

Economic Perspectives on Nanotechnology

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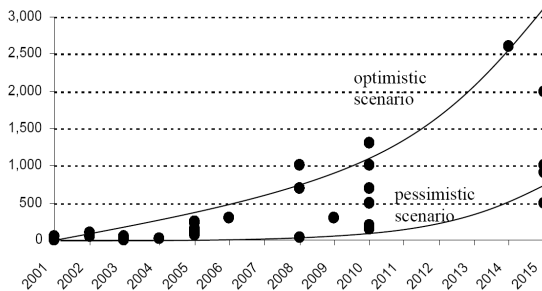
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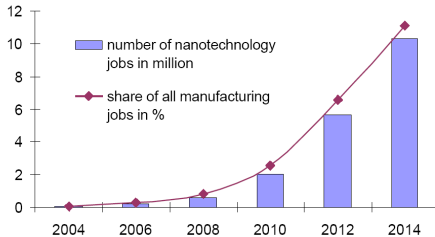
World Market Projections

- Roco by 2015 Nano will be visible at the macro level: \$1 trillion worth of products *world wide*



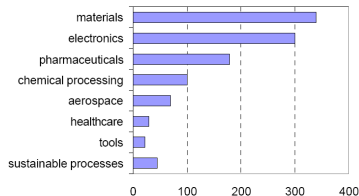
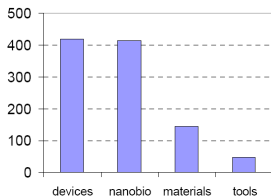
- Note: World GDP by 2015 approximately 60 trillion. Source: Hullman, 2006.

Employment



Some Estimates Optimistic

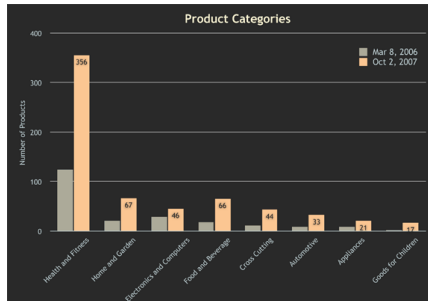
- 2014, Lux Research estimates that \$2.6 trillion in manufactured goods will incorporate nanotechnology, or about 15 percent of global output (not of GDP)
- Nanotech *larger* than communications and information technology—10 times larger than biotech



- Source: Lux (2004), NSF (2001)

Inventory at Woodrow Wilson Project on Emerging Technologies

- Grown by nearly 175% (from 212 to 580 products) since March 2006.



- **Cosmetics, Clothing and Personal Care categories are largest**

Rosy Forecasts?

- Nano is not worth a trillion
- Only *participates* in a 1 trillion worth of products
- Assume US mfg is 10% of the world and world market is 1 trillion
- To reach 0.1 trillion by 2015 in the US:
- If nano participates in 3% of manufacturing (probably high)
- Output of these goods must grow by 25%
- But if nano is only 1%
- Output of these goods must grow by 40%

Utopian-dystopian Views of Nanotech

- Early literature on nano visionary, grandiose and *scary!*



- Drexler “Principles of mechanical engineering applied to chemistry”
- Bill Joy (2000) article in *Wired* “Why the Future Doesn’t Need Us”
- Utopian side also discussed by Drexler, Kurzweil *The Singularity is Near*
- Human enhancement, global material abundance?
- Debate is now largely over?

*I believe that we all wish our course could be determined by our collective values, ethics, and morals. If we had gained more collective wisdom over the past few thousand years, then a dialogue to this end would be more practical, and the incredible powers we are about to unleash would not be nearly so troubling. ..The only realistic alternative I see is relinquishment: to limit development of the technologies that are too dangerous, by limiting our pursuit of certain kinds of knowledge.
Bill Joy Wired (2000)*

Why is Debate Over?

- Much of nano's *promise* has not materialized
- Much of the *fear* of nano has subsided
- Drexler and Joy have both recanted
- Little scientific basis for either utopia or dystopian vision
- We know the risks...mostly
- Already prepared for most of them
- Example: Size matters!

- Main risk: that social and ethical concerns will block development

Backlash to Nano is Serious Threat

- Local moratoria in Berkeley, Cambridge
- ETC in Canada called for a moratorium on all nano scale activities
- Until they could be shown to be *safe*
- Royal Society and Royal Academy of Engineering (July 2004):
- Factories and labs *treat manufactured nanoparticles and nanotubes as if they were hazardous*
- Remove them from the waste streams
- Set lower occupational exposure levels for manufactured nano particles
- **Without first doing the science!**

Saw Moratorium in Biotech

- Analogy to biotech skillfully discussed by Kay and Sandler
- James Watson now calls recombinant “DNA moratorium letter” is a mistake
- Excellent example of fallacy of precautionary principle
- Moratorium in nanotechnology in Berkeley and Cambridge
- Both Joy and Drexler have since reputed their visions
- Radical reaction is to call for *upstreaming*
- Broad control of the relationship between science and society
- Not a focus in on *implications* of research;
- **May come into conflict with basic conceptions of freedom**

Any efforts by governments or industry to confine discussions to meetings of experts or to focus debate solely on the health and safety aspects of nano-scale technologies will be a mistake. The broader social and ethical issues must also be addressed. Intellectual property issues must also be on the table. Who will control the technologies? Who will benefit from them? Who will play a role in deciding how nanotechnologies affect our future? ETC Group

Are There Real Risks?

- Literature still at the level of commentary rather than evidence based research
- Large surface area per volume can make NM more reactive chemically
- Mobility of particles: both in human body and environment *may* become a problem
- Studies beginning to show up
- How should we deal with these risks?

How we got rich...an economist's tale

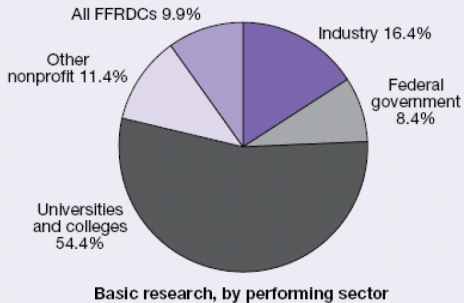
- Specialization and trade (Adam Smith)
- Production function $Q = f(K, L)$
- But empirically $\hat{Q} > \hat{K} + \hat{L}$
- Science and technology (Robert Solow)
- How does technology emerge and diffuse
- Hot area of research...old viral propagation models not so good
- Externalities (spillovers), learning by doing, evolutionary
- Occasional revolutionary *general purpose technology*

How We Didn't Get Rich...

- Income redistribution to the poor and needy
- Environmental protection-BANANA
- High interest rates (risk aversion)
- Precautionary principle
- Concern for sustainability
- Protection of intellectual property
- Government regulation
- Public participation in innovative process *through* the political process
- Fear of potential misuse of technology

No Role at all for Government?

- Public v. private goods
- Kenneth Arrow (1950) *Knowledge is Public Good*
- Public goods underproduced because of free-ridership
- Positive impact should be subsidized and negative impact taxed
- If marginal damage high then direct regulation a possibility
- Otherwise taxes are generally agreed on best instrument
- **Subsidize basic research...most positive externalities**

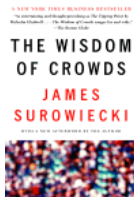


FFRDC = federally funded research and development center

NOTES: Figures rounded to nearest whole number. National R&D expenditures estimated at \$313 billion in 2004.

Govt Role in Promoting Technological Change

- *Wisdom of Crowds*
- Get lots of people involved...offer prizes block monopolies
- Diffusion requires reduced IP rights to get to marginal cost pricing



- Most economists believe that patent protection is now *too strong!*

Coase Theorem

- Efficiency of market and income distribution are separable policy objectives
- If some are hurt by market forces, help them directly
- Do not upset marginal equalities (marginal cost = marginal benefit)
- Use lump sum transfers to redress social justice problems
- E.g. do not lower the price of gasoline to help the poor; vouchers
- Do not block technologies because of effect on “livelihoods”
- **Fundamental to standard economic thinking**

Costs Per Life Saved of Various Regulations

Regulation concerning ...	Year	Agency	Cost per life saved (\$ millions)
Childproof lighters	1993	CPSC	\$0.1
Food labeling	1993	FDA	0.4
Reflective devices for heavy trucks	1999	NHTSA	0.9
Children's sleepware flammability	1973	CPSC	2.2
Rear/up/should seatbelts in cars	1989	NHTSA	4.4
Asbestos	1972	OSHA	5.5
<i>Value of statistical life</i>			7.0
Benezene	1987	OSHA	22
Asbestos ban	1989	EPA	78
Cattle feed	1979	FDA	170
Solid waste disposal facilities	1991	EPA	100,000

What Has Govt Done

- NNI 2003 codified in 21st Century Nanotechnology Research and Development Act
- Invest in R&D and coordinate govt activities
- Strategic Plan NNI released in 2004
- 11 Federal agencies directly funded, another 11 indirectly
- Education and workforce development (NIOSH-CDC)
- Facilities and instrumentation (NIST)
- Environmental protection (EPA)
- FDA-nano particles to in food storage (anti-microbial)

What Has Govt Done?

- Government spending on nanotechnology grew to \$6.4 billion in 2006
- Up 10% from \$5.9 million in 2005
- U.S. no longer holds a dominant position
- Europe as a whole outspent the U.S. on government nanotech R&D
- Asian companies spent the most on corporate nanotech R&D
- Russia...oil profits spent on developing nano
- Using purchasing power parity (PPP) –China reaches second place

Regulation

- Regulation seen as *negative technical change*
- Regulation, so far, has been light-handed—despite critics
- Most regulation already in place
- *Consumer Products Safety Act* of 1972 requires manufacturers to ensure goods are *safe*
- Federal labs have strict ethical and safety rules already
- Private labs and facilities are subject to OSHA rules for worker safety
- *Toxic Substance Control Act* 1976 (EPA) already regulates chemical substances

Dupont-Environmental Defense Framework

- Supported by funding from EPA
- Describe material and reasonably foreseeable applications
- Profile the life cycle: base set of data
- Anticipated routes of exposure
- Using bridging studies to data bases of known toxins and carcinogens
- Based on structural similarities between CNT and asbestos fibers

Response of Labor and Environmental Groups

- April 2007: Open letter to the International Nanotechnology Community at Large
- Greenpeace, Natural Resource Defense Council, AFL-CIO and others
- *Fundamentally flawed* because it is *voluntary regulation*
- Govt has not acted quickly enough and with sufficient resources
- Should be guided by TSCA section 4A
- Takes position that *all nanomaterials* should be *proven safe* (all nanomaterials lacking comprehensive toxicological evidence of safety)
- **If not, *protective action* is necessary under TSCA**

Future is Optimistic

- Comprehensive government regulation of health safety and environmental issues *not even on the distant horizon*
- Too many materials
- Too much uncertainty
- Government now professes “deep ignorance” of health, safety and environmental effects
- FDA now says that drug with nanoscale properties *do not need separate regulation*
- **Fear of lawsuits may be the most important and effective regulatory device**

Any litigant or lawyer involved in toxic tort litigation can only wish that a similarly careful and painstaking approach had been followed by industry with respect to the development and use of “miracle” substances decades ago, such as asbestos fibers. Experience from asbestos and other toxic tort litigation demonstrates that industry cannot afford to wait for government regulation.

Dupont-Environmental Defense

- So far as govt-private balance on Nano pretty good
- “Don’t fix it if it ain’t broke”
- Exceptions may be patents and OTT
- Radical voices have faded but are still present
- Comments, questions...