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Policies for the weightless economy

by
Danny Tyson Quah
Professor of Economics
LSE and Centre for Economic Performance
D.Quah@lse.ac.uk, http://econ.lse.ac.uk/~dquah/

I thank the Social Market Foundation for allowing me the opportunity to speak to you this evening. My talk tonight is on "Policies for the weightless economy." In this presentation, I would like to make four points:

1. The weightless economy is the natural next stage in the historical sequence of technical progress.
2. Technical change is now and always has been the main engine of economic growth and therefore employment. Sure, factors like (a) stable prices or low inflation; (b) the acknowledged rule of law; (c) a secure environment for entrepreneurship and property rights; (d) openness to trade and international competition; (e) labour market flexibility, and so on, play a role in directing economic *performance*. But that is not the same as contributing permanently to long-run economic growth. Ultimately, the only lasting impact on growth of these factors and others like them might rest only on how they help shape technical progress.
3. The weightless economy is out there now. It is not just a US road-show. It has arrived in the UK, and is currently appearing in many parts of the developing world. And, it is doing very well, thanks for asking.
4. This does not mean, however, that governments and societies do not need to craft the right policies for and form appropriate social attitudes towards the weightless economy. Indeed, now more than ever, the responses

are critical. Whether growth will continue or our economic performance languish depends on how, as a society, we react to the changes emerging around us.

1. WHAT IS THE WEIGHTLESS ECONOMY?

In modern economies, value and wealth have picked up and moved on. It used to be that the larger our plot of land, the more we ended up contributing to society, and the wealthier we saw ourselves becoming. Similarly, time was, the more extensive our factory assembly line and the more massive our construction cranes, the better our position in the economic food-chain. Not so now.

On the list of the world's 20 wealthiest individuals in 1998, three Americans appear because of their role in computer software. The three command between them US$85 billion. By comparison, the three wealthiest individuals in the UK rich from tangible production—steel, land and property, and food production—own, in total, only 7% of that US$85 billion.

Of the 20 wealthiest individuals in the US, the three software global billionaires are joined by another three in computers and then two others who are media magnates.

To keep perspective, we must remember this economic power comes not from a windfall discovery. It is not that society suddenly realizes that something it had not previously valued turns out to be something it cannot live without, and where these individuals just happen to be sitting atop a pile of the stuff. Nor does it come from the spoils of one nation plundering another. These individuals provide something that others find useful or enjoyable, and are willing to pay good money in exchange.

Computer software and entertainment media comprise parts of the weightless economy. More generally, in the weightless economy, I include information and communications technology or ICT; name brands and aesthetic designs; new media and electronic libraries and databases; intellectual property; and certain kinds of services (but not all). There is an economic-theoretic reason I group these together, not because they seem high-tech or, worse, trendy and cool. (I return to this below.)

Portions of the weightless economy sometimes go by other names: The emerging digital economy; the knowledge-based

economy; the new economy; and so on. All these labels have their advantages, but I prefer the weightless economy.

The *digital economy* suggests computers and only computers; sure computers are an important part of the weightless economy, but they are not everything.

The phrase *new economy* escapes this difficulty and sounds frightfully all-encompassing. (I have to be careful here as some friends, for whom I have the highest intellectual regard, like this term and use it a lot.) But, truth is, every year most of what's interesting is new, and therefore the phrase *new economy* runs the risk of trying to be all things to everyone, every time.

The *knowledge-based economy* is a term long past its sell-by date. The global economy became knowledge-based 5,000 years back when Sumerians in the Tigris-Euphrates basin started carving trade accounts onto clay tablets. A knowledge base for economic prosperity has likely been achieving full resonance ever since, through a clever little bit of knowledge, early humans beat out the physically superior Neanderthals for survival 50,000 years ago. This had profound effects on our welfare, for here we are, and the Neanderthals not.

More to the point, however, the term *knowledge-based economy* is elitist and offputting. It suggests that eggheads and boffins will be running the economy; it suggests that the creation of knowledge is how economic value too is produced; it suggests that one's place in the new emerging economic order is threatened unless one can be constantly carving out nifty new pieces of knowledge.

The evidence, in my view, points at something less self-serving for anyone banging on about the importance of the knowledge-based economy.

2. IS THE WEIGHTLESS ECONOMY FOR REAL? HAS THE WEIGHTLESS ECONOMY COME TO THE UK?

All right, so we know the definition for what comprises the weightless economy; and we know what it is not. But is it really out there?

Begin with information and communications technology. This is likely the best-documented and highest-profile part of the weightless economy; it is this segment for which the most reliable statistics are available.

A first piece of evidence then would be the sheer magnitude of economic resources commanded by those very wealthy individuals mentioned above. These people are putting useful things into the hands of ordinary folks, every day, for the latter to go about routine economic life. The wealth of these very rich individuals is one estimate of how essential and pervasive are the goods they produce.

Or, we can approach this from a different angle. The weightless economy, from the items listed above, must have to do with processing information rather than shifting material goods. On this definition, Fritz Machlup had concluded that as of 1958, already 35% of US GNP was produced by information workers. Marc Porat's 1976 study, updating and extending Machlup's work to use data through 1967, claimed the primary information sector—financial services, communications, education, information processing equipment—amounted to 25% of GDP, and that the secondary information sector—R&D, advertising, management—came to a further 21% of GDP: The total, 46% of GDP.

These numbers are impressive, but not terribly useful for our purposes. From what I can tell, neither economic theory nor concern for the feasibility of ongoing growth and employment informed choice of the different sectors to study. Thus, the figures just cited included, for example, personnel and spending on religious instruction (although admittedly small), and clerical and sales workers. It is not that I take a position here on religion and economic growth. But staring at these tabulations, one comes away thinking they just comprised everything that's not agriculture, mining, or conventional manufacturing.

The weightless economy should not be viewed as simply a negation of what were the traditional strengths of the economy. Instead, the weightless economy should be taken as forward-looking and bearing the capacity for continuing growth and employment. The clearest example of this—again, that for which I have the most data—is information and communications technology. The other items I mentioned above—name brands and aesthetic designs; new media and electronic libraries and databases; intellectual property—will need to be described some other time. But, when added back in, they can only increase the size and extent of what I now document.

We should be clear: ICT is not just for rich countries or just for the rich within a society. It's true that in 1990 over 1 billion of

the world's inhabitants lived on less than US$1 a day. It's true that in 1997 India had an annual per capita income of only US$340, and highly unequally distributed at that: over half its population (of just under a billion) survived on that "less than US$1 a day" threshold. Yet India is now a major offshore software development centre. In 1997 the Indian software industry employed 260,000 people (160,000 on the subcontinent itself) and generated revenues of US$2 billion. Out of that, 60% were export earnings for the Indian national income accounts. In India, this industry has grown at better than 50% per year for five years (1992–1997). Sure, a lot of Indian software work is body-shopping—low value-added data entry and Cobol accounting fixes—but a growing proportion is high-value customized applications and professional consultancy. Indian programmers might earn only one-tenth of their Western counterparts, but that is still double what their counterparts earn in the Indian Civil Service.

Success story though this is in India, that US$2 billion is just the tip of the iceberg. In 1997 worldwide IT services generated US$350 billion; software added another US$400 billion. Since services are typically about one-fifth of company IT budgets, this implies a global IT industry exceeding US$1.5 trillion in total. By comparison, in 1997 UK GDP was just about £0.9 trillion or US$1.4 trillion, thus about the same size as the worldwide IT industry or a little smaller.

Closer to home, projected 1998 total UK spending on IT—across private and government sectors—is £44 billion: That's £2,000 for each of the 22 million workers employed in the UK.

These are, in my view, big numbers on the spending and earning side. But to be persuaded of its importance, we must see ICT not just produced; it must also be used and consumed on an everyday basis. Here, however, like many things that work well, we don't notice ICT around us until it fails. So, this final piece of evidence on the size of ICT and by implication the weightless economy is indirect, but perhaps more telling.

One of the fun things one learns in graduate school in economics is to set up scenarios that seem faintly ludicrous, but then argue them through to their logical conclusion. A perennial favorite is to ask, Wouldn't high inflation in the US be a good idea because (a) there is too large a stock of US currency outstanding for just honest, law-abiding citizens to be holding; (b) it must all be due to the trafficking of illegal drug-smugglers and evil gun-runners who

insist on being paid in untraceable currency. Inflation—lowering the value of paper currency and increasing prices on everything else—then merely taxes that part of the economy with which none of us have any sympathies (that we are willing to articulate at any rate). So, central bankers: Inflate away!

For this evening's purposes, the image you should carry from this story is that, regardless of how much one tries to purposefully hide one's stock of currency holdings or even just unwittingly continue one's use of currency, high inflation—like an all-marauding, all-enveloping, quantum-physical action-at-a-distance angel of death—insidiously and effortlessly roots out those pieces of paper, and lowers their value, by magic, without ever having to identify whoever is holding them.

The Year 2000 computer problem is like that. The Year 2000 problem, or Y2K for short, arises because many logic timekeepers have short-sightedly recorded only the last two digits of the year, and kept track of time by asking, How many years has it been since 1900? When year 1999 becomes year 2000, so the story goes, all hell will break loose. If this is right, then the activity leading up to then as well as whatever ensues afterwards, will reveal the ICT around us—much like high inflation ought to ferret out all those illegally-transacted pieces of paper currency.

No one knows the true extent of Y2K. It might be alarmist claptrap or, it might be a profoundly under-estimated disaster waiting to happen. Y2K certainly shows, however, that the ICT component of the weightless economy goes well beyond whizz-bang spreadsheet color graphics and cutesy computer Office Assistants taking us on a tour of Windows 95.

In one analysis, following a perfectly reasonable logic, trillions of critical computer records will be wiped out; planes will fall out of the sky; gas pipelines will explode; the 65 Soviet-made civilian nuclear power stations will undergo meltdown throughout the former Warsaw Pact countries; stock markets around the world will crash; telephone lines will go dead; power brownouts will shut down business and industry; elevators will refuse to work in high-rise buildings everywhere. Financial chaos will ensue, and health and education delivery will stop.

Well, either that or nothing will happen.

The disaster scenario, crazy though it might sound, continues to be contemplated by almost everyone for the same reason that we like to watch University Challenge on the BBC: The things in it are

a little out of the realm of ordinary everyday life. But they're not so far out that we think them completely impossible to appreciate and understand. Transportation, utilities, banking, hospitals, communications: all have significant parts run by computers. In the US, over 250 different computers run the Federal Aviation Authorities' air traffic control systems. Hundreds of thousands of microprocessors—with time-keeping devices—are embedded in cars, microwave ovens, telephone answering machines, and cash dispensers. Total disaster just doesn't seem completely out of the question.

Whatever the outcome that will eventually realize, the current volume of discussion, debate, and putative repair actions allows an indirect estimate of ICT's pervasiveness. This is almost surely an under-estimate, moreover, since presumably there must be *some* pieces of ICT out there that do not suffer from Y2K.

One well-regarded estimate of Y2K's worldwide cost is US$600 billion; another forecast, adding in lawsuits and damage claims, takes that number over US$1 trillion.[1] In the UK in March 1998, the Prime Minister announced setting aside £30 million for training to deal with Y2K in the private sector. Coping with Y2K in the government sector alone might cost up to £3 billion, of which £600 million will be for the National Health Service. The World Bank has set up a Trust Fund to deal with Y2K in developing countries, to which the UK has committed £10 million. The Information for Development program in the World Bank has just finished a competition offering US$250,000 to the best submission for coping with Y2K in the Third World.

Add to these ICT figures the contributing numbers for new media, electronic databases, intellectual property—pretty soon we're talking real money.

3. ECONOMIC ESSENTIALS

Why do the different pieces of the weightless economy belong together?

I argued above that the term *the knowledge-based economy* gives an inaccurate picture of what is happening in the economy. Its coverage extends over quite inappropriate subjects and historical periods; it is often self-serving; and it diminishes the speaker's credibility (or at least it should).

In a different sense, however, the term *knowledge* is more than apposite: This doesn't mean that everything in the weightless economy is knowledge; it does mean that everything in the weightless economy *has the same economic properties as knowledge*. The difference is not just nit-picking. It prevents confusion over the substance of the debate, the magnitude and importance of the economic question, and the appropriate stance of government policy and social response.

In 1962 the Nobel Prize-winning economist Kenneth Arrow published a paper on the allocation of economic resources for carrying out inventive activity. Reading that paper from the perspective of the 1990s, one senses the urgency, brought on by the Cold War, of coming to grips with scientific advance, military procurement, and the race with the Soviets for economic prosperity and growth. None of these strikes as great a popular resonance now, although I will argue that reinterpreting Arrow's analysis makes it more than ever trenchant.

In his paper Arrow gave the first formal description of certain peculiar economic properties of knowledge. Arrow pointed out that the economics of knowledge was subtle because knowledge displayed indivisibility, inappropriability, and uncertainty. These three properties are common to all the pieces of the weightless economy that are out there today. I will return to the third of these further below, but look first at indivisibility and inappropriability.

By indivisibility, Arrow meant that knowledge is, *infinitely expansible*: the usefulness of knowledge does not diminish with its use. Along the same lines Thomas Jefferson, in 1813, referred to:

> "… the thinking power called an idea, which an individual may exclusively possess as long as he keeps it to himself; but the moment it is divulged, it forces itself into the possession of everyone, and the receiver cannot dispossess himself of it. Its peculiar character, too, is that no one possesses the less, because every other possesses the whole of it. He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine, receives light without darkening me. That ideas should freely spread from one to another over the globe, for the moral and mutual instruction of man, and improvement of his condition, seems to have been peculiarly and benevolently designed by nature, when she made them, like fire, expansible over all space, without lessening their density at any point, and like the air in

> which we breathe, move, and have our physical being,
> incapable of confinement or exclusive appropriation."

Jefferson concluded from this that inventions, like ideas, cannot be the subject of property. Or, in Arrow's language, the rewards from creating ideas and knowledge are inappropriable.

There is a larger social issue here, speaking not just to the rewards for intellectual pursuits like academic research. Infinite expansibility implies that only the first discovery, formulation, implementation, or creation of a piece of the weightless economy counts for society's welfare. Reinventing the wheel gets no points for improving the lot of humanity. Paradoxically, then, from the perspective of social efficiency, a winner-take-all reward structure—trivial though those winner rewards might be—appropriately matches individual outcomes with social contribution.[2]

How does this apply to the weightless economy? If Britain is indeed moving towards the creative and knowledge-based economy—notwithstanding the criticisms of that profound, rigorous social thinker Ben Elton—what do these observations based on economic theory imply for our ability to add value and generate wealth?

The vivid picture to draw here is that of a chunk of word-processing software, sitting somewhere on a satellite server encircling planet Earth: That set of computer instructions—a string of 1s and 0s—can be used by me for technical composition in my office in London, without loss, at the same time as by my counterparts in Stanford California, Boston Massachusetts, Tel Aviv Israel, and Bangalore India. How is the creator of that software supposed to keep track of the usage and multiple copies created in computer memory, and charge consumers appropriately?

Just as these intrepid writers go about their work, so too do multiple users—placed in arbitrary locations on Earth—plug into and draw on the encyclopedic, financial, biological, or chemical design data warehoused on computer disks in the Docklands, Chicago, Singapore, or any other data haven. Just as easily and freely do viewers, anywhere anytime, enjoy multiple instances of the movie *The Wings of the Dove*; game-hobbyists appreciate the puzzles of the Doctor Who CD-ROM produced by the BBC and Studio Fish; students and cognoscenti worldwide attend and participate in lectures by world experts that they otherwise would not be able to reach.

It is easy to understand why "death-of-distance" observers note that it is timezones rather than geographical separation that will determine patterns of global economic activity. Nor are the economic activities described above too far from what some, carelessly perhaps, might call the output of *Cool Britannia*. What rewards structure is appropriate or feasible in such economies?

Our focus here is not now on the specifics of these examples: A priori economic reasoning reminds us the rewards from weightless economy activity are inappropriable. Once an idea or computer content or piece of financial data or recording of a musical performance—each of which is simply a string of 1s and 0s—is given out to the first user, it is freely reproducible (physically at least, if not legally), and it disseminates over all the earth, beyond control.

Yet, we see the purveyors of software, media, and other forms of intellectual property among the very wealthiest individuals in modern society.

We might well understand why, say, WorldCom Inc., which owns the world's top Internet Service Provider UUNET, has delivered for its stockholders an average annual return of 53% in the decade ending 1996. A company like WorldCom furnishes the pipes down which scurry the 1s and 0s of the weightless economy. Those pipes spell big money. WorldCom topped by almost 60% BT's US$19 billion bid for the US communications company MCI. For WorldCom, this would have allowed them to be a one-stop shopping centre for all modern communications needs: Internet access; voice and data; local and long-distance. For BT, this would have been a route into the US$180 billion US local and long-distance telecommunications markets.

But a moment's reflection suggests that if it were just 1s and 0s running down these channels and those digital bits of logic earned no appropriable rewards for their creators, then private enterprise alone could not support these markets. And yet it does, mostly.

The creators of these 1s and 0s are no economic slouches: Microsoft and Oracle have made their executives unbelievably wealthy. Rupert Murdoch's News Corporation is a global powerhouse. EDS and SAP, the American and German accounting, database, and inventory control software companies, are all-pervasive in modern economic life. Why they have been able to break the Jefferson-Arrow prediction of inappropriability?

One easy answer—naïve and simplistic—is that these providers of digital bits content are just legal monopolies extracting

excess rent from the consuming public. They have been able to twist legal systems into allowing them distribution control over Jefferson-Arrow knowledge-like commodities. Moreover, not only do they have monopoly power and property rights, their natural marketplace is global and unbounded, for there are neither increasing marginal costs nor steep transportation duties to restrict the range of customers they can supply. No wonder they are the economic giants that they have turned out to be.

This somewhat simple-minded reasoning applies, incidentally, to pop stars, opera singers, all music and film companies, authors and paper publishing houses, producers of trademarks, symbols, advertising, and so on—all the elements of the weightless economy. If markets were competitive (the reasoning goes), and others in the marketplace could clone content, price on all these products should quickly get (close) to zero. Indeed, that outcome would be not just morally satisfying—in this reasoning—but socially efficient as well, for price would now have been driven to marginal cost. That that does not happen then simply reflects a tradeoff that society early on made: Dynamic ex-ante incentives to create ideas, knowledge, and other elements of the weightless economy should be balanced against the static ex-post monopolistic inefficiencies that systems of intellectual property rights inflict when they function correctly.

The truth is, as usual, likely more subtle. The large companies are not simply riding out the benefits of persistence, path-dependence, and first-mover advantage—the usual predictions for monopolies in increasing-returns models. These companies scramble and innovate furiously to keep ahead of the pack of contesting competitors. Those initially in place first and already dominant have not always remained so: IBM's stock-market valuation fell by over US$75 billion in the late 1980s—adjusted for inflation, that's about double Bill Gates's 1998 net worth. Following this near-death experience, IBM remade itself, and now sells more software worldwide than does Microsoft. Netscape Communications Corp., first in place with a widely-used net browser, finds itself struggling for survival, as its browser share on desktops has halved over the last two years. Xerox Corp., with its technology lab second to none in the world, responsible but unrecognised for many of the most useful technical innovations the last two decades, has not itself garnered a single commercial success from all its creative output.

Evidently, just being first and creative and generating insanely great ideas is no guarantee of economic success.

The first lesson, therefore, is that adding value and maintaining one's position in the weightless economy is not just playing old-fashioned monopolist in an increasing-returns world. Leaving out important elements of reality, the message is that to begin operation in the weightless economy one doesn't need to expend high setup costs—a large factory, heavy machinery, or an extensive plot of land. Because of this, any current market leader can be easily overtaken. What counts is to recognize a consumer need, and then to have a computer to implement the first instance of one's software or music product. No doubt this simple image ignores much that is relevant. But it's a usefully vivid and not entirely misleading picture.

The second lesson is that one adds value by bundling and packaging. Some might deride this as the triumph of Marks-and-Spencer style over content. But there are only so many uniquely brilliant insights and conceptual breakthroughs that humanity can use at any one time. Bundling and packaging are no different from telling a joke more than once; the value added is positive even though that joke—its critical idea component—is already floating about in the weightless economy. Thus, JP Morgan freely gives out on its website financial data and models it has painstakingly put together. The data and models are infinitely expansible and have distribution that cannot be controlled. From this activity, however, the hope is the potential customer gets hooked into thinking finance the JP Morgan way, and then who better to facilitate trading but JP Morgan itself.

The third lesson specific to infinite expansibility and the weightless economy is that redistribution is not the same as expropriation. Unlike a piece of land or a factory, elements of the weightless economy can be moved from rich to poor (or poor to rich) without the original owners experiencing loss. Thus, social redistribution is no longer the issue—what matters is what happens following the redistribution, which occurs pretty much automatically anyway.

4. TECHNOLOGY AND GROWTH: WHAT TO DO?

I now turn to the third of the Jefferson-Arrow observations on the weightless economy, namely, uncertainty. By this, one doesn't mean risks endowed by nature, but instead the uncertainty on how useful

or usable is a piece of knowledge or a component of the weightless economy. A historical perspective provides insights.

In the late 1950s and early 1960s those economists who invented growth accounting found that technical change explained almost 90% of US economic growth in the first half of the 20th century.

This 90% figure is remarkable for several reasons. Most interesting is that this period of economic history was not going through the white heat of the Industrial Revolution. This, remember, was long after when James Watt and Matthew Boulton raced against time at the Patent Office to get their steam-engine business in place. This was long after Charles Babbage and George Airy held public debates on the appropriate subject matter and economic financing of science. By the late 19th century, permanent telegraph cables across all major countries had been laid, and the telephone exchange had appeared, saving Alexander Graham Bell's invention from the deathtrap of fixed, dedicated-line communications.

By 1900 the US was already criss-crossed by 200,000 miles of railtrack (grown twenty-fold from 1850). Whether US railroads were technically superior to European ones had come down to whether huge freight cars with double bogies and automatic central couplers were preferred to smaller four-wheeled wagons using screw-couplings and side-buffers. This is hardly stuff that keeps policy-makers and academics awake at nights when they can instead be thinking about global information infrastructure and education provision over the Internet. By 1908 Henry Ford's Model 'T' was being produced on assembly lines—and its engineering and stylistic design would remain unchanged for the next twenty years!

Some technologies were newly developing, of course: The Wright Brothers' flying machine only became airborne in 1903. But commercial aircraft, like the space-age technologies coming out of the Second World War—atomic and nuclear energy, mainframe computers, television—really affected ordinary people's lives only later, after 1950.

Let's face it: Early 20th century US was technologically boring. Those of us who pore over magazines like Wired and study the new technologies daily coming out of Intel, Sony, or Microsoft imagine the first fifty years of the 20th century—two human generations—should have produced something comparable to the 10-billion fold

increase in power that computer chips experience in that length of time. Instead, nothing.

Despite this, technical change accounted for *90% of economic growth!* Compare technical change then with that now—almost all concentrated in the weightless economy. The real price of computing has been falling by 30% a year for the last two decades, a halving every two to three years. Communications has had its real price decline, although only by a relatively modest (but still spectacular) 8% a year for the last 70 years. Relative prices and sector-specific productivities just don't change this much without economic behavior also altering. Therefore, while in the 1960s the IT share of total business equipment investment in the US was only 3%, this rose to 45% in 1996.

Some observers point to this IT increase simultaneous with US productivity growth falling from 1.7% (over 1947–1973) to only 0.5% (from 1973–1992) as evidence on the uselessness of IT in particular and the fragility of the weightless economy in general.[3] This so-called *productivity paradox* has been made much of ever since Robert Solow's original remarks on this in 1978.[4]

Be that as it may, even without attempting to calibrate knock-on spillover effects, IT industries themselves directly accounted for over one-quarter of US economic growth in the five years 1992–1997. In the US in 1996 employees in the software and software services industries numbered over 1.2 million and earned an average of US$56,000 per year, double that of the private sector average. In those industries, individual earnings and aggregate employment—both price and quantity—have been growing at 7% a year for the last 10 years.[5] It is hard to look at these numbers and think of the weightless economy as generating neither employment nor profitability.

Note the dissonance: On the production and supply side, IT in particular and the weightless economy in general show all the healthy signs of growth. On the consumption and demand side, however, doubts surface. Some point to either the productivity paradox or to more philosophical, moralistic dimensions on whether this new, weightless economy is really providing the appropriate goods. Sometimes, there are questions on whether the public should really be allowed this diet of an intangible, almost frivolous side to modern economic life: Perhaps people should confine themselves only to better food, bigger houses, faster cars. The 1s and 0s of the weightless economy are, perhaps, a playful luxury.

Earlier in this section I compared the pace of technical change now to that in the early 20th century, and indirectly to that in the Industrial Revolution of the 18th and 19th centuries. These earlier episodes were all, with hindsight, judged to be economic successes, built on technical progress. Contemporary observers in the 1780s wondered if, with the technical changes emerging around them, people would be forever displaced from gainful employment. People and economies adapted. Employment at the end of the 20th century is 20 times what it was as the Industrial Revolution was just getting underway.

Of course, whether the technical changes pointed to by the weightless economy will turn out to be comparably fruitful as those of the Industrial Revolution remains to be seen. But there is a different historical episode which, instructively, turned out to have a lot less happy ending.

This is the utter failure of the Industrial Revolution to materialise in China of the 14th through 19th centuries. All technological prerequisites were present in China long before the Industrial Revolution in the West of the late 18th century. China should have grown explosively. But, instead, everything petered out. Why?

In information processing, China had the putative headstart. It introduced paper 1,000 years before the West, and printing in about 700AD. Chinese water clocks of the 11th century were more accurate than contemporaneous European mechanical ones. For transforming the material world around them, the Chinese were casting iron in blast furnaces by 200BC, centuries earlier than Europe. Spinning wheels for textiles and water power were developed at about the same time as in the West. The Chinese invented gunpowder: that they made only fireworks from it, not weapons for killing, is to their credit—not, as many commonly think and Rousseau is supposed to have said, a sign of backwardness.

Yet, with all these technological wonders, China did not experience an Industrial Revolution to set the world afire. It was ahead of the world in 1300; it was far behind by 1900.

Why? The supply side of technology was present; the demand side was not. The Chinese state committed what, with hindsight, we now know to be an egregious sequence of mistakes. In China, most technological development was in the hands of the government bureaucratic elite. New technology was controlled and not permitted to be widely used by the population. Indeed, the state saw

a subversion of its power as the most likely outcome should the populace learn of and articulate a demand for the new technology. No diffusion of ideas and tools took place, and the Industrial Revolution that might have been instead died.

What does this have to do with the weightless economy? The easy interpretation is that the weightless economy is the for-now culmination of technological development. Whether society embraces the fruits of the weightless economy and, through the usual workings of the marketplace, goes on to encourage further its development matters a great deal.

Policy-makers in particular and society in general have a choice: Europe of the Industrial Revolution? Or China of the 14th-century?

5. CONCLUSIONS

In this presentation I have tried to argue four points:

- Technical change is now and always has been the main engine of economic growth and employment.
- The weightless economy is the natural next stage in the historical progression of technical change. But the rules of engagement—whether in business or policy—differ from those in more traditional industrial economies.
- The weightless economy is here now.
- Society faces a choice: How it responds is critical for our continuing economic prosperity.

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[1] These numbers are from Gartner Group and Ciga Information Group, respectively.
[2] This doesn't say, of course, that the *dynamic* process is itself efficient.
[3] This is total factor productivity; the figures are from Martin Baily's study described in Brynjolfsson and Yang (1996).
[4] Bryjnolfsson and Yang 1996 and Sichel 1994 provide recent statements.
[5] These numbers are calculated from US Commerce Department (1998).