Capitalism in the age of robots: work, income and wealth in the 21st-century[1]

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My title is "Capitalism in the age of robots" and my aim is to consider the possible long-term impact of rapid technological progress – and in particular of work automation and artificial intelligence. And I will sometimes use the word "robots" as shorthand for any sort of machine – any combination of hardware and software – that can perform any sort of work, rather than specifically meaning something which looks like a human, with legs, arms and a smiley face.

I will argue that the rapid, unstoppable, and limitless progress of automation potential will have profound implications for the nature of and need for work, and for the distribution of income and wealth. But also profound implications for the very meaning of some concepts and measures which play a fundamental role in economic analysis – in particular productivity growth and GDP per capita. At the limit indeed, one can question whether the very concept of "an economy" or of "economics" – if defined as the study of production and consumption choices amid conditions of inherent scarcity – have any meaning in a world where, eventually, all human work activities can be automated.

And while the world of near total automation which I describe is still many years away – at least 50 and maybe 100-- I will argue that gradual progress towards that future state is already having and will increasingly have, profound, paradoxical and potentially harmful, as well as potentially beneficial, consequences. In particular I will suggest that:

- The faster the underlying pace of technological advance, the lower the measured productivity growth rate will be
- Automation threatens income from activities essential to human welfare – but not income gained from zero-sum competition
- The more rapidly information and communication technology progresses, the more that wealth and income derive from inherently physical and subjective assets, such as land, brands, or beauty.
- In already rich developed countries increasing productivity growth should not be a major long term public policy priority
- Better skills cannot solve the problem of rising inequality : but excellent education must enable people to live fulfilled lives as engaged citizens, and is needed to prevent a radical decline in social mobility

[1] An earlier version of this paper was presented at the Azim Premji University in Bangalore in October 2017

- Ageing and low fertility are small and manageable problems ; youthful and growing populations are no blessing

Most of my remarks will address the challenges in the already rich developed world . And here my essential message is that in a world where work per se is decreasingly required, we cannot rely on the free-market reward for different types of work to deliver acceptable social balance.

But I will also suggest that the challenges facing already developed countries pale into insignificance compared with those facing low income and high population growth countries hoping to follow the path of, for instance, South Korea and China towards middle and high income levels. In a world of radical automation possibilities, these challenges seem insurmountable, but we have to ensure that somehow they are overcome.

Structure of the lecture

I set out my arguments in six sections

1. When, not if. It is likely that we are in the early stages of a technological revolution which will eventually result in the automation of almost all economic activity, almost all work activities. When considering automation potential, the question is when, not if.

2. Explaining the Solow paradox Nobel Prize winner Professor Robert Solow famously commented that "computers are everywhere but in the productivity statistics". But there is here no inexplicable paradox since super rapid technological growth is bound to result in a proliferation of low productivity jobs, zero-sum competitive activities, and increases in real consumption which never show up in GDP statistics.

3. Meaningless measures in the Hi-Tech Hi- Touch economy Rapid technological progress will make GDP measures decreasingly useful indicators of improving human welfare and will have the paradoxical effect of creating an economy dominated by inherently physical and subjective assets and capabilities, and by zero sum activities, with income distribution strongly determined by asset ownership and rents

4. "Average is over"? In rich developed countries, rising income and wealth inequality is inevitable unless we choose deliberately offsetting policies.

5. The old ladder destroyed. Historical experience illustrated only one way to achieve rapid economic catch up – starting with low wage export-oriented industrialisation. In a world of robots, that old ladder will no longer exist.

6. Implications for economic theory. In a world of ubiquitous robots, many of the assumptions of neoclassical economics become decreasingly valid or relevant.

1.When, not if

There have of course been many previous waves of technological advance. But as Eric Brynjolfsohn and Andrew McAfee argue in *The Second Machine Age*, [Brynjolfsohn and McAfee 2014] a compelling case can be made that information and communication technology has features which make it likely to have a uniquely powerful impact.

Three factors in particular combine to produce that unique impact:

- First the sheer pace of hardware improvement along many dimensions, with processing speed, memory, and communications bandwidth all tending to develop in line with some variant of Moore's law – something like a doubling of capacity or halving of price every 18 months to 2 years or so. That process has given us all mobile phones with processing power many times more powerful than NASA used to put a man on the moon. And as Brynjolfsohn and McAfee illustrate through the powerful analogy of "the second half of the chess board", the really big impact is still to come.[2] If computing power doubles every 18 months, then in just under half a century (48 years, 32×18 months) it increases 4.3 billion times. But if it keeps on increasing at the same rate , over the next 48 years it increases another 4.3 billion times from a massively higher base. Even if absolute physical limits begin to slow the pace of progress, we will be able within 50 years to deploy unimaginably massive quantities of computing power, and as that computing power becomes available, multiple work activities which till now have resisted automation will become automatable.
- Second, the simple fact that once one copy of a piece of software has been written, the next million, or the next billion, or next 10 billion copies cost next to nothing.
- Third the progress of artificial intelligence, supported by massive computing power and by self driven machine learning, which as Nick Bostrom argues in *Super Intelligence* [Bostrom 2014] makes it inevitable that we will at some stage create combinations of hardware and software equal to humans in almost all aspects of intelligence . And, indeed makes it inevitable that once we have achieved that point, we will then progress rapidly to "super intelligence" far beyond human capability, since once a machine is more intelligent than a human, it will be able to learn faster, with no limits based on its learning ability by the gradual process of biological decay and eventual death which afflicts all human brains.
- Fourth the application of machine learning to specific activities, which means that we do not have to write code specifying how to lay a brick, or sew a shirt, but can

[2] The analogy refers to a myth about the inventor of chess who presented a chess set to an emperor. In gratitude for the wonderful new game the emperor asked the inventor what gift he would like in return . When the inventor asked for just one grain of rice for the first square on the board, 2 for the second square , 4 for the third and so on till square 64, the emperor, amazed by such a modest request, willingly agreed . By square 32 the emperor, now due to hand over 4.29billion grains of rice (about 120 tonnes) , was beginning to learn his mistake, but a great emperor could still afford that. But for the 64th square the due payment was 18.4 million trillion grains, or about 515 bn tonnes, almost a thousand times total global rice production even today.

simply move robot arms through the process, with the machine coding itself to achieve perfect future repetition.

Given these inherent technological characteristics, it is a reasonable assumption that eventually we will be able, if we want, to automate almost every activity which today we call "work" and for which people receive income[3]. And while "eventually" may be far away, it seems more likely to be 50 to 100 years hence, than in say 300 or 500 years time.

Obviously the process of automation will take time, and the pace will vary by category of work activity. A recent report by McKinsey Global Institute [MGI 2017] has attempted to identify which types of activity and which sub- elements of which jobs, might therefore be most susceptible to automation today, and how that might evolve over time. To do that analysis requires four steps:

- The first is to identify what types of fundamental capability, physical or mental, are most amenable to effective replication by a machine given current technology (Exhibit 1). Thus for instance "fine motor skills" requiring intricate dexterity (e.g. sewing) are today further away from being automatable than the gross motor skills required to drive a pallet truck and to pickup and deposit pallets in the correct place.
- The second is to identify which of these capabilities are required to perform different types of "work activity", and how much of labour force time is devoted to these activities. (Exhibit 2) This analysis shows, for instance, that 18% of all hours worked in the US are currently devoted to "predictable physical activities", and that 51% of these hours of human work could be automated away even with current technology. "Management" activities by contrast account for only 7% of all hours worked, and only 9% of this 7% is currently amenable to automation.
- Thirdly, one can map "activities" to occupational categories, and define a hierarchy of jobs more or less susceptible to automation (Exhibit 3) In the McKinsey analysis, sewing machine operators, and agricultural graders and sorters are significantly more vulnerable to automation than fashion designers, psychiatrists or legislators. And here we should note the crucial point that total employment in an occupational category can be significantly threatened even if no individual job could be entirely replaced (at least today) by machine activity. Each job involves a combination of activities, some more automatable than others, but it is possible to break the jobs into their different elements, automating some aspects of each job but not the others, but still ending up with lower total employment. The fact that a robot cannot not do everything which a particular human in a particular job does, might still leave 100 employees doing that type of job vulnerable to automation which would radically reduce the total number of jobs available.

[3] Note the fact that "we will be able to automate all existing work activities" does not mean that we will necessarily do so, nor does it mean that there must be either mass unemployment or a huge increase in leisure hours . Indeed as I argue later I think it highly likely that we will "find things to do " and proliferate new activities, and that most people in 2100 will still work for income , often perhaps as many hours as today. But I will also argue that the expanding potential for automation of the production both of existing goods and services and of future possible goods and services will still have a profound impact on the nature of our economy.

- Fourthly, McKinsey recut the jobs not by occupation but by sector of the economy, with, for instance, accommodation and food services far more susceptible to automation, at least today, than health and social services and education. (Exhibit 4)

Of course these findings reflect the precise assumptions made, and different analysis of the same broad sort can suggest somewhat different relative rankings. But the overall thrust of the McKinsey analysis is credible, as too are their scenarios for how potential and actual automation might evolve over time. Here we have to distinguish two different timescales (Exhibit 5):

- First the timescale over which it will become technically possible to automate an increasing percentage of existing work activity. Here McKinsey suggest that in a technologically optimistic scenario, the percentage could rise from 50% of all hours worked today to 80% by 2030 and approach 100% by 2045, while with slower technological progress, it might only rise gradually to 2045, but still reach close to 100% soon after mid-century.
- And second, the timescale over which technological possibility will be matched by actual technology application, given the possible trends in labour and capital cost and given the inevitable delay with which any technology diffuses across the economy. McKinsey's "Adoption" scenarios, suggest near complete automation of existing job activities somewhere between 2060 and 2100.

These scenarios are of course just that, scenarios, and one could challenge the specific timescales which McKinsey presents. But given the fundamental nature of information and communication technology described earlier, the debate is, I believe, simply about the precise position of the lines on Exhibit 5, not the eventual end point. The question is when, not if.

So for the purpose of this lecture I will not focus on precisely when near total automation might be possible , or how much might have changed by say 2030 or 2040. Instead I will make the assumption that sometime between 50 to 100 years from now near total automation will be possible , and that we are heading in that direction even if we do not know the precise pace : and I will consider what implications follow for the shape of our economy, for the meaning of key economic concepts and measures, and for how we ensure high-quality lives and cohesive societies in both the rich developed and still developing worlds.

2. Explaining the Solow paradox

But if we are in the early stages of an ICT driven wave of automation, why is measured productivity growth slowing down?

As Professor Robert Gordon has pointed out, the great years of productivity growth in the US economy were 1929 to 1970, long before computers had any significant impact on production processes, let alone artificial intelligence and robots (Exhibit 6). [Gordon 2016]

The subsequent 45 years have seen much slower growth. As Professor Robert Solow commented as early as 1987 [Solow 1987] "*you can see the computer age everywhere but in the productivity statistics*" and the experience of the last 10 years seems even more disconnected from the story of rapid and accelerating technological progress: from 2008 to 16, UK output per hour worked barely grew at all.

Does this illustrate at very least that accelerated automation has so far had minimal impact, and as a result cast doubt over projections of dramatic impact in future?

My answer is no. For as I shall argue in this section, it is quite possible that an acceleration in underlying technological progress, which allows us to achieve dramatic productivity improvement in existing production processes, can be accompanied by a decline in total measured productivity. This is because of three effects:

(i)The proliferation of multiple new low productivity jobs, or of higher value jobs not amenable to future productivity growth, which are taken up by workers no longer required in increasingly automated sectors

(ii)The rising importance as societies get richer of "zero-sum" economic activities, some of which are reflected in income measures of GDP, but some not, but none of which are essential to further progress in human welfare

(iii) The growing importance, particularly in a world of zero marginal cost software replication, of products and services provided at very low cost or for free, which are likely to be inadequately captured in measured productivity growth and GDP per capita

(**I)The growth of low and static productivity jobs**

When we think about productivity growth, many of us start with a standard mental model which involves increases in agricultural productivity and a shift from farms to factories. (Exhibit 7) We start with 100 farmers, producing 100 units of food, and somehow they work out how to become more productive – requiring, say, only 50 farmers to produce 100 units of food, and allowing 50 workers to move off the farms to the factories where they produce cars and washing machines and televisions and mobile phones, and do so quite as productively as the now more productive farmers – so that total economy productivity doubles.

In this standard model, productivity growth is an endlessly repeatable process. (Exhibit 8). That's because manufacturing is susceptible to productivity growth quite as much as agriculture, and because once workers begin to move not to yet more factories but to service jobs – in retailing, in restaurants, entertainment services - these sectors also achieve productivity growth through automation.[4]

[4] I should stress at this point that there is nothing in my arguments in this lecture which implies either that manufacturing output or employment is somehow inherently more important or valuable than service output, or that services as a broad category are unsusceptible to technology improvement. A restaurant meal is as valuable a contribution to human welfare as a washing machine : some services (e.g back office data

And despite what I am about to say, this model of endlessly repeatable productivity growth is still and will continue to be to some extent valid . I am sure we will continue to achieve some measured cross economy productivity growth. And indeed as I argued earlier, in the long run we may be able to automate almost all activities in all sectors of the economy.

But it is important to realise that in principle another development is possible.

- For if instead, once the farmers have become more efficient, those who remain farmers have no desire to buy manufactured goods from the now surplus labour, but instead only wish to employ them as domestic servants. (Exhibit 9)
- … then it is possible that the new domestic servants will receive less income than the farmers, their output valued at less per capita than each farmer's food production
- … so that total measured GDP and productivity will rise by less than the doubling clearly achieved in physical terms within agricultural.
- … and in this model , even if agricultural productivity continues to double in every time period, measured total productivity growth for the whole economy will eventually asymptote to zero if the new economic activity – being a domestic servant - simply cannot be automated. (Exhibit 10)

Rapid productivity growth in one sector of the economy, reflecting rapid technological progress, can therefore be combined with low overall productivity growth, if freed up labour moves into low productivity growth sectors. This indeed was Professor William Baumol's insight in a seminal article published 40 years. [Baumol 1967] Total productivity growth is as much driven by the productivity and productivity growth potential of the sectors into which workers move, as in the sectors where jobs are automated away. Rapid technological growth can be and often is accompanied by a proliferation of low productivity jobs.

And while Exhibit 9 and 10 illustrate this phenomenon in the case where all the new jobs are low-paid, it is also possible that the new jobs will be quite highly paid, but will still display little potential for future automation. Thus for instance, in Exhibit 11, suppose the 50 more productive farmers choose to have 45 low paid domestic servants, but also to employ five artists, singers, entertainers and fashion designers who are paid twice as much farmers. Then the immediate impact on measured productivity is more positive than in Exhibit 9, but the rate of productivity growth will still asymptote to zero over time, if painting, singing, entertaining and fashion design cannot be automated.

So we can have a productivity revolution in some sectors of the economy, combined, in extremis, with economy wide productivity growth declining towards zero over time.

Indeed it could be argued that that is what essentially happened in the aftermath of the first agricultural revolution, which developed in the fertile crescent of modern day northern

processing) are likely to see some of the fastest rates of productivity growth ; service jobs are as real and can be as satisfying and high paid as in manufacturing : and I think it almost inevitable that by 2100 all the factories in the world will employ no more than a minute share of all workers (maybe less than 1%) making any attempt to ensure a large share of "real manufacturing jobs" an impossible objective.

Iraq some 8,000 -10,000 years ago and which subsequently spread to other parts of the world.

- There was a revolution in agricultural productivity as people moved from being hunter gatherers and pastoralists to settled farmers with cultivated plants and domesticated animals ; feasible food production per acre and per person employed increased .
- … but there was no shift to a path of ever increasing productivity across all sectors
- …. and it seems likely that average living standards for the mass of the population actually declined [Scott 2017]
- … as the surplus created by increased agricultural productivity was absorbed by a proliferation of unautomatable jobs devoted to serving the owners or controllers of the agricultural surplus – whether in the form of huge numbers of low paid domestic servants and temple/pyramid builders, or smaller numbers of higher paid priests and skilled artists.

We had an initial productivity revolution in one sector, followed by overall productivity stagnation for several millennia thereafter.

We tend however to assume that this pattern will not repeat in the modern world, and in one respect we are almost certainly right to do so. For one reason why there was only a one- off spurt of productivity in the first agricultural revolution, is that human beings simply couldn't work out how to increase productivity in anything other than agriculture, whereas today we have processes of organised scientific discovery and entrepreneurship which continually identify ever more opportunities for technological advance and productivity improvement.

To some degree therefore the modern economy is bound to display some aspects of the standard paradigm shown on Exhibits 7 and 8.

But it is important to note that the balance between the endlessly repeatable progress shown on Exhibits 7 and 8, and the asymptotic process shown on Exhibits 9-11, is determined by three factors:

- The first, just noted, is whether in some fundamental sense, there is inherent potential to improve productivity in the "new sectors" and whether societies are clever enough to identify them
- The second, is what the initial productivity spurt in a particular sector does to the distribution of income,
- And the third, is how those who enjoy higher incomes as a result of the initial productivity spurt choose to spend their increased income

So that in the simple model of Exhibit 7 and 8:

- If the increased real income made possible by productivity improvement accrues entirely to the reduced number of remaining farmers, presumably because they enjoy ownership of land whereas the eventual non-farmers never enjoyed it or lost it during the transition

- …and if the farmers then choose to spend their increased income on domestic servants and entertainers rather than on buying cars or washing machines or automatable services
- ….we could observe a slowdown of productivity growth over time, even if society possessed the collective knowledge and capability to make cars, washing machines and automatable services if it wished

Theoretically therefore we could observe rapid and indeed accelerating technological progress in some sectors of the economy but declining productivity growth overall. And there are I suggest numerous indicators of this effect at work in modern rich societies and as well as in still low or middle income countries:

- Consider for instance the case of "Deliveroo" drivers in London, riding around town on that cutting-edge piece of technology known as the bicycle, to deliver whatever you want direct to your door (Exhibit 12)
- Or look at the US Bureau of Labor Statistics forecast for job creation by category between 2014 to 24, with 8 out of 10 of the fastest growing job categories paid far below the average wage, and with these jobs concentrated in those activities which at least for now we find more difficult to automate – personal care aides, home health aides, nursing assistants and cooks[5] (Exhibit 13)
- Or consider a recent report in the Economist magazine about factory automation in India (Exhibit 14), with the factory manager clear that production jobs are bound to disappear, but confident that he can "*somehow find jobs for everyone*", "as *drivers or watchman if necessary*", but almost certainly over time, at a considerably lower rate of pay. [The Economist 2017]

That phrase "somehow find jobs for everyone" captures indeed part of what goes on in a modern economy facing multiple automation possibilities. We find things to do and that means that the rate of measured productivity growth is far below what it could potentially have been.

For suppose in the Exhibit 7 and 8 example, all the farmers each owned property and each were equally successful, and each benefited equally from the increase in productivity. Then the result might well have been that everybody would simply work far less, leisure hours would increase significantly, and everyone would do their own domestic service. In which case measured productivity growth would be far more rapid and would continue at a constant high pace, as hours worked continually collapsed.

So part (though only part) of what is going on in modern rich economies today, is that ;

[5] In Section 4 I will suggest that some of these services (e.g. personal care aides) while low paid can be of great importance to human welfare, and that societies should choose to place a higher value on them than will result from free market competition in an world where cheap labour is plentiful because of rapid automation in many sectors of the economy

- We have extremely rapid progress of productivity growth in some sectors, which would show up as rapid and perhaps accelerating overall productivity growth if we chose to take the benefit in the form of increased leisure.
- … but that for a complex combination of reasons related to the distribution of income, the consumption choices of those enjoying higher income, and the incentives for everyone to seek a job even at a very low wage
- …we instead see a proliferation of low productivity jobs.

In addition, we see a proliferation of zero-sum activities.

(**ii)Zero-sum activities**

Let's return to the simple model and imagine another possibility. Farmers become doubly productive, the number of farmers falls from 100 to 50 producing the same amount of food, and of the 50 now freed up to become nonfarmers, 25 become criminals and 25 become police employed to defend the farmers against the criminals.(Exhibit 15)

What is the impact of this on income per capita, on human welfare, and on measured productivity ? There are two things worth noting:

- First, I think we can all agree that in some fundamental sense there has been no increase in human welfare – there is no more food per capita to consume: there are no new services other than "criminal services" and "police services", and nobody positively enjoys paying for "police services" or receiving unwanted "criminal services". There are no new activities of real benefit to human welfare (though of course the police services are essential to stop the criminal services generating a negative impact)
- And second, that the impact on measured GDP depends on GDP accounting conventions. In general these conventions tend to exclude criminal activity from GDP and to count various categories of public service at input cost. As a result the net impact of the changes shown on Exhibit 15 is that GDP does increase but not by as much is in the standard model shown on Exhibits 7 and 8, where non farmers entered factories and produced manufactured goods.

So it is possible that rapid productivity improvements in a particular sector of the economy unleashes a proliferation of "zero-sum" activities, in which different people compete against one another for a share of the economic cake, but where all of their activity adds not at all to the sum total of goods and services which are capable of increasing human welfare.

And it is striking how many activities in a modern economy are to a degree zero-sum in nature, or as the economist Roger Bootle describes them "distributive" in their impact on total prosperity, rather than "creative". [Bootle 2009]

Look around the modern economy and think about the following activities :

- Very clever cyber criminals and the army of very clever cyber experts employed to defend against their attacks

- Legal services :
    - Whether in the personal sector: divorce lawyers or compensation lawyers pursuing claims for accident, medical malpractice, or financial misselling
    - Or corporate sector lawyers protecting intellectual property rights or defending against the malpractice suits
- Tax accountants and tax lawyers employed to minimise tax payments, and government tax officers trying to control them.
- Marketing and advertising executives and communication consultants , devoting their skills to convincing us that product A is better than product B , cause A better than cause B
- Much of financial trading and some of asset management, where studies show that unnecessary churn can add unnecessary cost and that active management often adds no value over index investing
- The huge computing resources absorbed in Bitcoin mining, which by some estimates consume 30 terrawatt hours of electricity per annum , as much as Morocco's entire annual consumption
- Financial regulators and the increasing army of compliance officers and auditors
- Much corporate finance activity, focussed on deals which (even in terms of narrowly measurable shareholder value) often create no enduring value , but absorb the high talent energies and provide the high incomes of numerous investment bankers, lawyers, and senior executives.
- Many talented and committed people working in think tanks and the policy arms of NGOs, seeking to persuade us that policy A is better than policy B and that noble cause A is worth supporting
- The multiple government officials required to design and administer multiple public policies at national, regional and local level
- The large numbers, particularly in the US but growing elsewhere, of professional political campaigners, lobbyists, and communication experts devoted to ensuring that one politician succeeds versus another (to the benefit of one set of constituents versus another) or to gaining influence on policy or commercial advantage versus other firms. And the sophisticated data analytics, which firms such as Cambridge Analytica provide to support this activity

Most of these activities are legal: some may be admirable ; and all of them are inevitable within a free-market and democratic society in which ideas and market propositions can compete; but all of them to some degree have a "distributive" character, in the sense that the application to them of greater human talent and energy does not produce more goods and services of inherent value to human welfare, but ensures that, for instance, one side in a legal case, a political argument or a market prevails against another.[6]

[6] It is fair bet that many people reading this list of zero-sum distributive activities will find some examples more intuitively obvious than others, and that the reaction will reflect political ideology. To many left wingers it will be obvious that some financial activity and quite a lot of advertising is "socially useless" : to many right wingers it will be equally clear that regulators and bureaucrats are a dead weight cost and that to achieve productivity growth we must minimise their numbers. But in fact zero sum activities can be found in public and private

And while I suspect that most readers will be willing to accept that at least some of the activities described above are to a degree "zero-sum" in nature, even activities which would seem to have more inherent value to human welfare, or to be more inherently "creative", are also to a degree zero-sum/distributive in nature. Thus

- Good education is precious in of itself, and better education may build "human capital" which delivers individual and collective economic benefits. But as thoughtful experts such as Alison Wolf point out, higher education in particular can also play a role as a very expensive form of job market signalling – you go to a top university in order to signal that you have the abilities to get there. [Wolf 2016] And universities in turn, particularly in the US but increasingly elsewhere, can get caught in a competitive arms race of increasing expenditure and increasing fees, to ensure that they are the most highly ranked job market signalling centre, in turn generating ever increasing levels of student debt, but with no certainty that aggregate human welfare is increased.

- And fashion design is to degree a creative artistic process; and in rich societies where more basic human needs are already met, it has an intrinsic value, adding to the variety and enjoyment of human life. But while I would rather live in a world where companies are free to compete for our attention for the latest fashions and brands, we have no reason to believe that the fashions or brands of 2050 will make human beings on average any happier or more fulfilled than in 2018. Fashion competition is an endless circular process, and the fashion designers and marketing experts are to a degree involved in a zero-sum competitive process, each trying to outcompete the other for our attention and wallet.[7]

The extent of activities which are zero-sum/distributive (and we should note that any one activity can be part creative and part distributive) thus reaches far beyond the most obvious cases –such as cyber criminals and the cyber experts defending against them.

And in their impact on measured GDP, human welfare and personal incomes, the zero-sum activities have three interesting features.

Arbitrary impact on GDP . First their impact on measured GDP is somewhat arbitrary. Divorce lawyers are in GDP because they are paid for out of personal income, even if an increase in the skill and price of divorce lawyers cannot increase human welfare, given that the impact of better lawyers on both sides cancels out. But if lawyers (or accountants or cyber experts) are employed within the corporate sector, their activity does not contribute to GDP.[8] So if we get a proliferation of those zero sum activities which happen to be

sectors, in charities and companies, in left wing and right wing think tanks, and can involve the application of multiple different skills across all conventionally defined sectors of the economy

[7] Fashion design can also be seen as an example of the higher paid variant of unautomatable activities – priests and entertainers – referred to on Exhibit 11. The categories of unautomatable and zero sum activities are not absolute and mutually exclusive – any individual activity can be part zero sum (distributive) and part value creating, and can be either largely non automatable or susceptible to different degrees of automation

[8] Note that while the labor compensation paid for these legal services (or for any other category of zero sum activity) is included in GDP, total GDP does not increase as a result since either (i) there is an offsetting

"intermediate" rather than "final" goods and services , we can have a drag on the growth of total measured GDP and productivity, even if

- in some welfare producing sectors of the economy (producing goods or services that deliver true increases in human welfare) rapid productivity growth is being achieved
- and even if information technology is also being applied ever more effectively to the zero sum activities – even if for instance , artificial intelligence is being used to enable lawyers ever more effectively to analyse all relevant precedents .

High skills and high incomes Second, it's quite striking what a large proportion of these zero-sum activities are well-paid, and as a result how much high quality human talent is devoted to competing for the distribution of the total income available, rather than to producing valuable end products or service consumed in the current year, or to the processes of scientific research, technological development, capital investment, or process redesign which might increase the flow of valuable products and services in future.

Less vulnerable to automation Third, focussing on zero sum activities may be a very rational career choice for high talent people, not only because the jobs are high-paid, but also because they may be less susceptible to being eliminated through automation. This is not because information and communication technology cannot be applied to these sectors – there is huge potential to use advanced AI and big data analytics in legal services: but because the long-term impact of applying AI is different as between essential and zero-sum activities and in a quite paradoxical way:

- If we use advanced technology to automate predictable physical activities – in, for instance, agriculture, manufacturing, distribution and warehousing, or cleaning hotel rooms - the number of jobs in those activites will almost certainly fall over time, as increased productivity outweighs our desire for increased total consumption of the end products and services supplied
- But if we apply artificial intelligence to search for all legal precedents relevant to a case,that might have no impact on the total number of highly paid divorce or corporate lawyers, but simply mean that the intensity with which they research each case ever increases. Precisely because this is a zero-sum activity, in which what matters is not how most efficiently to produce a defined product or service, but how effective one side is versus the other, there may be literally no limit to how much processing power lawyers will use in support of human judgment, and the jobs and income levels of top lawyers may well be safe, even if at a more junior level manual search activities are automated away.

Thus paradoxically, radical automation:

- May eventually reduce towards zero the number of people involved in those economic activities essential to produce the goods and services which support human welfare

decrease in the Gross Operating Surplus of companies (the other key component of GDP) ;or (ii) Gross Operating Surplus is maintained because the additional corporate costs of employing lawyers/cyber experts etc. is recovered via higher prices for end goods/services, so that while nominal GDP increases, higher inflation means that no increase in real GDP occurs.

- .. while having no such impact on the amount of human labour devoted to zero-sum activiti
- … which may therefore grow in relative importance as we "find things to do"

Now let me at this point clarify one thing: it may seem that I am disparaging "zero-sum activities" and suggesting that all the lawyers, cyber security experts, regulators, financiers, private tutors, think tank policy experts, politicians, advertising executives, communication consultants and fashion designers, should cease what they are doing and become nurses, doctors, construction workers or research scientists.

Well, no I am not saying that. If I was, I would certainly be disparaging myself, since a significant part of all my work activity throughout my career has been devoted to zero-sum activities, and much of my income and wealth has derived from them. Many zero sum activities are admirable : many idealistic young people, for instance, work for less than they could earn elsewhere in policy oriented charities and think tanks promoting causes in which they passionately believe. And indeed I think it is absolutely inevitable that zero-sum activities account for a large amount of human work activity, and almost certain that over time, as technology enables us to automate an increasing share of the work activity required to deliver human welfare, an ever-increasing proportion of all economic activity will be essentially zero-sum[9].

- As we get ever more productive, there are bound to be fewer people employed[10] in producing all the goods and services required to deliver welfare enhancing goods and service
- So that unless we take the benefit of increased productivity in the form of increased leisure we must in aggregate "find new things to do"
- And there is a natural tendency rooted in human nature, for us to compete with other people for relative status ; and even if one individual were free from that desire, to the extent that others wish to compete for relative status, he or she would still need to compete to enjoy any product or service which is to be degree positional and in inherently scarce supply– in particular attractively located property
- And political processes necessarily involve competition between competing ideas, and it is better to have that competition than not, even if more money and more talented resources devoted to that competition cannot produce a better result since the efforts on each side simply cancel out.

[9] Some economists and policy makers recognise the existence of distributive activities and growth of distributive activities but argue that if only we made markets more competitive and efficient such distributive activities (and many categories of economic rent) would disappear. The implication of my argument is that the potential impact of such policies is greatly overstated. For while I accept that there can be a useful role for policy which somewhat reduces the intensity of zero sum competitive activities (e.g. US tort reform would be very desirable and so too might Tobin taxes on trading activity) I believe that the growth of zero sum activities is an inevitable consequence of the pace of potential productivity improvement combined with the inherent tendency of human beings to engage in status competition and to disagree about how economic resources should be distributed and other political choice issues resolved.

[10] By "fewer people" here , we should mean "fewer full time equivalent people" , recognising that each individual person's work activity may be part zero sum (distributive) and part creative

- And I would rather live in a world of competing fashions and brands, even if I know that much of that competition cannot possibly deliver a permanent increase in human welfare

All of which implies carries important implications for optimal public policy to which I will turn in Section 4. But to sum up the impact on the implications of zero-sum activities for the Solow paradox:

- If the percentage of activities which are zero sum increases over time
- … and if, rather arbitrarily, some count as intermediate rather than final consumption for national accounting purposes
- …that could explain a slowdown in measured productivity growth
- …. even if <u>every single activity</u> (non-zero-sum or zero sum) was susceptible to and actually experiencing ever more rapid automation

(iii) Nil or low cost products, services and benefits

The first two effects which I have considered may seem to suggest a somewhat pessimistic outlook for the impact of technological progress on human welfare. We get a huge acceleration in human ingenuity, in our ability to automate economic activities and dispel the need for work, and instead of an accelerated increase either in human welfare or leisure, we get a proliferation of low paid low productivity jobs and of zero-sum activities, as we all keep working hard, but without a commensurate improvement in aggregate human welfare.

But the third effect potentially goes the other way. For it is also possible that our measurement of GDP and productivity severely <u>underestimates</u> the benefit to human welfare of great breakthroughs in knowledge and productivity.

Imagine that sometime in the next 50 years, a small number of very clever people, supported by ever more powerful computers, and by self- generating forms of artificial intelligence, manage to create a suite of wonder drugs which enable all of us with absolute certainty to live until we are 100 years old, with disease-free lives. No children dying before they reach adulthood ; no middle-aged deaths from heart attacks ; no debilitating diseases like multiple sclerosis or Parkinson's ; no pain from rheumatism: no gradual loss of mental capacity from Alzheimer's. We would all surely agree that this would be an enormous benefit to human welfare.

But let's consider how the production and sale of these wonder drugs would appear in estimates of nominal and real GDP over time.

First let's focus on nominal GDP and let's assume that the drugs are developed by private companies and sold initially under patent protection. The sequence of impacts on nominal GDP would be as follows. (Exhibit 16)

- In the period of initial research and development, the earnings of the scientists and their assistants and related expenses might show up in GDP if the salary cost were capitalised, but not if it was expensed.
- Then we get to the period when the drugs are sold under patent protection; and here the sales revenues mean that a large money value is added to nominal GDP, reflecting not just the production cost but a significant rent payment to the pharmaceutical company to cover its intellectual property right and recoup its development spend.
- Finally however, when the drugs come off patent, the price collapses, and what is left in nominal GDP is simply the cost of manufacture, which in an era of ever greater automation will relentlessly decline towards zero.
- At which point a hugely important contributor to human welfare will account for only a minuscule proportion of nominal GDP and almost nil employment, while, elsewhere, lots of zero-sum activities account for far greater employment and in some cases also enter GDP.

But now let's consider measures of real GDP. Will the huge benefit to human welfare show up there? The answer is perhaps, but that whether and to what extent will depend on some public policy choices, on pricing during the period of patent protection, and on how effectively government statisticians capture the impact of rapid price declines in their estimates of general inflation (the "GDP deflator" which converts nominal GDP trends into real). Thus:

- If the price in the initial patent protected period is very high, and if estimates of the GDP deflator take full account of the dramatic reduction in price which occurs when the drugs come off patent, then these wonder drug may produce a big and sustained increase in measured real GDP even if, in the long term, they play hardly any role at all in nominal GDP.
- But if calculations of GDP deflators imperfectly capture the scale of the post-patent price decline, the huge increase in human welfare may be underestimated in measures of real GDP
- And if instead of organising drug R&D via private firms with patent protection, we paid for it out of public expenditure , and set the initial price to be just sufficient to recoup the costs of development (Exhibit 17); or if we regulated the private patent price below what the market would support (but sufficiently high to incentivise the development);

  .. then the value entering nominal GDP would be less, and the subsequent price decline less, and the resultant impact on real GDP and productivity growth less

  … even though the human welfare benefit would be just as great as before (and perhaps higher if a lower initial price enabled a larger number of people to afford use of the drug earlier)

Thus in a world where potential increases in human welfare derive primarily from improved knowledge of how to produce some good or service, with the subsequent marginal cost of actually producing the good or service close to zero and forever falling, estimates of real

GDP per capita, and of real productivity increase, are crucially dependent on the details of GDP accounting conventions, and on our treatment of intellectual property rights.

And it is therefore in theory quite possible that massive productivity improvements, hugely beneficial to human welfare, might not be reflected adequately in measured GDP.

So how effective are our processes for assessing all the price changes that should logically enter the GDP deflator and thus our measures of real GDP and productivity growth over time?

Professor Martin Feldstein has argued persuasively that they are very imperfect. [Feldstein 2015] Indeed having looked at the complexity of the calculations required, he concludes that the task is "*impossibly difficult*". And having looked at what government statisticians actually do, he argues that they are almost bound to underestimate the scale of productivity improvement.

While avoiding any precise quantification he therefore concludes that "*the result is that the increase in real incomes is under estimated, and that the common concern about what appears to be the low growth of average household incomes is misplaced*", since "*these low growth estimates fail to reflect the innovations in everything from healthcare to Internet services to video entertainment that have made life better during these years"*

I agree with much of Feldstein's analysis, but with an important caveat to which I will return in Section 4. For while I think it is clear that measured total economy productivity growth – dependent as it is on imperfect price adjustment calculations – can fail to reflect the speed of innovation and productivity growth in specific economic activities, I think we need to be more careful about assuming that those innovations have always "*made life better during these years*".

Innovations in health clearly have that effect. But let's consider instead the dramatic explosion in the computing power and communications capacity embedded in our mobile phones, in Internet services such as social networks, and in computer games. What is undoubtedly true is that in each of our pockets and on our desks, we have computing power massively greater then NASA deployed to get a man on the moon in 1968: and that the price we pay has collapsed (in some cases effectively to zero), endlessly reducing the apparent importance of these services within nominal GDP: and that our statistical methods for estimating this price collapse and thus for estimating the growth of "real output" might well fail to capture this explosion in productivity.

But if we ask a separate question – are today's children, equipped with computer games and with access to social networks of a technological power unimaginable 30 years ago, happier, more fulfilled, and less stressful than children 30 years ago, it is not certain that the answer is yes ; some commentators indeed would argue that there have been significant adverse welfare effects.

So that is important to recognise two <u>quite separate</u> questions:

(i) do statistical measures of real GDP per output tend to indicate less rapid technological progress than is actually occurring,

…and then separately…:

(ii) is the impact of that technological progress a clear positive for human welfare

And it is possible for the answer to (i) to be "clearly yes", while the answer to (ii) is "sometimes yes" (healthcare innovations) and "sometimes perhaps no" (ever more complex computer games)

For this and other reasons to which I will return in Section 4, I believe that Martin Feldstein is wrong to conclude that the underestimation of underlying productivity growth in measured GDP statistics means that concerns about stagnant real wages are necessarily "misplaced".

But leaving discussion of that issue till later, the implications of these "nil or low-cost benefits" for the Solow paradox is clear. One of the reasons why "*computers are everywhere but in the productivity statistics*" is that our estimates of real productivity growth fail to account effectively for some of the most dramatic increases in productivity.

The three effects combined – an illustrative quantification

The three effects combined can easily explain the Solow paradox.

Their impact is course one of degree only – they do not mean that no measured growth occurs. Many new activities to which surplus labour moves can in themselves be automated; many growing activities across the economy are not zero-sum in nature; and a significant proportion of the benefits flowing from falling prices for some goods and services are captured in measured GDP.

But it seems certain that the effects are powerful enough to explain the apparent paradox of expanding opportunities for automation combined with mediocre and declining productivity growth. For quite modest assumptions about the extent of these effects can explain significant reductions in measured productivity. Thus:

- If over a period of 25 years, the proportion of workers employed in low-wage and (at least for now) non-automatable activities grew from 10% to 20%, this would produce a productivity growth rate averaging 1.6% (and declining gradually over time), even if in the vast majority of the economy which could be automated productivity growth continued at an unchanged rate of 2% per annum.
- Similarly, if over 25 years, zero-sum activities grew from 20% of economic activity to 30%, with 50% of zero-sum activity reflected in GDP but 50% not, measured productivity growth would equal 1.77% even if every activity in the economy, considered in itself, enjoyed 2% per annum productivity improvements. Meanwhile total growth in the end products and services relevant to human welfare would grow at just 1.46% per annum

- Finally, if over 25 years high-tech sectors accounting for 20% of the economy achieved productivity growth of 5% per annum, delivering ever greater product quality at a declining price , and if imperfections in GDP calculations meant that a third of this growing output was not captured in estimates of real GDP, an underlying total economy productivity growth rate averaging 2.4%, could be combined with a measured productivity growth rate of only 2.0%

Each of the three effects separately considered can thus have a material effect on total measured productivity growth. In combination, they could explain much or all of the Solow paradox. Thus as the illustrative quantification on Exhibit 18 sets out, it is possible to imagine a set of not absurd parameter values such that :

- Productivity growth slowly rising form 2.5% to 2.7% in the automatable sectors of the economy
- Would result in an aggregate measured productivity growth rate slowly decreasing from 1.9% to 1.5%

Crucially too if the pace of growth of the unautomatable and zero-sum activities were themselves functions of productivity growth in all the automatable sectors, with more rapid automation freeing up more workers to perform low-wage and zero-sum activities – then an acceleration of potential productivity growth could produce a slowdown in measured productivity growth.

We do not therefore face an inexplicable paradox, but rather something seemingly counterintuitive but in fact almost inevitable:

- That if we live in a world of accelerating technological progress, with eventually limitless potential to automate jobs
- … it is almost inevitable that we will also observe a slowdown in measured productivity growth

Solow's paradox is exactly what we should expect to see. And it is likely to apply in future even more strongly than over the last few decades.

3.Meaningless measures in the hi-tech hi-touch economy

The three effects which explain Solow's paradox have always been present to some degree. Industrialisation in 19th-century Britain was accompanied by a rapid growth in domestic service employment. A significant proportion of all human work activity has always been zero-sum in nature. And GDP measures have always been imperfect.

But it is highly likely these effects increase in importance as we get richer, and as technological progress accelerates.

- As we get richer, we approach satiation in the consumption of many goods and services whose production can be relentlessly automated – there is a limit to how many cars and washing machines we wish to buy- and the more we reach those

limits the more that labour must inevitably shift to activities which cannot be automated

- As we get richer too, competition for relative status becomes a more important determinant of individual personal welfare , and that may increase the intensity of zero-sum competition
- And while real GDP measures have always failed to capture many improvements in human welfare, the distinctive features of information and communication technology - collapsing hardware costs and zero cost software replication – greatly increase the potential for under-measured productivity improvements.

Increasingly as result we live in a world in which

(i) Our standard assumptions about how to measure economic and human welfare progress are breaking down

(ii) And in which the measured economy becomes dominated not by the production of welfare enhancing goods and services, but by non produced assets, rents and distributive games

Standard assumptions collapsing

Economic policy is usually based on the assumptions that (Exhibit 19)

- Technological potential can and will drive productivity improvement across all sectors of the economy
- The impact of this productivity growth is well captured in standard measures of real GDP and of output per hour worked
- The growth of GDP per capita is closely correlated with improvements in human welfare

Of course this logic was never believed to be absolute: good economics always recognised qualifications to each of these assumptions. But in the developed world until a few decades ago, and still in much of the developing world today, these assumptions may well have been "good enough" to provide a reasonable guide for policy.

- For when people first move from farms to factories and then from gradually automating factories into newly emerging service sectors
- …so that for the first time in history people can own cars, washing machines and televisions and enjoy piped sewage systems, restaurant meals, and hotel stays by the beach
- …it may be broadly true that underlying productivity improvements of say 3% per annum are reflected in measured per capita income growth of around 3%, with human welfare also improving quite rapidly, so that each generation feels better off than the one before.

But these assumptions are becoming far less secure in a world where there are many activities counted in GDP which cannot possibly increase human welfare, many benefits to

human welfare not counted in GDP, and where rapid productivity growth in some sectors of the economy is increasingly offset by the proliferation of low wage jobs elsewhere.

As a result our standard GDP measures are becoming both:

- Less meaningful indicators of the underlying pace of technological change
- And less useful indicators of increases in human welfare

Rents , games and unproduced assets

To understand the impact of change in a particular direction it is sometimes useful to consider what would follow if that change continued to its logical extreme.

So consider a deliberately extreme vision of how productive activities might be organised within a developed economy in 2100.

Substantially all of the work activities which deliver the current goods and services required for human enjoyment are performed by "robots"[11]. Solar powered robots, built by other robots, guided by software written by AI systems, do all of the mining and manufacturing, all transportation and wholesale and retail distribution, all cleaning of buildings and sweeping of streets , and all the data collecting and processing activity needed to provide us with the goods and services which we enjoy consuming. All houses can be and are largely are built by robots : all gardens could if we wanted be weeded and mowed by robots ; and most medical processes are better performed by robots than by humans – all surgery, all radiological analysis, and all pathology tests.

What then does this economy look like in measured GDP terms - indeed does it meet our definition of an economy at all?

Paradoxically at first glance, I suggest it will be an economy in which asset values, personal and corporate incomes, and therefore GDP aggregates, are dominated by property values and various forms of rent ; in which employment is dominated by low-wage face-to-face services : and in which measured productivity growth – whether looking back or forwards - will be very slow, unless increased leisure has driven a major reduction in average hours worked. And while the extreme end point is far off and may never be reached, we are already seeing signs of a move in that direction.

Non produced assets. In a world where all current goods and services can be produced at ever collapsing prices, the relative value of desirable things which are inherently uncreated, such as land in desirable locations, will almost inevitably increase. As Thomas Piketty's analysis illustrates, developed economy wealth to income ratios have increased dramatically in the last 50 years [Piketty 2014] ; almost all that increase is explained by rising property

[11] I reiterate here the point I made at the very start of this lecture – by "robots" I do not mean something which necessarily looks like a human, with legs, arms and a smiley face , but rather any "machine" – any combination of hardware and software capable of performing work activities .

values (Exhibit 20), and almost all that rise is in turn explained by rising land values. [Schularick 2014] And as the UK National Income Accounts show, over the last 20 years, the vast majority of the increase in Britian's national assets has been explained not by the process of capital accumulation which standard economics describes, but by growth in the value of "unproduced assets" of which 95% is land. (Exhibits 21 and 22) In the hi-tech world of limitless automation possibilities, this rising relative price of the most physical thing of all- land - is likely to continue. But so too is the divergence in land values between different neighbourhoods, cities and regions, as richer people , for whom most current goods and services are trivially cheap, devote an increasing share of their income to competing with one another for the right to own and occupy houses or apartments in the most attractive locations or in the cities where the highest paid jobs are available.[12]

Property rents If property values increase relative to current prices , so too will property rents, delivering increased rental income to landlords ,and increasing the proportion of measured GDP which is accounted for by either actual or notional (i.e owner occupier) rents.

Intellectual property rents. In a world of extreme automation potential, huge rents are likely to flow to a very small number of individuals and corporations, but with the precise amount strongly determined by the rules on intellectual property rights which societies choose to apply. If the very small number of very talented IT experts or companies who develop particular forms of artificial intelligence to support the production of particular goods and services, are able to establish long-lasting property rights to the technology or application, they will receive huge incomes, and those rents will be counted in GDP even if the current cost of manufacturing those goods and services is close to nil. But if intellectual property rights are more strictly limited - either in terms of the category of innovation to which they can apply or length of time for which they last - both the individual incomes and the rents counted in GDP will be greatly reduced.

Games, creativity, subjective values and stardom. Returns to stardom, to design, to brands and to inherent physical skills will also likely increase. Yes it will be possible for a team of robots to beat Manchester United, but the relative income of human football stars is likely to increase as their fans, enjoying many of the necessities of life at almost zero cost, will be able, to devote a still greater share of income to following their heroes, whether directly through ticket purchase or indirectly through the purchase of celebrity endorsed products. And yes it will be possible to buy perfectly adequate clothes at almost zero cost, but the very fact that many necessities are trivially cheap, will increase the disposable income which can be devote to the purchase of high fashion clothes or accessories which capture people's

[12] The phenomenon of rising property prices in elite cities, with major implications for affordability, for inter generational equity and for future social mobility , is already quite strikingly global. The Financial Times reports that lower paid workers in California are being "*priced out of the American Dream*" [Financial Times 2018] : China Daily runs frequent articles about huge apartment price-to-income ratios in leading cities such as Shanghai and Shenzen [China Daily 2018]; and a UK Resolution Foundation report shows how home ownership among younger age cohorts has collapsed most dramatically in London (from over 50% for 25-34 year olds in 1984 to 17% today) , with real weekly expenditure excluding housing falling over the last 15 years.[Resolution Foundation 2018]

imagination via design or branding . The pay of successful fashion designers will be huge and implicit rents paid to the owners of well nurtured brands will increase alongside those paid for real estate and intellectual property.

Zero-sum activities. In a world where most necessary production tasks are fully automated, a rising percentage of all human activity, in particular high talent human activity, will probably be devoted not to welfare enhancing products and services, but to zero-sum competition for the distribution of property, rents and political power. The relative importance of all the zero-sum activities described in Section 2ii is likely to increase. There will be more cyber criminals and cyber defenders, a still greater share of US GDP devoted to fighting elections unless constrained by new campaign finance laws, and top divorce lawyers will command ever higher incomes.

Low-wage unautomated activities. But in terms of sheer numbers of people, and as long as people need to work in order to earn adequate income, employment will likely be dominated by low-wage jobs performing activities which still cannot be automated , or which we choose not to automate even though we could. In the very long run, higher income earners will in theory not need human workers to serve at their parties, mow their lawns, clean their houses , or look after them in nursing homes . But if people simply prefer to be served by other humans, and/or if low-paid workers need to offer their services at very low wages to secure adequate income, numerous categories of low-wage unautomated activity will continue to be a permanent feature of the economy long after the point at which they could in theory be automated.

Measured productivity. And if that is the case, measured productivity growth may be low even if each year an ever smaller number of human beings is required to supervise the robots which produce almost all of the goods and services important for human welfare. Unless that is, we have chosen by then to take the benefits of technological progress in the form of increased leisure. For if instead of proliferating low wage or zero-sum activities, everyone in 2100 chose to work just five hours a day, the economists of 2100 would likely be talking not about an ever present Solow paradox, but about the productivity miracle which information and communications technology had unleashed over the previous century.

Obviously we are far from this 2100 vision today. But even if we are simply beginning to move slowly in that direction, even if, as it were, each decade brings us 5% closer to this envisioned end point, that would still have profound effects on the distribution of income and the nature of jobs, in both developed and developing economies, with important implications for appropriate public policy.

4. Developed economies : "Average is over"?

The fundamental problem created by rapid and accelerating technological progress is often described as one of employment – "*where will the new jobs come from* ?". And when I turn in Section 5 to the developing world, I will suggest that this is a crucial and pressing concern.

But in the rich developed world, the most important issue is almost certainly not jobs but incomes. For despite the presence of underreported productivity improvements and unless we design deliberate policy responses, we are almost certainly heading towards a world of steadily rising inequality to which the standard default response – give everyone better skills- will prove an inadequate response.

Incomes not jobs

Some people fear that automation means mass unemployment. Others reassure us that we have seen waves of automation before and that prophets of technological unemployment have been proved wrong in the past. Some of the arguments put forward by the optimists are unconvincing, but in the long run they are right that there is no limit to how many jobs can in principle be created.

- The least convincing argument is to point out that a specific individual company (e.g. Amazon) has itself "created jobs" (i.e. increased its own number of employees), ignoring the fact that the total number of jobs in all of retailing – physical and online combined - is now falling.
- Nor is it convincing to argue that the growth of a profitable firm or sector "*creates jobs in the rest of the economy*" simply because income earned in one job, company or sector is spent on other products and services. All economies involve an endless circular process of earning and spending, but that obvious fact tells us nothing about the equilibrium level of employment relative to the working age population. Even in an economy with massive unemployment, all the income earned in one job or sector would be spent to buy output from others.
- But there is a reasonable argument that provided labour markets are flexible and nominal demand maintained at an adequate level , and after some (potentially significant) adjustment period, there is no inherent limit to the number of new jobs which can emerge to absorb labour made redundant from existing processes. If people have to work in order to gain income, if there is no floor to allowed wage rates, and if fiscal and monetary authorities ensure a moderate rate of growth of nominal GDP, sufficiently low prices will eventually induce demand for new service provision. At some wage rate, Deliveroo services will be profitable and will create jobs.

But in a world of ever increasing automation potential, that full employment equilibrium may be accompanied with ever rising inequality, and there are signs of that trend already at work. For over thirty years, incomes have diverged from the median at both the top and bottom of the US income distribution, (Exhibit 23) and rapid technological progress is almost certainly one of the drivers of that divergence.

- At the top end of the income distribution, returns to high skill in the development and application of information and communications are and will remain huge. But they are likely to be concentrated in the hands of the small number companies and individuals needed to create all the software and apps needed by our increasingly automated economy. The giant dominant software and application companies of the

Internet age create huge equity value and sky high incomes, but with a startlingly small number of employees. (Exhibit 24)[13]

- In the middle and bottom of the income distribution, meanwhile, the fact that predictable physical jobs are the easiest to automate, will mean continued significant job losses, and it is likely that many of the workers displaced will only find new jobs in the low-wage sectors of economy illustrated by the BLS figures on Exhibit 13.

Nor should this technologically driven tendency towards increasing inequality surprise us, for we have been here before. The word "luddite" is frequently used in a derisive sense, signifying people too dumb to realise that while technology destroys some jobs, new employment opportunities continually emerge. But in their analysis of the potential distributional consequences of new machine deployment, the handloom weavers of the 1820s who joined Ned Ludd's campaign of machine destruction were entirely rational. For the first 30 -40 years of the 19th century industrial revolution, labour's share of UK national income fell precipitately , and real wages stagnated despite significant productivity improvement driven by factory automation. [Allen 2009] And if the steam driven factories had never been developed, many individual handloom weavers would have enjoyed higher real incomes throughout their lives. Smashing machines was rational, even if ineffective because technological progress could not in reality be halted.

Without countervailing policies, rising inequality may therefore be the inevitable consequence of our increasing ability to automate existing work activities. And rising inequality might be undesirable, both for intrinsic reasons ,and because likely to drive strong and potentially harmful political reactions.

Two arguments are however advanced against these hypotheses.

<u>Unmeasured benefits to the rescue ?</u>

The first is Martin Feldstein's argument already considered , in which he suggests that that real income growth is seriously underestimated, and that "*the common concern about what would appear to be low growth of average household incomes is misplaced*" since income estimates "*fail to reflect the improvements in everything from healthcare to Internet services to video entertainment that have made life better over the last few decades*"

On this, I am unconvinced for two reasons:

- First because, as argued earlier, while the impact of technological advance on the production of goods and services may not be fully captured in measures of real GDP and productivity, some of that missing productivity growth may not deliver improvements in human welfare. There are two logical steps in the standard assumption model shown on Exhibit 19, and <u>both</u> may be increasingly breaking

[13] The only Internet based giant whose total employment is at all comparable with the major global companies of the old economy is Amazon, with 566,000 employees and a market cap of $823bn, but this is still small compared to the 2.2million employees of Walmart worldwide and the overall impact of the shift from bricks and mortar retailing to on-line retailing is a huge reduction in total employment

down. Under-recorded improvements in healthcare may truly be delivering improvements in human welfare not present in measures of real GDP. But whether life has truly got better as a result of always-on mobile phones, more sophisticated computer games, and the spread of social networks is debatable: equally reasonable people could easily argue that the effect has been positive, negative, or net neutral.

- And second because, even when it is clear that an under-recorded productivity improvement is also an unmeasured benefit to human welfare, that may not provide a full answer to the social stresses created by increasing inequality in monetary income and access to positional goods. Suppose that by 2100 my imagined wonder drug has been introduced and everyone enjoys 100 years of healthy life. Clearly that would be a big advance for human welfare, even if the production of the drug by then accounted for no more than a minuscule proportion of GDP. But I strongly suspect that the citizens of 2100 will simply assume that those 100 years of healthy life are their birthright, along with free sunshine or free use of the English language. And the fact that they get that health benefit for free, may not assuage the welfare detriment they feel if they are relative losers in the monetary economy, receiving low wages, unable to afford attractively located property, facing a long commute to work, and paying such high rents and commuting costs that their real consumption on some other categories of expenditure has fallen rather than risen. Extreme inequality in the distribution of the goods and services which do enter monetary income and thus GDP, may create a sense of social injustice and tension even if life has got better in some ways not accounted for in GDP measures.

<u>Rising inequality but so what ?</u>

The second somewhat related argument, put forward in Tyler Cowen's provocative book "*Average is over*", [Cowen 2013] is that rising inequality of money income, while inevitable, will not lead to social revolt , since low income earners can enjoy adequate living standards as long as housing costs are kept low.

Cowen imagines a world where "*say 10 to 15% of the citizenry is extremely wealthy and has fantastically comfortable and stimulating lives*" while "*much of the rest of the country will have stagnant or maybe falling wages in dollar terms, but a lot more opportunities for cheap fun and cheap education*", because of the free or near free services which the internet makes available. These people will not be able to afford to live well in the successful big cities where the 10 to 15% congregate, but will tend to migrate, in some cases during working life but in other case during retirement, to those parts of the US – such as Texas – where plentiful land and easy zoning rules make housing (admittedly for many in "*tiny houses*") easily affordable.

In addition talented bohemians who want nothing to do with the rat race competition of the top 10-15%, will tend to congregate in those cities (currently for instance Berlin or Detroit) where past economic changes have left a legacy of surplus housing and where enjoyable, fulfilled and less stressful lives can be financed from modest incomes derived from artistic or craft activities.

The future may therefore be highly unequal, not just in outcome but in opportunity, but cheap houses, clothes, food, video entertainment and computer games will ensure that there is no social revolt. As a result "*We shouldn't really expect rising income and wealth inequality to lead to revolution and revolt …. the long term picture will be fairly calm and indeed downright orderly".*

Cowen's imagined future is in part a deliberate provocation, but also a reflection of a conservative political creed which accepts the world as it is and denies both our ability to change it and the ethical case for seeking to do so. So in response one must be clear whether one accepts that normative position : I do not . To me Cowen's future is a dystopia, and we cannot accept the degree of inequality, not only of outcome but of opportunity, which it entails. We should try to produce a better and more equal result even if we can only be partly successful.

But even if one rejects Cowen's ethical proposition, his analysis captures three important insights:

- First that in the already rich developed world, increasing inequality may not mean absolute poverty in the way it did when the Luddites were smashing machines or when America was stuck in the Great Depression of the 1930s. Low monetary incomes may not mean such destitution as to produce effective political support for significant redistribution.

- Second, that in a world where automation makes many goods and services cheap, the cost of housing and of transport, both heavily determined by location, play a major role in determining relative living standards. Low wage earners living in big successful cosmopolitan cities, will typically have very limited disposable income after housing and transport costs. Moving to lower cost locations may increase disposable income even if wages are still lower.[14]

- But third that the inevitable consequence of spatial segregation between the rich and successful – congregating in cosmopolitan cities - and the rest, living at least in retirement in low-cost housing locations, will be massively to reinforce inequality of opportunity, with the inheritance of well-positioned housing assets becoming a crucial determinant of how easy it is to move to the elite locations[15].

Given these insights, what policies would successfully address the challenges which rapid technological progress will bring?

[14] It is also worth noting that the scope for this spatial response differs greatly between different countries and continents : it may for instance be inherently greater in the US with a low population density and large areas of quite empty land and easy planning rules than in the more densely populated countries of western Europe

[15] See footnote 12

Rebooting productivity growth – not a key priority

One standard and seemingly obvious response to the decline in productivity growth which Robert Gordon has highlighted is to propose policies that might reboot it. The policy prescriptions vary according to political ideology – deregulation or increased skills, increased public investment or lower taxes – but the objective is shared.

And while I aim in this lecture to challenge conventional wisdom, a focus on increasing productivity may still have merit in some circumstances. The factors I described in Section 2 can explain much of the Solow paradox, but not the dramatic collapse of UK measured productivity growth after 2008. Focused analysis of why some countries lag others in measurable components of productivity growth has value, and useful policies prescriptions may follow. [16]

But over the long term attempts to increase the productivity growth rate of developed countries are likely to be unnecessary, ineffective, and will not solve the major problems we face:

- Unnecessary because provided that we have reasonably competitive markets, education systems that deliver an adequate supply of highly skilled people, and adequate levels of public research and development, a remarkably small number of high talent people are almost certain to drive continued rapid progress of ICT and further rapid productivity growth in those sectors of the economy which can be automated

- Ineffective at the level of measured GDP, and thus measured productivity, because still faster productivity growth in the most automatable sectors may well be offset by a still faster proliferation of low productivity jobs and zero-sum activities, while still faster price declines and growth of zero cost benefits will likely be under-recorded in measures of real GDP.

- And unlikely to solve the big problems facing rich developed countries since :
    - Still faster productivity growth in automatable sectors will not solve and indeed could exacerbate the problems of increasing inequality
    - Nor will it necessarily assuage fiscal pressures limiting the adequacy of key public expenditures such as on healthcare. If we automate still faster jobs in manufacturing, retailing, and back-office processing, and surplus

[16] It is however notable that most international comparisons of productivity focus on those specific sectors of the economy, in particular manufacturing, where the concept of productivity has some clearly definable meaning (e.g. number of cars produced per hour worked appropriately adjusted for quality) and say little about "productivity" in sectors such as legal services, financial services, the fashion and design industry or politics, where the very concept of productivity is undefinable and /or its measurement meaningless and circular (e.g financial trading rated as "highly productive" if traders make high incomes ; and a consumer brand "highly productive" if consumers pay a premium price). Over time the sectors where we can meaningfully define and measure productivity will decline in relative importance.

> labour moves to zero-sum competitive activities, often highly paid, we will not necessarily be left with more resources devoted to healthcare. To afford better healthcare we need to ensure that resources shift to that sector, and that will require an increasing percentage of GDP devoted to healthcare whatever the rate of productivity growth.

None of which implies a technophobic opposition to technological advance. In a free society where people can choose to be researchers, innovators and entrepreneurs, technological advance will occur whether we like it or not: and in an economy where people are free to choose where to work and what products to consume, new technologies will be applied to automate existing activities and to create new products and services . And some of those new products and services (though not necessarily all) will drive increases in human welfare.

But driving still faster productivity growth will not solve the most pressing problems. The most important choices facing advanced rich societies in the future will be how we spend the fruits of increasing productivity and how to distribute it, not how to further increase the pace of advance.

The standard inadequate response – better skills

Faced with the challenge of technological change and the automation of existing jobs, the default policy prescription across the political spectrum is to "equip people with the skills to flourish in a world of continuous change". Sometimes indeed, it seems to be implied that if only everybody learned to code, they would all flourish in this IT intensive world

And I am passionately in favour of as many as people as possible having as broad and deep skills as possible, which should include people having a reasonable understanding of the extraordinary information and communications technology which is shaping the lives. In addition I believe that better education is a crucial element of our response to the social challenges which radical automation potential will bring.

But we must also face two realities :

- First, that in a world of ever increasing automation possibilities, we only need a very small number of very clever IT literate people to write all the code we need for all the robots, all the apps, and all the computer games, and that we need only a miniscule fraction of the global population to drive inexorable progress towards ever more profound artificial intelligence and the super intelligence. Three decades or more since we first began to talk of living in a computer age, the total number of workers employed in the development and production of computer hardware, software and applications, is still only 4% of the total workforce, and the US Bureau of Labor Statistics predicts just 135,000 new jobs in software development over 2014 to 2024, versus 458,000 additional personal care aides, and 348,000 home health aides. (see Exhibit 13) . Total employment in the giant mobile phone, software and Internet companies which dominate global equity values is a minute drop in the

global labour market (Exhibit 24). Facebook, with a market capitalisation of $500 billion, employs just 25,000 people.

- Second that however many people learn to code, and to develop apps and computer games, all of the income from app and computer game development will still accrue to the very small number of people who are skilled enough or lucky enough to create the most popular apps or games. If an increasing percentage of the total workforce is employed in difficult to automate face-to-face services, the equilibrium wage rate for those jobs may be influenced hardly at all by whether they have the skill required to be an adequate, but still second tier, software developer.

We almost certainly face a challenge of rising inequality to which better skills – however intrinsically desirable – will prove a wholly inadequate response.

Possible policy responses

So if still faster productivity growth is not the priority and better skills not an adequate response , what policies are relevant in a world where we will need ever decreasing work input to produce the goods and services required to deliver human welfare?

Let me suggest six policy areas which at least deserve detailed assessment.

Income support such as Universal basic income, (UBI). Universal basic income paid for out of overt redistribution is one possible response. The case in favour is straightforward : that in a world with a limitless "reserve army of robots" we cannot rely on free-market competition to deliver the real wages and minimum adequate incomes which make people in some sense equal citizens of society. So we should ensure that everyone receives an absolute basic income whatever their competitive position in the labour market.

But while the general principle is compelling, there are reasons why UBI should not be the seen as an all purpose panacea. Work, and adequate remuneration from work, delivers a sense of status and self-worth which a pure monetary subsidy cannot replicate. And as the relative importance of property prices and rents grows – with rising average property prices to income but also increasing divergence between regions and cities – the monetary income required for an adequate living standard varies greatly between different locations; policies aimed at ensuring affordable housing may therefore be a more cost-effective and targeted policy response than a UBI alone.

And if our aim is to ensure that everyone can enjoy a reasonable standard of living even if they earn low money wages, the provision of high-quality public services - health, education and public transport , and shared public spaces – attractive cities and countryside and beaches open to all – may be more effective policy tools than straightforward monetary transfers.

Offsetting the concentration of income, wealth and rents . In a world where most new wealth derives from uncreated increases in the relative price of land, and where without intervention differential inheritance will have a huge influence on life chances, there is strong case for increasing the effective taxation of real property wealth, capital gains, and inheritance. And in a world where an increasing percentage of income derives from

intellectual property rents there is, as Dean Baker has argued cogently [Baker 2016], a good case for restricting the breadth of application of IPR (the categories of "invention" which can be protected) and for reducing the length of IPR and copyright protection. As both Bill Janeway [Janeway 2018] and Marianna Mazzucato [Mazzucato 2018] have pointed out, much apparently "private" innovation builds upon public support for basic scientific discovery and initial technology deployment, and most innovations would be developed even if the incentive of IP protection were somewhat reduced. Recent policy, both domestic and international, has however tended in precisely the opposite direction, unnecessarily increasing the protection of intellectual property rights and rents.

High quality urban development Macro and micro economists often pay little attention to the physical realities of spatial development, city design, architecture and transport systems. But in a world where land located in desired locations is likely to account for a rising share of all wealth, and where, as Tyler Cowen has stressed, the cost of housing and of commuting is a crucial driver of adequate living standards, the geography of economic development plays a vital role. The more that we can make multiple cities attractive places to live, and multiple areas within each city attractive, via good public transport, attractive public spaces, and the provision of high quality cultural and sporting amenities, the more we can mitigate, at least to some degree, the intensity of competition for the positional good of locationally specific real estate.

Adequate wages and status for caring services. As the BLS data on Exhibit 13 highlighted, jobs in face-to-face caring services – personal care aides, nursing assistants, home health aides are growing rapidly. These are among the low paid low measured productivity and (at least for now) unautomatable jobs to which labour shifts as automation reduces jobs in other sectors. But they are also jobs which deliver high inherent welfare benefits, and ones which may always be best provided in a face to face form, even if automation becomes to a degree possible[17]. Such jobs however are unlikely to be paid adequate wages or afforded adequate status without political decisions to afford adequate expenditure.

Celebrating craft skills We need to recognise that over the coming century more people are likely to find satisfying jobs as skilled gardeners, artists, cooks, craft brewers, small urban organic farmers and beekeepers than as software developers. Other than through the design of our education systems there may be few public policies either required or likely to be effective in driving this development: but at least as it happens we should welcome it.

Increased leisure. In addition, it would be ideal if there were an increasing tendency to take some of the benefits of our remarkable technological advance in the form of increased leisure rather than in the endless proliferation of zero-sum activities.

[17] Partial automation may however have an important role to play. Japanese companies, spurred by the rapidly ageing population and declining work force are, for instance, working on robots which can perform social care functions such as lifting an elderly person into a bath. We may never wish to see a world in which elderly people are cared for entirely by robots without human contact , but a social care system in which difficult physical tasks are performed by or assisted by robots could be one in which the quality of human emotional support (whether from family members or paid for service workers) is improved .

Education for life and citizenship For many years in most developed economies, public education policy has tended to reflect an instrumental and narrowly economic philosophy: better education and skills deemed desirable because they will raise the productivity growth rate, provide the skills which business needs, and offset rising inequality of outcome. But in a world where rapid productivity growth can be driven by a very small number of highly talented people, where still higher productivity growth should not be the key objective, and where better skills alone will not solve the problems of rising inequality, this focus is severely misplaced. Arguably instead we should refocus education around three objectives (i) equipping as many people as possible to lead fulfilled lives even when humanity's need to work has largely disappeared ;(ii) ensuring that inevitable inequalities of outcome do not create ever more severe inequalities of opportunity between income groups and regions (iii) empowering people to be equal and active citizens, equipped as best possible to distinguish fact from fiction, to respect other people's arguments, and to understand the complexity of the challenges we face, in a world where one disadvantage of ever more powerful information technology is the impetus it has given to fake news and the manipulative reinforcement of initial prejudices.

<u>Facing our real, our permanent problem</u>

As John Maynard Keynes put it in his 1930 essay "Economic Possibilities for our Grandchildren" once the problem of production is solved, "*for the first time since his creation man will be faced with his real, his permanent problem, how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well"*

I believe we are clearly on route to "solving the production problem" so completely that driving further productivity growth should no longer be a primary objective of policy. But resolving the challenges created by a world of limitless production in return for little necessary work, will likely prove far more difficult than achieving rapid technological advance, and many standard theories and policy assumptions will provide little useful guidance.

At least in the rich developed world, however it must surely be possible to meet the challenges: after all the fundamental problem is simply an embarrassment of technological riches.

And in the rich developed world, the challenge will be made easier by demographic slowdown. Likely future falls in the number of people aged 20 to 64 (Exhibit 25) are conventionally bemoaned as posing an insurmountable problem of insufficient workers to support an ageing population. But while the more extreme potential reductions (for instance in Japan) will certainly create major challenges, in general the problems are hugely overstated and the significant costs benefits of demographic slowdown often ignored.

In a world where we will be able to automate almost all work activities, a slightly declining "working age population"[18] will not mean insufficient workers to look after pensioners, will imply a somewhat less rapid expansion of zero-sum and low productivity activities, and will usefully mitigate rising inequality [Turner 2014]. As several recent reports have noted, fears that "robots" will take jobs and lead to low pay are for good reasons largely absent in the East Asian countries facing the most rapid demographic slowdown [see e.g. CNBC 2018]

Overall indeed the challenges faced by developed economies are insignificant compared with those facing some parts of the still poor and developing world.

5.Developing economies – the old ladder destroyed

In some already middle income developing world nations, the challenges posed by potentially radical automation are broadly similar to those facing the rich countries. Several of the themes discussed above are as relevant to social and economic challenges in Brazil, Mexico, Malaysia and China as in the US or Western Europe. But for countries still well below middle income levels, radical automation potential combined with rapid population growth could create almost insurmountable barriers to economic catch up. The classic ladder up which other countries have climbed out of poverty is being destroyed.

Between 1800 and 1950 a huge gap opened up between the standard of living of the rich countries – in particular in North America and western Europe – and most of the rest of humanity. Over the last 70 years, a small number of countries have achieved remarkable catch up, growing per capita income far faster than rich countries operating at the frontier of technology, and at least partially closing the gap.

Almost all of these countries have achieved catch up using the same development model. Export oriented labour intensive manufacture has made it possible to absorb surplus agricultural labour: rising income from manufacturing has made possible high savings and investments; and high investments, in both plant and machinery and infrastructure, has supported rising productivity and real wages. That is essentially the path which Japan followed in the 1950s and 60s, Korea and Taiwan from the early 1960s, and China after the opening up of the early 1980s. And in each case, labour intensive and initially low wage manufacture, producing goods for export, played a crucial role in unleashing the subsequently self-reinforcing process of development.

But as Exhibit 4 illustrated repetitive physical activities in low-wage labour intensive manufacture are the most automatable of all activities. Initially such automation is easiest where hard objects are manipulated – in the auto and electronics industry. But at some time the relentless progress of artificial intelligence and robots will make it possible to automate

[18] It is also important to note that the conventional use of the age range 20 to 64 to define the "working age population", even when considering long-term multi-decade trends, is absurd in a world where rising life expectancy, and rising health at any given age, mean that average retirement ages can and will inevitably rise over time.

the manipulation of soft materials as well – with "sewbots" making it possible to automate apparel and footwear manufacture.

A recent ILO report suggested that 60-90% of low paid jobs in ASEAN textiles and clothing industries could disappear through automation. [ILO 2016] The recently opened Adidas "Speedfactory" in Bavaria will employ 160 workers to make 500,000 pairs of shoes per annum : if the rest of its production becomes equally automated , the roughly 1 million workers currently employed in Adidas's supply chain across the world could fall by over 90%.

Of course the fact that automation will eventually become possible still leaves the question of when: and the fact that automation is physically possible does not mean that it will be immediately introduced. That will depend on the relative cost of robots versus employees, and on relative wage rates in the developed and developing worlds. Provided wages remain low enough in developing economies, automation may therefore be delayed far beyond the point when it becomes physically possible.

But as the technical feasibility relentlessly advances, and as over time the costs of factory automation equipment decline, it is simply a matter of time before the economics will favour a return of many manufacturing activities to the developed world - but with very few jobs. And the pace of that return will be speeded by the fact that automating factories and locating them close to end consumers will enable a dramatic improvement in the speed with which fashion driven companies can respond to changing customer preferences.

Just as with almost all existing jobs in the developed world, so too with export oriented manufacturing jobs in the developing, the question is not if they will be eliminated by automation but when.

Indeed the Indian economy already provides strong indications that automation is severely limiting job creation. Given demographic trends, India needs to create 10 to 12 million new jobs per annum to keep unemployment and underemployment stable, but despite GDP growth now running at 6 to 7% per annum, recent job creation falls far short of that level. Indeed there are signs that formal employment in leading sectors such as export oriented manufacture, IT, back-office processing, and generic pharmaceuticals may already be declining as Indian companies apply state-of-the-art technology to automate their activities even though labour is available at extremely low cost.

Despite being still a low income country, India, as Exhibit 14 illustrated, therefore already displays the developed world phenomenon in which rapid technological progress in some sectors and jobs is offset by the proliferation of low paid service jobs in activities which at least for now are difficult to automate. But since India already starts with a huge low productivity informal economy, and since unlike in the developed world its population and workforce will continue to expand rapidly for another 30 years, the scale and severity of the divergence between Indian regions and income groups will likely dwarf rising inequalities developed world.

But despite these challenges, India may still achieve good enough growth to end the 21st-century, facing only the same problems which by then will face the rich developed world. Even if they provide employment to only 10% of the workforce, it already has major internationally competitive businesses, and while their employment may hardly grow, rising output and incomes will support a growing consumer economy. And if fertility rate declines continue, the population and workforce will peak around 2050, with gentle decline thereafter helping to reduce the job creation challenges.

By contrast, the countries of Africa, where population is projected to increase over 4 times by 2100, face a potentially insurmountable challenge.

Ending demographic denial

Across many emerging economies, the supposed benefits of a "demographic dividend" are a familiar refrain. Politicians and business leaders alike – whether in Nigeria, Pakistan, Tanzania, or a host of other countries – talk glowingly of how fast-growing and youthful populations will create huge investment opportunities and fuel rapid economic growth. But the term "demographic dividend" is being seriously misused.

The East Asian nations which achieved successful catch up did indeed enjoy a "demographic dividend" but that did not mean sustained high fertility and rapid population growth continued over many decades, but a transition which combined both a significant one-off increase in the working age population **and** a rapid and significant fall in fertility. That combination produced a high ratio of workers to dependents – both retirees and children – making it easier for high savings to support high investment. Rapidly falling fertility in addition ensured that each generation of workers inherited a larger per capita stock of capital : and smaller family sizes made it easier to afford high private or public education spending per child, leading to rapid improvements in workforce skills.

If instead fertility rates stay well above replacement level for a long period of time, there is no demographic dividend. Per capita capital stock grows only slowly, and a rapidly growing working age population makes it impossible to create jobs fast enough to prevent widespread and growing unemployment.

That is the bind in which much of sub-Saharan Africa is still stuck. With moderate GDP growth rates (averaging 4.6% over the last decade) offset by 2.7% per annum growth in population, per capita income has been growing at less than 2% per annum, versus the 7% which China achieves and India's rate of around 5% . And the huge job creation challenge will become far more severe if, or rather when, endlessly advancing automation possibilities mean that the rich world does not need cheap emerging economy labour to provide low-priced footwear, apparel, or other goods.

There are no easy answers to this challenge. But the first step in identifying an appropriate policy response is to recognise the severity of the situation and to cease the demographic denial which sees rapidly growing populations as a boon rather than problem.

Policies which would at least help probably include:

- Maximising the successful development of competitive manufacturing as a potential source of a small number of well paid high productivity jobs, while recognising the small total job creation potential
- Identifying and supporting sectors where employment is likely to be more resilient in the face of increasing automation potential – e.g. tourism and construction
- Accepting that there will inevitably be a large number of "Baumol type" low productivity jobs, while ensuring adequate basic income to prevent extreme poverty, and excellent education to mitigate the danger that inevitably unequal outcomes crystallise into ever increasing inequality of opportunity
- Ensuring high-quality female education and affordable stigma free access to contraception, to speed the demographic transition as much as possible

6. Implications for economic theory

The radical change in the nature of the economy described in Section 3 will make many standard economic assumptions no longer valid.

The theoretical case for believing that free markets will not merely perform better than planned economies but produce an optimal result of human welfare rests on the neoclassical theory of competitive equilibrium. Within that theory, three assumptions are presumed valid:

- First that free-market competition will produce an optimal allocation of the two factors of production, capital (K) and labour (L), combining within a production function Y=f(K,L) to produce the maximum income deliverable from any combination of K and L. Within this theoretical framework all labour is devoted directly or indirectly to the production of welfare enhancing goods and services, with no distributive/zero-sum activities. And free competition ensures that all workers receive income equal to their marginal private product which in turn is equal to marginal social product.[19]
- Second that the prices of goods and services produced and consumed, reflect the marginal benefit to both private and social welfare.
- Third, as a result, that the aggregation of all goods and services into national income (GDP) accurately reflects aggregate utility, allowing us to use measures of GDP per capita to draw valid inferences about the progress of total human welfare over time or its relative level as between different countries.

But in the face of radical automation potential and the resulting changes described in this paper, each of these assumptions is decreasingly valid since:

[19] Even standard neoclassical theory accepts of course that the result might be only "Pareto optimal" and that some redistribution may be required to produce a socially optimal result : but the assumption that marginal private product (and thus pre-tax income) equals marginal social product still carries important apparent implications.

(i) An increasing percentage of all human activity will inevitably be zero-sum ("distributive") in form, and our economic statistics, analytical approaches and theory need to address that reality. And in that environment, the idea that private marginal product necessarily equals marginal social product collapses. For each potential divorcee, the services of a good divorce lawyer deliver marginal private product, but at the aggregate social level there is no increment to human welfare. And that applies also – in whole or degree – to all of the zero-sum activities described in section 2 (ii). A CEO who successfully executes financial engineering based mergers and acquisition can deliver value for his or her shareholders, even if at the aggregate social welfare level no additional benefit results. A brilliant fashion designer can shift consumer expenditure from brand A to brand B even if in the long-term fashion is simply circular, and the aggregate welfare delivered via all fashion goods together bound to be no greater in 2050 than today. One implication is that any idea that rising inequality can be offset by greater "transparency and accountability" in remuneration decisions misses the key point. The key problem is not that top income earners are incompetently paid incomes above their marginal private product, but that marginal private product can be immense even when marginal social product is small.[20]

(ii) Beyond some level of income, the idea that all forms of additional consumption deliver equally important increments to human welfare breaks down. As described in Section 2 (iii), Martin Feldstein has argued that real GDP growth is under-recorded because our statistical methods "*fail to reflect the innovations in everything from healthcare to Internet services to video entertainment that have made life better during these years".* But we need to answer two quite separate questions (i) whether standard measures of real GDP fail to reflect the pace of technical progress which enables us to deliver ever more goods and services with less labour input - the answer is almost certainly yes ; and (ii) do increases in the flow of goods and services necessarily produce an increase in human welfare - here the answer may be yes for some hidden benefits (e.g. improving healthcare) but not necessarily for some other services, such as social networks and always on devices. We need theories which can distinguish the potentially different relationship between additional consumption and additional welfare for different categories of goods and services (Exhibit 26)[21]

(iii) As a result the value of GDP per capita as a measure of human welfare is already degrading and will inevitably decline over time. Our standard mental model makes

[20] It is indeed quite possible, and I suspect actually the case, that the net effect of all the remuneration codes and disclosure requirements which have been introduced (particularly in the UK) in an attempt to address the problem of "unfairly" high executive rewards, has been to increase top executive remuneration, since transparency increases the focus on relative pay rates between companies and drives the development of incentive systems which enable top executives to get paid a higher proportion of their private marginal product

[21] See Adair Turner, *Economics after the Crisis: Objectives and Means* [Turner 2012] for a fuller discussion of this and other themes considered in this Section

the two assumptions shown on Exhibit 19 but while each was adequately valid in the early stages of technological progress, each degrades as information technology progresses and as basic human needs become at least partially satiated. Maximising real GDP growth can no longer be the prime objective of economic policy when the measure we seek to maximise is gradually losing its meaning.

That can still however, leave a useful role for GDP measures in economic management. But as Feldstein has himself suggested the focus should be not on medium-term measures of real GDP as apparent indicators of living standards, but on short-term measures of nominal GDP as an input to monetary policy decisions which aim to ensure that employment does not divert unnecessarily from a full employment level. Interestingly indeed, that idea is not new; the British economist Lionel Robbins, writing in 1932, at a time when measures of national income were in their infancy, argued that they could never provide robust measures of human welfare, and that "*both the concept of world money income and of national money income have strict significance only for monetary policy*". [Robbins 1932][22] But while Robbins was right to spot the theoretical deficiencies of any GDP measures, they were arguably "good enough" to tell us quite a lot about human welfare progress in the early stages of technological development, and remain so today at the levels of per capita income still seen in many developing economies. Increasingly however they will become meaningless guides to the progress of human welfare in the course of the 21st-century

The changing economy described in this paper, also has implications for how to think about capital and wealth. In the standard neoclassical model, income is produced from the combination of two factors in the function Y=f(K,L), and capital is accumulated by capital investment funded from savings with $K_1 = K_0 + I$, and $I = S$. But we live increasingly in a world where productivity improvement (and in some cases human welfare benefit), can be delivered with very little capital investment: where most wealth resides in locationally desirable land, intellectual property rights and brands: and where most "wealth creation" derives either from changes in the relative price of already existing assets, or from the creation of intellectual property, brand and network externality effects. We will need new theories to understand the resulting dynamics and their implications, including in particular for inequality.[23]

And we need to pay for more attention to issues of "economic geography", recognising that the design of our cities and the relative success and scale of different cities within a nation or region, will have major implications for quality of life and social mobility.

[22] Simon Kuznets, one of the most important figures in the development of GDP measures, famously made the same point observing that "*The welfare of a nation can scarcely be inferred from a measurement of national income*". [Kuznets 1934]

[23] Professor Joe Stiglitz has already made an important contribution to that theory noting that "*it was the omission of land that represents the most important lacunae in my 1969 theory of the equilibrium distribution of wealth and income*" [Stiglitz 2015]

More generally indeed we need to recognise that "the problem of production" will inevitably be solved so completely as to become unimportant. As a result the most crucial challenge will not be how to produce more output for a given work input, but how to manage in a fair and sustainable way disputes about the distribution of those goods, services, and assets (both created and natural), which automation does not make available at ever falling and close to zero prices.

That will require us to balance the relative merits of individual freedom versus perceived fairness. Interestingly indeed it will require us to return to the essentially political case for economic freedom on which the "political economists" of the 18th and 19th century – Adam Smith, David Ricardo, and J.S Mill – concentrated.

As Amartya Sen has noted, the case for the market economy has for many years been stated predominantly in terms of the maximisation of income as a "*culmination outcome*" rather than in terms of freedom as an end in itself. [Sen 1999] [24] Those who, like me, will want to make the case for a market economy will need to return to that more fundamental justification, balancing the case for economic freedom versus other considerations, rather than hiding behind the argument that economic freedom is essential to drive still faster productivity and income growth.

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[24] As Sen puts it in the first chapter of "*Development as Freedom*", the Soviet Union was ultimately a failure in terms of human welfare not just, and perhaps not even primarily, because it failed to deliver increased GDP growth, but because it stymied natural human desires to be allowed to make one's own choices. Thus "*the merit of the market does not lie only in its capacity to generate more efficient culmination outcomes, but in the processes by which those outcomes are achieved*"

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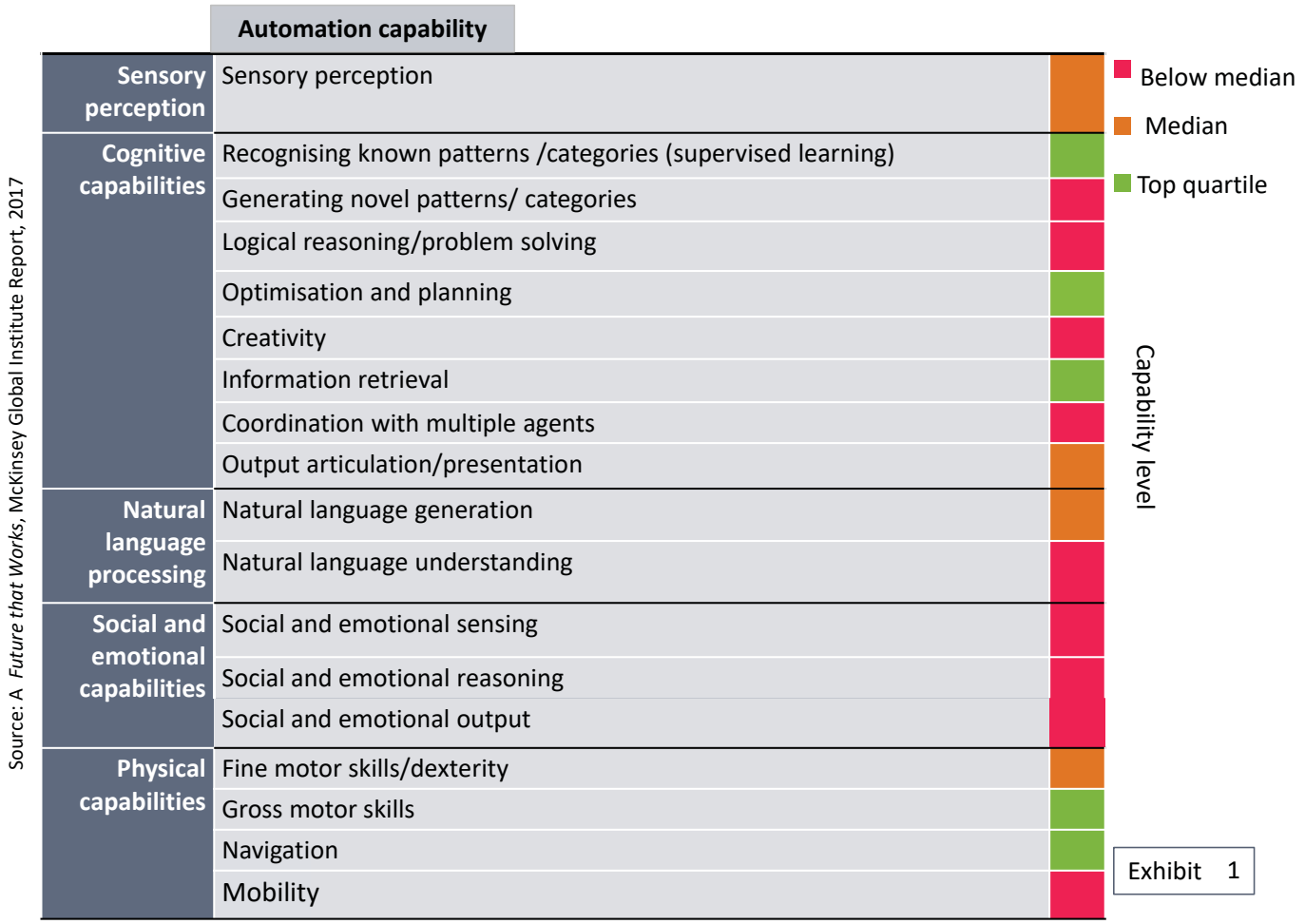
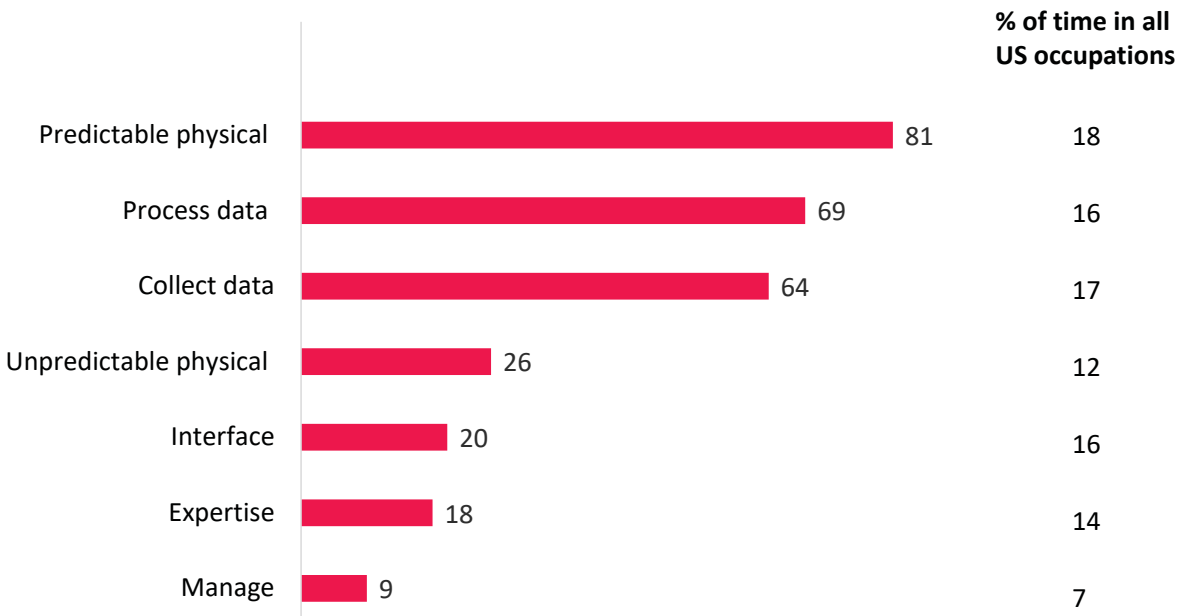
Current automation capability versus humans performance



Automation potential by type of activity

% of time automatable with current technology



Source: McKinsey Global Institute, A Future that Works, 2017

Automation potential by occupation

% of specific activities automatable

Example occupations

Sewing machine operators, graders and sorters of agricultural products
Stock clerks, travel agents, watch repairers
Chemical technicians, nursing assistants, Web developers
Fashion designers, chief executives, statisticians
Psychiatrists, legislators

% of specific roles and time which can be automated

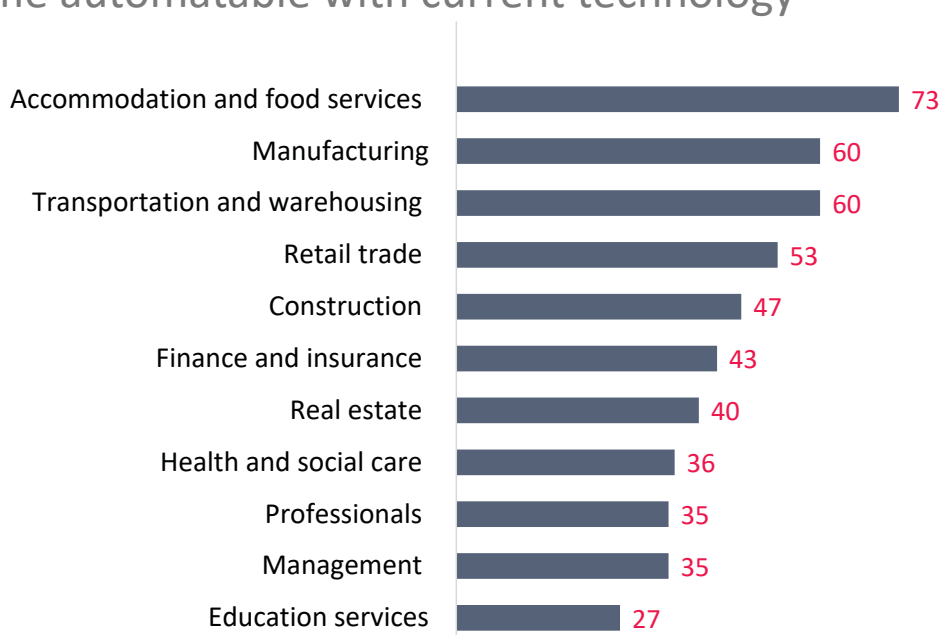
High

Low

Source: McKinsey Global Institute, A Future that Works, 2017

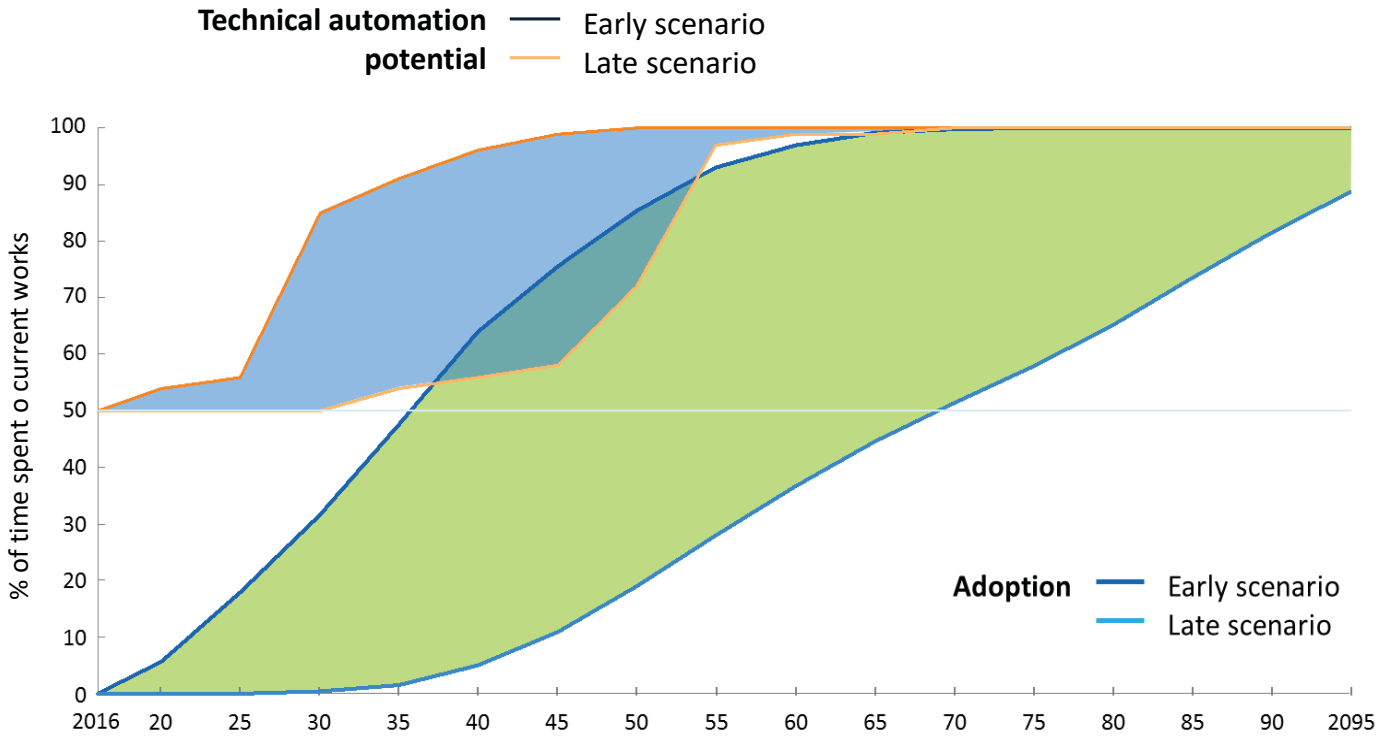
Potential to automate by sector

% of time automatable with current technology



Source: US Bureau of Labor Statistics McKinsey Global Institute Analysis

Scenarios for automation



Source: McKinsey Global Institute , A Future that Works, 2017

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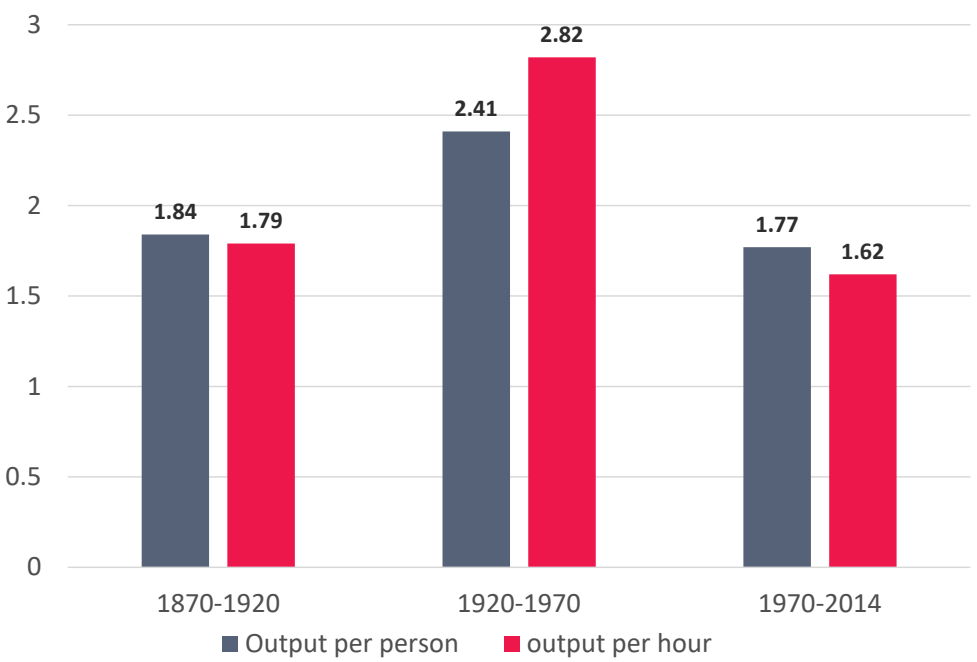
Exhibit 5

Productivity growth in the US

% per annum



Source: Robert Gordon, *The rise and Fall of American Growth* (Princeton University Press, 2016

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Exhibit 6

The standard paradigm

Starting Point

Technical progress

New position

50 farmers produce 100 units of food

50 workers produce 100 units of cars, washing machines, televisions, etc.

Measured total economy productivity doubles

Endlessly repeatable progress?

50 farmers produce 100 units of food

50 factory workers produce 100 manufactured goods

Further technical progress

- 25 farmers producing 100 food
- 50 factory workers producing 200 cars, washing machines, televisions
- 15 factory workers producing 60 units of computers, mobile phones and software applications
- 10 service workers producing 40 units of healthcare

400 units of value – productivity doubled again

The Baumol Effect

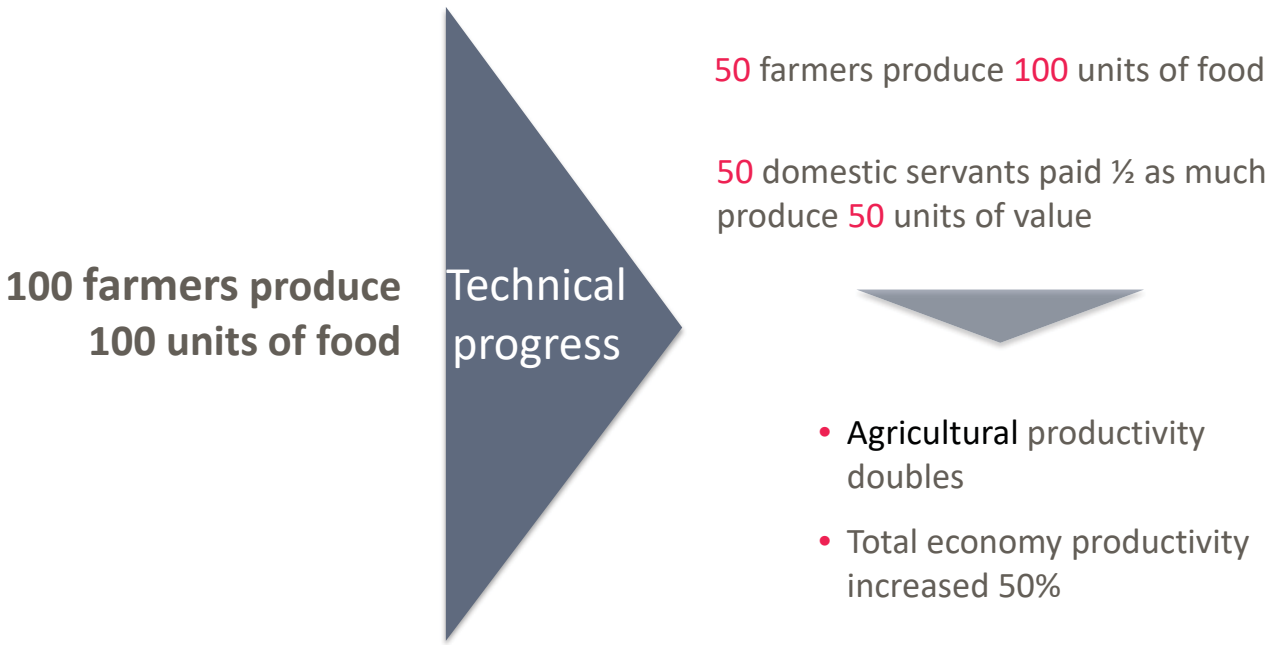

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Exhibit 9

Asymptotic rather than endlessly repeatable progress

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Exhibit 10

The Baumol Effect with high paid artists

100 farmers produce 100 units of food

Technical progress

50 farmers produce 100 units of food

45 domestic servants paid ½ as much produce 45 units of value

5 artists, singers, entertainers and fashion designers paid twice as much produce 20 units of value

Productivity growth still eventually asymptotes

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Exhibit 11

Twenty first century technology

London

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Exhibit 12

US Jobs growth forecast 2014 – 2024

	Occupational categories by speed of job growth	Forecast job growth (000s)	Median annual wage May 2014 ($000s)
1	Personal care aides	458	20
2	Registered nurses	439	67
3	Home health aides	348	21
4	Food preparation and serving workers	343	21
5	Retail sales persons	314	18
6	Nursing assistants	262	25
7	Customer services reps	253	22
8	Cooks, restaurant	158	31
9	General and operations managers	151	97
10	Construction labourers	147	31
	Total top 10	2873 (29%)	
13	Janitors and cleaners	136	23
14	Software developers, applications	135	95

All sector average: 36

Source: Bureau of Labor Statistics, www.bls.gov; Projections of Occupational Employment, 2014 – 2024

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Exhibit 13

The Baumol effect in India:

Automation of tea packing

A manager explains what will happen when he opens the crates:

His job will go. And his over there; and that one's too

But the manager insists that, as in the past, he will somehow find jobs for everyone – as drivers or even watchmen if necessary

India's Economy: Just the job. **The Economist**, 16 September 2017

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Exhibit 14

Zero-sum activities in the simple model

100 farmers produce
100 units of food

Technical progress

50 farmers produce 100 food

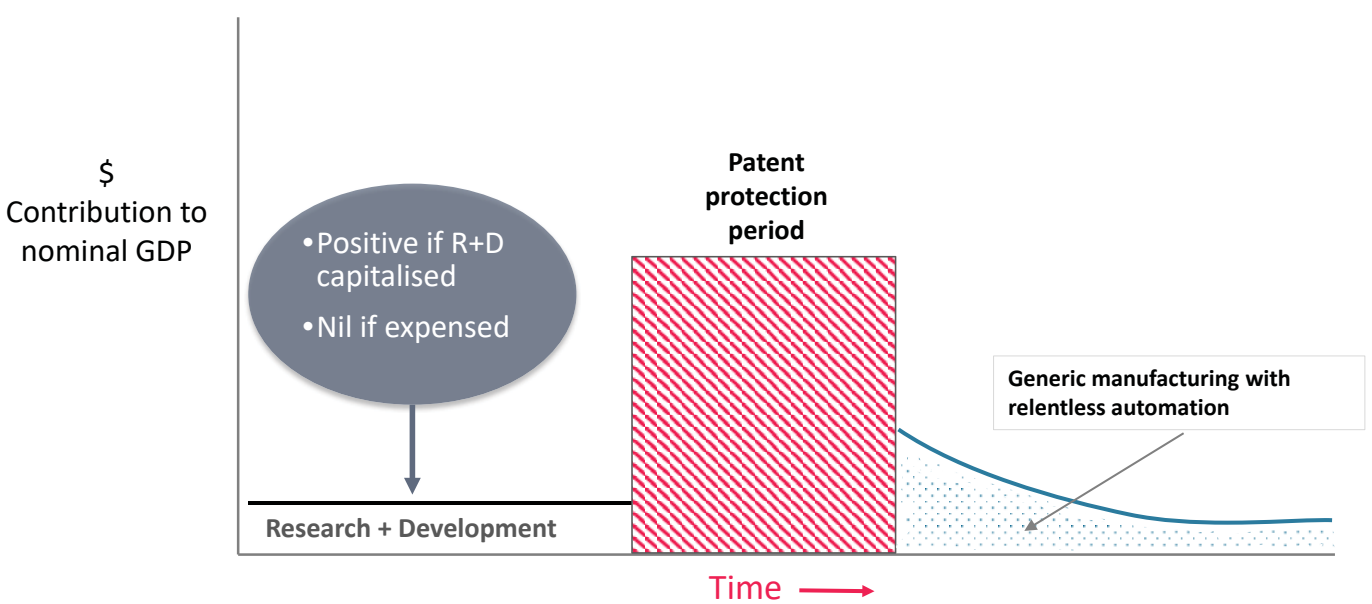
25 criminals

25 police paid same as farmers

- Total measured productivity increases 25%
- But no human welfare benefit of increased consumption

Wonder drug contribution to nominal GDP

With private development and patent protection



Wonder drug contribution to nominal GDP

If government or charitable development

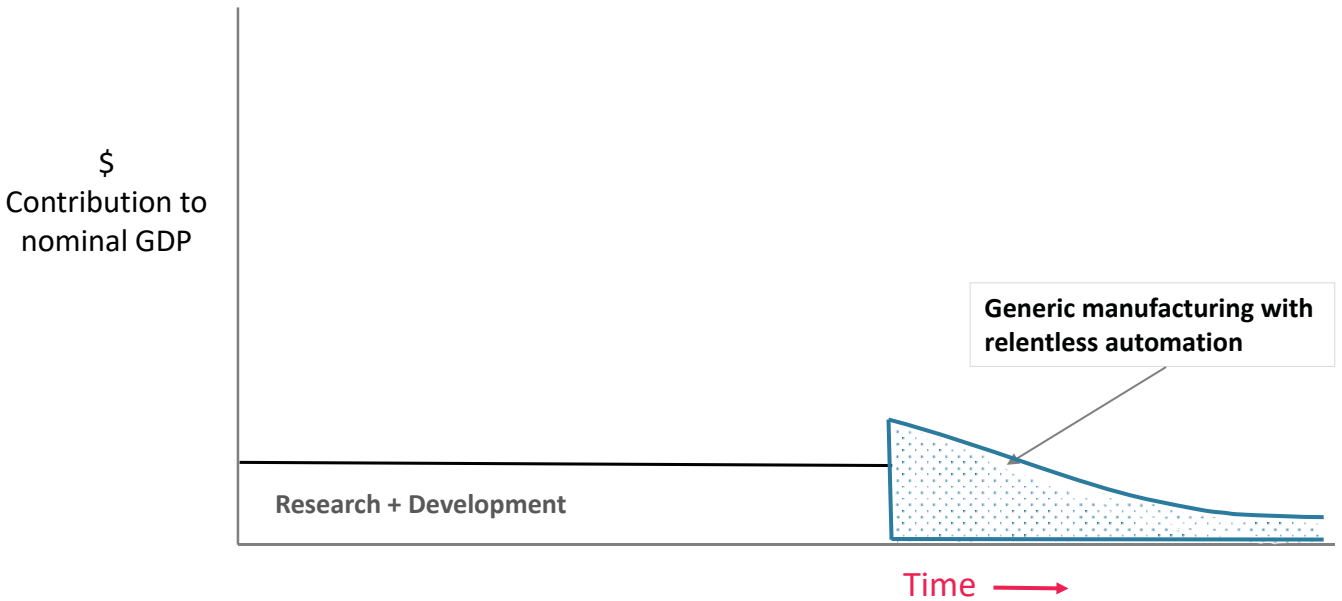


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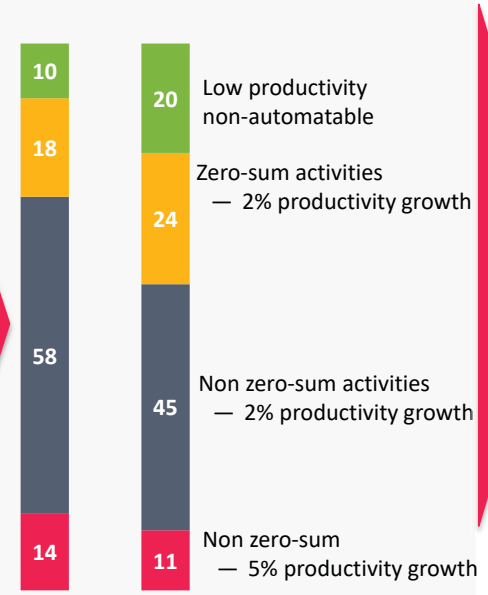
Exhibit 17

Three effects combined: An illustrative scenario

Assumptions	% of employment
Non-automatable low productivity	10% → 20%
Automatable	90% → 80%
of which: Zero-sum	20% → 30%
Non zero-sum	80% → 70%
… with 50% of zero-sum activity in GDP and 50% not	
Productivity growth in automatable sectors: 2% p.a. in 80% of activities 5% p.a. in 20% of activities	
Under-recorded benefits = 33% of growth in the high growth sectors	

Breakdown of Employment



Productivity growth

Of automatable sectors:
2.5% increasing to 2.7%

Of all sectors:
constant around 2.05%

Of measured GDP:
1.9% declining to 1.5%

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Exhibit 18

The standard assumption

Technological advance drives productivity improvement across the economy

Which shows up in GDP measures of output per hour worked and per capita

Which provides a good measure of improvements in human welfare

Imperfect but adequate assumption in farm → factory transition

… but becomes more imperfect in face of information technology goes and proliferation of zero-sum activities

Imperfect but adequate assumption as income grows from $1000 to $20000 per capita

… but becomes more imperfect as incomes rise and basic needs satiated

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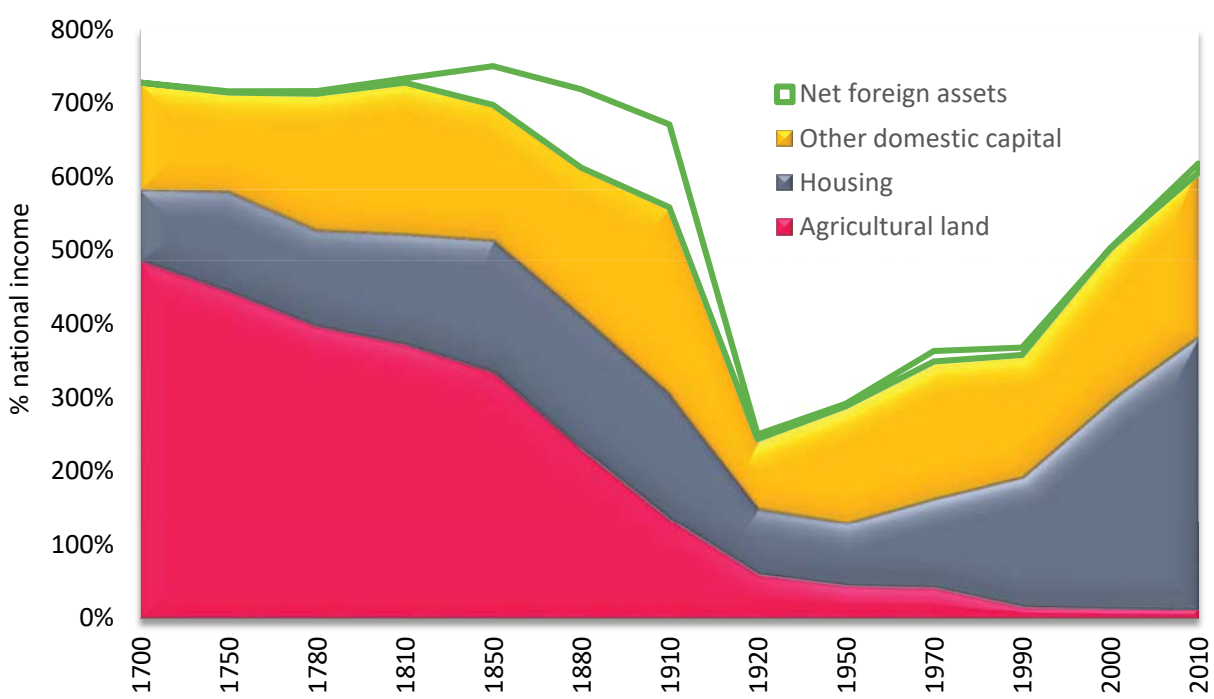
Exhibit 19

Capital in France 1700 – 2010



Source: *Capital in the Twenty First Century,* T. Piketty (2013)

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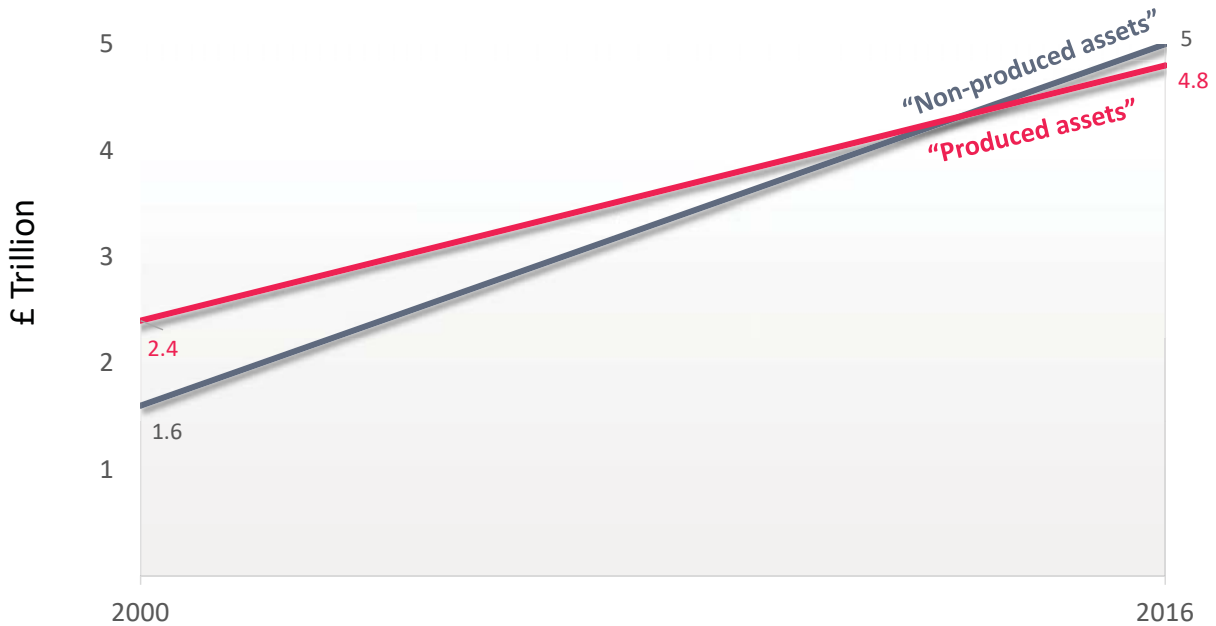
Exhibit 20

The rising importance of non-produced assets

UK National Balance Sheet 2000 – 2016



Source: UK Office for National Statistics: *Statistical Bulletin on the UK National Balance Sheet*

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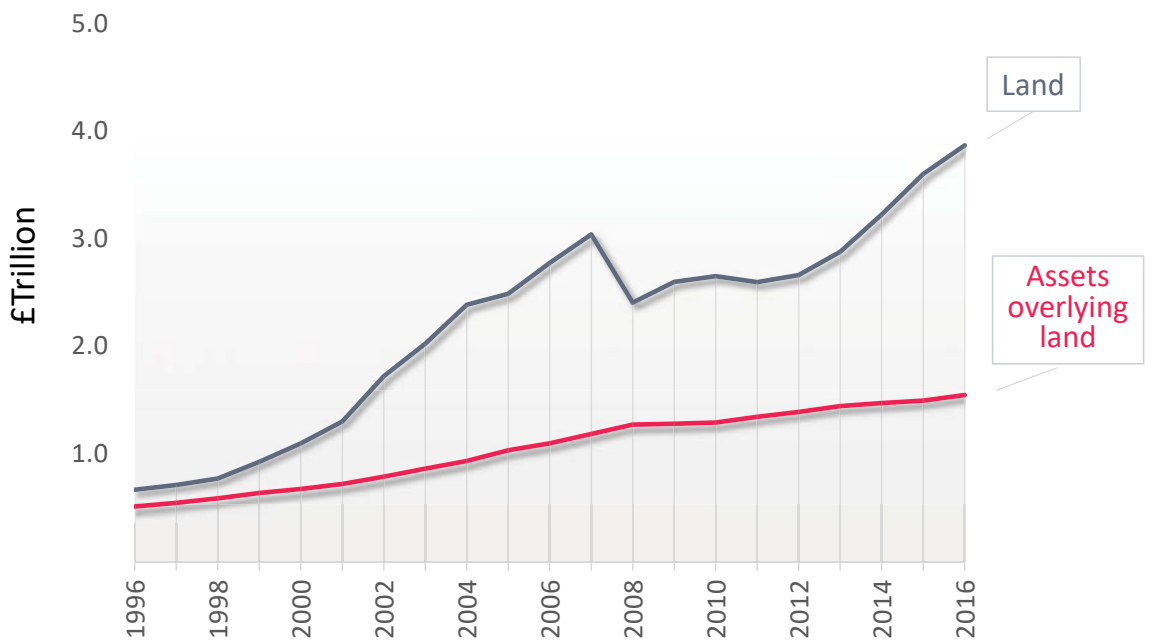
Exhibit 21

UK Household land and buildings



Source: ONS, *Statistical Bulletin on the UK National Balance Sheet:* 2017 estimates, Fig. 3

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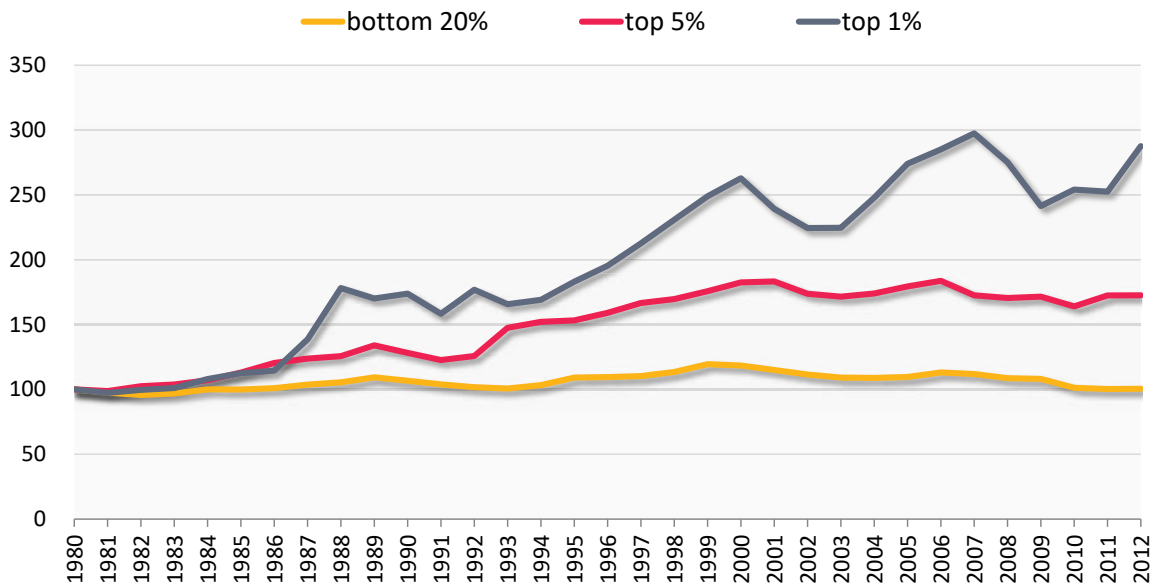
Exhibit 22

Average income increases US

(1980=100)



Source: US Census Bureau; World Top Incomes Database

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Exhibit 23

Wealth and employment in ICT businesses

	Market Value ($bn) (27 Apr 2018)	Employees (000s) (2017)
Microsoft	736	~ 124,000
Alphabet Google	716	~ 72,000
	502	~ 25,000
Alibaba Group 阿里巴巴集团	455	51,000
Tencent 腾讯	472	45,000

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Exhibit 24

Population aged 20-64

Millions

	2000	2015	Projected 2050	Projected 2100
Japan	79	71	50	35
China	774	928	733	482
Europe	441	454	382	325
Americas	459	582	684	610
India	532	736	1029	867
Africa	352	536	1298	2485

Source: UN Population Database: Medium Fertility projection: 2015. un.org/popin

Different marginal utility of different "goods"

Good health?

Branded fashion goods?

Congestion and environmental damage?