The employment effects of nanotechnology: Informed speculation, going beyond the R&D sectors

Aashish Mehta

Center for Nanotechnology in Society UC-Santa Barbara

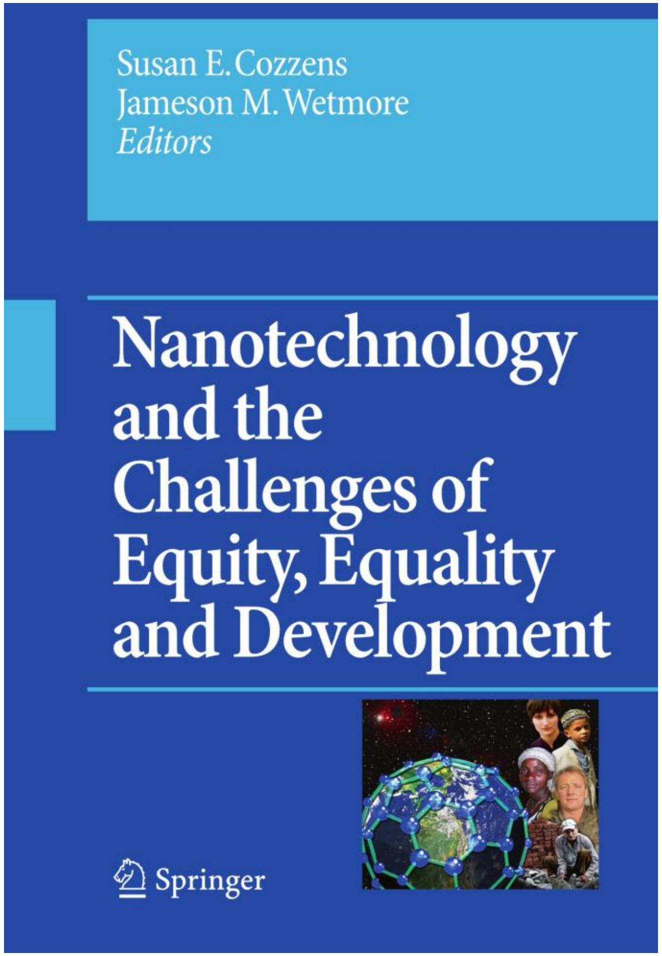
5 November 2013

<u>QUESTION:</u>
HOW WILL NANOTECHNOLOGIES AFFECT THE DEMAND FOR LABOR (OF DIFFERENT TYPES)?

Motivation

- Many excellent studies of the distribution of:
  - The benefits to consumers of nanotech products.
  - Their EHS costs.
  - The economic rents earned on nanotech development.
  - Political power in nanotechnology development.

- Almost no work on its employment implications.



Motivation

- Many studies of nano R&D activity using publication and patent data
- R&D - small & elite:
  - 0.7% of US employment estimated to be in R&D (2007 Census).
  - Upper bound calculation: If R&D could hire half the workers who earned post-graduate sci-tech degrees between 1951 and 2010, this would be 4% of the 2010 workforce.
- Outside R&D, the effects of nano depend upon how it is incorporated into workplace technology and into products.

Data Constraints

- Labor force surveys and census data only suitable source on employment, but:
  - nanotech is employed/produced in parts of many industries.
  - ‘nanotechnologist’ is not an occupational classification.
- Similar classification problems preclude studying import/export data for nano content.
- Data scraped off the web pose inferential problems, requiring laborious follow-up.

Roadmap

1. The employment effects of a technology that enables a *specific* product / activity.
   - Sidebar: Demographic effects

2. The employment effects of a *general-purpose*, enabling technology.

1. THE EFFECTS OF A TECHNOLOGY THAT ENABLES A SPECIFIC PRODUCT / ACTIVITY.

NB: Technology adoption increases profit if it either:

- Increases perceived product quality.
- Reduces the cost of production.

Intuition

Technology adoption has ambiguous effects on labor demand.

- Tech-enabled quality improvements in one product:
  1. Increase labor demanded to produce that product.

- Tech-enabled reductions in the production cost of one product:
  1. Usually render its production less labor intensive, holding output constant (Luddite Concern).
  2. Increase labor demand because falling prices stimulate demand for output (Capitalist Comeback).

Digging deeper: Quality improvements

- Products A and B have qualities q_A, q_B; demands $y_A\left(\underbrace{q_A}_{(+)}, \underbrace{q_B}_{(-)}\right), y_B\left(\underbrace{q_A}_{(-)}, \underbrace{q_B}_{(+)}\right)$; and conditional labor demands $L_A^C(y_A)$, $L_B^C(y_B)$.

- Thus: $L_p = L_p^C\left(y_p(q_A, q_B)\right); \mathrm{p} = \mathrm{A}, \mathrm{B}.$

- Effect of improving the quality of A on total employment:

$$\frac{dL}{dq_A} = \frac{dL_A}{dq_A} + \frac{dL_B}{dq_A} = \underbrace{\overbrace{\frac{\partial L_A^C}{\partial y_A}}^{(+)} \overbrace{\frac{\partial y_A}{\partial q_A}}^{(+)}}_{(+)} -$$

- Quality improvements are more likely to create jobs if:

1. The improved product is relatively labor intensive.
2. It creates new product demand rather than diverting existing product demand.

Digging deeper: Cost Reducing productivity gains

- A and B have:
  - productivity θ_A, θ_B;
  - product demands $y_A\left(\underbrace{p_A}_{(-)}, \underbrace{p_B}_{(+)}\right), y_B\left(\underbrace{p_A}_{(+)}, \underbrace{p_B}_{(-)}\right)$;
  - production costs $c_A(\theta_A), c_B(\theta_B)$ the decline with θ_A, θ_B; and
  - conditional labor demands $L_A^C\left(\underbrace{\theta_A}_{(-)}, \underbrace{y_A}_{(+)}\right), L_B^C\left(\underbrace{\theta_B}_{(-)}, \underbrace{y_B}_{(+)}\right)$.

- Assuming that costs determine prices, this implies that:

$$L_p = L_p^C\left(\theta_p, y_p\left(c_A(\theta_A), c_B(\theta_B)\right)\right); \quad \mathrm{p} = \mathrm{A, B}.$$

- Effect of rising productivity in *A*:

$$\frac{dL}{d\theta_A} = \frac{dL_A}{d\theta_A} + \frac{dL_B}{d\theta_A} = \underbrace{\frac{\partial L_A^C}{\partial \theta_A}}_{\begin{pmatrix}\text{Luddite}\\ \text{Concern:}\\ (-)\end{pmatrix}} + \underbrace{\overbrace{\frac{\partial L_A^C}{\partial y_A}}^{(+)}\overbrace{\frac{\partial y_A}{\partial p_A}}^{(-)}\overbrace{\frac{\partial c_A}{\partial \theta_A}}^{(-)}}_{\begin{pmatrix}\text{Capitalist}\\ \text{Comeback:}\\ (+)\end{pmatrix}} +$$

Job

Scorecard: Employment Effects

Cost reducing technologies replace expensive factors of production.

e.g., Outpatient procedures; vertical farming; mechanized fabric production; Robotic surgery; MOOCs; medical apps.

Today, this means replacing skilled workers.

Effects on demand for:	Skilled Labor	Unskilled Labor
Quality improvements in nano-enabled activities		
Employment in nano-enabled activities	↑	?
Employment in substitute activities	↓	↓
Cost reductions (productivity increases) in nano-enabled activities		
Luddite concern	↓↓	↓
Capitalist Comeback	↑↑	↑
Job Diversion	↓	↓

Sidebar: Demographic Effects

- Nanotech, particularly nanobio, could alter labor demand by facilitating demographic change.
  - Increases in longevity.
  - Enhanced fetal viability.
  - Result in increased dependency ratios, increasing demand for healthcare, savings vehicles.
  - These are relatively skill-intensive services.

Scorecard: Employment Effects

Effects on demand for:	Skilled Labor	Unskilled Labor
<u>Quality improvements in nano-enabled activities</u>		
Employment in nano-enabled activities	↑	?
Employment in substitute activities	↓	↓
<u>Cost reductions (productivity increases) in nano-enabled activities</u>		
Luddite concern	↓↓	↓
Capitalist Comeback	↑↑	↑
Job Diversion	↓	↓
<u>Demographic shifts</u>		
Rising dependency ratios	↑↑	↑

2. THE EMPLOYMENT EFFECTS OF A GENERAL-PURPOSE, ENABLING TECHNOLOGY.

General Purpose Technologies

- Key features:
  - Utilized in most sectors of the economy.
  - Induces development of complementary technologies (in response to economic signals).
  - Adoption requires adaptation, support, learning, teaching, (reduction in transaction costs).

- Theoretical Effects:
  - Eventual increase in productivity, and in demand for skilled labor to enable learning/diffusion (Aghion & Howitt, 2002).
  - Secondary effects driven by induced innovation (see part 1).

Three GPTs in history

1. Electricity did not cause a dramatic expansion in skill demand and inequality (Goldin & Katz, 2009).

2. ICT did, due to the greater complexity of the technology and its uses.
   - ICT permits the automation of repetitive tasks, but increases productivity in non-repetitive tasks (Autor et al., 2003).
   - More demand for skilled occupations, less demand for unskilled occupations (Goos & Manning, 2007)
   - Less demand for labor overall in an badly educated economy (Brynjolffsen & McAffee, 2011).
   - ICT increases the value of the creative class –(Florida 2012): a group that extends beyond technologists to amateur *users* of technology.

Three GPTs in history

3. Nanotechnology:

- If it extends Moore's law, expect more of the same.
- If it does more than sustain Moore's law, the results could be very different:
  - Nano is more likely to be complementary to technical, rather than purely creative activity.
  - Nanotech facilitators likely to be a smaller elite.
  - Much more constrained by the technical capacity of the labor force.

Scorecard: Employment Effects

Effects on demand for:	Skilled Labor	Unskilled Labor
<u>Quality improvements in nano-enabled activities</u>		
Employment in nano-enabled activities	↑	?
Employment in substitute activities	↓	↓
<u>Cost reductions (productivity increases) in nano-enabled activities</u>		
Luddite concern	↓↓	↓
Capitalist Comeback	↑↑	↑
Job Diversion	↓	↓
<u>Demographic shifts</u>		
Rising dependency ratios	↑↑	↑
<u>GPT Effects</u>		
Moore's law	↑	↓
Demands of tech adoption	↑↑	↓
Net Effect:	Almost Certainly ↑	Probably ↓

Conjectures

- Skilled job creation likely.
- Not so much unskilled job creation.
- Educational bottlenecks could be serious.

General Purpose Technologies

- Definition: ".. a technology that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many Hicksian and technological complementarities." (Lipsey, Bekar & Carlaw, 1998)

	Initial Scope for Improvement	Wide / Varied Use	Complement arities	GPT?	Comment
Carbon Nanomaterials (bucky balls, nanotubes, graphene)	Yes	Yes	Yes	Probabl y	Strong when mixed in a matrix (kevlar), drug delivery, used in transistors, water filtration.
Quantum Dots (all built similarly, in test tubes)	Yes		Not known	Possibly	Act like electrons, but are much bigger than electrons – solar cells, single electron transistors, flourescents as biomarkers. Likely industry-specific.
Metal nano-particles					Similar synthesis process across metals, biotech, similar materials applications as carbon nano – but not always as effective yet.
Nano-oscillator					
Thin films (oldest - tecgmade by big			Yes		Enabling technology – used for electronics/photonics,

General Purpose Technologies

- Definition: “A GPT is a technology that initially has much scope for improvement and eventually comes to be widely used, to have many uses, and to have many Hicksian and technological complementarities.” (Lipsey, Bekar & Carlaw, 1998)

- Which (if any) nano-technologies are GPTs?

- Does minitiaturization (nano-electronics) mark a break from the last wave of GPTs (computers)?
  - Facilitator of Moore’s law. (see if there are papers on this).

- Note: uncovering the effect on labor markets of more than one GPT is hard.

Application: The Cost Disease

Illustration: Healthcare

- Thus, nano has three potential implications for healthcare sector:
  - More demand for healthcare.
  - Demand for higher-quality healthcare.
  - Displacement of skilled healthcare labor.

  → A “bedpan economy”?

GPTs and Labor Markets

- Autor’s stuff on tasks.
- Other stuff from Helpman.

Conceptual framework