The Invisible Hand and the Weightless Economy

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ABSTRACT

As modern economies grow, production and consumption shift towards economic value that reside in bits and bytes, and away from that embedded in atoms and molecules. This paper discusses the implications of such changes for the nature of ongoing growth in advanced economies and for the dynamics of earnings and income distributions—polarization, inequality—across people within societies.

Keywords: dematerialization, inequality, infinite expansibility, information technology, software, stratification, superstar technology

JEL Classification: D30, O30

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1. Introduction

This talk deals with the economic implications of the ongoing dematerialization in economic activity—in consumption and in production—that we observe of modern, advanced economies as they evolve and grow.

By dematerialization, I mean that extreme situation where economic value is embedded in logical units—bits and bytes of (possibly computer, possibly biological) memory. The distinction made is against the other extreme, that historical one where economic value manifests in concrete, physical, and material form.

Although my intent is more general (as we will turn to below) I find it helpful to have in mind clear examples of these polar extremes—of dematerialization and its opposite—before we plow further into the discussion.

Think, therefore, of computer software or gene sequences on the one hand; and titanium non-stick frying pans or an oil super-tanker on the other. All four of these can be identified with the very latest in space-age technology; all four of these are things that are inconceivable to earlier generations; all four of these have likely affected the well-being of each of us at some point. All, therefore, are instances of technical innovations that have taken advanced economies to the very frontier of the technology envelope.

At the same time, however, it should be apparent—if for now in the talk only at an instinctual level—that the first two objects differ profoundly from the last two. The first two are dematerialized: they would retain their economic value independent of the physical medium containing them. The last two are *not* dematerialized: their economic values are the values that they are precisely because these objects have the physical manifestation that they do.

Observers have, traditionally, labeled these instances of *disembodied* and *embodied* technical change—and left things at that. I wish to convince you that there is economic significance beyond just this—and I wish also to convince you that economies that are significantly dematerialized, or weightless (as in the title of this lecture), behave differently from ones that are not.

Moreover, I will suggest that, in reality, leading, advanced economies are

already significantly weightless, and therefore it is important to understand the consequences of these changes.

The remainder of this talk falls naturally into three parts. First, I describe some findings of recent empirical research on economic growth across countries and on the dynamic behavior of income distributions across people *within* societies. Why these findings relate to the main dematerialization theme of the talk may yet be unclear. However, they set the stage and raise concrete, substantive questions. They make explicit the broad sweep of economic realities that we wish to understand, and eventually to explain. It is convenient also to talk here about an important idea from recent theoretical research in endogenous growth, namely the idea of *non-rivalry* or *infinite expansibility* in technical progress.

Next, I will turn to some quick-and-dirty observations on dematerialization. Each of us has probably thought some about economic growth; each of us has used computers and thus software; and each of us has likely read a little about the history of inventions. These first observations then simply make explicit some immediate and useful connections relating those ideas. Not much will be needed here of subtle economic analysis. The observations are of the kind where one might simply say, "Oh, ok," and that would be the end of that.

But then in the following section I will build on those observations to provide some more subtle implications. The concepts appearing here—public goods, demand and supply, externalities, natural monopolies, and so on—will already be familiar. But how they assume significance in dematerialized economies is novel and, most important, immediately relevant in reality.

Finally a brief conclusion ends the presentation.

2. The Facts: Economic Realities in the Large

Many here will already be aware of the large quantity of recent economic research on the determinants of growth and catching-up, or 'convergence' across countries. (Robert Barro's Lionel Robbins Memorial Lectures this year provided a useful overview of that work.)

That research has achieved resonance with the public: UK politicians and journalists now phrase discussions in terms of "endogenous growth theory". Policy makers at the European Commission use notions like convergence to formulate programs for redistribution across European regions.

But that empirical research on growth and convergence—which we can think of as applying traditional methods of analysis—fails to uncover certain interesting facts. Fig. 1 shows some of these.

Fig. 1 is a 'busy' picture. Many things go on in it; we will need to appreciate what they are for the discussion to follow next.

In Fig. 1, the horizontal axis denotes movement in time: proceeding rightwards takes us away from the past and into the future. The vertical axis measures per capita incomes. These would be per capita incomes for countries or regions (in certain studies), or just incomes for individuals or families when we turn to income distributions across people within societies.

For a fixed instant or year or generation t, the shaded region represents a then-extant distribution of income. Any given shaded area thus measures the fraction of the cross section having particular levels of income.

As drawn in Fig. 1, period t has most of the cross section middle class—the bulge in the distribution is at medium income levels—few are very rich; few very poor. As time progresses, the distribution evolves to that depicted at time $t + s$. As drawn, the situation is then very different: there is a peak or a cluster at a high income level, and one at a low income level. The middle class is vanishing.

(The arrows show intra-distribution or churning behavior: some of the rich at time $t + s$ were already rich at the earlier time t; similarly some of the poor at $t + s$ were already poor at t. However, one also observes transitions of poor to rich, and vice versa from rich to poor.)

We can collapse the rich variety of dynamics that we see in this 'emerging twin peaks' figure into two observations that will remain important later:

(i) increasing inequality (from the spreading out of the distributions over time) and;

(ii) emerging stratification or polarization (from the peaks or modes appearing in the distributions at later time periods).

Within clusters, convergence happens; across clusters, it does not.

These conclusions—which we will hereafter call *twin-peaks dynamics*—obtain from more recent research on patterns of cross-country growth; they are conclusions unavailable in the traditional approach. Moreover, some economists conjecture that exactly such twin-peaks dynamics hold also for individuals and families within countries. Work is now under way investigating that.

A subtlety is useful to notice here: Since $t + s$ in Fig. 1 may only be in the future, not in the historical sample, the situation for time $t + s$ need not be directly observable. Some *model* is required to make these predictions; it was exactly such a model I used to derive Fig. 1.

When we subsequently discuss dematerialization, one of the most useful benefits from that discussion is to provide some understanding of the economic forces underlying the twin-peaks dynamics in Fig. 1.

Before continuing to that, however, it is useful to close the current discussion of cross-country growth by describing the notion of *infinite expansibility* (or *non-rivalry*) of technical change. For the current discusssion, it is this that is profound and important in endogenous growth theory. And, it is by extending the applicability of this notion that we can best grasp the economic significance of ongoing dematerialization.

An economic object is said to be *infinitely expansible* when its use by someone does not physically detract from its usefulness to someone else. Thus, the set of computer instructions underlying a word-processing package is infinitely expansible. Someone in Palo Alto, California can use that set of instructions without making those instructions any less useful to me when I am typing in my office at LSE. The same observation applies to the computer code that makes up a Web browser, as well as to the information content of the Web page that is being browsed.

A chocolate hobnob is *not* infinitely expansible. When someone in this audi-

ence consumes a hobnob, it is no longer useful in the same way to anyone else. In the usual stories for endogenous growth, infinitely expansible instructions are embedded in new production technologies, and while some of this flow of ideas can be privately owned, other parts of it add to a public stock of knowledge.[1] Accumulation of that stock drives economic growth.

Put differently, this idea of infinite expansibility in technical progress is used in traditional endogenous growth theory to explain how already advanced economies can continue to grow. It has, arguably, succeeded at this. But infinite expansibility has other interesting aspects to it. We turn now to those and then to dematerialization proper.

3. Dematerialization, 1

In the importance of infinite expansibility for endogenous growth, it is irrelevant whether new ideas are put to work in computer software, or in a spinning jenny, an open-hearth furnace, or anything else productive.

Thus, the notion of infinite expansibility does not by itself provide immediate insights into the workings of a dematerialized economy. Of course, it is a great strength of the infinite expansibility notion that it is so general: it aids understanding of technical change in Renaissance times, during the Industrial Revolution, and over the 20th centry—all simultaneously and without alteration. But that also means there will be features of dematerialization that it does not capture well.

Thomas Jefferson had, in fact, already recognized the importance of the infinite-expansibility idea much earlier:

> *If nature has made any one thing less susceptible than all others of exclusive property, it is the action of the thinking power called an idea, which an individual may exclusively possess as long as he keeps it to*

[1] In the language used in this literature, this means that these non-rival objects are also *partly excludable*. This latter concept will not be of as great interest in the current discussion.

> *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. Inventions then cannot, in nature, be a subject of property.*
>
> [Thomas Jefferson, 13 Aug. 1813 (letter to I. McPherson)]

The key insight to add in this talk is that with dematerialization, these concerns apply not only to the ideas underlying technical progress and inventions, but also to the very things we produce and consume.

The set of instructions underlying the Unix operating system is infinitely expansible. Similarly infinitely expansible are the computer codesets for video games like Super Mario Brothers 3 and Mortal Kombat, the content in Michael Jackson and Madonna music videos, Jurassic Park, Batman, and Disney movie tapes, all of Microsoft's software products, the broadcast content in TV signals, the collated information on Reuters terminal screens, and so on. Encryption and decryption algorithms are dematerialized; so is the stuff they encrypt and decrypt.

When economic value—produced and consumed—is embedded in bits rather than atoms, Jefferson's comments can be addressed not just to inventors and research scientists but to every economic agent. But then the "peculiar character" that Jefferson refers to magnifies and grows.

International trade becomes not a matter of shipping wine and textiles from

one country to the next, but of bouncing bits off satellites. With economic value having no clear points of physical entry and exit, international trade statistics become that much murkier and ambiguous. Keeping track of trade is no longer just counting the bottles and bales that pile up on the loading docks in a port.

Dematerialized economic value cannot respect geographical, physical, or national boundaries. Put differently, transportation shows infinite bandwidth when moving bits across space. In contrast, when moving atoms, bandwidth is limited and thus transportation costs and political boundaries matter.

This "growing weightlessness of GNP" is not a move away from manufacturing and towards services as traditionally construed. It is not just a change from an economy that makes big iron or cranks out heavy-metal construction cranes to an economy that makes hotel beds or provides janitorial support.

In the US—a leading, advanced, and successfully growing economy—by most accounts, dematerialized industries have already replaced defence and automobiles as the driving force in the economy. Data show that dematerialized industries already account for the largest volume of US exports (bigger than aircraft), and generate the greatest number of high-quality new jobs (more than health care).

However, national economies are but one instance of large-scale organized economic activity. Case studies show how successful corporations—such as GE, Nintendo, Ericsson, Bell Labs, Texas Instruments, and of course Microsoft—realize the significance and exploit the nature of the dematerialized things they produce. These organizations meet and work across large geographical expanse, as though physical distance weren't important. In these networked corporations, managers and production processes emphasize and exploit proximity in the space of ideas, not closeness in the sense of geography.

Macroeconomists have, to date, made little of such changes in industrial structure. But aggregate economies that are dematerialized and weightless must almost certainly behave differently from those that aren't. We turn now to findings from studies that have emphasized this distinction.

4. Dematerialization, 2

We have, so far, discussed some relatively obvious aspects of dematerialization—these concern ready implications from the physically disembodiment of dematerialized objects. In this part of the talk, we consider implications that might not be as obvious or as immediate.

The transfer of dematerialized objects occurs in ways different from that in traditional economic exchange. First, such objects cannot be really transferred, but merely replicated: the originating agent in a transaction cannot physically and credibly relinquish ownership of abstract content or ideas. For these commodities, trade is not exchange, but instead reproduction.

Second, trade in such objects is costly for some agents involved in the transaction, but not for others. When the dematerialized objects take the form of innovative ideas, they necessarily show an incomplete knowability: some ideas are good ones, others are bad, but they are impossible to discern ahead of time. If testing out the quality of ideas is costly, then free disposal by a receiving agent is no longer available. When, by contrast, the dematerialized objects take the form of software or broadcast content, they can be consumed only with the appropriate enveloping hardware. Thus, dematerialized content, while freely reproducible by the originating agent, is costly for a receiving one to use.

Third, consumption of dematerialized content often involves network externalities. A software product might be seen by technical experts to be inferior to a competing product, but ends up being used anyway because everyone else in one's workplace or circle of acquaintances already uses it. Benefits from collective insight into the quirks and shortcomings of the product may outweigh those from the isolated use of a technically superior alternative.

Fourth, successful dematerialized production does not entail a large upfront fixed cost. Unlike, say, requiring the experience, history, and manufacturing base of a General Motors or a British Aerospace to produce the next successful car or aeroplane, it only takes, in principle, one programmer with a C compiler working alone to produce the next killer application.

Fifth, with dematerialization, markets are no longer local or national, but instantaneously universal. Since transportation costs are irrelevant and transmission bandwidth is infinite, the natural marketplace for dematerialized objects is essentially unbounded.

Theoretical research studying the effects of these characteristics are only in early stages. Models being investigated are still abstract and highly stylized but the preliminary findings are intriguing. In some of these models, subgroups in societies form knowledge-based coalitions; a class structure endogenously emerges. Over time, small differences across social groups magnify. Depending on initial circumstances, patterns of polarization and stratification appear.

Distributions of wealth and income become more unequal as "superstar" effects take hold. To understand such effects, it is easiest to begin by asking, Why is the income distribution across opera singers so much more unequal than that across shoemakers? The reasons are two-fold, one on the demand side of the market, and the other on the supply side. Taking supply first, the production of opera by an individual singer is, on the margin, costless. Content in a performance by Cecilia Bartoli or Angela Gheorgiou can be broadcast to 2 people or 10,000, with no difference in effort by the sopranos concerned. Turning to demand, an audience prefers to listen to a single performance by either of these than to two performances by singers thought to be less talented. Objective criteria might show that for most listeners second- and third-ranked singers are barely distinguishable from the very best one, but nevertheless, the market share these second- and third-stringers have will be a discrete step below those of top acclaimed performers. In such superstar or "winner-take-all" situations, market size determines the distribution of incomes, magnifying up slight differences in talent. This contrasts with the workings of standard invisible-hand economies where income distribution and market size are unrelated.

Drawing the connections between the characteristics I have described above of dematerialized objects and those we have just seen of superstar economies, we see that increasing income inequality comes with ongoing dematerializa-

tion. However, dematerialization conditions add a further twist to these predictions. In standard superstar economies, it is the distribution of talent—given as endowments—that determine winners and losers. In dematerialized economies, however, winners and losers are made, not born. Thus, a dynamic dimension becomes important. In standard superstar economies, endowments are talent, fixed from birth, and thus those show infinite fixed costs of entry. But in dematerialized economies fixed costs of entry are minimal. Hence, at the same time that income inequalities become more extreme, *mobility* between rich and poor also rises. Societies then are willing to tolerate the increasing inequality because, simultaneously, greater fractions of the poor see opportunity to transit to being rich.[2]

Combining these different studies, it happens that their predictions fit well with the "emerging twin-peaks" dynamics of Fig. 1. Whether it is this dematerialization that is responsible for those features is still unclear, but further investigation is on the research agenda.

However, regardless of the outcome on that investgation, it is already clear that dematerialized economies show intriguingly different properties than displayed in traditional ones.

5. Conclusion

This lecture has presented some facts and theoretical findings relating to the increasing dematerialization in modern, advanced economies.

The "emerging twin-peaks" picture in Fig. 1 manifests when one studies cross-country income distributions. I have used the subtleties associated with dematerialization to explain such tendencies. The "fit" between stories and facts is far from perfect, but peculiariaties of dematerialization do predict both an

[2] Public acceptance of the National Lottery—this trade off between, on the one hand, regressiveness and inequality and, on the other hand, mobility and prospects of success (whether or not those are rationally evaluated) may reflect something similar.

increasing inequality and a clustering or polarization in the cross section. These effects likely have more to do with people within societies than with countries across the world, but similar forces might well be at work in both.

Parts of this talk have also described other aspects of dematerialization. Likely, those too have further economic significance. Work is in progress exploring those as well.

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[Appendix: 26-Feb-1996 Handout]

A.1. Introduction

Modern, advanced economies grow through technical progress. Such a proposition follows logically from just a little bit of analytical reasoning—and should not be at all controversial. The open questions are only the nature and source of that technical progress. Almost all economic analyses of growth now focus, rightly, on technical change. Only with ongoing technical progress, can factor inputs in limited supply—like physical capital and human labor—produce outputs in ever greater quantity and quality for societies to consume. It is thus that productivity and economic welfare increase.

Comparing present and historical economic realities, however, it is obvious that technical progress now differs profoundly from technical progress then: economic value, whether being consumed or produced, increasingly comes embodied in virtual units of logic—bits and bytes—rather than embedded in solid material of physical substance. Current frontier developments are designs embedded in software; previous frontier developments were concepts brought to physical life, for instance in a spinning jenny. Economists' concept of GNP would value modern software independently of how exactly the latter appears in physical form, or indeed of whether it does so at all. This is correct and proper. The nature of technical progress and thus of economic growth and consumption and production have changed. Most concepts of what is valuable—the things that people enjoy and consume—appropriately adjust to reflect that.

But while almost all modern theories of economic growth place technical progress center stage, this change in the nature of technology is not typically acknowledged explicitly. Most economists have traditionally thought it unimportant to distinguish between, on the one hand, technical progress that comes in the form of things like high-tech, titanium, non-stick frying pans, and, on the other, technical progress that comes in the form of things like software and information technology.

This paper describes some recent research that does draw that distinction, and indicates its importance. In this work, researchers are interested in the implications of ongoing dematerialization in modern economies—an "increasing weightlessness of GNP." This paper highlights conceptual subtleties in analyzing dematerialized economies; it then uses those subtleties to help explain certain stylized facts, regularities that we already observe in many modern economies.

The paper proceeds as follows. For background, it begins by describing some new empirical findings on patterns of cross-country development. These findings differ from those obtained by more traditional means: the findings lead to characterizing cross-country patterns of development in terms of stratification and polarization, not simply in terms of ongoing growth and convergence. Why this should be relevant for thinking about weightless economies may not yet be apparent: we turn next to making clear that connection.

The paper describes an idea much used recently to explain technical change and endogenous growth, namely that of *infinite expansibility*. Typically, however, this concept has been used only to understand how technological progress comes about, not to understand the nature of modern technical change.

The paper broadens application of this idea, and describes the conceptual subtleties that arise as a result. Appreciating these subtleties helps explain the patterns of stratification and polarization documented below, and generates predictions for what will ensue as economies continue to dematerialize.

The paper then concludes by highlighting particular areas for continuing research.

A.2. Some ready observations

- Growth and ideas. Technical progress.
- Cross-country growth; facts. (Figure 1.) Twin peaks. Polarization and stratification in income distributions.
- Infinite expansibility (non-rivalry). The knowledge and abstract ideas that underly technical progress: What happens if they do not remain just determi-

nant of technical change, but become also the things that economies produce and consume?

If nature has made any one thing less susceptible than all others of exclusive property, it is the action of 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. Inventions then cannot, in nature, be a subject of property.

[Thomas Jefferson, 13 Aug. 1813 (letter to I. McPherson)]

A.3. Economic implications a little less obvious

- Economic values embedded in bits; economic value embedded in atoms: software and information versus space-age titanium frying pans.
- Dematerialization; weightlessness in reality. Not janitorial services. Exports; high-quality jobs; driver of technical change. Case studies: GE, Nike, Nintendo, Ericsson, Texas Instruments, Bell Labs Research.
- Value independent of physical manifestation.
- Infinite bandwidth in transferring across space. Moving bits, not atoms.
- Irrelevance of physical geography. And national boundaries?
- Exchange and transfer: not wine and textiles. Thomas Jefferson again.
- Differential knowability.
- Irreversibility.
- Value increases, the more the commodity is out there.
- Superstars, winner-take-all economies; but with mobility. Why is the income distribution across opera singers so much more unequal than that across shoemakers? What dynamic considerations might make societies tolerate inequality?

A.4. Conclusion

- Twin peaks fact: patterns of cross-country development and within-country income distributions.
- Dematerialization: fragmentary and impressionistic evidence; much more documentation required.
- Subtle economic properties.
- Inequality, stratification, and polarization.

Fig. 1: Emerging twin-peaks distribution dynamics