

# **Growth and Wealth Creation in the Weightless Knowledge-Based Economy**

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Your Royal Highness, Ladies, and Gentlemen:

It is, for me, a great delight to be in Brussels this morning in this beautiful building, and a great honor, indeed, to be addressing this audience—one who has power to make things happen. This is a rare and valued opportunity for any academic in an economics department, relatively distant from real-world practice.

I will use the occasion to talk about growth in a knowledge-based economy.

To an unsuspecting observer, perhaps wandering by accident into this auditorium from the street outside, such a talk might seem inappropriate just at this time. For months now, the global economy has flirted with a serious worldwide downturn. Every day brings yet more news about financial crises, not just in the Far East but also in financial institutions in the West. The world holds its breath to see what will happen in Russia and in Brazil. All around there is general unease. Why talk about growth and long-run technical change, when so much else more important seems immediate and critical?

However, just as it is wrong and harmful when investors panic—shortsightedly obsessing on the immediate and losing sight of fundamentals—so too can we be overly close to events around us, and forget that longer-run issues of economic performance remain at stake. Just as economic gyrations in the Far East have been large and violent, so too the changes wrought by technology, and powerfully by technology's most recent developments.

In this talk, I address four points:

1. What the weightless economy is. One possible description is that the weightless economy is the natural limit of developments put in motion by the knowledge-based economy. In focusing on this limit, we can appreciate

- better the implications of the knowledge-based economy, stripping away inessentials.
2. The weightless economy is here now and growing rapidly.
  3. Business practice and government policy must change, taking on board the lessons of optimal performance in the weightless economy.
  4. The growing importance of the weightless economy will pose challenges that only society, collectively, can solve.

### **Technology in Economic Life**

The knowledge-based economy might be taken to be nothing more than the proposition that knowledge matters for economic performance. Such an idea is both classical and new.

It is classical in that the economists who invented growth accounting in the 1950s had already estimated over two-thirds of economic progress in the 20th century to be due to technical change, i.e., to ongoing progress in knowledge generally defined.

Going back further, we might consider the first Industrial Revolution, where deployment of machines such as spinning Jennies and steam engines significantly boosted economic performance. These machines were the physical embodiment of new knowledge. The world was therefore by the time of the Industrial Revolution already a knowledge-based economy.

Take yet a different example. Knowledge is very much the essential ingredient in the mathematical development of the properties of  $\sqrt{-1}$ . (What else could be?) This knowledge allows understanding the properties of electricity and magnetism. Ultimately therefore, the spread of electricity usage throughout modern economies from 1899 on must be due to knowledge.

Such an interpretation of the knowledge-based economy—perhaps mundane, arguably low-key, undoubtedly pervasive—applies not only to the past. Its relevance continues today in poorer parts of the global economy. The World Bank's 1998 World Development Report reminds us that certain very basic knowledge of health and sanitary procedure has saved over 30 million West Africans from the affliction of river blindness. Turning to where room for improvement remains, a little knowledge (of the presence of readily-available treatments) will go a long way to alleviate the suffering of

the 2 million who die each year and the 900 million made ill by the dehydrating effects of diarrhea.

### **What is new in the knowledge-based economy now?**

These examples of the economic importance of knowledge are classical, illustrating principles at work in *any* economy. They shed no light on what is new and important now in the knowledge-based economy.

I propose instead that the *weightless economy* is where the economic significance of knowledge achieves greatest modern resonance.<sup>1</sup> I define the weightless economy to comprise four main elements:

1. Information and communications technology (ICT), the Internet.
2. Intellectual property: Not only patents and copyrights but more broadly, namebrands, trademarks, advertising, financial and consulting services, health care (medical knowledge), and education.
3. Electronic libraries and databases: Including new media, video entertainment, and broadcasting.
4. Biotechnology: Carbon-based libraries and databases, pharmaceuticals.

(In principle, 3. and 4. could be grouped together in one encompassing category *Libraries and databases*. However, listing separately the silicon- and carbon-based forms helps emphasize the broad coverage intended.)

A rationale and coherence inform the selection of these categories. The different items enumerated have two features in common: First, they are systems for managing knowledge. Second, they are knowledge-products, i.e., commodities whose physical properties resemble those of knowledge, regardless of whether the commodities themselves contain significant amounts of knowledge as traditionally understood.

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<sup>1</sup> Some readers might think of this also as an economy of *intangibles*. Usage differs, but often the term *intangibles* is intended to comprise among other things janitorial services and haircuts. As will become clear, most of what I will say below does not at all apply to this broader notion.

A visual metaphor might help. Appropriately interpreted, knowledge, at its most basic, is just a string of 1s and 0s, i.e., a bitstring. Any idea, any image, any information can be written as a bitstring. To read or interpret a bitstring, we use yet another bitstring. To manage bitstrings—to add them together, to merge them, to remove them, to mutate them—we use still other bitstrings. Bitstrings can be implemented in electronics, in silicon, or in carbon—the casing material is irrelevant; it doesn't affect how the bitstrings work, and it doesn't affect their value.

This picture (or model) of the weightless economy, we realize, is nothing more than a coming to life of the mathematics written down by Alan Turing and John von Neumann.

### **Is the weightless economy for real?**

We can assess if the weightless economy matters at three levels. We can look at individuals; we can look at firms; and we can look at entire economies.

First, people. In 1997 among the world's 20 wealthiest individuals, three were Americans who derived their wealth almost entirely from software. Between them, these three had total wealth almost ten times that held by the three wealthiest Britons involved in more tangible production (real estate, steel, and food). In the US list of 20 wealthiest, joining these three are three more in the computer industry and two others who are media magnates. In October 1998, the world's wealthiest individual (in software) had total wealth more than double that of the runner-up (not in software).

Apparently, the weightless economy rewards extremely well those who are successful in it.

Next, turn to firms. As the historical volatility of stock markets powerfully shows, gauging the economic success or failure of individual firms is difficult in general. However, averaging stock market performance over longer time periods and across individual firms in sectors of interest can give a more reliable picture. The five major ICT firms that likely every interested observer would name are Microsoft, Intel, Compaq, Dell, and Cisco. Between them, these firms had in 1987 market capitalization of US\$12 billion. By 1997, their combined capitalization amounted to US\$600 billion—a 50-fold increase over less than 10 years or annual growth of 45%. Such rapid

growth, sustained for such a long stretch of time, is remarkable by comparison with any other economic quantity.

Evidently, firms in the weightless economy that succeed do so powerfully.

Finally, consider countries. In the United States, the Information Technology share of nominal GDP has grown from 4.9% in 1985 to 8.2% in 1997. At the same time, IT prices have been fallen dramatically: the real price of computing has, by some measures, been declining by 30% a year for the last two decades, i.e., a halving every two to three years for the last twenty years. The real price of communications has, similarly, been decreasing at 8% a year for the last seventy years, a halving every eight to nine years. And, disk storage capacity has been increasing at 60% per year since 1991, while its nominal price has fallen a hundred-fold. Thus, without even taking into account the potential spillover effects from its increasing the productivity of other industries, the IT sector's direct contribution to real value produced has been substantial for the world's leading economy.

That this be true for the technologically advanced might not be surprising. However, IT contributes greatly to growth in some of the world's least developed economies as well. In India, per capita annual income in 1995 was US\$340: The majority of the population of 900m lived on less than US\$1 a day. Yet, India hosts a major offshore software center for the rest of the world. Software production in 1997 was a US\$2billion industry, employing 260,000 people. The industry in India had had revenues growing by 50% a year for the last five years, with over 60% generated as export earnings.

While these successes reveal the importance of IT (and provide a lower bound measure for the significance of the weightless economy), the potential for growth remains high. In total, the IT industry worldwide in 1997 was about US\$1.5 trillion— about one UK GDP—with total world GDP US\$28 trillion. Thus, the IT industry overall remains only 5.4% of total world production compared to, say, agriculture's 8%. Even noting that 80% of the global IT industry is concentrated in only five countries (France, Germany, Japan, UK, and US), IT is then only 7.1% of total GDP in these richest, technologically-advanced countries.

## **The Internet**

Narrowly, the Internet might be regarded as nothing more than one specific concrete manifestation of progress in Information and Communications Technology. One might then simply say that rapid and dramatic technical progress has been critical in enabling something like the Internet.

However, Internet technology could well have been put in place with no good application found for it. Historical examples abound where one side of a market—the supply side—comes on strong while the other—the demand side—languishes, with the result that no ongoing development occurs. We will see one instance of this further below.

But the Internet is *not* such an example. Radio, a relative simple undemanding technology took 40 years to achieve 50 million regular users. The Internet took 4.

Part of the Internet's rapid growth derives from its making easier the tasks that participants in the economy have always needed to perform: cheaper and easier exchange, faster dissemination of information, reduced inventories, greater outreach in both supply chain and distribution channel. Examples of this include Dell and General Electric. These companies have re-oriented their procurement and sales practices to exploit Internet communication—posting requirements and receiving bids for outsourced manufactures, designing and customizing merchandise for individual customers—while, at the same time, continuing their business of selling computers and electrical and electronic machinery. The volume of business done thus by Dell has grown six-fold over 1997 alone. General Electric has estimated that by reorganizing its supply chain around Internet procurement it has saved over 15% on factor input costs—a significant reduction compared to, say, typical changes in tariff rates from trade agreements.

But perhaps the more significant and telling part of Internet growth arises from the Internet's making possible what previously was not. Critical for this is the Internet's coupling with the other elements of the weightless economy. While tangible goods can be sold over the Internet, their actual delivery to the consumer will always be slow and will always eat up transportation costs. By contrast, the Internet itself can deliver directly weightless-economy goods and services. Health care and education (two large expensive sectors—across most advanced economies—where historically

productivity growth has been famously low), news, software, music, advertising, video entertainment, securities, banking and other financial services, database access, and consulting services can all be consumed over the Internet. The result, one expects, will be a dramatic reduction in transaction costs. Productivity will rise in precisely those areas that, traditionally, have seen poor productivity performance.

While growth rates for practically everything to do with the Internet have been astounding, the promise continues to be significant. Total 1997 Internet purchases amounted to only US\$7.6 billion. This is less than what Americans spent on cosmetics alone. It is dwarfed by the US\$50 billion that Europeans spent on tobacco products. The potential for growth and ongoing efficiency improvements remains high.

### **What the weightless economy is not**

The pieces of the weightless economy I have listed sometimes recall a *knowledge-based economy* or an *information society*. There is nothing wrong with such identification, in principle, but I find it not insightful.

For one, going even further back than examples I have already listed above, economies have been knowledge-based at least since Sumerians in the Mesopotomian river basin began carving cuneiform financial records onto clay tablets 5,000 years back. When Neanderthals and early humans existed side by side, the Neanderthals were the physically superior. Yet early humans survived; the Neanderthals did not. What explains this is, not improbably, a clever piece of knowledge that early humans had but the Neanderthals did not.

Perhaps a case could be made that the economic and business implications of knowledge-based society now are identical to those of knowledge-based societies then. I doubt such an argument would lead to useful insights. On the other hand, calling the weightless economy a knowledge-based economy certainly does no harm, provided we recognize the nuances that drive the examples I have described above.

The weightless economy does not resurrect any long-standing debate between the relative importance of the manufacturing and service sectors. Some manufacturing—semiconductors, network

routers, cables and wiring, computers and computer engineering, pharmaceuticals—will be part of the weightless economy; others will not. Some services—data processing, financial consultancy, education, health—will be part of the weightless economy; others will not.

Not all high technology is part of the weightless economy. An oil supertanker is hi-tech. However, no supertanker can be shipped via the Internet; nor can the function of a supertanker be replaced by any conceivable add-on to the Internet.

Neither is the converse correct. The weightless economy is not just high technology. Education is part of the weightless economy. Its technology hasn't changed in centuries. Some health care is high-tech; some of it isn't.

Finally, the weightless economy is not a destroyer of jobs. In the US, the fastest job growth is precisely in sectors associated with the weightless economy. From 1996 through 2006, the industry with top employment growth is projected to be computer and data-processing services, at 108%. The next fastest-growing industry is expected to be health services, at 68%. The Bureau of Labor Statistics forecasts that the occupations with fastest employment growth will be database administration, computer services, and computer scientists (118%); computer engineers (109%); systems engineers (103%); and then personal and home care aides (85%).

At the same time that employment growth is rapid, so too wages earned in these industries and occupations are high. In 1997, the average worker in the IT industry earned twice the national average across the private sector.

If anything, the weightless economy has been a powerful engine of job growth.

### **Special economic significance**

Why take the weightless economy to be distinct from the knowledge-based economy? How are weightless economy knowledge-products similar to knowledge?

How can knowledge be a critical ingredient in a weightless economy knowledge-product, and yet the two not be the same? An analogy is helpful here. Suppose knowledge were like paper money. Pulp that money, and re-form the result into a paper background for a pencil drawing. Let Picasso come along and execute that pencil

drawing, and call the result a weightless-economy knowledge-product.

Obviously, paper money is embedded in the Picasso pencil drawing; knowledge is embedded in the knowledge-product. The two—paper money and the pencil drawing; knowledge and the knowledge-product—are not the same even as their physical properties are identical.

While useful, this example is also profoundly wrong for it focuses on the properties of the paper shared by both money and the drawing. For knowledge and the weightless economy, on the other hand, it is not the carrier that is important; it is what the carrier carries. With apologies to Marshall McLuhan, in the weightless economy, the medium is definitely *not* the message: the message is the message.

What do we get from recognizing the commodities in the weightless economy as knowledge-products?

**First**, like knowledge, knowledge-products show *infinite expansibility* (a term due originally to Thomas Jefferson). They do not get used up, physically. Computer software does not have its usefulness drawn down the more users run it. Advertising imagery does not diminish in impact the more people view it; indeed, the opposite holds.

At the same time, a knowledge-product—unlike say a typical durable good—disrespects geographical distance. It behaves as if it could expand to fill all available space. I can, in London, be using a piece of software—located on some satellite server encircling the Earth—while someone else, working from Stanford, California does exactly the same, with the identical piece of software. Neither one of us suffers from the other's actions.

These statements remain true when I substitute in place of computer software any intellectual property or libraries and databases. They become false, however, when I discuss, say, a chocolate-chip cookie. When someone eats a cookie, it is no more. Nor can a cookie be consumed without being the consumer being close by, geographically.

**Second**, like knowledge, knowledge-products show *superstar dynamics*. To understand this, consider first the wheel: Society, appropriately, does not reward reinvention of the wheel, but multiple implementations of (the idea of) a wheel do get properly compensated. However, those multiple instances are fashioned out of hard physical material, and it is this last for which the buyer pays.

Knowledge-products, by contrast, are the idea and implementation rolled in one<sup>2</sup>—multiple implementations require no physical material. Thus, instances of a specific knowledge-product beyond the first should fetch zero price in a well-functioning market. Superstar dynamics refers to this first- (or winner)-takes-all characteristic of knowledge and knowledge-products.<sup>3</sup>

This does not say that knowledge-products are valueless: Water is essential to human welfare, but its price in modern societies is, for all practical purposes, zero. Bundling water with something else—adding carbonation to water, extracting it from distinguished springs, associating it with a powerful advertising image—can, of course, be a rewarding enterprise. Businesses can and do add value similarly to many knowledge-products in the weightless economy.

**Third**, like knowledge, knowledge-products have a chain of production that is irrecoverably intricate and uncertain. Applying more factor inputs in an effort to increase output can be self-defeating. Just as making nine men pregnant for a month each fails to produce a newborn baby, throwing more programmers at a software project does not typically make a complete piece of software faster, better, or more reliable. Similarly, financial consulting, a musical composition, or devising the central image in an advertising campaign calls for not many hands, but few. In scientific discoveries, the prevalence of Merton multiples—many researchers' working on the same problem results in the same discovery repeated simultaneously, rather than an isolated unique discovery occurring sooner—is evidence of this same non-additivity.

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<sup>2</sup> This overstates the case a little. Below, when we discuss copyrights and patents, distinguishing the idea and the implementation becomes important, even in the weightless economy. What matters here is not requiring significant physical material for an implementation.

<sup>3</sup> Sometimes, this attribute or something similar is labeled *increasing returns*. I prefer not to use this because it lacks specificity. Increasing returns in economies can arise in many ways. Superstar dynamics, on the other hand, refers to something very particular. Insights useful for the latter need not apply to increasing returns in general. Put another way, saying that knowledge-products show increasing returns (and ending the discussion with that) is like saying a mouse's immune system is simply a special case of non-elephantine biology.

## Useful Business Models and Social Policy

What improved business practice do these observations imply? Why, if knowledge-products resemble water, predicted to trade at zero price in well-functioning markets, are successful purveyors in weightless-economy industries so wealthy?

Early on in economic history, societies recognized a basic dynamic inconsistency: the zero-price outcome—efficient though it might be *ex-post*—results, with forward-looking producers, in no creation at all of any knowledge or knowledge-product. No innovation occurs; no technical progress takes place; societies stagnate.

This tension between *ex-post* outcomes and *ex-ante* appropriate incentives has historical precedents. Societies must have developed alternative schemes for rewarding producers in such situations. But since the weightless economy is mostly new, we need to look instead at the historical record on rewarding the production of traditional intellectual property.

*Patronage* is one scheme. This is a system such as when Emperor Joseph II appointed Mozart to a court position, allowing music to be composed as the latter wished (almost as an incidental by-product) and rewarding Mozart ostensibly just for being at the royal court. Government funding of certain kinds of academic research is similar. The defining characteristic in both cases is that the weightless-economy producer is the one who poses the question and then answers it—whether in music, economics, or physics.

*Procurement* is a second scheme. This is when the state of extant knowledge makes obvious what question needs to be addressed as the next step in intellectual advance. The funding agent—whether the Emperor commissioning an opera, a space agency seeking an improved clothing zipper, or the military requiring faster targeting algorithms—is the one who poses the question, and commissions research by weightless-economy producers into that question.

Weightless-economy products that result from patronage and procurement schemes might be made altogether public or portions might be kept secret. Examples of both exist in the modern weightless economy. The root Internet technology arose from military (US Department of Defense) procurement; the root Worldwide Web technology arose from CERN patronage. Both of these have had profound effects on economic performance.

Profit-seeking businesses in the weightless economy can well operate under systems of procurement and patronage. Businesses can add value by bundling a knowledge-product with something else that is not infinitely expandable: tailor-made consulting services, licensed customization and re-packaging of the underlying knowledge-product, tying an appealing image to a knowledge-product. This business model is used in the bottled-water industry and in haute couture, the same way it is used for distributing the Linux operating system and GNU software products. The model allows for viable industries in Internet service providers, health care, and education. Similarly, this business model correctly predicts the otherwise inexplicable success of the fashion garment industry in Tiruppur, south-central India—a major center of cotton-knit textiles, thanks to satellite and fax technology, in the midst of poverty and deprivation. The model puts in perspective the putative challenge that Internet dissemination poses for traditional higher education.

A third scheme for rewarding intellectual property deviates sharply from the first two in that the creator owns exclusive monopoly rights—for some specified time—on the product. *Property* (proper) is then the appropriate label for this.<sup>4</sup> Here, the tradeoff between ex-ante incentives and ex-post zero-price optimality is resolved in favor of the social inefficiency engendered by sanctioned monopolies. Patents, copyrights, and trademarks are examples of this scheme. The large, important example of *Property* in the weightless economy is commercial computer software.

A further key distinction should be drawn between patents and copyrights. The former is supposed to be awarded only when a knowledge-product is judged innovative and non-obvious. The latter, more easily given out, protects the implementation of an idea, but not the idea itself.

Which should societies prefer of these different solutions to the problem of rewarding producers in the weightless economy? The answer depends on details; no general conclusions are possible. Moreover, in many cases, the particular solutions societies have settled on have been the result of historical circumstances that are no longer relevant.

Policy in the weightless economy has to be proactive on the issue of appropriate rewards to producers. To do nothing is a particular proactive policy: It is a decision for that solution selected

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<sup>4</sup> I have taken these labels, the 3 *P*'s, from Paul David's writings.

by historical accident. A combination of monopoly rights, infinite expansibility, and superstar dynamics can lead to large inequalities in income and wealth across people—this might well be the outcome societies prefer. Or, it might not.

As the weightless economy continues to grow in importance, welfare losses from inappropriate policies can only increase in tandem.

Because knowledge-products are bounded neither by geographical location nor by increasing marginal cost, their natural marketplace is immediately global. Both social efficiency and individual profit-seeking incentives agree on this. But this also implies winners are superstars—they own the entire market, and there is only one of them. Those who come in second find no economic elbowroom. Rightly, they need to seek out new knowledge-products to make their own, not attempt me-too reproductions. Economic growth, through faster technical innovation, might be consequently higher.

## **Aggregate Policy and Demand**

Thus far, I have concentrated on policy and business behavior on the supply side of the weightless economy. The demand side too is important. The economic history of China, from the 14<sup>th</sup> through 18<sup>th</sup> centuries, is a tragic poster-child illustrating that a supply of technology, no matter how hi-tech and chockfull of good ideas, if unmatched by demand takes society nowhere.

The question I now address is, Why did the Industrial Revolution not occur in China, where all technological prerequisites were already present long before the late 18<sup>th</sup> century?

In information processing, China had the putative headstart. It introduced paper 1,000 years before the West, and printing about 700AD. Chinese water clocks of 1086AD 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 in Europe; spinning wheels for textiles and water power were developed at about the same time as in the West.

Yet, in the presence of all these technological prerequisites, 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? To repeat, 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, technological development was in the hands of the government bureaucratic elite. New technology was controlled. The state did not permit its wide usage by the population at large. 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.

## **Conclusions**

In this talk, I have described the weightless economy: It is the for-now manifestation of the evolving history of technological progress.

I have considered three main questions on opportunity and pitfall in the weightless economy. First, I have described tensions between individual profit-seeking incentives and social welfare. What business models are useful and appropriate for operating in the weightless economy?

Second, along related lines, I have discussed potential outcomes in economic growth and inequalities in income and wealth. What appropriate policies are is, typically, ambiguous.

Third, I have illustrated the potential for massive policy failure by describing a historical incident, where progress in technology was hindered through inadequate infrastructure—not as one might typically suspect on the production or supply side, but instead on the *demand* side of technology.

The actions that businesses and policy-makers will undertake, to support and foster ongoing technological developments in the weightless economy, will matter a great deal for our continued economic progress.