skill and temporal flexibility. Yet, their availability can crimp career

[4] Universally, information platforms relay relevant information at zero marginal cost to all with internet access.
[5] But so does low level delivery and manual work, thus facilitating labor exploitation.

aspirations of permanent employees, since they do not attract overheads such as office facilities, sick leave and pension or health fund outlays[6]. Estimates are that around a third of American workers are employed freelance (Weber, 2014). A 2016 Deloitte Touche Tomatsu survey found 42 per cent of executives expecting to augment their contingent workforce in the following three to five years. As this approach expands, more labor in wealthy countries will find itself domestically and internationally trade-exposed, both daily and long-term. It will access projects or a portfolio of work but, as in the developing world, not necessarily a regular job with entitlements (Johnson, 2016). Casualization and project-based work will likely exist in both the short and longer terms as defined. They will only be interrupted by a lack of opportunity or some organized, widespread and dramatic disputation. Emergent signs of the latter (regarding contract or employee status and benefits) can be observed in ride-share, food delivery and other technology platform companies.

3.4. Off- and on-shoring of labor

Cost-conscious firms in rich countries often cannot undertake production of their offerings and must outsource the function. Once R&D are completed, the manufacture and delivery of most goods requires some labor, the supply of which is contested globally. Now well established as a derivative of ICT and part of the New International Economic Order (NIEO), offshoring is facilitated by low wage and shipping rates: as Rose George (2013: 18) claims, 'it makes more financial sense for Scottish cod to be sent 10,000 miles to China to be filleted and then sent back to Scottish shops and restaurants, than to pay Scottish filleters.' Contracting out, and achievement of scale, are assisted by the worldwide reach of the International Organization for Standardization, and the Project Management Institute. Any disciplines not already multinational in character (e.g. accounting) are increasingly conforming, permitting work to be undertaken abroad by professionals in tertiary services, such as systems engineering and financial management (Edgar, 2005: 133). Labor-intensive, B2B services characterize the frontier in offshoring, which former United States Vice-President, Al Gore (2013: 4), has inclusively labelled a 'massive change' in the global economy.

Through 'brand management' from advanced to emerging economies, 'the developed world finds itself, once again, relying on the efforts of other, poorer, people' (King, 2010: 173). As Asia's initial industrialized nations acknowledge, outsourcing and offshoring seek the cheapest venues offering political stability and quality output. This challenging practice is assimilating, yet simultaneously filtering and ranking, developing countries. Their cheap free-on-board (f.o.b.) pricing invites profitable arbitrage along supply chains. Offshoring has allowed considerable knowledge transfer, aiding these nations' competitiveness and encouraging technological 'leapfrogging.' Transfer also characterizes on-shoring as migrant workers, especially skilled ones, enter and leave rich countries[7]. Owing to digitization, the entire service sector is increasingly contestable by foreign workforces.

In neoliberal globalization, the optimal business approach in developed economies is to commission work-ready, overseas labor, for only as long as it is needed (i.e. project-based). Domestic training costs, overheads, and excessive unionization are avoided and local wage rates might be undercut. Onshore workers are inevitably impacted. Hence, there arise two new wwws – the worldwide workplace and worldwide workforce (Wadley, 2008), neither featuring the human resource protections hitherto known in advanced settings. Global labor movement could continue throughout the century while openings exist, unless arrested by contra-indicated economic or political forces (e.g. the human rights of offshore contract workers).

3.5. Ongoing product and service development

Intensified IP embodied in goods raises efficiency in delivering services, with technologically incremental and radical impacts (cf. Dicken, 2015). Current trends, part of enhanced process engineering, include simplification, modularity, weight loss, miniaturization and multi-functionality, each adjusting the factor input mix.

As contributors to 'dematerialization', miniaturization and multi-functionality reduce the demand for raw materials, transport and storage (McAfee, 2019), which should recursively lessen needs for labor. Production management has moved from dedicated, through flexible, to reconfigurable manufacturing systems (Mehrabi, Ulsoy, & Koren, 2000; Zygmont, 1986), following the demand-driven, Japanese Kanban just-in-time (JIT) approach. With CNC (computer numerically controlled) plant, it has incorporated quality function deployment (QFD) and configuration management (CM), leading to electronic data management systems (EDMS) and product data management (PDM). These disciplines have evolved into product lifecycle management (PLM),

> …a process or system used to manage the data and design process associated with the life of a product from its conception through its manufacture, to its retirement and disposal. PLM manages data, people, business processes, manufacturing processes, and anything else pertaining to a product via a central information hub (Aras Innovator, 2016).

PLM can eliminate prototypes as a major cost and accelerate the product lifecycle by enabling 'speed to market' in commercialization (Hamm, 2006). It helped Boeing cut the development of its 787 Dreamliner to four years, compared with five for the B777 (PLM, 2021). It allowed Motorola to engineer products from fewer components supplied by fewer vendors (The Financial Times, 2017). Correspondingly, electric vehicle (EV) motors consist of (the low) dozens of parts, not thousands as in combustion engines (Beggs, 2013). Fewer components will move, reducing wear and maintenance work, and likening EVs to 'computers on wheels' (The

[6] The question emerges of whether laborers in wealthy countries deserve protection from those in other lands without obligations regarding minimum wages, environmental standards, child labor and so forth. Refer to Featherstone (2019) regarding risks to, *and of*, gig economy workers.

[7] Technology transfer also permeates mergers and acquisitions, an aspect less remarked upon. Theft and hijacking of IP are other conduits.

Economist, 2017a). The *Zeitgeist* is of Dickens' incremental refinement and technological upgrading of past 'ways of doing things', invariably with less labor.

Clearly, PLM will limit design phases, within which advanced nations foresee their future in goods and services. Intense research and development (R&D) is shrinking high-technology product life cycles and abetting obsolescence. At the 2017 launch of its Pixel 2 phone, Google claimed that, after only a decade, multi-functional smartphones were mature, making it difficult to find new products based on hardware alone (Gapper, 2018; Marks, 2017). Such developments prompt price falls in mass durables (and also advanced services such as gene sequencing). Hereby, value adding (which can vary returns to labor) and the comparative advantage of leading nations recede. High technology, disruption, and digitization combine to induce deflation within the macro-economy.

Both producer and consumer services are experiencing expansion of scope and scale. To illustrate, globalization is forcing merger and acquisition among law firms to allow seamless worldwide operations. Low-level legal work is being routinized and automated, some offshored. Domestically, predictive coding is fast-tracking basic work once undertaken by trainees and paralegals (Brighton-Hall & Hooper, 2017). Through 'deep parsing' and kindred algorithms, information technology has boosted efficiency in judicial outcomes and court procedures (Walsh, 2017). All this is disturbing for law graduates seeking job security in a pre-eminent part of the traditionally labor intensive service sector (Papadakis, 2016).

Product and service development will be prevalent in both the short and longer terms assuming that it is technically feasible and profitable. Speculation around obstacles is undertaken later in the analysis.

3.6. Economies of (global) scale

As a widespread agent of 'incremental' technological impact (Dicken, 2015), scale offers abundant opportunities for lowering unit labor costs in global supply chains due to internal and localization economies (Eliot Hurst, 1972). Through mergers, acquisitions, and the growth of companies, oligopoly replaces monopolistic competition in fields with high barriers to entry. For example, large-firm dominance characterizes automobile production. Design no longer targets individual countries, and recognized brands of erstwhile firms have been absorbed into larger conglomerates. A few multinational oligopolists thus produce 'world cars' from huge plants in selected nations led convincingly since 2008 by China (Dicken, 2015). Vehicles are shipped in roll-on roll-off car carriers, which displaced the less effectual lift-on, lift-off technologies of 30 years ago. With just 20–25 crew, such vessels of Panamax or greater size can move up to 8,000 cars (worth, say, $200 million) at around 20 knots. With its last local assembly plants shuttered, the million-plus Australian annual new vehicle market could be supplied by just three landings per week, due to global scale economies.

In other goods industries, container ships in the mid-1980s carried fewer than 5,000 TEUs (20-foot equivalent units), constrained by the dimensions of major canals. They have ceded to Suez-max (20.1 m draught, 240,000 DWT, beam 77.5 m) and post Suez-max vessels. The Suez Canal was deepened in 2009, and partly widened in 2015. Costing around a billion dollars each, the latest ULCSs (ultra-large container ships) transport from 10,000–20,000 TEUs at speeds to 26 knots to maximise efficiency.[8] Singapore and Rotterdam are among the few ports able to accommodate their draught of 21 or more metres (Paris, 2013). To improve reverse logistics, innovative *collapsible* shipping containers are now appearing (Pauka, 2014).

Mining is also pursuing scale economies in 'supermines', as in Peru's Cerro Verde. Under Freeport McMoRan, it will supply fully three per cent of the world's copper (Miller, 2016). Companies like Rio Tinto, the BHP Group and Newmont pioneer 'autonomous haulage,' consisting of driverless vehicles, trucks and trains (Evans, 2019), along with unstaffed drilling rigs so as to strip out labor costs and increase site productivity. To the probable disadvantage of local indigenous workforces, Das (2015: 260) reports that 'in combination with remote command and control technology…it is now possible to manage highly automated production lines and even large mines from distant sites.' Once extracted, minerals and other bulk commodities need transporting. Capesize vessels with a payload of 180,000 DWT have, since 2011, yielded to Valemax ships, which can carry 400,000 DWT at 15 knots[9]. The Chinese were set to commission 30 such VLOCs (very large ore carriers) in 2018, strongly disrupting already depressed, dry-bulk, shipping markets. In 2008, daily rates for Capesize vessels were around $US200,000 but latterly attract only $US3,000 (Paris, 2016).

Internal scale economies reappear more tangibly and accessibly on land. Plants can be monolithic, as is Boeing's 400,000 square metres at Everett, Washington, visible from space. For everyday firms in city suburbs and urban fringes, improvements in the construction and design of commercial and industrial real estate allow plant operations at a larger physical scale than before. Production and productivity benefit not only from internal expansion, but can also capture localization economies through co-siting of factories and services. Operations continue 24/7, accessing scale in the dimension of time. Such complexes afford efficiencies in interdependent linkages among producers, systems integrators, subcontractors and customers in B2B or B2C networks (Eliot Hurst, 1972). Logistics can be simplified and made agile, with increasing integration and inter-digitation of supply chains.

These various facets of expansion will continue at least over the short term until diseconomies of scale start to emerge as a result of: the law of diminishing returns; firms' inability to control large-scale operations; or market saturation. Oligopolies have managerial advantages over small companies and, additionally, can prosper at an expanded scale of production because of their deeper, U-shaped, long-run, per unit average cost curves.

[8] Unless they unfortunately run aground in the aforesaid Suez Canal, as did Evergreen Marine's 20,000 TEU UCLS *Ever Given* in March / April 2021.

[9] Apropos scale in shipping, likewise note Dream Cruises' and Genting Cruise Lines' proposal of 204,000 tonne, 342 metre long liners which, from 2021, will carry *9,000* passengers (Mathisen, 2019).

3.7. Advanced ICT development

From its historical and wartime origins, multi-faceted ICT can be associated with systemic and, possibly in the future, paradigmatic technological impact (Dicken, 2015). Oriented to labor impacts, discussion is now of key categories including automation, robotization, augmented/artificial intelligence and leading-edge computing and communication development.

Automation, defined as the ability of a machine to perform tasks without human intervention (Organisation for Economic Co-operation & Development, 1983), sponsors digitization and robotization. As early as 1985, Charles McMillion coined the words, 'automate, emigrate, or evaporate' to portray America's choices in the global economy. The international realtors, Cushman and Wakefield (2016), have stated that 'digital' is no longer about just technology but is a state of mind – open, transparent, nimble, dynamic, informal and creative, focused on community and experience. It is organic and eschews siloed thinking. Digitization (aka 'digital transformation') in organizations must start inside-out by jettisoning excess baggage. Corporate knowledge is collaboratively shared on the Cloud, driving strategy in multi- and transnational business. The realtors point to: GE, relocating its headquarters to Boston to tap that city's university sector; Deutsche Bank, aiming to become a digital financier; and Sephora, repositioning itself in the worlds of beauty and cosmetics. Firms lacking a 'digital culture' will arguably be left behind.

A key digital artefact is the *robot*, sn automatically controlled mechanical device programmed and re-configured to perform various material operations. It presumes a large workspace, several degrees of freedom, and the ability to use an arm with different tooling (Robot Worx n.d.). Usage has extended well beyond the 4D work categories – dull, dirty, difficult or dangerous – to include a fifth, 'dear', as in the displacement of expensive labor (Gottliebsen, 2017). Unlike robots, workers attract payroll taxes and are additionally exposed to pandemics and other personal disruptions. Today, many industries are in transition. Robotics characterize broadacre grain farming[10] more than horticulture, though the latter is increasingly introducing computer vision and picking capacity in row or trellis cropping, and running autonomous harvest vehicles from field to shed (Strong & Hernandez, 2018). Ranching could dispense with fencing due to the introduction of electronic collars, which enable comprehensive stock management (Cherney, 2018). Dock work and longshoring (stevedoring) are moving to 'high automation' (Marin-Guzman, 2019). In manufacturing, robots are standard for butchery, surface cleaning, welding, painting, palletizing, materials handling and assembly (Bouchard, 2014). They operate to the maxim 'think, sense and act' in food preparation, medical aids, surgery, commercial and military drones and weaponry ('killer robots'). While the end-vision is of robots building robots (The Economist, 2017b), the current phase comes with warnings about anomic work practices (as in humans having to 'keep up' with robots) and job loss. McKinsey has suggested that, by 2040, 45 per cent of United States workers are at risk due to automation, perhaps reflecting a Massachusetts Institute of Technology (M.I.T.) contention that every robot displaces 5.6 American positions. The World Bank has similarly predicted that 57 per cent of OECD jobs could be automated in the same period (Hanson, 2017).

In services, robotized warehouses, called 'dark sheds' because they require scant heating or lighting, are becoming common, affirming modern industrial assets as low-staff, high-end, mixed-use property with prominent volumetrics (height and bulk) to enable internal economies of scale (Cummins, 2018). New, highly automated distribution ('fulfilment') centers promise rapid delivery. France's Carrefour engaged Google in its online initiative while, in the United Kingdom in early 2019, Marks and Spencer commissioned the Ocado Smart Platform for its food delivery arm (Greenblat, 2019). In physical supermarkets, human shelf stackers are being replaced by sensor- and camera-equipped robots (Callaghan, 2019). As the line between physical and digital retailing blurs, Shanghai's BingoBox has pioneered the unstaffed convenience store, entered by use of a cell phone app. Items are scanned for payment, with theft prevented by real-name registration and video monitoring (Gottliebsen, 2017). Amazon has planned 3,000 cashier-less, inner-city grocery outlets across the United States (Soper, 2018). Banks are likewise closing staffed branches as customers move to e-commerce.

Automation of the tertiary sector has been considered since the early 1980s (Collier, 1983). Service industry robots are characterized by their physical or virtual representation, the latter relying upon software which works autonomously and learns over time. Regarding anthropomorphism, they can adopt humanoid or non-humanoid forms. Their task orientation can be cognitive / analytical (e.g. image analysis assistance for medical diagnosis) or emotional / social ('greeter' or reception robots) (Wirtz et al., 2018: 909).

The massive exhibitions of the Consumer Technology Association introduce robot trends with both household and busines applications. Products are moving from bespoke to more general machines with some multi-functionality and ability to consider context. Robots have 'ambition' and want to get to know people as a companion rather than as an appliance. 'Virtual assistants' feature language understanding, vision, facial recognition and answering capacity, and elements of emotional intelligence or 'intuition' (Chester, 2015; Olivarez-Giles, 2017). They are said to be expanding their skill base more quickly than can humans.

Augmented intelligence supplements, rather than replaces, human intelligence (Wigmore, 2017). Offered through wearable, injectable and other products, its labor-saving 'virtual assistance' incorporates algorithm-driven expert systems, natural language processing, knowledge bases, data mining, pattern recognition and machine learning[11] (i.e. computers learning without being programmed). Foci to date have been on self-surveillance, monitoring and quantification. IBM recommends the acronym I.A. (intelligence augmentation) to distinguish augmented intelligence from artificial intelligence (A.I.).

As examined in this journal since the early 1980s, *A.I.* is defined as intelligence exhibited by machines leading to goal-seeking behavior attuned to human needs. Anticipated by the Bank of America/Merrill Lynch to raise lagging productivity growth and

[10] The reference here is to large and increasingly autonomous tractors and headers (combine harvesters). Expensive and large-scale machinery can extend its market reach by way of specialized contract operators. Note, too, the impact of standard mechanization in Indian wheat farming, now costing many women their former weeding and harvesting jobs (Ulmer & Choudhury, 2019).

[11] At present, machine learning through its many iterations consumes vast amounts of (electrical) energy.

increase world GDP by $US15 trillion (contemporarily 18 per cent) by the mid-2030s (Commins, 2017), it spans sectors as the 'second wave' of digitization (Walsh, 2017). It is generating (once-off) employment, as specialized but often low-paid workers interrogate digital data to 'label' items requiring A.I. recognition (Metz, 2019a). Adams (2017) opined that a true A.I. system can learn on its own. He cited neural networks, which can make connections and reach meanings without employing pre-defined behavioral algorithms.

The current research frontier thus aims to understand 'machine behavior.' True A.I. can improve past iterations, becoming smarter and more aware to enhance its capabilities and knowledge. It can achieve 'deep learning' but, in paralleling human expertise and 'common sense', raises significant operational, agentic and ethical questions (World Economic Forum, 2018). Hanson (2017) views A. I. as a field in which strength (i.e. initial advantage) begets strength: its chief beneficiaries will be the United States and China. The latter in July 2017 announced a multi-billion dollar plan to lead the world by 2030. Conspicuously, in 2014 at the M.I.T, entrepreneur Elon Musk nominated A.I. as humanity's biggest existential threat, while the late Stephen Hawking remarked that it could be the worst event in the history of civilization (Kohler, 2018; Ong, 2017). The technology also attracts a fringe but well-qualified 'rationalist' community concerned about the prospects of super-intelligence and a supercomputer ruling the world (Chivers, 2019).

Regarding *advanced computing* applications, AI is not confined to open banking, the cashless society or cryptocurrencies.[12] In an ecosystem incorporating blockchain (Berg, Davidson, & Potts, 2017)[13], the incipient *force majeure* is quantum computing which, in early 2019, tapped 'supreme'[14], 200-qubit status. Complementing China's national quantum laboratory at Hefei and the United States National Quantum Institute, leading developers include D-Wave, Intel, Rigetti, Microsoft, Google (the Sycamore machine) and IBM (Davidson, 2019; Metz, 2019b). Quantum operations, now a national security imperative, will solve 'real problems' of complex construction, and consign present computing to 'the trash heap' (Shah, 2017)[15]. Apart from difficulties in creating chips to facilitate the classical / quantum interface, one of the challenges for nano-physics has been the instabilities of, and need to master, superposition, which allows qubits to hold zeros and ones simultaneously. It is being addressed in the development of different platforms. Superconduction (as pursued by Google and D-Wave) exploits the properties of metals (aluminium on a silicon substrate) at ultra-low temperatures to reduce resistance in quantum operations. The temperature issue also prevails in phosphorus-atom quantum computing which presently requires at an energy-intensive setting of 0.0015 K or minus 273 degrees Celsius. Another approach with capacity for up-scaling and of interest to western venture capitalists involves photonic quantum computers (Afifi-Sabet, 2020). It is a field in which the Chinese University of Science and Technology in Anhui province has recently posted some success. Honeywell has been advancing trapped ion quantum computing, while engineers in Sydney have created artificial atoms in silicon chips which offer improved stability (Gilbert, 2021). Fields impacted by advanced capacities in information technology will be the blockchain and synthetic biology. Such computing will have physical (robotic) and virtual expression, with a new field of 'quantum A.I.' rapidly appearing.[16] Military and strategic competition is powering these technology arenas.

Jeremy Rifkin (2014) writes of 'intelligent infrastructure' which, via 'hyper-automation,' merges *advanced communications*, energy, and logistics capacity within the internet of things, the IoT. Connection of savvy household and business equipment via ubiquitous linked sensors characterizes the arrangement. People, smart buildings and machines link freely with each other, often to adjust physical settings to optimal points (e.g. as in air conditioning temperature or building lock-up status). This networking will employ sensors and software to feed real-time, big data to nodes in businesses, homes and vehicles. There they will access A.I. combined with automatic monitoring and servo systems to improve efficiency, increase productivity and slash the marginal costs of production and delivery.

To Rifkin (2014: 16–25), the ubiquitous capacities of the IoT constitute a disruptive technology, which gathers and filters information, connects sources and destinations, and transforms economic and public life. It optimizes peer-to-peer (P2P) production, universal access and inclusion, thus creating social, rather than market, capital. Yet, within 10 years, the conventional internet is likely to be impacted by quantum computing which could quickly unlock its existing levels of encryption. Thus, a quantum internet is envisaged in which encryption is secured through quantum key distribution (CKD) based on the principle of entanglement. The vision, already in fledgling form, is to develop networks of quantum computers based on 'trusted nodes' which encrypt and decrypt data. Signal amplification would be incompatible along fibre optic link lines such that the idea of 'repeater stations' is being actively researched, all in the quest for speed, capability and data security (Battersby, 2021).

Such outcomes pending, the incremental exploitation of past successes should not be overlooked (Funk, 2015). Foundational to nanotechnology and materials technology, genomics and epigenics, digitization is prompting the convergence of disciplines (Turner, 2017). Communication technology is constantly evolving as millions of phone applications (apps) have become available. Supporting this vast selection, which augments personal efficiency, are dedicated innovations on other producer platforms. First, mixed, as opposed to virtual, reality blends physical and digital environments, enlarging modelling and testing capacity. Microsoft's HoloLens has thus been applied in architecture, engineering, tourism, surgery, and the defense forces (Callaghan, 2019). Second, Australia's Qantas has acted to monitor the fuel consumption of its aircraft engines (Bailey, 2016). Pioneered on the industrial internet, Predix, in alliance with GE in Austin, Texas, the app (the digital twin of the engine) will initially serve as a pre- and post-flight aid, subsequently

[12] Bitcoin and its competitors co-opt existing technologies to create an incorruptible clearing system independent of banks and within which data can never be changed (Kaminska, 2018).

[13] Following Berg et al. (2017), the distributed and decentralized ledger is composed of five technologies: cryptography; a database, which can be added to but not altered; peer-to-peer (P2P) networking; an application of game theory; and an algorithm for ensuring consensus about what is held in the ledger.

[14] 'Supreme' means capable of tasks which a classical computer cannot accomplish in any reasonable time.

[15] Somewhat hyperbolic, in that 'classical' machines will complement quantum computers.

[16] Details thanks to Emeritus Professor Gerard Milburn, School of Physics, The University of Queensland.

to enter the cockpit for in-flight guidance. It is tasked to reduce the airline's fuel bill by one per cent in its first 12 months.

Unit prices for technology fall as its capacity grows, multiplying incentives for capital substitution for labor. Few observers dispute the operational and safety gains of contemporary automation and its achievable time and cost savings, combined with the capacity to undertake new operations. ICT development will likely continue for several decades, maybe until continued innovation falters in benefit/cost or productivity terms. Meanwhile, its popular image and social licence are also important. Insight emerges from the World Economic Forum (2017) *Global Risks Report*, which, through surveys of business, government, academic and not-for-profit leaders, assesses oncoming technologies within a bivariate matrix calibrated one (low) to seven (high) in respect of negative consequences (C), and overall benefits (B) to society. Virtual and augmented realities (C3.8, B 5.3) rank centrally near blockchain and the distributed ledger (C3.9, B5.2). New computing capacities are regarded positively (C3.8, B6.1), while robotics and A.I. (C4.4, B5.9) materialize as more highly charged technologies, apparently because their capacity for labor displacement is acknowledged by, and is worrisome to, laypeople.

3.8. Interaction among the seven drivers

As elaborated, the factor mix is central to a production system supported by a given level of technology. Systems thinking allows preliminary analysis of the interaction of the seven labor-substituting drivers as an initial step to exploring potential socioeconomic pathways (Fig. 1). In interrelating predictability and control, discussion might extend only as far as the 'possible' future point of, say, 2100. It should cover the 'known unknowns' popularized by former United States Secretary of State, Donald Rumsfeld (Shermer, 2005).

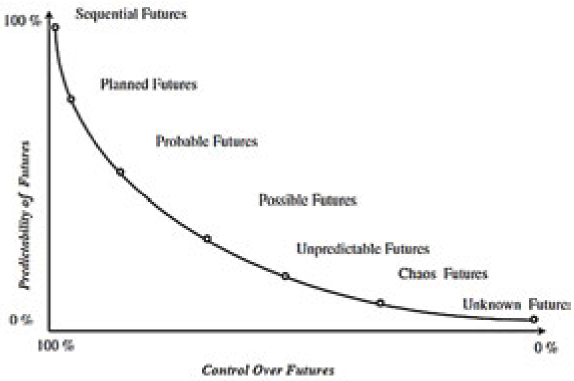

Fig. 1. Characteristics of futures.
Source: Stimson, Stough, and Roberts, (2006: 194). reproduced with permission.

	Shddow work	Zero marginal cost'	Casualization contracting	Onshoring and offshoring	Product and service development	Economies of scale	ICT
Shadow work		Strong	Strong	Weak	Strong	Uncertain	Strong
'Zero marginal cost'			Uncertain	Uncertain	Strong	Mixed	Strong
Casualization contracting				Strong	Mixed	Uncertain	Strong
Onshoring -- offshoring					Mixed	Strong	Mixed
Product and service development						Strong	Strong
Economies of scale							Strong
ICT							

Fig. 2. Structural analysis matrix of putative interaction among the seven drivers.
Source: Technique following Godet (1991) and Stimson et al. (2006); substantive adaptation by the author.

Further, Fig. 1 can introduce a structural matrix, to test the strength and direction of binary associations (Fig. 2). Powerful ICT development promotes and marshals the other six drivers through 'strong' affirmative links, notably in computational work, codification, interpretation and analysis, and the greater logistics management involved in expanding scale economies.[17] ICT could also pose counter-effects, associated, for instance, with 'product and service development,' as in the 're-shoring' of enterprize. Limited 're-industrializion' of developed economies is already occurring due to robotization and the intricate high technology embodied in certain business applications. 'Mixed' cells in the tabulation represent positive impulses in some industries but inhibition in others. Along with 'uncertain' entries, they call for far more empirical investigation of cross-impacts than is possible here.

4. Potential labor outcomes

Finn Bowring (2002), from The University of Cardiff, regards the aim of the most efficient organizations as the *elimination* of work. Technology and effort are themes which originally occupied Adam Smith: much later, Joseph Schumpeter (1954: 81–86) underlined Marx's case that capitalist evolution involves the 'creative destruction' of foregoing practices. Next, computing advances aroused debate circa 1980 (Castle, Lewis, & Mangan, 1986; Griffiths, 1977; Jenkins & Sherman, 1979; Jones, 1982), those texts now replaced by contemporary ones (Watson, Buchanan, Campbell, & Briggs, 2003; Hughes, 2007; Wooldridge, 2015; Livingstone, 2016; Dunlop, 2016). All this background notwithstanding, the seven capital-substituting and labor-displacing forces have seemingly never been analysed *collectively*.

Views about the demand for labor to 2050 are often hedged. Themes cluster around the impact upon workforces of scale economies and information handling, arguably the most impactful of the seven drivers examined:

- The World Economic Forum (2018) has used 'big data' to pinpoint job transitions for technology-displaced workers.
- While few are fully automatable, 60 per cent of all occupations have at least 30 per cent of technically automatable activities (Manyika et al., 2017).
- Two thirds of early career Australians believe that their job will not exist or will fundamentally change in the next 15 years (Chartered Accountants Australia & New Zealand, 2016).
- 47 per cent of United States occupations are at high risk because of automation (Frey & Osborne, 2015).
- Though generally positive about technology, Deloitte (2015) spells out the probability of automation in certain United Kingdom occupations.
- The same exercise was undertaken on a far larger scale with many more occupational categories by Angus (2015) for the New South Wales state government in Australia.
- 230 million knowledge workers (nine per cent of the global total) and 320 million manufacturing workers (12 per cent, ditto) could be impacted by disruptive technologies (Manyika et al., 2013).

Prominent in providing commentary are banks and multinational business services firms, which, for commercial reasons, cannot be too bearish. Nor are all the reports adequately time-phased. These qualifications call for open investigation of future labor dynamics via three scenarios:

- definable growth
- continuation patterns
- radical and apocalyptic viewpoints

Several phenomena could influence the time phasing (i.e. beginning to end points) of these visions. They include: access to increased economic productivity; the progress of Kondrat'ev waves and the Fourth Industrial Revolution; and the resolution of knowns and unknowns in technology and consumer markets. As between probable and possible futures (Fig. 1), chances for the first and second (growth and continuation) scenarios could prevail over the next 30 years as the drivers of labor displacement duel with the support for workforces offered by product and service development, scale economies, and ICT (Table 1). Absent systemic or paradigmatic breakthroughs or changed trends in factor substitution, the third (radical) one could become more relevant in the later 21st century. As per Table 1, it would rely on the labor-displacing forces but, more so, upon a loss of impetus among the three longer-term drivers for reasons suggested in earlier pages.

4.1. Definable growth

Within the first and most sanguine scenario, technology advocates, including the Japanese futurist Michio Kaku and the 'rational optimist', Matt Ridley (2010), maintain that the law of diminishing returns, conventionally applied to fixed and variable factor inputs, does not control the world of ideas. Similarly, the expansionary economist, Julian Simon (1981, 1996), held that scarcity could be solved by the application of more brainpower and innovation, a theme echoed today in endogenous growth theory (Romer, 2012). Unless capital restrictions and/or excessive barriers to entry arise, the more enterprising developing economies with large populations

[17] Within logistics, consider the opportunities for the expansion of offshoring introduced by the new fleets of ULCSs.

should have significant labor resources to leapfrog in technology and pursue appropriate industrial research from a lower cost base. They could become competitive with the last bastion of the advanced world, intellectual input.

Advocates argue that certain advanced, and some emerging, countries face labor *shortages* by 2030, due to an expanding service sector (Roberts & Yetsenga, 2016).[18] Ones with aging workforces and scant immigration are allegedly exposed (King, 2010: 175–80). Those futurists who have considered labor seem quite comfortable: as Jorgen Randers (2012: 67) comments in his 2052 forecast, 'the potential workforce will continue to grow for decades, providing one basis for continued growth in GDP…there is little reason to believe that participation rates…will decline…'

4.2. Continuation patterns

> There are good reasons for believing that technology will have little effect on the level of employment. It will, however, have an impact on the composition of jobs and the pattern of wages (The Economist, 1985).

According to this standpoint, much oriented to robotization, workers will lose jobs but, as in foregoing technological surges, they will be redistributed to new opportunities, some yet unimagined (Dunn, 2017). Automation will create a greater supply of goods and services, thus lowering prices. As more volume is sold, the increased trade will swell revenue and profits. Profits will facilitate expansion and lead to greater production of goods and services requiring more, not less, employment (Australia [Treasury], 1979). If secondary and tertiary education is appropriately configured, people in boring jobs will find brighter and more fulfilling alternatives. In the 'probable' future to 2030, the 'digital prairie' will feature opportunities, *inter alia*, for 'haptic interface programmers', 'voice UX designers' and 'vertical farm consultants' (Cognizant, 2018; Swan, 2018). Mike Cannon-Brookes, founder of the software provider, Atlassian, thus refers to 'a massive amount of jobs destroyed, a massive amount of jobs created' (McDuling, 2017). Oscar Salazar, Uber's first chief technology officer, maintains that 'nobody is creating companies to get rid of humans. I don't think that machine learning will replace jobs' (Fairchild, 2017).

The second scenario draws on the Boudreau (2016) survey of human resource and other executives. In surmising the future of work, he looks to: social and organizational reconfiguration involving greater corporate transparency; project-based and flattened relationships and overall agility; an inclusive global talent market in a truly connected world; exponential technological change; and human-automation collaboration. These trends should *create* jobs as interpreted via a 2 × 2 matrix covering:

- current full- and part-time jobs, with traditional forms of delivery;
- current roles, 'turbocharged' via the technological empowerment of the Cloud, A.I., personal devices and extreme customization;
- current work re-imagined, involving virtual platforms, projects, freelancing and taskforces delivered by traditional mechanisms; and
- 'über-empowered' – work re-imagined and delivered via the technologically turbocharged means just mentioned.

The last two categories are said to foster greater democratization of work.

Elaborating the case for 'continuation', Jeremy Rifkin (2011: 265–70) identifies four modern workplaces: the market, government, the informal economy, and civil society. The first three are likely to labor-shed, leaving the civil sector to generate employment. It can be characterized by its discretionary role in allocating certain goods and services, its public enterprize focus, and sectoral productivity differentials. Covering education, research, health care, social services, sports, the environment, advocacy and recreation, it is where people create social capital and pursue culture and a common heritage. There, relationships are an end in themselves and motivation is intrinsic, rather than, as in the market, extrinsic (cf. Ryan & Deci, 2000). Aging populations could demand different services, seeking interaction with people, not machines. Though often wage- and productivity-constrained, the civil society could by mid-century become as significant an employer as the market: building social capital involves human interactivity, whereas creating market capital relies on (cumulating) intelligent technology. Commons-based, peer production might be one local way of bringing the two forms of capital together (Kostakis, Niaros, Dafermos, & Bauwens, 2015).

4.3. Radical and apocalyptic perspectives

A counter to continuation is Rifkin's (2011: 265) wider admission that labor demand in advanced markets might itself be receding. As he writes, 'rethinking work this time around is more akin to the great upheaval that ensued when serfs were released from their indenture in a feudal economy and forced to become free agents and wage earners in a market economy.' Earlier, David Macarov (1985) wrote that the problem of unemployment remains and, with current technological advance, could become permanent. This view presages one by Nobel economist Robert Shiller (2017): 'my own theory about today's stagnation focuses on growing angst about rapid advances in technologies that could eventually replace many or most of our jobs…'

All three scenarios recognize current annual global population growth of 80 million people, a net 220,000 per day. More particularly, the world's labor force of somewhat less than four billion is expanding by around 46 million people per annum (Ghose, Majid, & Ernst, 2009). Dicken (2015: 322–23) writes that it quadrupled in the quarter century from 1980–2005. He further recalls a 2006 remark of the Director-General of the International Labour Organization (ILO) that 'we are facing a global jobs crisis of mammoth

[18] The sense of 'shortages' here is structural, and the problem could likely be resolved over time. The standard microeconomic remedy would involve an active labor market without excessive barriers to entry (i.e. global fluidity of supply) in which the wage level would adjust any imbalances in supply and demand.

proportions, and a deficit in decent work that isn't going to go away by itself.' A pointed refrain comes from the respected financial commentator, Satyajit Das (2015: 259), namely that 'a job is the main thing that stands between most people and penury.'

Keynes' (1930) lecture, 'Economic Possibilities for our Grandchildren' suggested that, by 2030, capitalism would have fulfilled its key role in satisfying human needs, creating a 'post-scarcity' economy (Harris, 2020). The threads above posit a different trajectory.[19] To Rifkin (2014: 16–25), capitalism's *raison d'être* will be displaced by 'a global network driven by extreme productivity [moving] us ever faster towards an era of nearly free goods and services' (cf. his aforementioned zero marginal cost society). Replacing the capitalist market and government as key organizers will be a new social and collaborative commons, that is, 'the oldest form of institutionalized, self-managed activity in the world.' It stresses open-source innovation, transparency, and a search for community which technology can easily deliver. Gore (2013: 33, 41) likewise refers to the 'disruption' of capital, labor, and natural resources producing a 'crisis in capitalism.' His case is that new jobs must be created, an obvious target being in 'the provision of public goods in order to replace the income lost by those whose employment is being robosourced and outsourced.'

Enlarging on these ideas, an apocalyptic sequel is provided by the European sociologist, Zygmunt Bauman (2007: 28, 30) who, in *Liquid Times*, foresees not only the demise of capitalism but possibly economic development at large:

> The volume of humans made redundant by capitalism's global triumph grows unstoppably and comes close now to exceeding the managerial capacity of the planet; there is a plausible prospect of capitalist modernity (or modern capitalism) *choking on its own waste products* which it can neither reassimilate nor annihilate…As for the 'redundant humans' who are currently being turned out in the lands that have only recently jumped under (or fallen under) the juggernaut of modernity, such outlets [i.e. new spatial frontiers] were never available; the need for them did not arise in the so-called 'premodern' societies, innocent of the problem of waste, human or inhuman alike [original round brackets and italics, current author's square brackets].

5. Theoretical development

5.1. Initial conceptualization

Within an inductive analysis, the need is now to inter-relate Dicken's (2015) technological impact gradient and the three scenarios modelling labor demand (Table 2). Shiller (2004: 10) likens information technology to an ice hockey stick: the blade connotes slow progress as the discipline emerged in the 1940s but, this century, we face the exponential growth represented in the shaft. 'Now that a critical mass has been reached, will we see a dramatically different effect on employment?'

Table 2 tackles that question. Today's advances most probably lie beyond incremental and radical innovation. The further one descends Dicken's (2015) classification, the larger the impact on labor could be. Growth and continuation scenarios connote 'known knowns' or, at most, 'known unknowns' (cf. Shermer, 2005). The third one additionally foreshadows 'unknown unknowns', next to be interpreted among advanced and developing countries.

5.2. Geo-economic contingencies

5.2.1. Advanced countries

From the early 1990s to the present, the share of developed western economies of world gross domestic product at purchasing power parity has fallen from just under 60 to 40 per cent (Wolf, 2018). Though prone to technological disruption, high-income nations cannot forsake capital substitution since 'investment' (a political mantra and imperative[20]) is the foundation of their productivity and economic standing. This reality, along with a possible labor surplus (endogenous or migration-induced), helps explain a stagnation in real wages and a rise in the share of capital in profits – backdrops to increasing social inequality (Piketty, 2014). Recent technology has patently benefited people more as consumers than as producers (Gapper, 2015).

In the real economy over 250 years, technology first relegated physical brawn, and then assimilated repetitive and programmatic roles such as mass information processing (thus displacing 'operatives'). Far more abruptly within the financial economy, it has, for the last 25 years, routinized tactical decision-making, with subsequent prospects of colonizing executive management via advanced algorithms and machine learning. Within the emergent 'cognitive computing,' its impact will materialize in tertiary services as quantum A.I. challenges white-collar jobs and, with them, the middle classes (Collins, 2013: 37–69). An important issue will be whether the market in rich countries can accommodate the supply of skilled and professional workers created by vocational and higher education. Andrew Yang (2017), founder of the entrepreneurship agency, Venture for America, writes that, 'I feel increasingly like we're working on islands of relative prosperity that are shrinking beneath our feet.'

A shallow and narrow response is constant demographic growth so that, despite capital intensification and technological advance, onshore construction and outfitting will supposedly grow and create economic multipliers. Yet, with those initial, goods-intensive and low-technology activities complete, labor redundancy could ensue. A related and increasingly prominent issue is uncontrolled immigration, presaging an informal and/or black economy and a cash workforce because, for an underclass, a precarious existence in an advanced nation beats unemployment and disadvantage in homelands. This hiatus suits unscrupulous employers involved in exploitation and quasi-slavery in franchise and other businesses, and regularly sweeps up foreign students and workers (e.g.

[19] Territory covered from different viewpoints in this journal, Volume 68, 2015.

[20] The call for, and rhetoric of, INVESTMENT! is usually directed toward capital, rather than into human resources.

Table 2
The nexus of technological change and labor scenarios.

Dicken's (2015) Gradient of Technological Change *(Choose a 'stimulus')>>>*	Nexus *(which matches)>>>*	Labor Scenario *(a 'response')*
Incremental	?	Definable growth
Radical		
Systemic		Continuation pattern
Paradigmatic		Radical / apocalyptic

Source: author

withholding of passports, extortion, blackmail, threats of reports to authorities) (Ferguson, 2017). All these exigencies demand a thoroughgoing population policy cognizant of future labor dynamics.

Benefitting well-organized and disciplined overseas recipients (i.e. managed, quasi-capitalist and communist economies), off-shoring will continue to erode advanced countries' manufacturing bases, former blue-collar solidarities and, increasingly, their labor-heavy tertiary sectors. The high-wage economies paint themselves (proudly) as brand managers undertaking product and service design to reinforce their comparative advantage. Longer-term, this posture is illusory. First, though they are creative and relatively employment-intensive, design and marketing will fail to absorb abundant labor reserves. Second, as capital substitution persists, ever more nations will contest R&D (at large, or by field), quickening the rate of process and product change. Following endogenous growth theory (Romer, 2012) and microeconomic models of cumulative causation, market forces could lead to long-run, inter-regional equilibrium on a global basis, but recursively deliver tepid personal income (Creighton, 2014). Global wage relativities could move toward greater equality but, with ongoing demographic and workforce expansion, at a much lower absolute level (viz. another aspect of a 'race to the bottom')[21].

5.2.2. Developing countries

This thesis of geo-economic flattening can be disputed by acknowledging assertive technology uptake and, hence, competitive shuffling, among the developing nations themselves. China, the world's second largest economy and a key offshoring and contracting haven, is investing heavily in robotics and A.I., aiming to overtake the United States by 2025 and dominate the market by 2030 (Aeppel & Magnier, 2015; Powley, 2014). Since May 2015, its 'Made in China, 2025' initiative has not only cornered world manufacturing but also emphasized domestic, cutting-edge componentry, assisted by some 40 nationwide innovation hubs (Hsu, 2017)[22]. Within its third phase of innovation (McKern, 2017), this country has supported Google's A.I. development due to its (China's) comparative advantage in massive data holdings from mobile payments, gaming, social media, search and news applications (Abkowitz & Lin, 2017). The initiative plays to its complement of unicorns (spearhead enterprises like Lianjia and Xiaomi, each valued at more than $US1 billion), which collectively match the capitalization of comparable start-ups in the United States (The Economist, 2017c). Further development, exemplified in commercial and military drones, aircraft production, wind turbines, power grids, industrial machinery, rare earth applications and an encompassing digital currency[23] (the e-yuan), contests still more high-technology fields (Fairless, 2020; Page & Sonne, 2017). Having succeeded under World Trade Organization rules in manufacturing and exporting general merchandise, China has deemed that it will need a technological thrust to lead global markets, rise above middle-income nation status, address population aging, and accommodate its still vast and under-employed labor reserves. Underpinning any broad projections is its ascendancy or otherwise – opening or closing out opportunities for would-be competitors.

For many poorer nations missing such upgrades, the third labor scenario could be worrying in the context of a 'possible' future. Economics Nobel laureate, Michael Spence (2014), has written that

> developing countries in the early stages of growth need to understand these trends. Labour, no matter how inexpensive, will become a less important asset for growth and employment expansion, with labour-intensive, process-oriented manufacturing becoming a less effective way for early-stage developing countries to enter the global economy

[21] For allied themes around futures for capitalism see, again, this journal, Volume 68, 2015.
[22] Other nations are disputing the public assistance allegedly behind this program.
[23] In any nation, a mandated digital currency will create huge data troves and enable mass monitoring of credit and consumer behavior.

Given the competition and product acceleration of vibrant R&D, capital-intensive products and service systems experiencing falling marginal costs could become so price-degraded that, even in low-income countries receptive to offshoring, they could challenge local wage rates. A harbinger is the Translokai digital ticketing system for public transport in Haiti, a land unremarked for its labor shortages (Edmond, 2016). Equally relevant is an ILO report that 56 per cent of the waged workforce of Cambodia, Indonesia, the Philippines, Thailand and Vietnam is at risk from automation in the next 20 years: so too the self-employed (Chang & Huynh, 2016). Occupations hosting routine tasks and explicit, codifiable procedures are more easily automated than those involving extensive, non-programmatic, abstract operations demanding judgment, problem solving, intuition, persuasion and creativity. Jobs based on non-routine, manual tasks requiring significant situational flexibility and human interaction are also thought to be resilient.

6. Conclusion

For risk- and loss-averse observers who favor not precarity, but an equitable, prosperous society for their business and children, Casselman (2017) recommends deep planning around the precautionary principle. This article has accordingly 'meshed' seven drivers of labor dynamics and strategically analysed three global workforce scenarios. In the trade-off of the physical and the virtual and acknowledging the constant quest to improve productivity to safeguard profits, labor demand and supply need careful monitoring. Within either of the first two futures outlined here and except in unfolding fields of innovation, huge companies could pose elevated barriers to entry, entrenching global oligopolies as the market form of the 21st century. One view, allied to the 'continuation' scenario, is that they will not only inhibit start-ups but also invest less because of their entrenched positions (Leigh & Triggs, 2017). More certain is that they will micro-manage labor and pit one country against another to obtain corporate welfare ('co-investments') from governments anxious to retain jobs. Resistance in terms of national wage and workforce legislation could falter due to an investment (capital) strike by footloose firms, so eroding a country's employment and GDP. Thus, we can redefine 'client states,' in their dozens, not as political flunkies, but as investment- and price-takers. Bald statistics can mislead: labor is ideally measured not in headcounts of full or part time staff and the unemployed, but in *hours worked* by paid employees and contractors. Jobs could become a critical resource, a detail overlooked by nations unaware of systemic phase shifts and the repercussions of potentially paradigmatic technological change. Real power lies no longer in government but with masterly lobbies, think tanks, and businesses 'too big to fail'. As politicians absorb corporate outlooks, we drift from democracy to plutocracy or oligarchy. Hence, another Nobel prize winner, Joseph Stiglitz (2012: 21), cautions that:

> For markets to work the way markets are supposed to work, there has to be appropriate government regulation. But for that to occur, we have to have a democracy that reflects the general interests, not the special interests. We may have the best government that money can buy, but that won't be good enough.

Since Keynes' (1930) essay, world population has increased nearly fourfold, prompting the capital / labor substitution needed for greater productivity to match demand and supply. Technology has done much of the heavy lifting. Yet, today, aside from exposing pointless 'bullshit jobs,' which reflect legacy over-staffing (Graeber, 2019), it must contribute more than just disruption (Gapper, 2015). In this respect, two long-range paradigm shifts merit strategic consideration. The first is that, having adopted all feasible opportunities to prune labor inputs, cost-conscious firms would seek efficiencies among the other three factor inputs – with effects unknown. The second is that, after five Kondrat'ev waves, humanity could be reaching a technological asymptote, making it difficult to conceive many meaningful, breakthrough products or services (cf. the Google Pixel case above). Overlooked in scholarly and serious circles, this roadblock (paradoxically, a *lack* of unknown unknowns) would dovetail with the third labor scenario to pose a conundrum equal to climate change (Wadley, 2020: 192–99). In ways different from that radically imagined by Rifkin (2014), it could confound conventional thinking and thwart advance, since there would be very few new offerings to spur labor uptake and economic development.

Given fast-evolving international competition, no nation can reliably prescribe domestic workforce outcomes (cf. Fig. 1). If the third, longer-term scenario materialized, a known-unknown will be how to accommodate the currently and future unemployed, lest they become lifetime-dependent upon a receding stock of welfare. Extensive, debt-funded, public support during the current pandemic could beget moral hazard. Amid advocacy of a four-day work-week (Barnes & Jones, 2020) and modern monetary theory, there exist questions of the viability of a Universal Basic Income[24] (Kohler, 2017; Widerquist, Lewis, & Pressman, 2005), and whether vested interests are positioning to sidestep an already-recognized problem. They might find such load-shedding difficult in a 'post-consumption', 'post-work' or 'non-work' environment in which owners of capital and labor are alienated and social cohesion threatened, not by excess Keynsian leisure but, rather, by too much unallocated time.

To combat degenerative incrementalism, higher entropy, and political and social drift, academics and policymakers in both market and command economies should substitute the prevailing idea of 'growth' with one of 'balance,' and treat labor futures as critical to humanity. Consequentially, and with strong empirical roots, the current article relegates the orthodoxy of 'optimism versus pessimism' for the compelling spectrum of realism/pragmatism versus illusion/denial. Assuming future research endeavor, it postulates a still open future around 'big picture' issues involving the four factor inputs which underpin *every* mode of production. In light of unexpected tipping points and systemic shocks, debate should test the labor scenarios and ask not only whether the radical / apocalyptic view is plausible but whether it is *inevitable*, as in a closed trajectory determined by unremitting globalization. In experiencing incremental through to paradigmatic technological change, any sustainable solutions will doubtless offer significant returns to

[24] A non-means tested, guaranteed public welfare entitlement for each adult.

individuals, institutions, economies and societies.

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