

# **The Weightless Economy in Growth**

by

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When an academic, scientist, or research engineer harps on about the knowledge-based economy, it's hard to take as anything other than shameless self-serving hyperbole. Knowledge is, after all, what these people are supposed to be producing, and now here they are, telling the rest of us that that's what drives the economy. Combine those self-promoting tendencies with the superficial observation that computers, the Internet, computer software, and other information technology—all products of scientific research—are more and more used in economic life: Little wonder that knowledge-economy and information-economy pushers are in full feeding frenzy.

This paper describes one analytical perspective on the modern knowledge-based economy—the so-called *weightless economy*—and compares it with more traditional views on the role of knowledge in economic growth. The paper argues that while conventional understanding of knowledge and economic performance has an essential role to play, distinguishing that from the economic implications of the weightless economy yields important insights.

## **1. What is the weightless economy?**

By the weightless economy, I mean that part of the economy comprising the following four categories:

1. Information and communications technology (ICT), including the Internet.
2. Intellectual property, including 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, which includes carbon-based libraries and databases, as well as 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.<sup>1</sup>

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.

A visual metaphor might help. Appropriately interpreted, knowledge, at its most fundamental, 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 economic life of the mathematics developed by Alan Turing and John von Neumann.

Documented elsewhere (e.g., Cairncross 1997; Coyle 1997; Quah 1997; US Department of Commerce 1998) is empirical evidence on the increasing size of different parts of the weightless economy. My discussion here takes those facts as given, and considers only the theoretical implications of this increasing weightlessness.

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<sup>1</sup> Some readers might think of the weightless economy 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.

## **2. Knowledge, technology, and growth**

Economists have *always* viewed the engine of economic growth to be technical progress.<sup>2</sup> By implication, advances in scientific and engineering knowledge— technology’s own driving input—must figure prominently for economic welfare.

But while economic analysis of the forces underlying capital deepening has traditionally occupied center stage, only recently has the economics of technical advances in growth been similarly studied.

Certainly, from at least Arrow (1962), economists have been aware of the subtleties in analyzing knowledge as an economic commodity. Knowledge displays *infinite expansibility*: extra copies can be freely made, and used and consumed without drawing down the physical functionality of the original. Such effortless expansibility applies not only in sequence with additional copies, but also without degradation across physical distance. But then, under perfect competition, the price of knowledge must be zero. It follows that marginal cost pricing ex-post—the standard outcome in competitive markets—cannot support costly creation ex-ante of the first instance of knowledge.<sup>3</sup>

Although I return to this below, it is useful for now to observe simply that societies have historically gotten around this difficulty by designing appropriate institutions. David (1992) usefully partitions those into what he calls 3P’s, namely, *property*, *patronage*, and

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<sup>2</sup> There has long been an understanding, mistaken in my judgement, that neoclassical growth economics (e.g., Solow 1956) emphasized physical investment and capital deepening as the ultimate source of economic growth. This misunderstanding arises from confusing the dynamics along a transition path with those of long-run steady-state growth (see, e.g., Durlauf and Quah 1999 and Keely and Quah 1999.)

<sup>3</sup> In intellectual property law and in the economics of industry, research and development, and science and technology, this feature has long been recognized (see, e.g., Dasgupta and David 1994, Dasgupta and Stiglitz 1980, Holyoak and Torremans 1995, and Reid and Roberts 1996). In those other areas, it has also led to insights on *winner-take-all* outcomes (or the economics of superstars) and *Merton multiples*, where competitive outcomes in research display excess concentration and over-investment (e.g., Dasgupta and Maskin 1987, Dasgupta and Stiglitz 1980, and Merton 1973). Only recently, however, have the aggregate growth and income distribution implications been studied. We will return to these below.

*procurement.* Almost all research in the economics of growth has considered the institution of property (i.e., patents) as the organizing framework for studying the role of knowledge in growth. Under this, knowledge is made *excludable*—its use is not permitted by other than its legal owners, who thereby are granted a monopoly on its exploitation.

Paul Romer's (1990) description, outlined in Fig. 1, provides one leading example of how many economists now understand the process of technological change and economic growth.

In Fig. 1, a stock of skilled workers—researchers, scientists, inventors, intellectuals—is available to generate ideas and new knowledge. The greater the number of researchers and idea-producers, the faster the economy grows. However, skilled workers face competing uses for their time and expertise: they can decide to be managers and lawyers, rather than research scientists. In equilibrium, returns equalize across the different lines of activity for skilled workers, thereby determining the growth rate of the economy.

But what is the return from producing knowledge? Upon obtaining a useful idea, the researcher obtains a patent for it, and sells that patent to a machine-maker. The machine-maker builds a machine around the idea. He then rents the machine to a monopolistically competitive manufacturing industry who, combining the machine with skilled managerial input, retail the final products to consumers. In equilibrium, the present discounted value of the stream of monopoly rent supports a positive equilibrium price on the patent.

Models in Aghion and Howitt (1992), Grossman and Helpman (1991), and others differ in focus and details from the description just given. For instance, Aghion and Howitt (1992) study Schumpeterian dynamics with the latest discoveries making obsolete earlier ones in a wave of creative destruction. Grossman and Helpman (1991) consider schemes where economic goods proceed up a quality ladder, through the application of resources to R&D. There is sufficient commonality, however, across all such models that Jones (1995) can persuasively criticize the entire class of “technology and growth” models by pointing out that while US scientists and engineers employed in R&D grew five-fold from 200,000 in 1950 to over 1 million in 1990, the growth rate of US GDP failed to increase by anything remotely comparable.

In the framework just described, consumers encounter knowledge only through physical goods embodying the new

technology. A chain of production runs from ideas being discovered through a patent protection scheme through a manufactured goods industry and finally to the consumer. Consumers are distanced from the producers of knowledge. Indeed, they need never be aware of the infinite expansibility in knowledge underlying production.

### **3. The weightless economy**

The feature of the weightless economy of greatest interest here is that it reduces distance between knowledge-production and consumers as suggested in Fig. 2.

Of course, consumers needn't literally be shoving, say, computer software into their mouths. Apart from food, that physical picture of consumption is only a metaphor anyway, and the visualization in Fig. 2 serves to emphasize what I take to be the important changes in a modern economy. Nor is the increasingly direct consumer involvement intended to be exhaustive. A lot of economic activity drawing on intellectual property will still be of the kind described in Fig. 1; the shielding of consumers from knowledge producers by patents and manufactured goods will remain.

Notwithstanding these caveats, the crucial property of advancing technology today is that it allows consumers to approach ever closer the chalk-face of scientific and technological advances.

I provide now two illustrations of this: First the growing importance of the Internet, and second the maintenance of copyright rather than patent as a leading form of intellectual property protection.

The growth of consumer software and widespread Internet use has been dramatic. Radio, a relative simple undemanding technology, took 40 years to achieve fifty 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 in this way 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.

Without getting overwhelmed with details, saying that the Internet allows users to come into immediate contact with producers of knowledge-products seems to me a useful description. Internet delivery of computer software, new media, video entertainment, health care advice, education services, pricing and supply data, and so on is exactly that diminishing of distance between consumers and the producers of knowledge-products.<sup>4</sup>

Turn next to copyright. Many knowledge-products—computer software, data compilations, entertainment and new media—are not typically made excludable by patent. Instead, they have, until recently, largely been copyrighted, not patented. They are, therefore, legally the same as literary works.<sup>5</sup>

Copyright protects an author's expression of an underlying set of ideas, but not the ideas themselves. Under most current legal systems, copyright is routinely awarded to any work showing originality, i.e., the work must not have been entirely copied, and must have had sufficient amount of labor, skill, and judgement involved in its creation.

Patents, in contrast with copyrights, require that an invention be novel, capable of industrial application, and innovative relative to the current state of the art. Patents comprise a much stronger form

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<sup>4</sup> To emphasize the point, this differs from a simple reduction of physical or geographical distance, a more specific feature nevertheless widely taken to be *the* defining feature of the Internet in economic life (see, e.g., Cairncross 1997).

<sup>5</sup> See, e.g., the UK Copyright, Designs, and Patents Act 1988. Section 1(2)(c) of the UK Patents Act 1977 explicitly excludes computer programs (Holyoak and Torremans 1995). However, in 1998 the US Patent and Trademark Office began to award patents for electronic-commerce business models—among them, Open Market's Internet marketing and payments system; CyberGold's attention-brokerage scheme; Priceline.com's buyer-driven, reverse auction model; Juno Online Services's advertisement-display techniques. Patent authorities reasoned that these were performed on computers, and thus were industrial, machine-driven processes.

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of intellectual property protection. For patents, the first to create the knowledge-product and thereby attain protection acquires the monopoly: There is a natural, winner-take-all feature to the system.

Returning to copyright, all that is needed is to show that the work must have been the author's own creation. But this implies that there must be more than one way to implement an idea, as otherwise the work could not have been the author's own creation. An important economic implication follows from this: Copyright is not an intellectual property right allowing excludability and monopoly operation. Under copyright, others can freely copy portions of any work that are "critical", for which only one way exists to implement the idea—because those parts of a work could not have been the author's own creation.

In copyright, priority is also immaterial. Unlike for patents, it cannot matter whether a creator is the first to create the original instance of a copyrighted knowledge-product. The central and critical idea in the knowledge-product is unprotected, and therefore can again be used by others.

Thus, just as knowledge-products are, in nature, easily copied, they are similarly so in a sense, under copyright law. From the perspective of those traditional knowledge and growth models described above, copyright in IT should not work at all. Or, if copyright works, it does so in a way different from that routinely used in modeling knowledge protection in models of economic growth.

Consumers are not concerned the same way rival producers are about being able to extract, for their own use, the critical good idea embedded in a copyright work left unprotected by law.<sup>6</sup> The entire package of ideas and attributes is the more important. Consumers do not generally find as attractive a knowledge-product generated by alternative producers who bundle the central unprotected attribute with other attributes differently implemented. (Because those other attributes are protected by copyright, by definition they must be implementable differently.) Consumers just want to enjoy the whole work conveniently, without inadvertently violating the law's fair-use provisions by, say, viewing the work in a computer's volatile random access memory. (This act is impossible to perform without, in effect,

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<sup>6</sup> Although even this is contentious: decompiling a piece of software to see the critical idea—who decides when a particular subtlety is critical anyway—is almost certainly illegal.

making a copy—albeit temporarily—and thus infringing the rights of reproduction on a copyright work.)

For knowledge-products protected by copyright, the distance between producers and consumers is smaller than when knowledge is protected by patent. The cost to a consumer of using a specific knowledge-product comes not only from the sticker price of the product, but from having to learn the norms, conventions, and subtleties involved in its use.

#### **4. Economic Behavior in the Weightless Economy**

What follows from recognizing commodities in the weightless economy as knowledge-products and from acknowledging the proximity of the consumer to their production? Three other properties of knowledge-products are critical.

**First**, recall that like knowledge, knowledge-products show infinite expansibility. 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 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. For knowledge-products, by contrast, multiple implementations

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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>7</sup>

This is not to say that knowledge-products have no value: 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.

### 5. 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?

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<sup>7</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.

The analysis of the weightless economy highlights 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 developed alternative schemes for rewarding producers in such situations. Since the weightless economy is mostly new, we need to look at the historical record on rewarding the production of traditional intellectual property, for guidance on how this tension in the weightless economy might best be resolved.

*Patronage* is one scheme. An example of this system is 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 appropriate 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 public, or portions might be kept secret. Examples of both exist in the modern weightless economy. The root Internet technology arose from 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, or 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 in 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.

The third traditional 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. This is the framework assumed in Fig. 1 and in most models of knowledge and growth. *Property* (proper) is the appropriate label for this. 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.

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.<sup>8</sup> 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 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.

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<sup>8</sup> Wright (1983) is a key reference.

Because the supply of knowledge-products is 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.

## **6. Conclusions**

In this paper, I have described the weightless economy in an economic analysis of growth.

I have considered three main questions on opportunities and pitfalls in the weightless economy. First, I have described how the weightless economy challenges traditional views on knowledge and economic growth. Second, I have examined the tensions between individual profit-seeking incentives and social welfare. What business models are useful and appropriate for operating in the weightless economy?

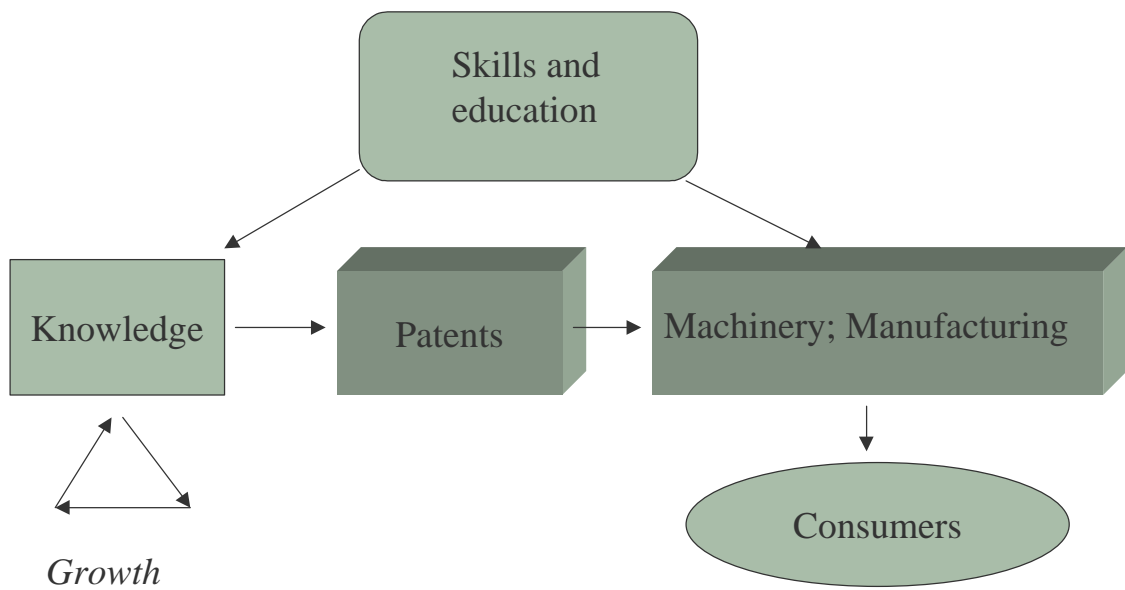
Finally, I have discussed potential outcomes in economic growth, industrial structure, and inequalities in income and wealth. Working out what appropriate policies are remains high on an ongoing research agenda.

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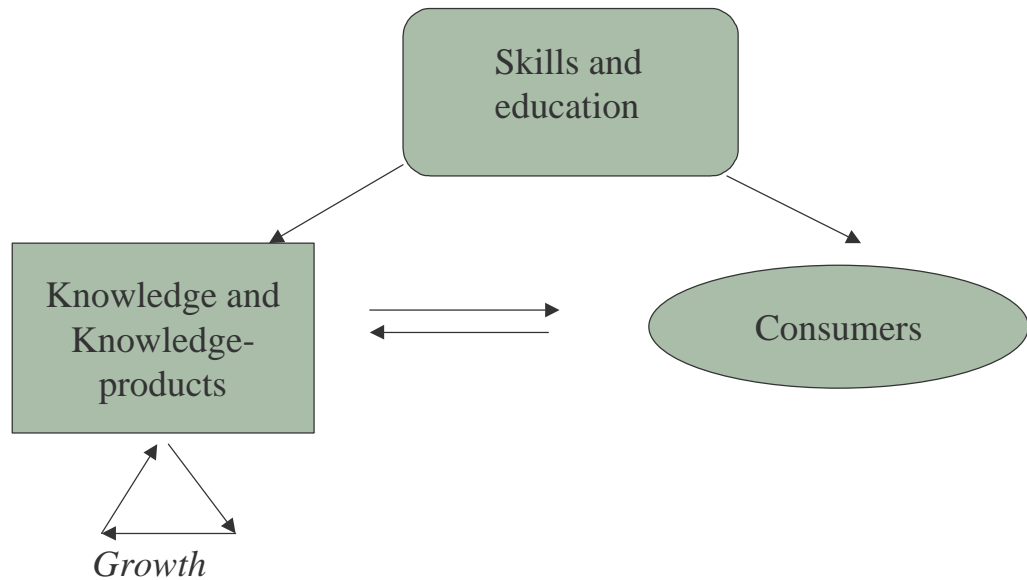
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# Technology and Growth



**Figure 1. Technology and Growth:** Patents and manufacturing mediate between knowledge-production and consumers.

# Growth in the Weightless Economy



**Figure 2. Growth in the weightless economy:** The weightless economy reduces distance between consumers and knowledge-production.