

**WHEN LESS LIABILITY MAY MEAN MORE PRECAUTION:
THE CASE OF NANOTECHNOLOGY**

David Dana, Northwestern University

I. INTRODUCTION

Ignorance may be bliss, but it is generally bad policy. That may be especially true with respect to existing and forthcoming products that embody the relatively new, still poorly understood technology called “nanotechnology.” Nanotechnology products offer the promise of highly beneficial uses, but also pose uncertain risks of adverse health and environmental effects. For products embodying nanotechnology, there is a powerful normative case for adherence to what I will call “the precautionary-study principle.”¹ The principle requires that the possible risks from these products would be explored (if in all likelihood not really understood) before their release to the marketplace. It also would require that possible risks are thereafter continually studied. Continual study after the release of products into the market is important because it allows adverse effects to be isolated and understood using improvements in the background science and real-world observations and reports from consumers and others who have been exposed to the products.

A central question, therefore, is how to shift the nanotechnology status quo toward greater adherence to a precautionary-study principle. To that end, this Article proposes a federal legislative regime of limited protections from tort liability for nanotechnology product manufacturers who engage in pre-market and post-market research regarding possible adverse health and environmental effects from their products. The central argument is: Less liability may mean more precaution, and hence be a good thing.

Nanotechnology is generally defined as technology that incorporates nanomaterials – engineered, extremely small materials, as small as 1/80,000th the width of a human hair.² Nanomaterials in current use in products employ common organic

1

² Precise definitions of nanotechnology vary but all seem to include the idea of extreme small size – including one or more dimensions in size less than 100 nanometers – and the fact that the atomic or molecular material was and is not simply found in its purely natural state but has been the subject of some imaging, measuring, modeling, and/or manipulation at the atomic or molecular scale. *See* Davies, at 7; International Organisation for Standardisation; U.S. National Nanotech Institute, available at www.nano.gov.

elements such as gold, silver, titanium, and carbon, but nanomaterials function very differently than larger materials made up of these same elements. Because of their distinctive size-related functional attributes, nanomaterials may be very useful in arenas ranging from cancer treatment to wrinkle. But the size-related attributes of these materials may translate into significant health risks. Notably, the extremely small nature of nanomaterials may allow them to pass various protective barriers in the human body and ultimately lodge in organs (such as the brain or lungs) where they could do damage.³ There have been relatively few completed studies, and these studies address only a few of the many forms of possible nanomaterials, but these studies, while not uniform in their results, suggests that some nanomaterials may have significant adverse health⁴ and environmental impacts.⁵

There is no consensus as to whether nanotechnology and nanotechnology products should be approached within the framework of the precautionary principle. Some commentators – and U.S. regulators -- have argued that there is an insufficient basis for the regulation of risks from nanotechnology, and have emphasized the need to secure the potentially vast commercial benefits of nanotechnology.⁶ These commentators have argued, in effect, against a precautionary approach to nanotechnology. In sharp contrast, some commentators and NGOS have called for a moratorium on the release of nanotechnology products until their safety can be affirmatively demonstrated by product manufacturers.⁷ In effect, the calls have been for the application of a strong form of the precautionary principle to nanotechnology products. In this strong form of the precautionary principle, which might be called the precautionary-certification principle, new technologies may not be deployed in the marketplace unless and until the manufacturer first can prove and hence certify they are risk-free or “safe.”⁸

These two positions are both too extreme. There are sound theoretical reasons to believe that, absent some commitment to precautionary action, insufficient attention will be paid to the downsides from nanotechnology products. For social welfare as well as pragmatic political reasons, however, the precautionary focus with regard to nanotechnology products should be consistent with a less demanding, more flexible precautionary-study principle. The credible risk posed by most nanotechnology products is not qualitatively great enough – and our scientific abilities to evaluate the risks in a reasonable time frame are too limited – to justify a blanket moratorium approach. What

3

4

5

6

7

8

is most obviously justifiable is greater realization of a precautionary-study principle with respect to nanotechnology products.

There are many obstacles to achieving that greater realization. For one thing, current laws and regulations in the United States (as well as other nations) do not provide a clear basis for requiring precautionary study on the part of nanotechnology product manufacturers.⁹ Nor has there been abundant public funding for research regarding nanotechnology's health and environmental risks.¹⁰ Moreover, even if there were a political consensus in support of new mandatory testing requirements and dramatically increased public funding, voluntary testing and monitoring by manufacturers would be an important component of any comprehensive precautionary study approach. Industry actors have special access to knowledge about emerging technology and product development and products, and can change and adapt quickly to follow a commercial marketplace that may move too fast for legislators and regulators and regulatory institutions to understand and react to on their own with mandatory testing requirements.¹¹

The heart of the Article is an exploration of the possible role of common law tort liability in both encouraging and deterring voluntary, precautionary study of new products generally and nanotechnology products in particular. A key variable in considering liability's role as an incentive or deterrent to testing is the manufacturer's subjective assessment of the probability that any injuries from its product would be detected by the injured parties and successfully attributed to the product *absent* research by the manufacturer itself on the adverse effects of the product. Another key variable is the legal standard for tort liability, and specifically how the applicable standard falls on a spectrum from the imposition of liability on manufacturers only for known risks on the one hand to the imposition of liability even for risks the manufacturer could not have reasonably foreseen on the other. The lower the perceived probability of detection without manufacturer research and the more the applicable liability standard veers toward requiring actual knowledge of risks on the part of the manufacturer, the more likely it is that the *ex ante* threat of liability will lead a manufacturer to choose *not* to conduct research into possible adverse effects, either before the product is marketed or once it is on the market. Consideration of these two variables in the nanotechnology context would tend to suggest that liability considerations indeed may be discouraging research into possible adverse effects of nanotechnology products under development and already on the market.

The closest precedent for the regime of limited liability relief that I propose is the regime of federal preemption of state torts that is afforded manufacturers of certain FDA-approved medical devices and drugs under federal statutes.¹² FDA preemption of

9

10

11

12

common law tort claims, however, is controversial, to say the least.¹³ In order to avoid the disadvantages and problems of the FDA preemption regime, any regime of liability relief for nanotechnology manufacturers who voluntarily engage in testing needs a number of components that would help ensure political accountability, scientific integrity, transparency, and a reasonable pool of compensation for injured people. The scope of preemption of state tort law claims would have to be specified by federal statute, not agency promulgation or interpretation, as it largely has been in the case of FDA preemption. Any such preemption should not include claims based on allegations that a manufacturer violated a tort duty by acting or failing to act in response to actual knowledge of adverse health or environmental effects. And there must be vigorous government oversight of both voluntary pre-market and post-market testing and monitoring, and the public must have reasonable access to the key information provided regulators. Finally, in order to prevent drastic denials of compensation while encouraging voluntary study, all companies would be required to maintain liability insurance, and companies that engaged in pre- and post-market testing would receive insurance subsidies in one form or another.

That the proposed nanotechnology regime would be voluntary, however, does suggest the need for certain institutional design features that would make no sense in the context of FDA-mandated testing of drugs and medical devices. In voluntary regimes generally, getting initial participation is often difficult due to uncertainties of costs and benefits of participation.¹⁴ As explained below, moreover, there would be strong incentives for some manufacturers to join a voluntary testing regime only once a number of other manufacturers of similar products have joined.¹⁵ Because the recruitment of initial or early participants may be difficult and would be very helpful in ultimately achieving broad participation in a voluntary testing regime, special incentives for early joiners may be warranted.

There are many possible objections to the proposed voluntary regime, one obvious one of which is why liability relief would or should be limited nanotechnology, as opposed to any new (or existing but untested) technology or substances that pose unknown risks. The reasoning of the Article might support liability relief for other substances and products for which it is plausible to assume that the fear of generating liability may lead companies to forego testing and monitoring they otherwise would have undertaken. My answer is largely pragmatic: the issue of nanotechnology risks and regulation is now a subject of public discussion and analysis, and nanotechnology products could be a good place to start to explore the merits of regimes of liability relief as a quid pro quo for voluntary testing. Were such a regime actually implemented, we could assess how well or not well it worked to advance overall public welfare, and perhaps then move beyond nanotechnology.

13

14

15

II. FRAMING THE NANOTECHNOLOGY PROBLEM

What exactly is the nanotechnology “problem” regarding human health and environmental risks? This Part argues that the essence of the problem is what we do not know. Any comprehensive response to the informational deficit regarding nanotechnology, this Part argues, should include not just mandatory testing and public funding, but also a voluntary testing and monitoring component.

A. The Information Deficit Problem

Very little is understood about the health, safety and environmental risks posed by the manufacture, use and disposal of products containing nanotechnology. The lack of adequate research and hence adequate understanding of the risks is a theme of every major report regarding nanotechnology. Academic commentators, NGOS, scientific societies, legislators, and major industry players agree that too little research has or is being done -- and, indeed, that too little is or likely will soon be known about these risks.¹⁶

In considering what needs to be known to understand nanotechnology and nanotechnology products better, it is useful to categorize the kinds of information that is not known and must be acquired or developed. One could develop a number of different list of categories, but I suggest these three : (1) information regarding risk assessment and monitoring metrics, criteria and methods uniquely suited for or tailored to nanotechnology; (2) information regarding the behavior and associated risks of different categories of nanotechnology and the significance of different pathways for the different categories of nanotechnology; and (3) information regarding risks associated with particular products that include nanotechnology.

The first category information – information regarding nanotechnology risk assessment metrics, techniques and methods – is the kind of information that is needed for assessing the risks associated with different types of nanotechnology and different nanotechnology products. Thus, the incompleteness in category one information is a constraint on the acquisition and development of category two and three information. Not surprisingly, therefore, many scientists have focused on the pressing need for investment in the development of what I am calling category one information. For example, a group of prominent nanotechnology scientists writing in *NATURE* in 2006 set forth a multi-decade agenda as to what methods must be developed for nanotechnology to be responsibly commercialized. This agenda underscores how much critical category one is not yet in place for assessment of risks, how big the task is for the development of the necessary methods, and how unlikely it is that this task will be substantially completed before hundred or thousands of new nanotechnology products are prepared for and introduced into the commercial marketplace. According to the *NATURE* agenda, key research goals should be:

¹⁶

*"Develop and validate methods to evaluate the toxicity of engineered nanomaterials, within the next 5–15 years."

*"Develop models for predicting the potential impact of engineered nanomaterials on the environment and human health, within the next 10 years."

* "Develop robust systems for evaluating the health and environmental impact of engineered nanomaterials over their entire life, within the next 5 years."¹⁷

Similar calls have been made by representatives of public interest NGOs as well as entities affiliated with industry. The Environmental Defense Fund has argued that "[e]ven before the research that will allow hazards and exposures to be quantified, a number of more fundamental needs must be addressed." because "[w]e currently lack a good understanding of which specific properties will determine or are otherwise relevant to nanomaterials' risk potential." And "[m]any of the methods, protocols and tools needed to *characterize* nanomaterials, or to *detect and measure* their presence in a variety of settings (e.g., workplace environment, human body, environmental media) are still in a very early stage of development."¹⁸ Lux Consulting, a private sector firm that advises nanotechnology companies, has likewise concluded that there is a great need for "*frameworks . . . for evaluating*" nanotechnology materials" and that greater "understanding [of] the basic science of nanoparticle EHS factors" is needed for "*safe* nanotech developments."¹⁹

The second category of information – information about certain categories of nanotechnology and certain pathways into the human body (such as facial skin) or environment for these categories of nanotechnology – has been the subject of sporadic studies and now some significant, but still relatively nascent, research programs.²⁰ For example, a number of studies have been completed on both carbon nanotubes and titanium dioxide.²¹ The completed studies so far often suggest inconsistent results or

¹⁷ See Andrew D. Maynard et al. Safe Handling of nanotechnology, *Nature*, 444, 267-269 (Nov. 2006). See also National Research Council, Review of the Federal Strategy for Nanotechnology-Related Environmental, Health, and Safety Research Committee (prepublication copy, at 3) (concluding that "[a] robust national strategic plan is needed for nanotechnology-related environmental, health, and safety research that . . . should focus on research to support risk assessment and management, should include value-of-information considerations, and should identify . . . Specific research needs for the future in such topics as potential exposures to engineered nanomaterials, toxicity, toxicokinetics, environmental fate, and standardization of testing."

¹⁸ See Environmental Defense, A proposal to increase federal funding of nanotechnology risk research to at least \$100 million annually) (April 2005) (statement of Richard A. Denison, Senior Scientist, Environmental Defense).

¹⁹ Matthew M. Nordan, President, Director of Research, Luxresearch, Nanotech Commercialization Has Advanced but Government Action to Address Risk Has Not, Sept. 21, 2006.

²⁰

²¹

conclusions regarding safety of categories of nanotechnology, and hence simply underscore the need for more research.²²

Moreover, even if there were more and better category two information, we would need research at the level of particular nanotechnology products. For one thing, because there is an incomplete public inventory of nano-components in current products (not to mention products under development), we do not have reliable knowledge regarding the full range of categories of nanotechnology that are or soon will be embodied in commercial processes and products.²³ And even if we had such an inventory, what we think is likely and certainly possible about nanotechnology is that the same categories of nanotechnology may behave differently with minor differences in production and formulation.²⁴ And the distinctive differences in the environment (human and otherwise) in which particular products are used and disposed of may mean that there are significantly different risks from products that contain exactly or almost exactly the same nanotechnology.²⁵

How much information, then, has been assembled regarding health and environmental risks from particular nanotechnology production processes and products in commercial use? We really do not know, because we do not know how much testing has been completed by private industry. What is clear is that almost no public information exists regarding product-specific risks from nanotechnology products.

As already noted, government regulation in the United States and elsewhere has not required pre- or post-market testing of products containing nanotechnology. There have been and are initiatives on the part of government agencies – and notably the federal EPA – to encourage companies to voluntarily provide regulators with the information they possess regarding their products. But, relatively little of the content of those submissions has been made public, and what has been made public suggests a selective response by industry to the call for voluntary disclosure to regulators.²⁶

We do know that some companies clearly are doing testing on nanotechnology products. Most notably, DuPont, in conjunction with Environmental Defense, has developed and publicized a testing protocol and reported on the cases of a few nanotechnology products it has considered for development.²⁷ But the DuPont initiative is so notable in part because we have no idea what so many major companies, not to mention smaller companies, are or are not doing.

22

23

24

25

26

27

One possible response to the insufficiencies in our risk assessment methods and metrics for nanotechnology, in our understanding of risks from categories of nanotechnology, and in our knowledge about product-specific risks, would be a moratorium on the release of new nanotechnology products – or even the continued marketing of those already on the market – pending the development of better assessment methods and better actual assessments. Indeed, in 2007, a broad range of NGOs called for such a moratorium as part of Principles for the Oversight of Nanotechnologies and Nanomaterials.²⁸ That group endorsed a precautionary principle regime which “would include prohibiting the marketing of untested or unsafe uses of nanomaterials and requiring product manufacturers and distributors to bear the burden of proof” or, more pithily, “Simply put, ‘no health and safety data, no market.’”²⁹

A broad-based moratorium, of course, would deny the public of some nanotechnology products that may have great utility to consumers and to the public at large. The very large economic value of current and projected nanotechnology products suggests that there is a great deal of consumer and other public utility at stake. In any case, there appears to be insufficient political support for a general moratorium either in the United States or elsewhere. But the information deficit regarding nanotechnology – in particular the deficit in what I have called category one and two information – does or should implications for one’s view how a non-moratorium approach to nanotechnology products should be conceived. Specifically, these deficits suggest that any conclusions drawn from pre-market-release testing as to safety must be tentative and should be openly acknowledged as such, and that a substantial emphasis must be placed on *post-market* release testing, monitoring and disclosure.

Where (as with nanotechnology) there are theoretical reasons for believing that there may be adverse human or environmental effects from a kind of technology embodied in a product and there is an acknowledged informational deficit regarding the risk assessment methods for that technology, pre-market-release testing can reveal only so much. Open acknowledgment of that fact -- and open embrace of a relatively undemanding stated goal for pre-market testing -- is therefore appropriate. A very demanding stated goal as to what pre-market testing must or should show, therefore, can have two possible, perverse consequences. If adherence to the goal is taken very seriously, then testing will be very expensive and prolonged and, even so, may often be deemed inadequate to make the necessary showing for commercial release. A too-demanding pre-market testing standard thus can become the equivalent of adoption of a moratorium. On the other hand, if there is a demanding standard but products are readily deemed to have met the standard notwithstanding the limits in what pre-market testing can reveal, there may be a tendency on the part of regulators, companies, and other

28

²⁹ One of the NGOs that endorsed the Principles – Friends of the Earth – has been particularly vocal in pushing for a moratorium, particularly in the context of cosmetics. See Other highly-regarded organizations, such as the UK’s Royal Society, have, while not endorsing the general moratorium approach, have argued for more selective regulatory reviews that might result in limitations on the commercial release of certain kinds of nanotechnology products, such as cosmetics containing []. See

stakeholders not to advocate for and/or engage in post-market monitoring and testing. Indeed, under the FDA registration system for new drugs, which does purportedly employ a very demanding standard for showings of safety based on pre-market testing, there reportedly has been an absence of adequate post-market monitoring, reporting, testing and disclosure, notwithstanding FDA's legal authority to require companies to engage in such post-market measures.³⁰

The limits in information regarding risk assessment and substantive information regarding different categories of nanotechnology and different pathways -- what I call category 1 and 2 information -- counsels in favor of post-market measures in two senses. First, to the extent that risk assessment and evaluation methods are improving over time, post-market assessments allow products to be evaluated using better risk assessment methods than were available at the time the product was under development and was released into the marketplace. Second, because pre-market testing is not entirely reliable in detecting adverse effects, the only means to detect such effects and prompt further study of them sometimes may be by means of direct observation of workers, consumers and others who have used or come into contact with nanotechnology products. The same argument has been forcefully made even in the context of conventional (not nanotechnology) drugs that have been subject to the pre-market FDA testing and approval process.³¹

Post-market-release testing is also important for another reason: hundreds of nanotechnology products are currently on the market that, as far as we know, never underwent pre-market testing or underwent testing that may have suggested potential adverse effects. For this set of products, post-market monitoring and testing may be the only feasible means for assessing risks of adverse effects of environmental, health and safety.

A nanotechnology product regime should include substantial, but realistically tentative, pre-market testing coupled with post-market monitoring and testing under conditions of transparency that allow for public accountability. There are three possible components of such a regime: mandatory product testing requirements, public funding for testing, and voluntary commitments on the part of companies to engage in testing and monitoring. These means are in no way exclusive, and all three may be needed in combination.

B. Three Components of a Precautionary-Study Approach to Nanotechnology

Mandatory Testing and Monitoring Requirements

One approach to achieving pre- and post-market testing of products, clearly, is mandatory pre- and post- market release testing. It is at least arguable that current laws

30

31

in the United States would not support such testing requirements. As Wendy Wagner and others have argued, US laws tend to be very precautionary with respect to a limited range of items (such as certain new drugs) and almost entirely non-precautionary with respect to everything else.³² As Terry Davies has suggested, a new law may be needed as a framework for mandatory pre and post market testing of nanotechnology products.³³ It remains to be seen whether interest group politics are such that we will see either the use of existing authorities to mandate more testing,³⁴ or the passage of a new mandatory testing law.

Even if a new law were enacted, there are reasons to suppose that it might be underinclusive or inadequate unless mandatory testing were supplemented by voluntary testing. Nanotechnology is a dynamic arena in which the kinds of nanoparticles and uses for them as indentified by industry may be expected to change quickly over time. Mandatory testing rules will have to include definitions of the scope of substances or products to be tested and the substance of the testing. These rules could readily become obsolete as the commercial marketplace evolves in different directions that regulators do not understand or understand well. Moreover, even if regulators can keep apace of changes in technology and commercial interest in emerging technology, it is inherently hard to change mandatory government rules quickly. Such rules can be expected to evoke opposition from at least some industry actors, and that opposition may well be enough, coupled with the well-known phenomena of legislative and regulatory inertia, to prevent rapid adoption of new rules. Even if new rules are authorized for implementation, implementation takes time.

Mandatory rules, moreover, almost always require voluntary compliance to be truly effective. In particular, regulators are not well-positioned to enforce mandatory post-market-release reporting and disclosure requirements, as they lack direct contact with distributors, vendors, consumers and others who may be the best source of such information. Thus, even in an ostensibly mandatory regulatory regime, voluntary efforts – cooperation and collaboration by industry – are important,³⁵ and hence so are the strength of the incentives for industry to engage in such voluntary efforts.

Public Funding

The public certainly could fund pre-and post-market testing of products containing nanotechnology components that would help reveal their health, environmental and safety effects. There has indeed been a call for increased federal funding of this kind,

32

33

34

35

at least on behalf of smaller start-ups in the nanotechnology industry.³⁶ Public funding, however, is unlikely to adequately fill the information deficits discussed above.

First, the competition for federal research funds is intense. Research regarding the environmental, health and safety implications of nanotechnology – research directed at what may be a real health and environmental problem, but is not *known* to be such – has and likely will continue to have difficulty attracting funding when legislators and regulators must make hard choices as to where to allocate funds. There are simply too many known problems or ailments or crises that could make use of funding. Nanotechnology safety implications is not an issue that has a singularly motivated and hence powerful interest group behind it, as (for example) does autism research, and also does not have a powerful, visceral hook for press coverage and popular mobilization.³⁷

Second, public funding, by definition, cannot address many questions of product safety without substantial information from and active cooperation of companies that are developing or have developed products containing nanotechnology. Whether research is funded by companies or by the public, companies must be willing to make disclosures that may be sensitive for trade secrets/business competition reasons and that may lead others to question the safety of the products and whether they have or will create harm. The promise of funding alone may well not be enough motivation, as the discussion of liability concerns in Part III suggests.

Finally, as a normative matter, it would seem inappropriate for the federal government to fund product-specific safety testing (category three information). Such testing would seem to be rightly regarded as part of the costs of the production of the product. Production costs – like profits from production – presumptively rest with the producer in a market economy. In a standard model of allocative efficiency, product-specific subsidies would result in the overproduction of new nanotechnology products, particularly ones that may entail especially costly testing. Moreover, any proposal to subsidize testing for smaller companies or start ups who cannot readily afford testing costs is likely to skew the marketplace for nanotechnology product development in favor of such companies. As a historic matter – for example in the FDA drug approval context -- product-specific testing has not been publically funded for either small or large entities, and the drug industry has included collaborations between start ups and larger companies, perhaps partly as a result. The federal government, however, could conduct some of the actual testing with company funding, in which case smaller companies could, collectively, perhaps take advantage of economies of scale they otherwise could not achieve.³⁸

³⁶

³⁷

³⁸ As Lux Research has advocated, there is a clearly a role for public funding of category one – framework and methods – research, as well as a role in supporting basic research that might be considered part of category two. Such research has sufficiently wide applicability to be regarded a public good or quasi-public good, and there is substantial precedent for public funding of public goods or quasi-public goods that have significant benefits for industry.

Voluntary Testing

As explained above, mandatory testing requirements and public funding together are unlikely to result in comprehensive product-specific research that tracks and keeps pace with developments within the nanotechnology industry. Voluntary testing and monitoring, at a minimum, is needed to fill in important holes in what any mandatory requirements cover in theory or (given highly imperfect information and limited resources on the part of regulators) in practice. More specifically, what is needed is voluntary testing and monitoring, coupled with affirmative cooperation with regulators and public disclosure. The relevant question then is, how can voluntary testing *with government oversight and public disclosure* be assured, or at least encouraged?

One conventional answer has been that the threat of common law tort liability will encourage companies to engage in voluntary testing in order to minimize harm to consumers and the environment and hence to minimize their potential tort liability. The threat of liability, it has been supposed, will lead companies to cut off production of dangerous products or recall ones already on the market, and will prompt full disclosure of the risks associated with products brought to or left on the market. The view that liability (or the possibility of liability) will encourage companies to invest in assessing risks from nanotechnology products appears to be shared both by those that oppose mandatory testing requirements as unduly intrusive or necessary and those that support tough mandatory testing and certification requirements.³⁹

The idea that the threat of liability will encourage voluntary testing and disclosure, however, presupposes two things that are not always true in all contexts and almost certainly not true in the context of nanotechnology products. First, this argument assumes a robust standard for liability whereby alleged tortfeasors are held liable even when they did not actually have knowledge of a potential hazard or risk or adverse effects or even arguably could have gained such knowledge only with great difficulty, if at all. Second, this argument seems to assume that the harms that would form the basis of the tort claims would be apparent to the victims and that the connections between those harms and their causes could be readily drawn by the victims and accepted by courts. But as discussed below, the American tort system largely employs a standard of liability in which the absence of actual knowledge of a risk or hazard or adverse effect is extremely helpful in avoiding liability, inasmuch as plaintiffs must show that the defendant either knew or reasonably should have known of the risk or effect. Moreover, with respect to many kinds of products, the harms may not become apparent for many years and may not even occur to victims as related to particular products, and indeed may be very hard for even the most determined plaintiffs to establish as having been caused by particular products.

Nanotechnology products, if they do have harmful effects, likely would fall in this category of products for which adverse effects are hard to isolate and connect to the

39

production, use or disposal of the products. Consider, for example, the possibility that nanoparticles in skin creams may have adverse effects.⁴⁰ Because most consumers do not even know which creams contain nanoparticles and which do not, almost no one would ever retain records as to which cosmetics he or she used over time. Moreover, if nanoparticles in skin creams indeed can permeate skin barriers and affect internal systems in the body, there might be any number of adverse effects from them. Many of these adverse effects might relate to conditions or ailments that might have a range of other causes, from genetics to diet to smoking. And these ailments or conditions might surface decades after the use of the product ended. Asbestos-based liability has dominated the American tort system in large part because asbestos exposure creates an easily identifiable, signature disease, asbestosis,⁴¹ but there is no *a priori* reason to suppose that nanoparticles in products would similarly result in signature diseases or conditions.⁴²

Moreover, the very defining attribute of nanoparticles – their incredibly small size – may mean that it will continue to be very hard to detect their presence in the environment.⁴³ As a result, it is and may well continue to be extremely hard to isolate nanoparticle pathways in the environment and prove that nanoparticles via these pathways caused human health effects or other harms that might be the basis for liability. The closest analogy would be endocrine disrupting chemicals, which may have some toxic effects but are pervasive in small quantities in the environment. Although much has been made of the possibility of tort liability related to endocrine disrupters, that liability in fact has not been imposed, perhaps because of the difficulty of establishing particular concentrations and particular pathways into the human body.⁴⁴ The possibility of environmental tort liability based on nanoparticle exposure may be even more uncertain, given nanoparticles small size and elusive nature, even assuming *arguendo* that nanoparticles in fact can and will cause human health or other harms.

III. MODELLING MANUFACTURER DECISIONMAKING

This Part develops a model that illustrates how the threat of liability may lead nanotechnology producers *not* to test products, and how limits on liability might produce more testing.

One way to think about the decisions of nanotechnology companies under the current tort system is to imagine how a particular nanotechnology product manufacturer (“the company”) might evaluate the decision whether to invest in researching any adverse health effects of a product while it is under development, before its introduction to the

40

41

42

43

44

market, and after its introduction to the market. Imagine that the product is a cosmetics such a wrinkle cream, that it contains a form of nanotechnology for which there is almost no or no existing research, and that is not, to the company's knowledge, a known component of any other product under development or on the market.

A. Assumptions

This model assumes that any assessment of the product's possible adverse effects would take significant time, and that any reasonably reliable conclusions regarding what can be gleaned about adverse effects cannot be made until the assessment is complete.⁴⁵ The model also assumes that the company believes it has some reasonably reliable sense as to how long the product, absent safety issues, would have a "run" on the market before it likely will be considered stale or obsolete and the company would introduce a new, differently-composed product to take its place.

In addition, the company believes it has some reasonably reliable sense of how well the product will sell at different times during this run. That a company would have such beliefs would seem essential for the company to even consider making an investment in product development and marketing at all. (Somewhat unrealistically, in the interest of simplicity, the model will assume that the company does not update or change its projections of how long the product will have a run in the market and how well it will sell once the product enters the marketplace.)

The model contains three distinct time periods, which contain two distinct decision points for the company. At T₀, the product is under development. T₀ is the company's first decision point, because any premarket testing for the product would have to begin then, so as to produce results by the time the product is scheduled for market release (T₁). Period One is the time between T₀ to T₁.

At T₁, the time of the product's release into the marketplace, the company has its second decision point. At that time, the company must decide whether to undertake post-market-release testing of the product, the results of which would not be available until T₂. By T₂, the product would have been on the market some time but still would have a significant amount of time left in its anticipated market run. Period Two is the time between T₁ and T₂.

After T₂, the company has no further decision points. Unless pulled from the market at T₂, the product will remain on the market until it has finished its anticipated market run and is obsolete. T₃ is the time at which the product has had its full anticipated market "run": the company will introduce a next generation product at that time to take its place. Period Three is the time between T₂ and T₃.

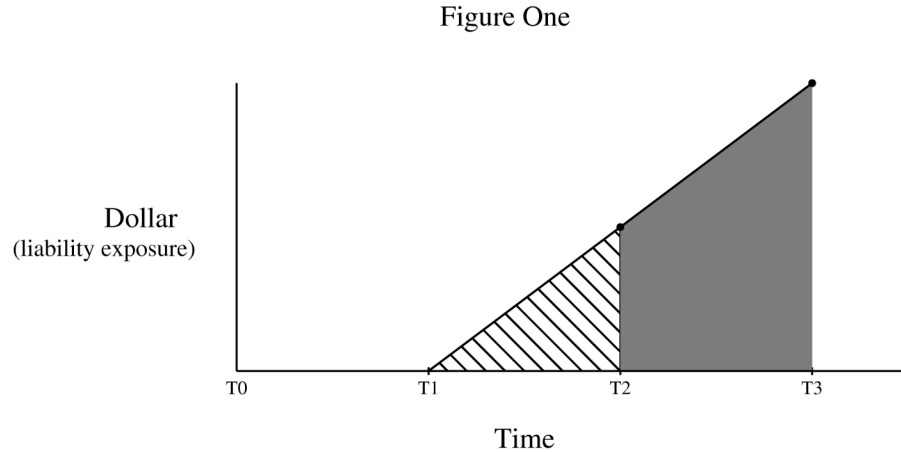
B. Variables

Damages (D) and Standard of Liability (S)

⁴⁵

The company realizes that, if the product causes adverse health effects and those health effects are linked to the product, the company might be incur substantial liability based on sales of the products during Periods Two and Three. As a baseline for estimating its liability exposure, the company might estimate the damages (in monetary terms) consumers would incur as a result of the product, assuming very adverse effects for a significant fraction of consumers of the product. They might also include an estimate of environment damages as a result of the manufacture and disposal of the product during those two periods. D is the damages attributable to the product.

Figure One depicts these damages estimates on the part of the company. Time is the variable on the x axis below. The variable on the y axis are total damages incurred up until time T . D_{T_2} represents total damages incurred during Period 2. D_{T_3} represents total damages incurred during both Periods Two and Three. The upward slope of the line on the figure reflects the fact that as time passes, more people purchase and use the product, and as more people purchase and use the product, the number of potentially harmed people increases. As that number increases, total damages increases. For products with rapid growth in sales over time, we would expect a shaper upward slope than for products that maintain more or less even sales over time.



Actual damages – even damages clearly attributable to a product – do not necessarily translate into a liability to pay damages under tort law. There are several different liability standards for manufacturer liability, ranging, in effect from liability only for sale and distribution of products known to be harmful to negligence to genuine strict liability. Depending on the applicable standard a manufacturer might always or sometimes or virtually never be held liable for damages attributable to its product. S will signify the applicable standard for liability.

The two relevant causes of action in tort law for producers of a nanotechnology cosmetic would be a cause of action for defective product design and a cause of action for failure to warn of risks associated with the product. With respect to both such causes of action, three key points in time according to both the case law and commentary are (1) the time the product first enters the market, (2) the time the product is sold to the particular plaintiff, and (3) the time at trial.⁴⁶ A central debate in tort law has concerned the question of when, if ever, should manufacturers be held liable for product risks that the manufacturer did not know about and perhaps could not even have known about at the time of the sale of the product to the plaintiff(s).⁴⁷ Arguments rooted in efficiency and fairness have been invoked to support and defend against manufacturer liability for failing to warn of or otherwise address unknown risks.⁴⁸

One position that some courts and commentators have sometimes articulated -- and that was most strongly associated with the deans of American tort law, [] Keaton and [] Wade -- is that a manufacturer is or should be liable for harms that at trial can be shown to have been caused by the product even if the manufacturer did not know or could not have reasonably foreseen that the product would cause such harm when the product was first manufactured and released to the market or when it was sold to the particular plaintiff.⁴⁹ This approach is sometimes described as hindsight liability or genuine strict liability, and it effectively removes any defense based on the absence of or limit in scientific evidence regarding causation prior to the time of trial.

At the other side of the spectrum from genuine strict liability is liability that requires a showing of actual knowledge on the part of the manufacturer of the harmful effects of the product at the time the product was sold to the particular plaintiff. Although actual knowledge has indeed been alleged in many of the best-known mass products liability cases,⁵⁰ it is not clear that any court has completely embraced an actual knowledge requirement in products liability cases. The state tort statutes in some states establish a strong form of the so-called "state of the art" defense; such statutes could be read to mean that scientific information or evidence developed after a product is introduced into the market cannot be used against the manufacturer in establishing liability.⁵¹ However, these statutes presumably were drafted with mechanical devices in mind (e.g. lawnmowers that turn out to malfunction), and have not been construed to mean that a manufacturer has absolutely no obligation to ignore developments in scientific evidence regarding drugs, chemicals or similar products after the product first

46

47

48

49

50

51

enters the market, even if the market was tested to the highest industry standards prior to it being first introduced into the market.⁵²

The Restatement [] articulates what is probably the standard that most courts in most cases within the United States now endorse. Under this reasonable foreseeability or “should have known” standard, manufacturers can be held liable if they should have known of the harm the product could create when they sold it to the plaintiff and nonetheless sold it without an appropriate warning.⁵³ Under this standard, lack of actual knowledge is not a defense, but neither can the plaintiff simply hold the manufacturers liable for risks and harms that the manufacturer could not have known when the products were sold to the plaintiffs. The Restatement approach is very similar to that followed in European and Japanese law.⁵⁴

The reasonable foreseeability/should have known standard is, of course, a kind of negligence standard. Indeed, citing the Restatement and similar authorities, some commentators have concluded that American products liability torts, although still sometimes labeled a strict liability domain, is squarely within the domain of negligence torts.⁵⁵ And like all negligence standards, the reasonable foreseeability/should have known standard used for products is flexible and imprecise, and subject to much-more or much-less defendant-friendly interpretations and applications. Indeed, there probably are few cases in which one could not plausibly argue opposite positions under this standard--that a manufacturer reasonably could not have reasonably foreseen an unknown product risk, or that a manufacturer reasonably should have foreseen the risk and engaged in more testing and product re-design or warned consumers of the risk. Everything depends on the conception of “reasonableness” one employs.⁵⁶

For the company facing potential liability, it might be logical for them to think of standard of liability as a spectrum variable, with proof of actual knowledge required on one end, a range of possible formulations of “should have known” in the middle, and hindsight/genuine strict liability at the other end. S will have a value of 1 at the farthest right/ hindsight liability end of the spectrum, which means that the company will be legally responsible for 100 percent of the damages its products cause. At the “actual knowledge required” end of the spectrum, S will have a value of 0, which means that the company will not be legally responsible for any damages its products cause, at least assuming the company will not market or continue to market the product without warning once it has actual knowledge of harm. The magnitude of S increases from left to right as “should have known” is applied as imposing an increasingly demanding duty on the manufacturer to find out about possible risks and mitigate or avoid them and/or warn of

52

53

54

55

56

them. In the middle of the spectrum, where $S = .5$, there is a 50% possibility that the court would conclude the manufacturer should have known, which in expected value terms, means that, *ex ante*, the manufacturer's expected costs would be 50% of the damages its products actually cause.

For the company, there could be two relevant S s. S_{T2} is the standard of liability applicable to Period Two consumers who sue after the company finishes its post-market testing and pulls the product at T2. S_{T3} is the standard of liability applied to Period Two and Three consumers at T3, after independent research shows that the product, which by then will have finished its market run, is harmful. Under current tort law, the applicable standard of liability is formally the same whether the manufacturer removes the product voluntarily based on its own testing and monitoring before the end of the product's anticipated market run or whether the products completes its market run and then independent non-company research toes the product to injuries of consumers and others (at or after T3).

L_{T2} , the total liability for the company Time T2, would thus be $(D_{T2})(S_{T2})$, again assuming the company finds adverse effects and pulls the product from the market. L_{T3} , the total liability for the company at T3 or after, would be $(D_{T3})(S_{T3})$, assuming that non-company research at T3 or later has shown that the product caused adverse effects during Periods Two and Three. One might generally assume that L_{T3} will be greater than L_{T2} because more consumers are exposed as of T3 than as of T2. If neither the company nor entities outside the company detect and establish the link between the product and injuries to consumers and others, however, there will be no liability whatever for the company at either T2 or T3 or after.

Probability of Detection/Attribution (P) and Research Costs (R)

The model assumes that the company believes that, absent its own independent research into the possible links between the product and adverse effects, there is a zero possibility that the product will be linked to adverse effects prior to the end of Period Three. For products whose potential adverse effects, if any, likely would not be obvious for years and would even then not be obviously linked to the product but instead could well be attributed to other causes or unknown causes, this would be a reasonable belief.

The company believes that there is some probability that, absent any research or monitoring for adverse effects on its part, the product could be linked to adverse effects by Time T3 or at some time thereafter. We will call that probability P_{T3} . The company's estimate of the magnitude of P_{T3} (and the actual P_{T3}) would depend on a number of factors. One of these would be any ingredient or component disclosure and labeling requirements, if any, for the product: the less those requirements are, the less likely it is that a link between adverse effects and product use could be drawn.⁵⁷

A second and crucial factor would be the extent of *non-company* investment in research that could shed light on the effects of nanotechnology generally, nanotechnology

57

in cosmetics, and nanotechnology of similar or the same composition as that found in the company's products. Public and academic research investments might have the biggest influence on the estimate, because the products of such research investments would be most likely to be widely disseminated and could be used as a basis for ultimately assessing – or at least raising the question of -- the effects of the company's product. Because nanotechnology research anywhere in the world might affect P_{T3} , public and academic investments levels throughout the world, and not just in the company's home country, would be relevant. The relevance of other companies' research would depend in substantial part on how likely it is that it would be shared with the public.⁵⁸

The legal standard for proof for admission of scientific evidence regarding causation of harm would also be relevant. The more demanding the standard for the admissibility of such evidence is, the more difficult it would be for plaintiffs at T3 or later to locate and/or generate evidence that would allow them to survive summary judgment in a tort lawsuit against the company. If, for example, the courts limit their vision of reliable and hence admissible evidence of causation of human harm to peer-reviewed, human subject clinical or epidemiological studies,⁵⁹ then the company's estimate of P_{T3} may be quite low, even if there is or is likely to be significant public investment in animal studies and other laboratory explorations of the possible toxic dimensions of nanotechnology. The overall attitude of the United States courts at the state and federal level in the last few decades has veered toward restrictiveness as to what kinds of causation evidence is sufficiently reliable to warrant admission,⁶⁰ so one relevant question for the company would be the likelihood that that trend would continue.

As noted, there are two possible research efforts the company could undertake – one during pre-market Period One, culminating at T1, and one during post-market period Two, culminating at T2. We will call the direct cost of the Period One research efforts R1, and the direct costs of the Period Two research efforts R2.

The company recognizes there is some probability that the pre-market, Period One research effort would detect adverse health effects, in which case the company would cancel the planned release of the product into the marketplace. We will call that probability P_{T1} . The company also realizes that there is some probability that the post-market research efforts would detect adverse health effects, in which case the product would be pulled from the marketplace at T2. We will call that probability P_{T2} .

One question is whether the company would assume that P_{T2} is greater when pre-market testing has been done and adverse effects are not found than when no pre-market testing has not been done. On the one hand, one might suppose that the finding of no adverse effects in pre-market research would or could give rise to a greater confidence level that the product in fact is not harmful and hence a greater confidence that post-

58

59

60

market research will not identify harmful effects. On the other hand, one might suppose that the more familiarity the company has with the behavior of the nanotechnology component of the product, the more effective it could be in structuring a post-market-release testing program that could find any adverse effects from the product. For example, if pre-market testing showed that certain nanoparticles tend to follow certain pathways, that would help the company know where to look, in the post-market-release period, for potentially problematic accumulations in consumers and the environment. These two effects – one tending to suggest a lower P_{T2} , the other suggesting a higher P_{T2} , as a result of pre-market testing having been done – might well cancel out.⁶¹

C. Comparing The Expected Costs of the Four Options

The first question for the company, presumably, would be what are the expected liability costs if the company does nothing – that is, invests in neither the pre-market, Period One research effort or the post-market, Period Two research effort? If the company does nothing, it faces a possible liability of L_{T3} , but it will be burdened with L_{T3} only if independent, non-company research identifies adverse effects and links them to the company's product. Thus, the expected liability costs if the company does nothing are $(P_{T3})(L_{T3})$. For the company, therefore, the relevant questions boil down to:

- Would conducting the pre-market research effort in Period One result in lower expected costs than $(P_{T3})(L_{T3})$?
- Would conducting the post-market research effort in Period Two result in lower expected costs than $(P_{T3})(L_{T3})$?
- Would conducting both research efforts result in lower expected costs than $(P_{T3})(L_{T3})$?
- If doing nothing (forgoing both research efforts) is not the expected-cost-minimizing choice, which choice is: conducting only the pre-market research effort in Period One, conducting only the post-market research effort in Period Two, or conducting both?

Period One, Pre-Market Investment

If the company invests in research during Period One, and finds that the product is harmful, the product will not be marketed and hence total liability will be zero, but the company will bear the direct research cost of R_1 . However, there presumably will be a relatively low expected probability of finding that the product is harmful by the end of the pre-marketing research: P_{T1} is presumably well below .5. If no harm is found, then

⁶¹ The model also assumes that the company's estimate of P_{T2} and P_{T3} are unconnected or independent variables. In the absence of a public disclosure requirement on the part of the company, that may be a reasonable assumption. However, if the company were required to disclose the research it conducted in Period One or Two, then, even if the company's conclusion were that the product is safe, the release of the research would increase the information available about the product and in that way might guide independent research and result in a higher P_{T3} .

the company could bear liability if independent research links the product to harmful effects by T3 or later. Thus, the expected costs of doing the pre-market research project is $R1 + (1-P_{T1})(P_{T3})(L_{T3})$. Undertaking the pre-market research is worthwhile if $R1 + (1-P_{T1})(P_{T3})(L_{T3}) < (P_{T3})(L_{T3})$.

Period Two, Post-Market Investment

Now let us assume that the company chooses to skip the pre-market research investment. If the product does go to market, then the research during Period Two could detect harm and result in the product being removed from the market at the end of Period Two, that is, at T2. The potential benefit for the company under this scenario is avoidance of the additional liability that otherwise might be imposed as a result of exposures that would take place during Period Three. If the Period Two research detects harmful effects, and the company pulls the product, the company will be liable only for L_{T2} . If the research is conducted but does not detect harmful effects but independent research then links the product to adverse effects after the product has run its market course, then the company will be liable for L_{T3} . Hence, the company's total expected costs if it conducts only the Period Two, post-market research are: $R2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3})$. It would make sense for the company to proceed with the Period Two research if $R2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3}) < (P_{T3})(L_{T3})$.

Combining Pre- and Post-Market Research

Another option for the company is to commit to undertake both pre-market, Period One *and* (assuming the product goes to market after pre-market testing) only post-market, Period Two research. The cost of pre-market research itself – $R1$ – remains the same whether or not post-market research is to be undertaken. If harm is detected and the products is never released to market, there will be no post-market costs. If no harm is detected during the pre-market research and the product is released to the market, there is the possibility that post-market research will detect harm and the product then will be pulled from the market. There is also the possibility that, if post-market testing does not detect harms and the product remains on the market, independent research will later detect harm. Either way, the company bears $R2$, the direct cost of post-market testing. Thus, the expected costs of the pre-and post-market research option are $R1 + (1-P_{T1}) [R2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3})]$.

Comparing the Research Options

We now have cost estimates for the three research options and the do nothing option. These are:

Committing to the pre- and post-market research options (“the pre & post research option”): $R1 + (1-P_{T1}) [R2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3})]$

Committing to pre-market research only (“the pre-market-only option”): $R1 + (1-P_{T1})(P_{T3})(L_{T3})$

Committing to post-market research only (“the post-market-only option”): $R_2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3})$

Doing nothing: $(P_{T3})(L_{T3})$.

For the company, absent the possibility of incurring LT2 liability as a result of its own testing and monitoring and the adverse effects they reveal, it would always be worthwhile to engage in post-market testing and monitoring if the condition is met that $R_2 + (1-P_{T2})(P_{T3})(L_{T3}) < (P_{T3})(L_{T3})$. That universe of cases is represented by the left side of the even diagram below. There is a universe of cases for which the avoidance of possible LT2 liability makes it worthwhile to avoid post-market testing and instead do nothing, which meet the condition that $R_2 + (P_{T2})(L_{T2}) + (1-P_{T2})(P_{T3})(L_{T3}) > (P_{T3})(L_{T3})$. The right side of the diagram represent those cases. There is an intersection area in the middle of the diagram consisting of cases that meet the two previous conditions and for which it is also true that $(P_{T2})(L_{T2}) > (P_{T3})(L_{T3}) - (R_2 + (1-P_{T2})(P_{T3})(L_{T3}))$. This is the universe of cases for which liability avoidance will lead a company to avoid post-market testing and monitoring that they otherwise would have undertaken.

How big is this intersection area? The answer, of course, all depends on the values we assign to the relevant variables. What we can say is that less testing or no testing may be a liability-minimizing option precisely in some cases when – on a social welfare basis – we would ardently want such testing to happen. Testing would be most attractive from a social perspective in those cases in which the testing would be highly effective at detecting any adverse effects from the product, such testing would be inexpensive, and the damages ultimately suffered by consumers and others would be huge if such testing does not occur and the product remains on the market without proper warnings. As described below, the company might well choose not to engage in testing in a subset of these cases – those in which the company perceives a very low perceived probability of detection of the product’s adverse effects on the basis of independent, non-company research.

The easiest way to see how liability-minimization can deter testing is to imagine an extreme case in which post-market testing would be extremely effective at detecting any adverse effects and would be extremely cheap to do. In such a case, there might be a 99 percent perceived probability that adverse effects (if there are any) would be detected by the company in post-market testing and such testing would cost almost nothing, perhaps a few thousand dollars. It would be reasonable under in such a case to round P_{T2} up to 1 and round R_2 down to 0. In terms of the intersection condition described above $[(P_{T2})(L_{T2}) > (P_{T3})(L_{T3}) - (R_2 + (1-P_{T2})(P_{T3})(L_{T3}))]$, that would mean that $(P_{T2})(L_{T2})$ now equals (L_{T2}) and that $(1-P_{T2})(P_{T3})(L_{T3})$ becomes zero. The company therefore will prefer doing nothing to engaging in highly effective, cheap post-market testing if the liability the company would expect to incur as a result of post-market testing (L_2) would be more than the liability the company would expect to bear if it does not test and keeps the product on the market without a warning $((P_{T3})(L_{T3}))$. The relevant question then is, when would L_{T2} ever be greater than $(P_{T3})(L_{T3})$?

One answer (but not necessarily the only one) is where damages that will be incurred by consumers and others in Period Three are just enormous relative to the damages incurred in Period Two but the independent probability of detection at T3 (P_{T3}) verges on zero. Where P_{T3} is of a similar magnitude to P_{T2} , the possibility of a huge L_{T3} should make the company decide to engage in post-market testing. But it might be a liability-minimizing strategy for the company to avoid post-market testing even when confronted with a relatively huge L_{T3} if P_{T3} is very small. For example, imagine that L_{T2} is 3 million, L_{T3} is 400 million, and P_{T3} is just .007. Recall that P_{T2} is effectively 1 and $R2$ is effectively zero. The expected costs for the company of doing nothing and not engaging in post-market testing would be $(400,000,000)(.07)$ or \$2.8 million, which is \$200,000 less than L_{T2} . In other words, doing nothing would save the company \$200,000 in expected liability in exactly the kind of case where post-market testing could yield great social benefits for minimal social costs.

D. Decreasing the Likelihood of Liability-Driven Avoidance of Post-Market Testing

Let's assume that the scenario just described or similar ones is likely enough to warrant attention. The question then is, how can any of the relevant variables be manipulated to make it less likely companies will avoid post-market testing that they otherwise they might have undertaken were it not for the threat of liability resulting from post-market testing? In the language of the previous discussion, that question boils down to, how can we make it more likely that $(L_{T3})(P_{T3})$ will be greater than (L_{T2}) ? There are essentially three possible manipulations of the relevant variables – increasing P_{T3} , increasing L_{T3} , and decreasing L_{T2} . The discussion that follows focuses on decreasing L_{T2} , which is the most realistic policy option.

P_{T3} – the independent detection variable -- is a key variable in terms of creating an incentive for the company to engage in post-market testing. Any increase in P_{T3} translates into an increase in the cost of doing nothing -- $(P_{T3})(L_{T3})$ -- and makes it more likely that post-market testing will be a cheaper option than doing nothing. Any given increase in P_{T3} , moreover, also makes the pre-and-post-testing option less expensive relative to all the other options. Increasing P_{T3} , therefore, might result in shifts not just from the do nothing option to post-market testing, but also shifts from just just-pre-market testing or just-post-market testing to both pre-and-post market testing.⁶² That may be a good thing, at least from the vantage of the precautionary study principle, which would seem to call for both pre- and post- market testing.

It is not obvious, however, that increasing P_{T3} is feasible. The best means of increasing P_{T3} probably would be an increased expenditure in public research. As

⁶² The reason this is so is that the pre-and-post approach, assuming non zero probabilities of detection of adverse effects for both pre and post market testing (that is, a non-zero P_{T1} and a non-zero P_{T2}), is the strategy that minimizes the possibility of the company ultimately bearing the cost represented by $(P_{T3})(L_{T3})$. Any increase in P_{T3} and hence $(P_{T3})(L_{T3})$, therefore, increases the expected costs of the pre-and-post option the least, and thus makes that option relatively less expensive than it previous was with respect to the other options.

already discussed, there has not been political support for substantial public funding to date. It is also not clear how much of an expenditure in such research would be needed to lead to significant changes in estimates of P_{T3} . Moreover, as already discussed, there are probably inherent limitations in public funding as a means to fill the product-specific or category three information deficit, and hence inherent limitations in the extent to which increases in public funding can boost P_{T3} .

One possible way to increase L_{T3} and hence the cost of doing nothing would be to alter the standard for liability applicable at time $T3$ and later. For example, if the standard of liability at $T2$ and $T3$ initially were a middle-of-the road “should have known” standard (e.g. $S=.5$), then a change to a genuine strict liability/hindsight standard at $T3$ and after would increase the magnitude of L_{T3} relative to L_{T2} by 100 percent. That change, in turn, could be enough to make post-market testing a liability-minimizing strategy when, before, doing nothing was the liability-minimizing strategy.

There is no tradition, however, of states and states common law imposing different standards of liability depending on whether adverse effects were detected by company research or were detected by independent, non-company research. One could imagine a federal that purports to force the states to adopt a stricter standard of liability (genuine strict liability that is) when the adverse effects were detected by independent, non-company research after the product had been on the market a long time and completed its market run ($T3$). But there would be deep federalism, fairness, and chilling-investment concerns about, and strong political opposition to, any federal law that would require states to shift from a negligence standard to a genuine strict liability standard.⁶³

As discussed below, there are plausible federal law changes that could result in the reduction or elimination of L_{T2} . A reduction or elimination in L_{T2} would reduce the attractiveness of the do-nothing option relative to the post-market testing options. It thereby would alleviate the problem of liability-avoidance leading companies to forego post-market testing.

However, reducing or eliminating L_{T2} could have perverse effects. L_{T2} liability is a component of the post-market testing option but not a component of the pre-market-only research option, so reducing L_{T2} will decrease the cost of the post-market testing option relative to the pre-market testing option. Moreover, L_{T2} is a more heavily discounted component of the pre-and-post market research option than it is of the only post-market testing option.⁶⁴ As a result, any given reduction in L_{T2} translates into a bigger cost reduction for the post market testing than it does for the pre-and-post research option, and hence decreases the cost of the post-market only testing option relative to the pre- and post-research options.

⁶³ [long footnote]

⁶⁴ L_{T2} is discounted by $PT2$ in the formula for the post-market-only option. L_{T2} is discounted by $(1-PT1)(P2)$ in the formula for the pre-and-post research option.

Table One summarizes the possible effects of the elimination of L_{T2} liability. As the center column reflects, the elimination of L_{T2} liability may result in no change – the lowest cost-option before may be the same after. It is also possible that liability elimination would reduce the costs of the post-market-only option and thus shift companies from doing nothing to post market testing only. However, it is also the case that the reduction in the cost of the post-market-only option may cause shifts from the pre-market only option or the pre-and-post option to the post-market-only research option.

TABLE ONE:

POSSIBLE SHIFTS WITH LIABILITY PROTECTION

LOWEST – WOST OPTION BEFORE LIABILITY PROTECTION	POSSIBLE LOWEST - WOST OPTIONS AFTER LIABILITY PROTECTION	POSSIBLE LOWEST- WOST OPTIONS AFTER CONDITIONAL LIABILITY PROTECTION
DO - OTHING	DO - OTHING POST-MARKET ONLY PRE & POST MARKET	DO – OTHING PRE & POST MARKET
PRE-MARKET ONLY	PRE POST PRE & POST	PRE PRE & POST
POST-MARKET ONLY	POST-MARKET ONLY	POST-MARKET ONLY
PRE & POST MARKET	PRE & POST MARKET POST-MARKET ONLY	PRE & POST MARKET

From a public policy perspective, these two possible shifts – the shift from pre market-only research to post-market-only research and the shift from pre-and-post market research to post-market-only research – are problematic. It is not always true that pre-market testing is preferable to post-market testing, but pre-market testing is essential because such testing, if it does indeed detect harmful affects, can avoid putting any consumers of other human populations at risk. By definition, post-market testing entails putting human beings at risk. And (as already suggested) one certainly might not want to encourage shifts from a clearly higher-research-investment, greater precaution option (pre-and-post testing) to a clearly lesser-research-investment, lesser precaution option (post-market-only research).

These problematic shifts could be avoided by making L_{T2} liability relief contingent on the company completing both pre- and post-market research. The right-hand column on Table One shows the possible effects of such conditional liability relief.

Conditioning liability relief on pre- as well as post-market testing raises the cost of obtaining the relief for companies, and thus presents a difficult tradeoff, from a policymaking perspective. On the one hand, conditioning liability relief avoids the creation of an incentive for companies to abandon pre-market research they otherwise would have undertaken. On the other hand, conditioning liability relief may mean that some companies that would have shifted away from a doing-nothing approach will instead continue to follow that approach and do nothing.

Which Products Will Be The Subject of Voluntary Testing

So far, we have spoken of a single nanotechnology product. However, a company may have many products that contain nanotechnology and that might be candidates for a regime of voluntary testing in return for liability relief. All else being equal, we might expect a company to choose those products with the greatest possible liability exposure -- those it expects to sell the most or that it suspects may have some dangerous aspect -- for enrollment in the regime of voluntary testing. In this way, the voluntary regime may focus attention to the products that pose the greatest perceived risks to public health. Mandatory testing requirements could also focus on such products, but in the context of the possible or planned imposition of mandatory testing requirements, the company would not necessarily have an incentive to share with regulators or the public its views (and the information behind its views) as to which products pose the greatest possible risks to the public and hence most warrant testing and monitoring.

Products Containing Identical or Substantially Identical Materials or Technology

In the previous discussion of choosing options, we have assumed that there is simply one company making a decision regarding whether and how to invest in research regarding possible adverse effects. For that reason, it was assumed that the only research that can produce L_{T2} liability is the Period Two research of that single company. But there may be many settings where several companies are producing substantially identical products, or more specifically, products that contain substantially identical materials or technology that may pose risks. For example, imagine two companies -- company A and company B -- that produce sunscreens containing precisely or virtually the same kind of nanomaterials in the same configuration. Pre- or post- market testing by company A could have an effect on company B whether or not company B chooses to engage in its own research. If company A detects harm as a result of its post-market research and recalls the product (or adds a warning), regulatory, market, and liability pressure may well force company B to take parallel action with respect to its product.

Let us first consider the case where there is no liability (L_{T2}) relief for a company that voluntarily tests its product and pulls the product if harm is detected. In that sort of regime, company B has a free-riding-related incentive *not* to engage in post-market research regarding its product. If company A finds that the product is harmful in post-market testing and both company A and company B therefore must pull their products from the market, company B is (all else being equal) better off than if it had undertaken the safety research: both company A and B will bear costs in terms of lost sales and

perhaps liability awards, but at least company B will have avoided R2, the direct costs of research.

Now consider the case where liability relief is available for any company that conducts post-market testing (in our model, Period Two testing) and finds harmful effects and removes the product from the marketplace. Any incentive company B might have had to free ride on company A's research now would be countered -- and perhaps more than offset -- by its incentive to obtain liability relief by engaging in testing. It might well be economically rational, therefore, for company B to agree to participate in a research-for-liability-relief program if company A has already agreed to participate and thus increased the likelihood of detection of harmful effects, but refuse to participate if company A has already refused to participate. Another possible incentive for company B to agree to participate in a program after Company A has already agreed is that there might be savings from pooling research funds or merging research efforts with Company A.

One implication of this analysis is that securing the initial participants in any research-for-liability-relief program is particularly important for -- and may be particularly challenging -- for any such program. The first participant does not have as strong an incentive to join, all else being equal, as the second or third participant. In order to give all potential participants equally strong incentives to participate, the extent of liability arguably should be tiered, with greater relief going to early-to-agree companies and lesser relief to the later-to-agree companies.

Producers of Products Containing The Same General Category of Potentially Risky Materials or Technology

Large clusters of products may contain similar materials or technologies, and research regarding one or more of these products thus might help inform and focus research regarding the other programs in the cluster. For example, drug A may alter mood disorders through the same theorized chemistry as drug B but may have different active ingredients. The discovery of a correlation between use of Drug A and heart attacks would not prove that such a correlation exists between use of Drug B and heart attacks, but the discovery almost certainly would provide an impetus to study heart health within the pool of people using Drug B. In the nanotechnology context, we believe that the same basic type of nanotechnology may behave differently in different product formulations. But research regarding any nanotechnology product may shed some light on nanotechnology generally and hence all nanotechnology products, and certainly research on any nanotechnology product containing a particular element (such as silver or carbon) may shed some light on the range of nanotechnology products containing that element.

In terms of the model above, one way to understand the effect of some company's research on others is in terms of the variable P_{T3} , the probability that a product will be established as having harmful effects as a result of non-company research once the product has finished its market run ($T3$). We can imagine a company A and a company

B that produce the same general category of nanotechnology. The research completed by company A, if made public, would add to the body of scientific evidence and understanding and, in that sense, would be equivalent to additional academic or public research. That additional contribution to public knowledge would presumably increase (if minimally) the likelihood that any adverse effects from company B's product will be identified by the time that product has finished its market run at T3. Company A's additional contribution to public knowledge, in other words, would boost company B's estimate of P_{T3} and hence boost the expected cost of the doing nothing option. If we imagine not just one company engaging in research but 100 companies engaging in research, we can imagine that that research would significantly boost company #101's estimate of P_{T3} that that company will use in choosing whether to continue to do nothing or instead commence research and follow the lead of companies #1-100.

One possible implication of this analysis, like the analysis regarding substantially identical products, is that broad voluntary engagement in research efforts within an industry could itself result in more, even broader engagement in research in the industry – at least if the results of all the research were accessible to the public. If the goal is to significantly increase voluntary research regarding products that contain a general category of technology that is poorly understood and potentially risky, an important hurdle is to secure a research commitment from a good number of the companies in the industry. Special incentives for early committers can produce the dividend of voluntary engagement in research by companies that will then follow suit in part because of their perception that the research that will be produced by the early committers, on net, will increase the likelihood that adverse effects could one day be tied to their products.

IV FDA PREEMPTION AS A MODEL FOR FASHIONING A VOLUNTARY-TESTING-FOR-LIABILITY-RELIEF REGIME FOR NANOTECHNOLOGY

Liability relief as a *quid pro quo* for voluntary testing is a policy or legal reform that could, in theory, be adopted at the state, federal or international level. Because at least initial state or international adoption seems less likely than federal adoption, this Part focuses upon how such a federal regime could and should be structured. But first, it is worth explaining the difficulties with a state-based or international approach.

The basic political economy of state legislatures and courts would work against the adoption of any liability relief reform in the context of nanotechnology products. State courts, applying existing state common law, perhaps could reduce liability for companies that engage in voluntary pre- and post-market testing of products. More readily, state legislatures could adopt such liability relief by statute. But states are unlikely to adopt such measures. and, even if they did, are not well-equipped to ensure that the appropriate kind of testing and monitoring actually was undertaken. For an individual state, a reduction in liability means (presumably) a reduction in resources available to its injured citizens. Liability relief is thus an in-state cost. The manufacturers (and perhaps even distributors) of nanotechnology products sold or consumed within a state in many cases would be based outside the state and indeed might

be based outside the United States altogether. The benefit of liability relief, or at least much of it, thus is an out-of-state-benefit. Of course, state judges and legislators may be moved by the argument for a need to give companies an incentive to test products, and may understand that more testing will benefit consumers and others. But, even then, most of the consumers and others who might benefit from more testing will be out-of-state and, once again, the plaintiffs who would be limited by liability relief are all in-state. Under these circumstances, it is difficult to imagine states spearheading liability relief-for-voluntary-testing reforms.

Even if states were open to adopting liability relief, they would not be well-positioned to implement it. States do not have the staff and other resources to oversee pre- and post-market voluntary testing and monitoring (let alone to undertake such testing with company funds). There are no state drug associations akin to the FDA; there is no state institute of health comparable to NIH. The building blocks for meaningful oversight and administration are found at the federal, not state, level. And knowing that, even state officials and politicians who see the case for liability relief are likely to look to the federal government for any liability reforms tied to oversight of testing.

At the international level, any proposed legal reform confronts the basic limitations is the deep difficulty of bridging national differences and sovereignty concerns to form binding and enforceable accords. Tort liability, in particular, has long been regarded as a domestic/national prerogative, and is not the subject of even significant “soft” international law. There are also no international oversight agencies as such akin to the FDA. One might imagine international coordination once the US, Japan and the EU adopted some kind of liability program, but action at the nation state level almost certainly would have to come first.⁶⁵

It would thus seem that any liability relief-for-testing regime would have to be, vis-à-vis and within the United States, a federal regime established by federal statute. Tort liability is, of course, a traditional domain of the states. Congress has interfered with state prerogatives vis-à-vis tort, despite federalism concerns, in two situations. The first is where some good or activity deemed essential to national welfare is arguably not being produced or might not be produced because of liability threats (such as nuclear power, certain types of aircraft).⁶⁶ The second is where a through regime of mandatory federal testing administered by and approval given by the FDA has (arguably) ensured that a product reflects a considered federal judgment as to the balance of benefits and costs.⁶⁷

⁶⁵ Another consideration of institutional design is how a regime of voluntary testing for US liability relief would dovetail with international law. Under the WTO’s evolving jurisprudence, a US statute providing liability relief in return for testing probably would pass muster as long as the stated purpose of encouraging testing would be the protection of US consumers and others from effects realized in the United States from the use and disposal of imported products, as opposed to protection of foreign workers and others from adverse effects from the manufacture of the products outside the United States. There might, therefore, be some limits on the testing that could be asked of foreign companies vis-à-vis worker exposures and safety. [CITES]

⁶⁶

⁶⁷

An implicit rationale for FDA preemption may be that if companies are to be willing to take on the costs and the burdens of a thorough approval process, including testing, they need to or at least should be able to set aside concerns about state tort liability that might require even more testing, even more limits on releases of product, and even more product warnings.⁶⁸ Liability relief from state tort law for voluntary testing of nanotechnology products under federal oversight would be similar to liability relief from state tort law for mandatory testing and approval by the FDA: in both cases, testing with oversight would translate into some reduction in liability

FDA preemption of common law tort law, however, has been and remains extremely controversial. A regime of liability relief for voluntary testing of nanotechnology products, depending on the design of the regime, could be subject to the same kinds of objections. Indeed, there might be even more concern about a voluntary regime, inasmuch as, it might be suspected, federal regulators will feel pressured not to be rigorous with industry participants for fear that they would cease their voluntary participation. To be tenable and succeed, therefore, a liability relief for voluntary testing and monitoring regime should have the component discussed in the following sub-Parts.

Genuine Statutory (Rather Than Agency) Preemption

One of the most controversial aspects of FDA preemption of state tort actions is that federal statutes, in plain language, do not clearly call for such preemption of tort actions at all. Instead, the courts (and in particular the United States Supreme Court) has grounded a finding of preemption in the FDA context on a reading of exceedingly ambiguous language in the relevant statute and/or on federal agency opinions that preemption is appropriate and furthers the goals of the federal regulatory scheme.⁶⁹ As a result, commentators – as well as some of the Justices – have criticized FDA preemption of common law suits as a joint creation of the courts and federal bureaucrats, instead of Congress.⁷⁰ For example, Justice Ginsburg criticized the Court’s finding of preemption of state common law suits under the Medical Device Act (MDA) as “not mandated by Congress” and “at odds with the MDA’s central purpose: to protect consumer safety.”⁷¹

Preemption doctrine makes Congressional intent the touchstone of when state law, including common law, is preempted.⁷² This is appropriate because, in a federal system where state perogatives necessitate respect, preemption should be regarded as an exceptional or unusual action and hence one that has courts should recognize only with clear direction from the only federal branch of government explicitly authorized to make

68

69

70

71

72

federal law, Congress.⁷³ Thus, to be fully legitimate, any regime of voluntary testing for liability must be built on specific language in federal statutes providing when and to what extent state common law claims are preempted.

Preemption Limited To Torts Based on Failures to Test or Monitor

Another source of controversy regarding FDA preemption of state tort case has been that it has been extended to risk or dangers of which the manufacturer/defendant allegedly had clear knowledge. Defendants have argued, with some success, that they were not required to warn of risks they comprehended as long as the warning they did issue had been approved by FDA.⁷⁴ Critics of preemption in this context argue that federal regulators sometimes do not understand or receive the necessary data or are unduly pressured to accept incomplete warning.⁷⁵ To the extent this is so, federal preemption rewards companies for sitting on “bad” formation and knowingly endangering the public without warning.

These same concerns all counsel in favor of circumscribing tort preemption as a *quid pro quo* for voluntary testing and monitoring to state tort claims predicated on allegations that the manufacturer failed to conduct adequate testing or monitoring and hence did not apprehend the risk from its products and make decisions based on knowledge of those risks. The goal of such a limit on preemption would be not to reward commercial immorality, and to make companies think twice, *ex ante*, before intentional marketing of products without warning of *known* significant risks or without taking other appropriate measures. Moreover, because a voluntary regime would not mandate any particular labels or warning labels for products, companies could not argue that they had every reason to think they need not have or should not have included any warning in addition to those required by federal regulators.⁷⁶

Government Oversight and Transparency

In the FDA drug and device approval context, there have been strong claims made that there has been too little vigorous agency oversight of private research, and too little transparency, and hence too little oversight by the general public of failures of regulators.⁷⁷ The litany of charges includes that large companies pressure scientists to reach favorable results; scientists fail to disclose all conflicts or private finding sources; there is an inadequate accounting by regulators and lack of public information regarding studies that are abandoned, suspended or left open indefinitely because preliminary results would not be helpful to the sponsoring company; and the public lack access to the

73

74

75

76

77

data in studies submitted to regulators.⁷⁸ Inadequate funding of FDA and other oversight bodies is another theme of the critics.⁷⁹ Along with the criticisms have come many proposals, including: more government research with public funding, a public registry for all initiated studies with updates, public access to the data supporting or underlying private study results relied upon by regulators, and thorough disclosure of conflicts requirements for scientists and so on.⁸⁰

All of the concerns about oversight and public access – and all the possible reforms – that have been invoked vis-à-vis the FDA mandatory approval process would have relevance to a voluntary regime of testing and monitoring as a quid pro quo for liability relief. These oversight and transparency concerns would need to be addressed for a voluntary regime to gain widespread legitimacy. One particularly thorny issue concerns confidential business information: nanotechnology product developers and producers have and probably will continue to insist that such information is embedded in much of their testing data and reports, and that such data and reports therefore cannot be disclosed to the public.⁸¹ Specific guidelines and review mechanisms, however, must be used to ensure that “confidential business information” is not invoked expansively to curtail all meaningful public access.⁸² In addition, even with respect to core confidential business information, there could be checks on regulatory oversight that might satisfy public concerns, such as release of detailed summaries by regulators and designated NGO (or other designated third-party inspectors) access to and review of the data.

Subsidized Insurance as an Alternative Liability- Relief Mechanism

FDA preemption is perhaps also controversial because it can leave some injured persons without any compensation. One of the essential roles of the tort law is compensation, after all.⁸³ The same concern would apply to injured persons whose suits would be preempted or partially preempted by any nanotechnology liability relief regime based on voluntary testing. One can of course argue that a regime of liability relief does not necessarily result in anyone being denied compensation because, in the absence of liability relief, companies might not have tested their products and the information regarding adverse effects would not have come to light. However, in any particular case, it will be impossible to know whether the information regarding adverse effects and their causes would have come to light even in the absence of the promise of liability relief. Moreover, from the *ex post* perspective of an injured person and his family, what truly

78

79

80

81

82

83

matters is not *ex ante* incentives and considerations of institutional design but just the current moment and whether compensation is available now for very real injuries.

From the perspective of honoring the compensation mission of the tort system, the best way to provide liability relief would not be limits on liability *per se* but rather subsidies for liability insurance. The federal government already provides insurance directly or re-insurance guarantees in some contexts,⁸⁴ and could also subsidize part of the cost of private insurance premiums for companies that opt into a pre- and post-market testing regime for nanotechnology products. Insurance subsidies could be as powerful an incentive for companies as direct liability relief, while avoiding the problem of the uncompensated injured. And insurance subsidies could be combined with partial tort preemption in a blended regime that would mean reduced, but not eliminated, compensation for injured persons.

There are, however, several problems with an insurance subsidy approach. First, there is a significant history of (in the view of many) industry capture of government insurance or insurance subsidy programs.⁸⁵ Second, government insurance subsidies are, like direct funding of research, a government expenditure that must compete with a great many other possible claims on government resources. It is true, however, that the magnitude of insurance subsidies may be hard to calculate and they are partly to be paid, if at all, in the future, so they are not particularly visible in the budgeting process.⁸⁶ But that opacity, while making them more politically viable, also makes insurance subsidies more susceptible to interest group manipulation.

The value of insurance subsidies as a means to incentivize participation in a testing regime would be enhanced if the subsidies were tied to a requirement that all producers of nanotechnology products carry adequate liability insurance that does not exclude nanotechnology-related claims. With a mandatory insurance requirement, small start up companies that might be somewhat insensitive to long-term liability risks would have an incentive to test generally to keep private insurance premiums down (to the extent insurers would give them credit for testing) and an incentive to test products so as to qualify for government insurance subsidies. Indeed, the availability of subsidies might help counter the arguments of such companies that they simply lack the cash for testing and insurance and therefore will be driven out of business if additional costs are foisted upon them.⁸⁷

It is true, nonetheless, that the liability relief regime outlined here might be of greater advantage to larger, more-liability-sensitive and perhaps better-funded companies than small start-ups with potentially limited lives as legal entities. It is also true that the adoption of mandatory insurance requirements with liability relief or subsidies for

84

85

86

87

voluntary testing might change the patterns of organization among producers of nanotechnology products. We might observe fewer stand-alone start ups and more collaborations and (in terms of product development) earlier collaborations between start-ups and larger companies. But such a shift in industries that produce nanotechnology products might be a good thing, reflecting the fact that the production and marketing of potentially very risky products (as with FDA approved prescription drugs) may require the extensive participation, if not dominance, of relatively large corporate entities.

Features Unique to a Voluntary Regime

As the discussion in Part [] suggests, the goal of obtaining significant participation by industry makes it essential that there be some early participants who can in effect draw in later participants. Greater liability relief could be offered to early participants as an inducement, perhaps in the form of greater insurance subsidies than those that would be made available to later participants. Another inducement for early participants might be their ability to advertise to consumers and others that they have opted into and met the guidelines of a safety regime, whereas (if that were true) their competitors had not yet done so. As Wendy Wagner has suggested (although not in the nanotechnology context), legal authorization and protection for companies to make such claims might offer enough of a competitive advantage to encourage testing that they otherwise might have been foregone.⁸⁸ Whether companies would regard the ability to make such claims as advantageous is unknown, but if they do, that ability, coupled with special liability relief incentives based on early entry into the voluntary testing regime, might be enough to energize an initial round of participation that could set the ground for broad industry participation.

V. CONCLUSION: NANOTECHNOLOGY AND BEYOND

88