Harvard Business School

624-067
JANUARY 12, 2024

TEACHING NOTE

Fusion Industry Association: Igniting the Future of Clean Energy

Case Synopsis

The Fusion Industry Association (FIA) is a non-profit organization that represents the interests of companies developing commercial fusion systems. With initiatives across the private and public sectors, the FIA is working to make fusion energy a reality. While there has been a surge of technological breakthroughs, promising regulatory developments, and major investments into this industry, many key issues remain uncertain: the regulatory landscape, consumers' perceptions, the vertical and horizontal structure of the industry, geo-political tensions, sources of capital, and more.

This case study provides a unique view into the ways in which firms can coordinate their efforts in the context of an emerging technology that has tremendous potential to impact businesses and society. The case is set in the perspective of Andrew Holland, the CEO of the FIA, and it provides students with a view of the challenges of managing multiple organizations with interests that are aligned, but not perfectly. It also provides a brief introduction to the fusion energy sector more generally.

Case Placement

This case is useful in classes related to the following topics: (1) the management of innovation, since the case highlights the tradeoffs of firms coordinating their innovative efforts with each other; (2) entrepreneurship and the commercialization of science, since this industry is populated almost exclusively by young firms, many of whom have close connections to university-based research; (3) the connections between market structure and innovation, since a key debate of the case is how the vertical and horizontal structure of the industry will shape the likelihood that fusion becomes commercially viable; and (4) lobbying and regulation, since the case involves multiple discussions of the ways in which the government influences the industry (e.g., legal requirements, funding for research). At the Harvard Business School, this case is taught in the second-year Tough Tech Ventures course alongside a companion case on **Commonwealth Fusion Systems**, which is focused on the emergence of one of the largest fusion energy companies at the timing of both cases. The **Fusion Energy** technical note provides more detailed descriptions of the physics, technologies, and regulations involved.

This note was prepared by HBS Professors Kyle R. Myers and Joshua L. Krieger, independent researcher Walter Frick (Nonrival), and HBS Senior Lecturer Jim Matheson for the sole purpose of aiding classroom instructors in the use of "[Case/Course Title for Disclaimer/Footer]," HBS No. [Case Number]. Funding for the development of this note was provided by Harvard Business School and not by the company. It provides analysis and questions that are intended to present alternative approaches to deepening students' comprehension of business issues and energizing classroom discussion. HBS cases are developed solely as the basis for class discussion. Cases are not intended to serve as endorsements, sources of primary data, or illustrations of effective or ineffective management.

Learning Objectives

The FIA case is designed to help students understand the following concepts:

- The tradeoffs of being a "first mover" in the face of technological and regulatory uncertainty, and the role of positive and negative externalities in shaping the value of collective action by firms.
- The relationships between market structure, horizontally (e.g., number, size, and age of firms) and vertically (e.g., integration with suppliers), and the externalities of innovation.
- The relative merits of "push" (e.g., research grants) and "pull" (e.g., research prizes) incentives in the context of public investments in science, specifically, and the process of engaging with policymakers more generally.
- The potential positive externalities of "mega-funds" that pool investments to attract large sources of risk-averse capital and the features of markets where such an approach is more or less feasible.

Supplemental Materials & Reading

Supplemental Material

- PowerPoint slide deck (HBS No. 5-624-082). These slides are meant to be used throughout the case discussion and are referenced in the teaching plan as **TN PPT Slide N**, where "**N**" refers to the slide number in the bottom right-hand corner. Note, the deck contains some empty slides (unnumbered) to be used as dividers and so that slides are only on-screen when they are relevant to the current discussion.

Supplemental Readings

- Bryan, K. A., & Williams, H. L. (2021). Innovation: Market Failures and Public Policies. In *Handbook of Industrial Organization* (Vol. 5, No. 1, pp. 281–388). Elsevier Science: Amsterdam.
- Gruber, J., & Johnson, S. (2019). Jump-starting America: How Breakthrough Science Can Revive Economic Growth and the American Dream. Hachette: UK.
- Kerr, W. R., & Nanda, R. (2015). Financing Innovation. *Annual Review of Financial Economics*, *7*, 445–462.
- Hall, B. H., & Lerner, J. (2010). The Financing of R&D and Innovation. In *Handbook of the Economics of Innovation* (Vol. 1, pp. 609-639). North-Holland.
- Pisano, G. P. (2006). *Science Business: The Promise, the Reality, and the Future of Biotech*. Harvard Business Press: Brighton, MA.

Suggested Assignment Questions

1. Why are fusion companies willing to fund the FIA?

2. If you were an executive at one of the firms in the fusion industry, how would you prioritize the major issues outlined in the case: (1) continued development of fusion-related regulations, (2) consumer sentiment and education about fusion energy, (3) the structure of the industry in terms of the number and sizes of firms, (4) geo-political relationships and events, (5) access to financial capital for the industry?

3. What would the most ideal, but plausible, industry structure that would allow Holland to achieve his objective of bringing clean, safe, sustainable fusion power to the world? Aside from engaging with the government and consumers, what sorts of institutions, arrangements, or other activities could the FIA undertake to develop the most innovative industry possible?

4. What are the tradeoffs of financing the industry with a "mega-fund" as outlined in the case?

Case Analysis

The analysis of this case is presented in five sections. The first section details the role of externalities in the context of managing innovation amidst an entire industry (e.g., from the perspective of an industry association). The second section contains further discussion of externalities, but more specifically as it relates to the connections between market structures and innovation. The third section details some connections between regulations, consumers, and the pace of innovation in an industry. The fourth section provides a summary of the tradeoffs from using "push" (ex-ante) versus "pull" (ex-post) incentives to induce innovation from a group of self-interested parties. Finally, the fifth section provides summaries and references to relevant material on the legal boundaries of industry-level coordination as well as references to summaries of the emergence of other technology-intensive industries that can be used to compare and contrast to the fusion industry at the time of the case.

Section 1: Innovation Externalities

Set in the perspective of Andrew Holland, the CEO of the Fusion Industry Association, this case provides a unique way to highlight the importance of considering externalities and market frictions when managing a collection of self-interested entities be they people, teams, or, as in this case, companies.

An analogy can be made between the so-called "triple product" (or "Lawson Criterion") of fusion energy and one way of conceptualizing how industry coordination can generate value. In short, the physics of nuclear fusion indicate that the amount of energy produced by the reaction is a function of the proximity of the particles, the particles' temperature, and duration the particles are held at some proximity and some temperature. Thus, if the reaction is made to occur closer, hotter, or longer, more energy can be produced. Similarly, there are three factors that will govern how much value coordination over some activity can generate for an industry. As is the case when a single organization is considering some activity, they must weigh the benefits and costs (e.g., via a ROI or NPV calculation). But when the industry's perspective is adopted, a third factor, the size of the externalities associated with that activity, must be accounted for.

TN Figure 1 Triple Product of Fusion and Industry Coordination

Fusion Energy ("Lawson Criterion")	**Industry Coordination**
Closer × Hotter × Longer	Higher benefits × Lower costs × Larger Externalities (within firm) (within firm) (within industry)
⇒ More fusion energy produced	⇒ More value from coordination

Source: Case authors.

Within the teaching plan below, **TN Board 3** provides an elementary graphical depiction of positive and negative externalities that can be used with students less familiar with the concept.

For simplicity below, the terms "private" and "social" value will be used to reflect the incentives of individuals and the collective. But in the context of the case, "private" will refer to the perspective of an individual fusion business and "social" will refer to the perspective of the fusion industry. More generally, "private" could refer to a worker and "social" to the organization. In this way, an appreciation of the externalities of innovation is relevant whether the manager is trying to organize innovative activities within a business, an industry, or a country. This conclusion about the broader usefulness of finding ways to internalize externalities is at the center of the class wrap at the end of the case discussion.

Broad categories of innovation externalities—Some of the earliest work on the theory of externalities of scientific and inventive activities are contained within "The Rate and Direction of Inventive Activity: Economic and Social Factors," (1962) a volume of papers from the leading economists of the time.[1] Modern treatments often group the sources of externalities of research into four categories, two positive and two negative. Jones and Williams (2000) estimate a macroeconomic model that allows them to quantify the size of the distortions created by these four externalities,[2] which are detailed here:

1. *Imperfect price discrimination of consumers*: This positive externality arises from the fact that producers cannot charge each consumer their full willingness-to-pay for a product (once it is invented), which implies that producers do not invest in the invention of some new products whose social value is larger than the cost of invention because they cannot appropriate enough of this social value to recoup their fixed costs of invention. Jones and Williams (2000) estimate that the internalization of this externality in isolation would increase private R&D by roughly 140%.

2. *Imperfect price discrimination of other suppliers*: This positive externality, often embodied in "knowledge spillovers" between firms and the process of "cumulative innovation" where one discovery begets another, arises from the fact that producers cannot charge other producers their full willingness-to-pay for the products or information that their own innovative activities produce (e.g., new knowledge about technologies, reduced uncertainty about demand). Just as friction (1.) above, this under-incentivizes research from the focal firm. Jones and Williams (2000) estimate that the internalization of this externality in isolation would increase private R&D by roughly 16–36%.

3. *Business stealing*: This negative externality, sometimes referred to as "creative destruction", arises from the fact that innovators often capture "entire" markets even if their innovation embodies only a marginal improvement. Formally, consider the following scenario: an incumbent monopolist has fully captured all of the value in a market of $\$M$ based on a product of quality Q; a new entrant produces an innovation with quality $Q'>Q$; this innovation grows

the total market size to $\$M' > \$M$ and the entrant fully captures all of the value of the new market $\$M'$; the total social value generated is $(\$M' - M)$, so the new entrant should only have been willing to invest that amount into R&D; however, since the total private value generated is $\$M'$, the new entrant is incentivized to invest more than is socially optimal. Jones and Williams (2000) estimate that the internalization of this externality in isolation would decrease private R&D by roughly 24%.

4. *Duplicative efforts*: This negative externality arises from the fact that two (or more) firms may invest in R&D projects with correlated success probabilities. Formally, the social returns to scale in R&D investment may be more concave than the private returns to scale in R&D investment. Jones and Williams (2000) estimate that the internalization of this externality in isolation would decrease private R&D by roughly 20–50%.

Overall, the work by Jones and Williams (2000) and other macroeconomic analyses (Jones & Summers, 2022) indicate that, on net, the positive externalities dwarf the negative and the social value of investment in innovation, broadly construed, is much larger than the private value.[3] Microeconomic analyses that identify natural experiments in R&D spending in the arenas of publicly-funded basic science (Azoulay et al., 2019), R&D at small firms (Myers & Lanahan, 2022), and R&D at large corporations (Bloom, Schankerman, & Van Reenan, 2013) have found corroborating evidence to this effect—the value of research spreads far out from the scientists, firms, and corporations that make the investments. Related work has shown that the information externalities generated by firms innovative activities, especially after the failure of certain technologies can be large (Krieger 2021).[4]

Financing Frictions—Even if the four externalities of research above could be addressed, there are a number of other frictions in the financing of innovation that could inhibit socially optimal rates of invention. Hall and Lerner (2010) and Kerr and Nanda (2015) provide an excellent summary of these frictions.[5] Overall, the uncertainties, asymmetric information, and moral hazard problems inherent to innovative activities (as well as idiosyncrasies of tax structures) can quickly give rise to inefficient capital constraints. However, addressing the frictions that constrain the flow of capital would involve activities with positive externalities (and therefore are under-invested in by individuals, but are ideal opportunities for value creation by an entity such as an industry association).

One specific friction relevant to this case is the presence of large, fixed costs that must be sunk before a low-probability success may be realized. In short, investors are too risk averse to invest in any single "project" (e.g., an individual, a team, a business) because the risk-adjusted expected value is too low. Yes, the industry has seen some very large investments (e.g., the case notes one firm receiving a $1.8 billion round of fundraising), but the question posed by the teaching plan below is: "Is it enough, and if not, how can the industry attract more capital?"

One of the potential solutions highlighted in the case is the concept of a "mega-fund." Fernandez, Lo, and Stein (2015) provide an excellent primer on this concept.[6] Through the lens of externalities, Andrew Lo and his colleagues recognize that there are increasing returns to scale in securitization. More projects grouped together in a single financial vehicle creates diversity, which lowers the overall risk profile of the investment, which makes the investment more attractive to a large share of potential investors. Fernandez, Lo, and Stein (2015) note the dramatic difference in the size of the equity market that represents more traditional investors in high-risk endeavors (e.g., venture capital) compared to the debt market (e.g., bonds), which includes investors with a much lower risk tolerance but a much larger total amount of capital. **TN Board 7** presents an elementary example of risk pooling to clearly illustrate this point to students. That example also highlights a crucial assumption about the value of this sort of approach: that there is not excessive correlation in the risk of the underlying assets. If the success of each fusion project in the mega-fund is independent of the other projects, then the risk can be diversified. However, as those success probabilities become correlated, the value of the mega-fund

diminishes. This point about diversified projects connects back to the discussion above about technological diversity in the industry, an emphasis made in *Section 6* of the teaching plan below.

The Penguin Effect—The teaching plan below introduces the broad notion of externalities in the context of an emerging technology using the "penguin" analogy first coined by Farrell and Saloner (1986): "*Penguins who must enter the water to find food often delay doing so because they fear the presence of predators. Each would prefer some other penguin to test the waters first*."[7] There, the authors were concerned with the externalities of consumers' adoption of goods with network effects. In the teaching plan, we extend the analogy to reflect more broadly the positive and negative externalities of a business being a first mover in an emergent industry.

Section 2: Market Structure and Innovation

All of the externalities referenced in the previous section (and many more forces) give rise to important relationships between the structure of markets and the pace of innovation within those markets. Thus, a key question of the case discussion will be: "*What would be the ideal market structure for delivering commercial fusion energy, which is the stated goal of the Fusion Industry Association?*" This case provides an opportunity to survey the ways in which the horizontal (e.g., number, size, and diversity of firms) and vertical dimensions (e.g., supply-chain consolidation) of an industry are relevant to this question. In the teaching plan, the instructor asks the students for ideas about how the FIA could influence the market structure to help promote innovation (see *Section 5* of the teaching plan). Below, some of the potential levers and their relationship to innovation and externalities are discussed.

Number of firms—Section 3.3 of Bryan and Williams (2021) provides an excellent overview of "Competition policy" and innovation, which largely focuses on the relationship between the number of firms in a market and the pace of innovation. As they note, theoretical and empirical results are often frustratingly ambiguous or contingent on a number of specific factors. However, one of the more generalizable theories relevant for this case discuss is that of Aghion et al. (2005), which puts forward an "inverted-U" relationship between competition and innovation. In short, innovation incentives are low for more concentrated markets because (or so long as) firms in monopolist-like positions need not introduce new products to capture rents; innovation incentives are also low in extremely competitive markets because (or so long as) the rents accrued to an innovator will quickly be competed away, which diminishes the value of investing in innovation in the first place. Thus, there exists some "middle" amount of competition that incentivizes firms with some market power to innovate in order to escape competition with the promise that the resulting rents will not be quickly competed away. What exactly this optimum might mean will of course depend on the context.

Age and size of firms—The advantage of large firms vis-à-vis innovation is straightforward: they are likely to be less resource constrained and therefore willing and able to invest in innovation. See Krieger, Li, and Papanikolaou (2022) for empirical evidence that a positive shock to firms' net worth leads them to develop more novel drugs.[8] Conversely, the classic work of Holmström (1989) provides a theoretical rationale for smaller firms being more capable of innovation. He shows how the incentive structure for any single task depends on the full portfolio of tasks possible in an organization. Since this portfolio of tasks grows larger and more diverse as organizations grow, larger firms face larger costs of effectively managing those tasks which, along with an increase in bureaucratization, steers them to incentive tasks that are easier to measure which are, by definition, less innovative.[9]

Technological diversity of firms—On one hand, as an industry becomes less technologically diverse, there is a greater risk that the industry's "portfolio" will become too narrow, which will make it susceptible to certain disruptions and may also lead the industry to herd around a suboptimal equilibrium (see Dasgupta and Maskin 1987).[10] On the other hand, as an industry focuses on a smaller number of technologies, there is more potential for increasing returns to scale, which may take the form

of, for example, cheaper access to inputs, more productive division of labor, or more efficient coordination on technology standards all of which could lead to larger innovations that generate new value as opposed to leading to competition centered around business stealing.[11]

Vertical integration—In theory, the degree of vertical integration has an ambiguous effect on innovation. On one hand, it can allow firms to coordinate their R&D activities, which could produce more innovations in the downstream market. On the other hand, it may reduce competition in the upstream market that otherwise may either have (i) incentivized more innovation in that upstream market and/or (ii) generated lower prices on inputs that would allow downstream firms to invest more into R&D (i.e., it can raise costs for rivals). Furthermore, consolidation along the supply chain increases its susceptibility to disruptions. As one empirical case study, Yang (2020) studies these tradeoffs in the "System-on-Chip" (upstream) and smartphone (downstream) industries and finds that consolidation would increase innovation (and welfare). Interestingly, the results also indicate that subsidies to the upstream firms are more effective at spurring innovation than such subsidies on the downstream firm.[12]

Section 3: Regulation and Consumers' Response to New Technologies

Ex-ante versus Ex-post Regulation—It has long been appreciated that stricter regulations on new technologies can create value by forcing the production of information that decreases consumers' uncertainty, but producing that information is costly and it may also delay (or prevent) the introduction of new technologies.[13] For the purposes of this class, it is useful to introduce students to the tradeoffs of ex-ante regulation (e.g., costly approval processes or product trials) and ex-post regulation (e.g., inspections or liability exposure).

TN Figure 2 Ex-ante versus Ex-post Regulation of New Technologies

Ex-ante (approvals, trials)		**Ex-post** (inspection, liability)
←less	Financing constraints	more→
←less	Risk appetite	more→
←more	Safety by fixed costs (pre-entry)	less→
←less	Safety by variable costs (post-entry)	more→
←*Concerned about adverse selection*		*Concerned about* → *moral hazard*

Source: Case authors.

TN Figure 2 summarizes the tradeoffs of these alternatives from the perspective of the industry as highlighted in the academic literature on this topic,[14] which forms the basis of a discussion in the teaching plan below (see *Section 3.3* of the teaching plan). An overarching lesson of this case that connects issues of both regulation and investment in the context of innovation is how concerns about adverse selection (here, that technologies that are inherently risky will enter the market and have negative externalities on the industry) motivate the use of ex-ante regulations for screening; conversely, concerns about moral hazard (here, that technologies that require costly monitoring in order to minimize risks after they enter the market) motivate the use of ex-post regulations to encourage activities such as maintenance and oversight. An analogous version of this lesson appears in the discussion about the tradeoffs of push versus pull incentives for innovation below.

Collective Action by Consumers—This case asks students to ponder the costs and benefits (and externalities) of engaging with consumers to educate them about a new technology as well as the ways in which consumers themselves can influence regulations that affect an industry. The teaching plan includes references to the nuclear fission industry, which experienced a sharp growth in regulations (and therefore costs of entry) after a series of incidents in the mid-to-late 20th century. The teaching plan also uses collective action amongst consumers to help illustrate the nature of externalities. One particularly helpful frame of reference that the teaching plan is motivated by is Mancur Olson's "logic of collective action."[15] According to Olson, smaller, more concentrated groups with more at stake can organize more effectively because the benefits of collective action are worth the costs of coordination. When a new technology poses a risk that affects a specific group disproportionately (e.g., a community near a chemical plant), those consumers are more likely to mobilize and advocate for protective measures. Thus, we should expect most consumer groups to be relatively small and polarizing in the sense of having a lot to (privately) benefit from in their actions. This is not always the case though, as Trumball (2012) points out; beyond the simple algebra of costs and benefits that the case discussion focuses on, large groups with diffuse interests can also prove quite effective in their lobbying efforts.[16]

Section 4: Push Versus Pull Incentives for Innovation

A key choice when investing in innovation is whether the manager should make up-front investments and provide resources to innovators so they can conduct their work (ex-ante, or supply-side investments) or instead offer rewards, such as prizes, to innovators after they have conducted their work (ex-post, or demand-side investments). The former, "push" incentives, lower the cost of innovation; the latter, "pull" incentives, increase the benefit of innovation. In a simple world, where benefits less costs are all that matter, this choice is irrelevant. However, in the context of innovation, there are a number of dimensions that might push the manager to prefer one approach to the other.

In the context of this case study, this question applies to whether Holland and the FIA should lobby the US government to invest more in fusion energy using push or pull incentives. But clearly, the framework of tradeoffs surrounding these two incentive schemes is relevant to all sorts of innovative activities including those inside of firms.

There has been a large amount of theoretical and empirical research on the relative merits of push versus pull incentives for innovation. **TN Figure 3** summarizes this literature along dimensions of the innovators (i.e., their financial constraints, their risk aversion) and the manager (i.e., how costly is it for the manager to identify high-quality innovators and high-quality inventions ex-ante). The summary conclusions in **TN Figure 3** are a synthesis of the literature included in the endnotes.[17]

When innovators are financially constrained, they do not have the resources necessary to invest in the pursuit of the innovation, which makes push incentives more valuable [Row 1 of **TN Figure 3**]. When innovators are very risk averse, the prospect of making their own private investments in hopes of an uncertain payoff is less appealing than receiving ex-ante support even if it is equal in expected value (just as a risk averse consumer is willing to pay a premium for insurance) [Row 2 of **TN Figure 3**]. If the costs the manager faces when screening for innovators ability (prior to investment) are very low, then the relative merits of push incentives are higher the manager can better guarantee those ex-ante investments are made to high-quality innovators [Row 3 of **TN Figure 3**]. Conversely, if it is easy for the manager to ex-ante specify the parameters of the technology (i.e., it is easy for them to describe exactly what they are looking for), then pull incentives become more useful [Row 4 of **TN Figure 3**]. Overall, while both approaches involves some degree of adverse selection (e.g., attracting low-quality innovators) and moral hazard (e.g., innovators over-reporting their costs) the literature suggests that push incentives are more useful when the manager is more concerned about attracting high-quality innovators and they are less concerned about how those innovators will make use of the investment

(adverse selection looms large); conversely, pull incentives are more useful when the opposite holds (moral hazard looms large).

TN Figure 3 Push versus Pull Incentives for Innovation

Push ($ → work) "supply side"		**Pull** (work → $) "demand side"
←more	Financing constraints of innovators	less→
←less	Risk appetite of innovators	more→
←more	Can specify "good" innovators ex-ante	less→
←less	Can specify "good" technology ex-ante	more→
←Concerned about adverse selection		*Concerned about moral hazard→*

Source: Case authors.

In the teaching plan, the instructor asks the class which seems most suited for the fusion industry; there is no clear answer. Rather the goal is to introduce this spectrum to the students and then, as they debate it in the context of the fusion industry, ensure that the students are arguing along these dimensions.

Section 5: Legal Definitions, Examples, and Additional Reading

Legal Boundaries and Definitions — The full details of the legal specifics surrounding industry associations specifically, and the bounds of legal coordination amongst firms and antitrust law more generally, is well beyond the scope of the case. Still, as indicated in the teaching plan below, it is important to communicate to the students that there are legal boundaries to be aware of. Most trade associations in the US, including the Fusion Industry Association, are registered with the Internal Revenue Service (IRS) as a "business league." The following, excerpted directly from the IRS description of business leagues being eligible for tax-exempt status under 501(c)(6), provides a useful definition and description:

> *A business league is an association of persons having some common business interest, the purpose of which is to promote such common interest and not to engage in a regular business of a kind ordinarily carried on for profit.*
>
> *To be exempt as a business league, an organization's activities must be devoted to improving business conditions of one or more lines of business (as distinguished from performing particular services for individual persons). It must be shown that the conditions of a particular trade or the interests of the community will be advanced. Merely indicating the name of the organization or the object of the local statute under which it is created is not enough to demonstrate the required general purpose.*
>
> *No part of a business league's net earnings may inure to the benefit of any private shareholder or individual and it may not be organized for profit to engage in an activity ordinarily carried on for profit (even if the business is operated on a cooperative basis or produces only enough income to be self-sustaining).*

> *To be exempt, a section 501(c)(6) organization must receive meaningful membership support.*
>
> *Trade associations and professional associations are business leagues. Chambers of commerce and boards of trades are of the same class as business leagues, but rather than promoting one or more lines of business, their efforts are directed to promoting the common economic interests of all commercial enterprises in a given trade community. The requirements for exemption of these organizations are substantially the same as for business leagues.*[18]

If the instructor is interested, additional details on the legal standing of industry associations can be found at the Antitrust Division of the US Department of Justice, the Internal Revenue Service, and the Federal Trade Commission.[19]

Historical Examples of Industry Associations—The teaching plan below (and the supplementary slides) include two references to illegal instances of industry collusion as well as two references to examples of industry associations in emerging technology markets lobbying the government regarding how technologies are defined, which has important implications for how they are taxed (in the case of cable TV in the 1950s) or how they are eligible for public funds (in the case of virtual reality in the 2020s). The teaching plan includes descriptions of these references and links to further reading material as well.

Other Industry Examples: Fission and Biotech—The teaching plan below includes some references to the nuclear fission industry since it is both quite related from a technical standpoint, but also because it is "older" in the sense of being commercially viable for longer. The introduction of the teaching plan includes a comparison of the two processes, which is referenced again in the teaching plan when debating the costs and benefits of regulation and the role of consumer advocacy groups. For further reading on the history of the fission industry, see Mahaffey (2010) or some of the in-depth technical reports from the Breakthrough Institute who has done some very interesting and relevant analyses of costs in the fission industry. One of those analyses is highlighted in the teaching plan.[20]

There is also much to be learned from the emergence of other industries and how the forces discussed here played out in the context of other technologies. Pisano (2006) provides an excellent overview of the challenges and opportunities throughout the emergence of the biotechnology industry. Many features of the fusion industry are reflected there: risky investments over long time horizons, continually evolving science and technological breakthroughs, and a diverse possibility of solutions to similar problems. There are also interesting differences that could prove useful in a comparison of the two industries (e.g., intellectual property in the form of patents is relatively more important in the biotechnology sector since the focal technologies, therapies, are more amenable to the patent system). The teaching plan does not expand on any comparison to the biotech industry, but the instructor could find many opportunities to do so.

Geo-politics of Fusion—The geo-political issues of fusion energy are a broad and dynamic enough set topics to be worthy of many case discussions. The FIA case study itself does not contain much specific information about this topic, because the focus of the case is more so to highlight frameworks for managing an industry and the importance of externalities. Thus, the teaching plan touches on this topic very briefly, instead providing a line of questioning that quickly pivots the discussion to financing and the issue of the mega-fund. Still, it is useful for the instructor to have some working knowledge of this topic, which can be had from any number of sources including the Council on Foreign Relations, the Government Accountability Office, or the Center for Strategic and International Studies. These, and other sources, are referenced in the endnotes for the instructor to search at their own interest.[21]

Gruber and Johnson (2019) provide an excellent discussion of the geo-politics of innovation more generally.[22] While they are primarily focused on the United States, the book emphasizes the importance

of understanding the externalities of innovation. Chapter 8, in particular, is quite relevant to this case study on the FIA as it discusses a number of examples that highlight the geo-politics of innovation at the industry level (e.g., synthetic biology, hydrogen fuel) and at the country level (e.g., Taiwan, Singapore, China, Canada).

Teaching Plan

An 80-minute class session can be organized into the following parts described in detail below:

Part	Length
1. Introduction	10 minutes
2. First Movers and Externalities	15 minutes
3. Regulation and Coordination	10 minutes
4. Push Versus Pull Incentives	10 minutes
5. Market Structure and Innovation	10 minutes
6. Geo-politics and the Mega-fund	10 minutes
7. Open Discussion	10 minutes
8. Summary	5 minutes

1. Introduction (10 minutes)

1.1. Fusion Overview

The supplementary PowerPoint slides provide an engaging introduction to the case by highlighting the progress we have made over the past century in our understanding of nuclear fusion. The slides are designed to be on the screen for the full duration of the class, with empty slides as placeholders for certain periods of transition.

The instructor can begin with an opening as follows:

> *Today, we're going to be talking about fusion. To appreciate just how far we've come in the past century, I want to start by noting that up until the early 20th century, we did not have an accepted theory of how stars worked! It was not until 1920 that a physicist, Arthur Eddington, first hypothesized that it was fusion that powered the stars.* [Show **TN PPT Slide 1**] *Here is the excerpt from Arthur's paper, "The Internal Constitution of the Stars," where he notes that the amount of hydrogen in stars could be enough for fusion to fully account for the energy that they emit in the form of heat and light. Fast forward 100 years and now teams around the world are building immensely complex machines that are, essentially, making stars in a bottle—here we can see construction of the Wendelstein 7-X Stellerator in Germany in 2011* [Show **TN PPT Slide 2**]

To quickly get the students participating, and to ensure that there is a baseline understanding of fusion in the class, the instructor can ask for a student to describe how energy is generated by fusion in the simplest terms possible. Furthermore, it is helpful to ask for the difference between nuclear fusion and nuclear fission. This distinction is useful for two reasons: first, it ensures that the students

understand how fusion works; second, the contrast is relevant to the business models of operating in the respective industries, which is something that will be highlighted shortly in the discussion.

> **Q:** *Who can give us the simplest, clearest description of how fusion works; how would you describe it to a child in grade school? And who can contrast nuclear fusion with nuclear fission?*

If the instructor would like, they can follow students' answers up with a question such as "*Wait, I thought Newton taught us that energy cannot be created or destroyed, just conserved?*" To this, there will likely be at least one student who will clarify that Einstein taught us that energy can be converted into mass and, most importantly for this discussion, mass can be converted into energy.

Next, the instructor can show **TN PPT Slide 3**, which provides very simple diagrams and comparisons of nuclear fusion and fission. The goal with this initial discussion is not to get bogged down in the specifics of the physics, but rather for the students to demonstrate a basic understanding of fusion and fission as energy sources. Students generally think they know more about fission than fusion given historical developments. A simple way of distinguishing between the two is that fusion involves less radioactive materials, but it is much more difficult to sustain because the reaction requires an immense amount of force to initiate. Conversely, fission is much easier to sustain because it is a chain reaction, but it involves more radioactive materials that are difficult to manage.

To provide slightly more information and context on fusion, the instructor can then provide a discussion of **TN PPT Slide 4**, which contains two key details. First, it describes how the goal of fusion energy is to generate a system that can produce more energy than is put into it, as described by the "Q" factor: the ratio of energy produced per energy used. Second, it describes the three levers that physicists have in order to generate more output from a fusion reaction: pressure, temperature, and time; this formulation is known as the "Lawson criterion" or the "triple product". These points are crucial contextual facts that all participants in the industry must understand. Furthermore, the instructor can make a memorable analogy to the triple product later in the course. Also, later in the class when discussing technological diversity in the industry, the three components of the triple product provide a precise way of delineating between different technologies: two technologies are meaningfully different if they are focused on increasing different parts of the triple product (e.g., some technologies focus on primarily maximizing temperature (T), some focus on primarily proximity (n), and some focus on combinations). Still, the instructor should take care not to spend too long discussing this and quickly shepherd the class forward.

1.2. Prioritizing issues per private benefits and costs

To outline a roadmap of the class, the instructor can introduce the key issues facing the industry and note that the class will involve a series of discussions about each issue, which will ultimately culminate in a debate about prioritizing these issues. When doing this, the instructor should force students to initially take the perspective of a single firm in the industry and not yet consider industry-wide effects; this is the framing of **Assignment Question 2**, so it should be easy to encourage students to adopt this perspective. Doing so will eventually help emphasize the importance of externalities and understanding the difference between the private (i.e., single-firm) and social (i.e., industry-wide) returns to certain activities.

The instructor can introduce the initial debate about priorities as follows:

> *This case is set at such an exciting and interesting time for fusion energy. There have been some large technological advances, thanks to high-temperature superconducting magnets, and some large investments, with a couple of firms receiving hundred-million- and billion-dollar fundraising rounds. To set the stage for our discussion and outline our class, let me list the major issues that the case lays out …* [Board the "Issue" column of **TN Board 1**]

> *The FIA is not a large operation, and Andrew Holland only has 24 hours in a day, so like any good manager, he needs to prioritize these issues. And since Holland represents the firms of the fusion industry – they are responsible for his salary, and they reap the benefits of his work – I'd like to get your opinions on how a single "representative firm" in the industry might view the potential benefits of engaging with each issue and how that representative firm might view the costs of trying to effect change on the issue.* [Board "Hi Benefit" and "Low Cost" headers of **TN Board 1**].

The instructor should solicit students' preliminary beliefs about the private benefits and costs of engaging with each issue from the perspective of a representative firm. Again, it is useful here to force the students to assume that there is no FIA, no coordination between firms is allowed, and each firm must decide on its own how to engage with the issue. It is also useful to note the names of the students who discuss each issue; then, later in the class, the instructor can return to these students when their particular issue of interest becomes the focus of the class discussion.

> **Q:** *Before we start discussing each issue specifically, I want to get a summary of all of these issues from your perspective as an executive at one of the firms in the industry. And for simplicity, just for now, let's assume that the FIA does not exist, and you can't coordinate with other firms in the industry. In this scenario, what issue is the most important for your firm; how large are the benefits and how low are the costs? We'll get to the FIA in due time, but for now, I want to hear what the firms are thinking individually.*

The instructor can ask students to rate the benefits and costs of each issue on some small scale (e.g., 1-5) and record these marks alongside the issues (as shown in **TN Board 1**). Ideally, the instructor can get students to rate all of the issues on the list.

2. First Movers and Externalities (15 minutes)

Still with the perspective of a single firm in the industry, the class can then debate the tradeoffs of being a "first mover" in this industry. The purpose of this discussion is to start to uncover the externalities in the industry and the ways in which a single firm's interests may diverge from the industry's interests. The instructor can open this discussion as follows:

> *There are a lot of big issues here* [Reference **TN Board 1**], *so being the "first mover" in this industry to engage with them seems like a daunting prospect. More generally, being the first mover is often cited as an advantage, but that's less clear in this particular context. So, I'd like to debate some of the pros and cons facing firms in the fusion industry as they consider how much they want to be the first, or second, or third mover.*
>
> *One fun and useful analogy people often use to describe this scenario involves penguins.* [Draw the penguins-on-a-cliff diagram of **TN Board 2**] *There's a bunch of penguins at the edge of a cliff, trying to decide whether to jump in or not, but the water is dark and it's unclear if the water is full of fish (for dinner) or sharks (and the penguins are dinner). Penguins solve this problem by herding up on the edge until one lucky, or unlucky, penguin gets pushed in and then everyone learns. Firms can, hopefully, be a little more strategic than this and decide if they want to be the first to jump off the cliff or not.*
>
> **Q:** *So, what are the pros and cons facing a manager at a firm when they're debating being a first mover, here in the fusion industry specifically, or any other new technological areas more generally?* [Collect answers on **TN Board 2**]

Using the students' answers, the instructor should board the generalizable pros and cons (from the perspective of the focal firm) as indicated on **TN Board 2**. If time permits, the instructor could also ask if the students would want to be a first mover or not in the fusion industry given the details of the case.

While outlining the tradeoffs of being a first mover in an emerging industry, the discussion will almost certainly include references to the externalities that the first mover generates—they may have positive externalities on other firms by reducing uncertainty about demand or regulations; they may have negative externalities on other firms by capturing demand or steering regulations in a direction that is only beneficial for them. The instructor can help students start to realize the importance of these externalities with a question such as the following:

> **Q:** *Why do you think the fusion industry has opted out of the "penguin model" of un-coordinated randomness, and instead have chosen to fund the FIA and Andrew Holland as coordinators? Why don't each of the firms in the industry just each hire their own lobbyists; why don't they all stay guarded and private and not talk to each other about any of their efforts? Who needs an "industry association" anyway?*

This question mirrors **Assignment Question 1**, and students should quickly realize that this context of an emerging technology involves many decisions that have positive and negative externalities on the industry. The instructor can emphasize this by returning to **TN Board 1** and adding a new column to collect students' thoughts on the magnitudes of externalities associated with each issue (in the rows). This also provides a clear path for the rest of the class—discuss each issue in more detail and debate the importance of externalities.

> **Lesson:** [After a student mentions externalities] *Yes, externalities! In fact, going to back to our "prioritization" list, something I want to emphasize today is that now that we're adopting the perspective of managing an industry, we need to care not only about the private costs and private benefits each firm faces from their actions* [Board "(1 firm)" above "Benefits" and "Costs" headers on **TN Board 1**], *but also the externalities that their actions have on each other in the industry.* [Board "Externality" header in **TN Board 1**] *When we take this new perspective of managing the entire industry, Holland's perspective, the focus is not just on issues with high benefits and low costs to any single firm. Now, Holland and the FIA must focus on coordinating activities with high benefits, low costs, and large externalities. If there is an opportunity for a single firm to do something that has large benefits and low costs for them, that's great, they should do that by themselves without the help of other firms. But if there is an opportunity where the benefit to any single firm is smaller than the costs they'd incur alone, but the benefits aggregated over the entire industry are greater than the costs (i.e., there are positive externalities) then this is exactly the type of opportunity the industry association should focus on.*

The instructor can even make a parallel between the "triple product" of fusion:

> *Earlier, we talked about fusion arising from the "triple product" of proximity, temperature, and time (Lawson's criterion). Here we now have the triple product of industry associations: they need to focus on issues that have high benefits, low costs, and large externalities.* [Board multiplication signs in **TN Figure 1**]

2.1. Simple Graphical Example of Externalities

Depending on how familiar the class is with externalities, the instructor can use the following exercise to provide the students with a clear graphical and mathematical example:

> *Let me walk us through two very simple examples to make sure this is clear.* [Board **TN Board 3** while describing the examples] *First, let's consider the case of a positive externality. Suppose there is some market, M1, with four firms, each capturing an even quarter of the market. Now, suppose there is some activity that a firm could undertake, such as lobbying for less burdensome regulations, that would cost some amount C but increase the size of the total market to M2, where*

M2 = M1 + B, and each firm would continue to capture one quarter of (the now larger) total market value.

Q: *First, let's assume the firms don't coordinate with each other and a single firm must pay the full cost but evenly split the benefits. When would a single firm ever be willing to pay C?*

A: One competitive firm pays C if it is smaller than B/4.

Q: *Now, if these firms coordinated and formed an industry association, where they share costs and benefits, when would they be willing to pay C?*

A: Coordinating firms pay C if it is smaller than B (i.e., when B/4 > C/4).

Great, now let's clearly illustrate coordination amongst a negative externality. Suppose the initial conditions are the same; there are four firms equally capturing the value of a market. But now, suppose that one of these firms, F, can lobby for a specific regulation that decreases the total size of the market (M2<M1) but puts them in a position to capture a larger fraction of that new market (F2>F1).

Q: *When will firm F be willing to pay C?*

A: When (F2-F1) is greater than C.

Q: *And if F was in an industry association with the other firms, when would they agree to pay C?*

A: Never, since the total value of the market decreases.

These examples show how coordination can help firms share in the costs of activities that benefit them all (via positive externalities) that would otherwise be avoided or ensure that firms account for the costs they impose on other firms (via negative externalities).

3. Regulation and Coordination (10 minutes)

3.1. Legality and Examples of Coordinated Lobbying

Near this point in class, it is important to emphasize to the students that coordination over certain activities can be illegal. The precise boundaries of legal coordination and the legal status of industry associations is well beyond the scope of this class session, but any interested students can be directed to some of the resources included in the Case Analysis (see *Section 4*). Still, discussing the reasons why certain collusive behaviors are illegal provides yet another view of externalities and plants the seed of an analogy that the instructor can return to at the end of class (that managing an industry has parallels to managing a country):

Coordination can clearly generate value for the industry. [Reference **TN Board 3** if the instructor conducted the exercise] *However, there are certain activities that firms are legally banned from coordinating on: for example, setting prices; how they compete in the labor market. Still, some businesses engage in this type of coordination, and they get caught.* [Show **TN PPT Slide 5**] *One way to justify these sorts of practices as being illegal is that they are instances of negative externalities that the government wants to avoid—for instance, price colluding firms generate a negative externality on consumers, and firms agreeing not to compete in the labor market generates a negative externality on workers.*

In order to transition away from the legalities of coordination, the instructor can ask the students if they have ever been a part of industry-wide conversations, where organizations were trying to create some positive externalities or avoid some negative externalities.

> **Q:** *Before we jump back into the specifics of the fusion industry, can anyone share some examples of discussions they've been a part of, at the industry level, centered on managing externalities that firms were having on each other? Of course, you probably were not using the word "externality" in those discussions, but you might have been coordinating how to, for example, lobby policymakers or make a joint investment that would benefit all of the players in the industry.*

When students provide examples here, it is helpful to push them to be as clear as possible about the nature of the externality they were trying to manage. One useful way to illuminate this is to ask the student providing an example to play out the counterfactual scenario where they did not coordinate and make clear that either a negative externality would have borne out or a positive externality would not have.

3.2. Regulations and Lobbying

Next, to transition the class onto the first issue of regulations, the instructor can use **TN Slides 6–7** to provide students with two examples of industry associations conducting effective, legal lobbying efforts in the context of an emerging technology. These two examples also highlight the importance of understanding how technologies are classified by policymakers; what may seem like merely debates about semantics can have very important implications.

> *Thankfully, the FIA has been following the letter of the law, and the case highlights how they lobbied regulators to classify fusion as a technology that is closer to a particle accelerator than it is a nuclear fission reactor, with the former being subject to much "lighter" regulatory burden (10 CFR 30) compared to the latter (10 CFR 50/52). Before we debate this approach, I want to emphasize the importance of this sort of policy engagement. It is not just about definitions for semantics sake, the classification of technologies can have very important implications.*
>
> *Take this example from the birth of the modern cable TV networks.* [Show **TN Slide 6**] *In the mid-1950s, the TV industry, which was just starting to emerge, was initially found to be a "wire and equipment service" that was subject to an existing 8% federal excise tax, which increased the prices customers were facing (without contributing to firms' revenues). The industry association, the NCTA, supported a legal case from a consumer (Gus Pahoulis) to challenge this definition, and they were successful.*[a]
>
> *For a more recent example, we can look to the virtual reality industry.* [Show **TN Slide 7**] *As the specifics of the CHIPS and Science Act of 2022 were being debated, it was clear that a tremendous amount of investment could be made into certain technologies deemed "societal, national, and geostrategic challenges" by the administration. Originally, virtual reality was not on this list. But the XR Association lobbied, and they were able to get "immersive technology" onto number 6 of the list. This may seem like a small win, but without this language, the industry may not have been a recipient of any of the billions of dollars expected to be awarded under this Act.*[b]

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[a] See the following for more on Pahoulis v. US and the courts' debates about the excise tax: Parsons, P. (2008). *Blue Skies: A History of Cable Television*. Temple University Press; Peteet-Kilgore, P.L. (2013). Yolanda Barco's Impact on the Cable Television Industry.

[b] See the following news article for more coverage on the XR Association's efforts as it relates to the CHIPS and Science Act: Bordelon, B., Oprysko, C., "Everybody in Washington wants a byte of the CHIPS law," *Politico*, Mar. 17, 2023, https://www.politico.com/news/2023/03/17/chips-law-companies-washington-lobbying-00086687, accessed 2023.

The case study makes it clear that the FIA has been quite successful, so far, at steering regulatory groups towards a framework that involved lower expected costs for businesses (i.e., avoiding the regulations put in place for nuclear fission reactors). This may motivate some students to suggest that regulatory issues are no longer a concern. But it is useful to remind these students that, at the time of the case, the regulations had not been finalized and the goal of the following discussion is to see what lessons the students can uncover about engaging with regulators during the emergence of new technologies. In order to foster a discussion that is not too specific to fusion, the instructor can open this section of class with a question such as the following:

> **Q:** *I'd like to dive further into each of the issues on our list* [Reference **TN Board 1**]*, this time paying more attention to the externalities associated with that issue. Let's start with the issue of regulation. Before we get into any of the complexities about the "Code of Federal Regulations," which the case describes, a question for you all: Why do governments make it difficult and costly for business to introduce new technologies into the market?*

This framing of the question helps students take a step back from the case specifics and prompts them to quickly think of externalities yet again. The answer to this specific question is *negative externalities* associated with risk – firms may introduce uncertain technologies that cause more harm (to society) than the firm could ever be held responsible for. If the students are struggling to conceptualize negative externalities at this point, the context of new drugs and the US Food and Drug Administration (which regulates new drugs) may prove useful: "*What would happen if there were no requirements for new drugs, there was no Food and Drug Administration or any such regulator, and any business could sell any therapy on the market?*" The instructor can push on this point with follow-up question such as: "*Yes, we'd get more drugs, but, in this extreme case of no regulation, what do you think the quality of those drugs would be? Do you think consumers would be able to learn drugs' true quality in a way they would be happy with? Do you think that if a new drug caused damages that the legal system could fully hold the drug's inventors accountable?*" The important conclusion is that, in principle, governments create regulations surrounding new technologies in order to minimize negative externalities (of course this involves a tradeoff of risk and innovation). Arriving at this conclusion also plants the seeds for the parallels between managing an industry and running a government—in both cases, it is essential to understand externalities.

The instructor can then press on to debating the externalities of engaging with regulators:

> **Q:** *How large are the externalities of engaging with policymakers here in the fusion industry in 2024; if firms were left to their own devices and didn't coordinate via the FIA, do you think the resulting regulations would be in the best interest of the whole industry?*

For this, and each of the following, discussion of externalities, there are no conclusive answers about the specifics in the context of the fusion industry at the time of the case. There are large uncertainties along all dimensions. The purpose of this discussion is to highlight the presence of both negative externalities (e.g., firms may individually lobby for regulations that help them but hurt the industry) as well as positive externalities (e.g., if firms were to all lobby for the same regulations, the probability that those regulations would be enacted would increase; that is, there are increasing returns to scale in lobbying effort). The instructor can summarize students' thoughts about the overall magnitude of externalities associated with regulatory (lobbying) activities in the third column of **TN Board 1**.

3.3. Tradeoffs of Ex-ante Versus Ex-post Regulation

One particularly interesting question to pose here is whether the students think the industry should push for more ex-ante regulation (e.g., approval requirements) or more ex-post regulation (e.g., exposure to legal liability in the case of damages):

> **Q:** *Let's assume for a moment that the Nuclear Regulatory Commission is determined to get some new regulations on the book, but they're indifferent as to whether those regulations are (1) "ex-ante" regulations in the form of costly approval processes firms must undertake before entering the market, or are (2) "ex-post" and in the form of inspections or liability exposure that increases the degree to which firms can be held responsible for any damages they cause. Do you think Holland and the FIA should push for more ex-ante or more ex-post regulation?*

TN Board 4 provides a way of collecting the students' thoughts on this question. One possibility is for the instructor to sequentially discuss the dimensions (center column) and ask the students questions of the form: "*If [dimension] is higher or lower among the firms in the industry, should they be in favor of more ex-ante or ex-post regulation?*" As outlined in the case analysis above, the legal and economic literature on this question suggest that ex-ante regulation is more efficient when adverse selection concerns loom larger (e.g., which technologies enter the market at all), whereas ex-post regulation is more efficient when moral hazard concerns loom larger (e.g., how technologies are maintained to prevent damages). This question may prompt some students to note that the answer depends on what the industry thinks consumers will do if negative events happen (multiplied by their belief about the probability of the negative event happening). This can serve as a useful transition into the next section focused on consumers.

3.4. Coordinated Consumers and Risk Versus Regulation

Next, the instructor can turn students' focus to coordination among consumers and discuss the differences when thinking about coordination when there are many more individuals with much more diverse preferences and beliefs:

> *As we mentioned earlier, many regulations are intended to protect consumers from negative externalities. Looking at our priority list* [Reference **TN Board 1**], since *consumers are next on our list, I'd like to talk about how they coordinate, since I think we all know of examples of consumers influencing regulations either directly through lobbying or indirectly with their votes. Now, there are obviously many more consumers than firms, and as someone who struggles to coordinate a dinner party with more than 4 friends, I know the costs of coordinating consumers must be very large… and yet, we all have seen consumer advocacy groups out in markets lobbying for changes.*
>
> **Q:** *Why do we still see consumer interest groups despite large coordination costs? If everyone has such relatively little to gain, they'd never coordinate—but they do. Do we think that every consumer has the same preferences, especially over the benefits, or costs, of new technologies?*

The answer of course is that there are some consumers who have very strong (positive or negative) preferences and beliefs that make coordination a worthwhile endeavor for them.

> [In response to a student who notes the point above] *Yes, some consumers have a lot to gain or a lot to lose, especially in the context of new technologies. This is why we shouldn't be surprised that consumer advocacy groups often appear quite polarized. Consumers who do not face large benefits (or losses) from a new technology won't be willing to pay the costs of coordination.*
>
> *One related area where advocacy has become quite polarized is nuclear fission* [Show **TN PPT Slide 8**]. *As of early 2024, each of these three, very large and influential, non-profit organizations were opposed to nuclear fission as an energy source. Furthermore, note that (at least in these headlines) it is not "nuclear fission" that they oppose, but just "nuclear".*

> **Q:** *How concerned should Holland and the FIA be about similar sentiments forming about fusion? Are there large externalities facing the industry in terms of consumer sentiment? How would you suggest they go about trying to influence consumer sentiment?*

In response to this question, students may mention ideas such as launching consumer education campaigns or engaging with universities to support training programs for fusion-related fields. The instructor can judge the students' stances to fill out the "Externalities" column of the "Consumer" row of **TN Board 1**.

At some point, a student might also note that the industry could lobby for stricter regulations from the government in order to convince consumers that fusion is safe. If not, the instructor could inject this point along the following lines:

> *Earlier, we were quite happy that the FIA was able to get the Nuclear Regulatory Committee to classify fusion in a way that would require much less costly investments.*
>
> *Couldn't FIA have lobbied for stricter regulations in order to credibly signal their commitment to safety and shift some of the risk to the government? If we look at what happened to the nuclear fission industry* [Show **TN PPT Slide 9**]*, we can see what happened after some of the largescale public accidents in terms of the growth in regulations driven by the decline consumer sentiment. This graph shows how many dollars (y-axis) and years (x-axis) it took to build nuclear fission power plants that were completed before the Three Mile Island accident in 1979 (in blue) compared to those that were completed after (in red). For students who aren't aware, in 1979, one of the reactors at a fission plant in Pennsylvania experienced a partial meltdown and it became a very public incident. It was not as severe as the Chernobyl meltdown; however, it drastically changed US consumer sentiment regarding fission.*
>
> **Q:** *Now with this in mind, how do you think the fusion industry should approach this connection between regulations and consumer sentiment?*

One notable issue to nudge students towards during this discussion is the difference in the physics between fusion and fission. As noted in **TN PPT Slide 3**, fission involves more radioactive material and is, fundamentally, a chain reaction. On the other hand, fusion involves lighter, safer elements, and it is not a chain reaction. Another interesting question to debate on is whether consumers would react differently depending on the level of regulation in an industry (i.e., "*How much less would consumer sentiment decline if there was an equally-size accident in a heavy regulated industry versus a lightly regulated industry?"*). This overall discussion can be summarized as follows:

> **Lesson:** *This discussion illustrates how, in the context of an emerging technology, you can think of the debate about regulations as a debate about who should bear the (ex-ante) costs and who should bear the (ex-post) risk – lighter ex-ante regulations will often imply lower fixed costs but higher ex-post risks for the businesses; higher ex-ante regulations increase costs for businesses to enter the market but shift the risks onto the government. Furthermore, you should note that putting the risks on the government is, implicitly, putting the risks on voters since that is who the government responds to (and consumers and voters are not always the same). So, if you're going to push for light regulations, it makes sense to also push for a lot of consumer education (especially consumers most likely to be voters) since those are complementary investments.*

4. Push Versus Pull Incentives (10 minutes)

4.1. Externalities of R&D

Continuing with the theme of engaging with governments, the instructor can move the discussion to the topic of public investments in new technologies. This also provides another opportunity to emphasize externalities, this time in the context of businesses' research.

> *Let's move on from regulations and talk about another major way that governments are involved here: as a funder. For example, the US Department of Energy's (DOE) Office of Science had an annual budget of $8.8 billion in 2024.[23] There are 17 DOE national labs that employ more than 50,000 people.[24] The case mentions the gigantic ITER project, which has total cost estimates approaching $20 billion, of which the US government might contribute upwards of $6.5 billion.[25] Before we talk about trying to influence these billions of dollars, I want to make sure we understand what the government is doing here.*
>
> **Q:** *Before we dive back into the specifics: why do governments fund science and other innovative activities? In 2022, US businesses spent approximately $670 billion on R&D; why did the US government spend another $160 billion on top of that?* [26]

A student may quickly reference externalities again, but they may not have an immediately clear understanding of the externalities of science, so it can be helpful to ask for specifics: "*What are the specific ways that science involves externalities? What are the mechanisms through which one businesses' investment in science generates value that they cannot capture? Are all externalities of science positive; how could one firm's R&D create a negative externality for another firm?*" Some students may draw attention to other reasonable factors that influence public spending on science but are less relevant to this case discussion (e.g., voters derive some indirect consumption value from science; politicians may use investments in science as a way to steer funding into their local districts). These are not trivial points, but the focus should remain on the nature of externalities in science.

The instructor can collect students answers to this question in the form of the four key groups of externalities as illustrated on the left-hand side of **TN Board 5**. The instructor can wrap this high-level discussion is as follows:

> **Lesson:** *When firms conduct R&D, there are two broad ways in which they generate externalities beyond the boundaries of their own organizations. On one hand are positive externalities – it is very difficult, if not impossible, for firms to charge everyone a price that equals their willingness-to-pay; it may be impossible to set a price at all. This implies that some of the value firms create for customers (i.e., new products) or other producers (i.e., new information) with their R&D cannot be captured. On the other hand, there are negative externalities – if a firm invents a new product that is better than another firm's existing product, the private benefit to them could be stealing the entire market; but the benefit to the industry as a whole is only the size of the growth in total demand, which may be much smaller* [Reference negative externality example from **TN Board 3**]. *This implies that some of the value they capture from their R&D was already out there in the market. Similarly, two firms may invest in very similar projects such that the likelihood that one of them succeeds is less than twice the likelihood that either of them succeeds – this is duplicative investment.*
>
> *Our best estimates from researchers that study these forces suggest that the positive externalities dominate the negative, and overall, firms may only capture a small fraction of the total value that their R&D generates; many estimates suggest this fraction is roughly on the scale of ¼ – this*

> *means that, overall, firms will likely underinvest in R&D compared to what someone running the whole industry (or the whole economy) would want them to.*

The instructor can focus the students back on the fusion industry and the question of government investment with the follow question:

> *We started this discussion by noting that the government invests in research under the assumption that the positive externalities are (much) larger than the negative.*
>
> **Q:** *Here in fusion, do we think there are large externalities from research that could be used to motivate the government to invest more in fusion research; should the FIA be lobbying for more federal investment?* [Record overall student sentiment in "Externalities" column of the "Gov't Financing" row of **TN Board 1**]

The discussion immediately preceding this question may motivate students to quickly answer in the affirmative. However, the instructor can push back with the following inquiries: "*You say there are large positive externalities to be had from further fusion R&D; however, the case talks about venture capitalists investing hundreds of millions of dollars into fusion businesses right now. Surely, they are not thinking about positive externalities, the entire point of venture capital is to create and capture value.*" This can encourage students to think more specifically about the types of research that could possibly generate a large amount of value for the industry but capturing that value from that particular type of research would be difficult for any single firm (e.g., more fundamental R&D that is applicable to all fusion reactor designs).

4.2. Tradeoffs of Push and Pull Incentives

With the externalities of science in mind, the instructor can then push the class into a debate about the relative merits of using "push" versus "pull" funding structures to incentivize science. This discussion will be set in the context of the US government funding fusion science and covers some of the policies mentioned in the case such as research grants and tax deductions (push incentives) versus milestones and prizes (pull incentives); however, at the end the instructor will be able to draw parallels to the management of innovation more generally (e.g., within firms).

> *Let's get back to some specific details, and let's assume for a moment that Andrew is convinced that he needs to lobby for more government funding of fusion. He still faces a decision about the specifics of what the funding could look like. Should he lobby for more grants for academics, or for more tax breaks for firms, or for a large prize to award to the first team that achieves $Q > 1$? Government support can come in many different ways, and one way to organize the possibilities here is whether they are "push" or "pull" incentives* [Board "Push" and "Pull" Headers of **TN Board 6**]. *With a push incentive, managers are focusing on the supply side of the market and are awarding resources that lower the costs of conducting the research. With a pull incentive, managers are focusing on the demand side of the market and are awarding resources that increase the benefits of successful research.*
>
> *Before we debate whether Andrew should be lobbying for more push or pull incentives from the government, I'd like to walk through some more general features of the science at hand and talk about when we'd like to push or pull in general.*

The instructor can then proceed to discuss the four attributes listed in the middle of **TN Board 6**, and ask students questions of the form: "*When [attribute] are larger, should the manager look to push or pull incentives for innovation?*" Depending on the class's potential comfort with the concepts of adverse selection and moral hazard, the instructor could choose to engage with those dimensions or not.

Once **TN Board 6** is complete, the instructor can ask the students for their thoughts on how the fusion industry currently appears on these four attributes and what that implies for the optimal government support structures.

> **Q:** *Using this framework we've just produced; do you think Andrew should be lobbying the government for more push or pull styled investments in fusion? Should he be trying to get a bunch of basic science research grants funded (push), or should he be lobbying for a subsidy to the price of energy if it is produced via fusion (pull)?*

After debating this question, it may be useful for the instructor to ask the class for a few examples of push or pull incentives that the students have seen or been exposed to in their careers. Ideally, the instructor could solicit examples from within businesses (e.g., a manager using a prize to incentivize new ideas (pull); employees having guaranteed time to work on projects of their own choosing (push)). The more varied the students' answers, the more generalizable this tradeoff of push versus pull incentives will appear to the students, which the instructor can summarize as follows:

> **Lesson:** *Often, a dollar is a dollar. But in the context of innovation, investing a dollar before someone does the research can be very different from investing a dollar that is paid after the research is done. Pushing innovation with "upfront" or "ex-ante" investments can be more powerful when the innovators are financially constrained, risk-averse, and it is easy to identify who is the best. Conversely, pulling innovation with "prizes" or investments that pay off "ex-post" can be more powerful when innovators are hard to spot, but you know exactly how to specify the result you're looking for. How much of a push versus a pull you want to undertake will depend on how willing you are to tradeoff concerns of adverse selection (e.g., attracting innovators of lower quality) versus concerns of moral hazard (e.g., disincentivizing innovators to make investments of their own). And you should note that this particular tradeoff of push-versus-pull incentives is not unique to industry-level problems, these same things will play out across teams and individuals inside your organizations too.*

If the instructor debated the merits of ex-ante versus ex-post regulation earlier, they should reference the parallel that, in both cases, concerns over adverse selection warrant more ex-ante investment (i.e., regulations prior to market entry, push incentives for innovation) while concerns over moral hazard warrant more ex-post investment (i.e., regulations and liability after market entry, pull incentives for innovation).

5. Market Structure and Innovation (15 minutes)

The next portion of the class centers on a discussion of how the market structure for the fusion industry can influence the pace of progress and, therefore, a debate about what sort of market structure Holland and FIA should be working towards. To transition from the prior section, the instructor can say something along the following lines, which invites students to consider their answers to **Assignment Question 3**:

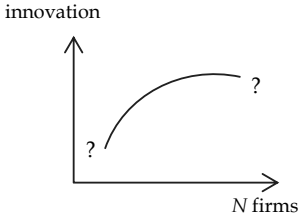
> *The governments' decisions on these issues of regulations and the financing of R&D, and many other issues, can have important effects on the structure of an industry. And besides lobbying the government on these dimensions, the FIA can use other mechanisms to try to influence the structure of the fusion industry.*
>
> **Q:** *What is the ideal market structure for the fusion industry right now? The FIA's objective is to make commercial fusion a reality, and that means innovating. We have our four key externalities of innovation up on the board* [Reference **TN Board 5**]*; what sorts of changes would you make to the industry to encourage firms to undertake more activities with positive spillovers and less*

activities with negative spillovers? Should the FIA promote more competition, stronger intellectual property rights, should they host research conferences, etc.?

The instructor can then help the class debate students' answers. A list of potential answers is on the right-hand side of **TN Board 4**, and as illustrated there, the instructor can diagram on how the proposed activity either internalizes the externality or, in some cases, amplifies the externality (e.g., promoting a diverse set of technologies to be active in the industry can minimize the negative externality of duplicative efforts, but may increase the negative externality of business stealing). The specific connections between the "levers" and the externalities will depend on how exactly the students specify the activities underlying the levers. When students propose activities, the instructor should push the student to clarify how that activity promotes innovation through one of the externality channels.

One particularly interesting dimension to discuss is the level of competition in the industry. Here, if the instructor chooses, they can reference some of the academic work discussed in the case analysis (e.g., Aghion et al. 2005). **TN Figure 4** presents a simplified summary of that work, indicating how economic theory suggests an inverted-U relationship between competition and innovation (Aghion et al. 2005); however, some empirical evidence suggests more of a plateau (i.e., Igami and Uetake (2020), which motivates the question mark on the right-hand side of the curve), while other suggests that monopolists may innovate more than a duopoly (i.e., Goettler and Gordon (2011), which motivates the question mark on the left-hand side of the curve).[c27] The instructor could draw a small version of **TN Figure 4** on the board during this discussion. The key takeaway from this specific point is appreciating the complexities through which levels of competition can affect the presence of externalities in a market and, therefore, the incentives for innovation.

TN Figure 4 Competition and Innovation



Source: Case authors.

The instructor can then ask the class to revisit the priority list in light of the discussion and then wrap the discussion about market structure and innovation:

> **Q:** *Looking back to our list of potential priorities* [Reference **TN Board 1**] *how important are the externalities from coordinating over the industry's structure (e.g., number, size, and diversity of firms, vertical integration in the supply chain)?* [Record overall student sentiment in "Externalities" column of the "Industry Structure" row of **TN Board 1**]
>
> **Lesson:** *As managers of a single organization, you will be faced with decisions of how to grow the value of your organization, and those decisions will be based on your organization's capabilities and the competition you face in the market. Some of the growth you will achieve might come at the expense of your competitors, and your shareholders and stakeholders may very well be happy with*

[c] Furthermore, there are some unique case studies of organizations, such as Bell Labs, that were a part of highly concentrated industries but were responsible for significant innovations.

that. But when you have the whole industry's perspective in mind, the growth of a single organization doesn't matter unless it grows the whole industry. This puts industry associations in a challenging position of sometimes needing to make firms compete harder with each other, do things they don't necessarily want to do, or not do things they want to do, which can be a difficult proposition in the short-run but may prove crucial to long-run success for the industry.

6. Geo-politics and the Mega-fund (10 minutes)

Next, the instructor can push towards a discussion of the final two issues on the priority list of **TN Board 1**. The "geo-politics" issue will likely draw a significant amount of student interest; however, a full-fledged discussion of navigating geo-political issues in the context of an emerging technology is well beyond the scope of this case. Furthermore, the fluidity of these issues makes it difficult to draw generalizable lessons in such a short time. However, not mentioning the topic at all can improperly minimize the practical importance of these matters. Thus, the instructor can use the following line of questioning in order to touch on the geo-political topic very briefly and then quickly enter a more detailed discussion of financing.

First, the instructor can solicit a small amount of input from students on the issue of navigating geo-politics:

> **Q:** *We've covered a number of large issues already, moving down our potential priority list* [Reference **TN Board 1**], *how large of a priority do we think geo-politics are? The case references some potential pressures to not have the industry become to concentrated in particular regions and some concerns that, in their race to attract fusion, some countries might enact regulations with unintended long-run consequences for the industry. If you were Holland, how would you go about engaging with these issues?*

After receiving a few comments on the question above, the instructor can pivot the class into a focus on financing using the following comment:

> *Now, we could spend an entire class, or even an entire semester, discussing the strategies for navigating geo-political issues like this. One of the challenges here, and this is not particularly unique to fusion, is that there are certain regions of the world that have control over very large amounts of capital, but the objectives of the leaders who control that capital are unclear.*
>
> *The case highlights an alternative way of helping the industry access larger amounts of capital: a mega-fund. Let's shift our focus to that now.*

With the class now focused on the mega-fund, the instructor can first make sure there is a common understanding amongst the students using a combination of questions with the class (e.g., "*Can someone explain the fundamental idea of a mega-fund?*") as well as **TN PPT Slide 10**. The instructor should also familiarize themselves with one or more of the academic papers describing the mega-fund concept (Alhamdan et al. 2023).[28]

When describing the mega-fund, a student will likely mention the concept of "risk pooling." Depending on the financial expertise amongst the students, it can be quite useful to present the students with a highly stylized example of how risk pooling is useful in the context of innovation. **TN Board 6** includes such an example that can be delivered to the students as follows:

> *Before we discuss some of the downsides of something like a mega-fund, I want to be clear about the benefits. To illustrate the benefit of risk-pooling in the context of innovation, consider the following wager I would like to offer you:*

> *You roll a 6-sided die. If you get a 6, I will pay you $1 billion. If you don't, you must pay my $1 million. This gives you about a 17% chance of winning, which implies that the expected value of playing is about $166 million, a positive value bet, but one with an 83% chance of you owing me $1 million. By a show of hands, who likes that bet?*
>
> *What if I offered you the opportunity to pool your risk with 9 other friends, 10 rolls total, where the 10 of you would need to evenly split all losses and wins. Does the expected value change? No. Is the probability that at least one of you wins 17%? No. That probability is given by $1-p^n$, where p is the probability of failure (5/6), and n is the number of rolls (10). This equals about 84%, which implies that this pool of 10 friends has an 84% chance of at least one winner, and, if only one person wins, the payoff after splitting losses and wins is about $99 million per person. If you could pool with 19 other friends, the chance of at least one winner is roughly 97%, where a single-winner scenario would pay off about $98 million.*

This provides a very positive view of risk-pooling in general and can be used as a bit of a strawman to motivate the students to think about the downsides of this approach?

> **Q:** *This seems terrific! What could go wrong? What are the downsides or costs associated with a risk pool or a mega-fund as it is outlined in the case?*

This question mirrors **Assignment Question 4**. Based on the following discussion, the instructor can fill out the right-hand side of **TN Board 6**, collecting the pros and cons of a mega-fund and the factors of the fusion industry that make it more (or less) amenable to such an approach.

One particularly useful limitation of risk-pooling, particularly in the context of the example on the board, is to note that it hinges on the dice rolls being independent. When students are debating the merit of a mega-fund, they may correctly not that assuming independence here is not realistic—yes, there is a diverse range of technologies being tested, but researchers are working off of similar knowledge bases and there are a number of correlated risks they all are exposed to. To emphasize how this decreases the benefits of pooling, **TN Board 6** (bottom left) includes some results from how the example gamble changes if the dice rolls are correlated.

Depending on the instructor's interest, they can keep this discussion at a high level where the specific financial vehicles inside of the mega-fund are not debated; or the instructor can ask students to propose specific ways of aggregating risks (e.g., which assets should be grouped versus kept separate) or attracting capital from investors with different risk tolerance using **TN PPT Slide 13** as a backdrop for the discussion.

To begin to move the class to the final open discussion about how Holland should prioritize his efforts, the instructor can ask a more pointed question about the usefulness of a mega-fund in the fusion industry and, conditional on that, whether it is something that involves large externalities in a way that the FIA should become involved:

> **Q:** *Should Holland work on the creation of a fusion mega-fund? The case notes that there have been some large fundraising rounds so far, approaching billions of dollars; do you think there is still untapped demand amongst these firms? And do you think that, without coordination around something like a mega-fund, the industry will not be able to attract sufficient capital?*

There is no clear answer here. Rather the point of this discussion is to ensure that students can correctly debate the merits of attracting capital via a mega-fund style of risk pooling. The key source of the externality to emphasize is the combination of the high-risk work underlying fusion (e.g., high fixed costs, long timelines, low success probabilities) and the risk aversion of potential investors that makes investment in any single firm not worthwhile.

Lesson: *This discussion has highlighted how the pooling of risks can create positive externalities when investors are risk averse and not willing to invest in any single risk. Note that this is the same principle of insurance. But in the same way that insurance companies get worried when they have a small number of clients who have correlated risks, the benefits of something like the mega-fund hinge on the industry maintaining a large and diverse array of technological pursuits, which may come at a cost. Furthermore, this illustrates how the industry's financial structure is going to be connected to its market structure along some of the dimensions we talked about earlier.* [Reference **TN Board 5**]

7. Open Discussion (10 minutes)

At this point, the class should have discussed the specifics and generalizable lessons associated with each issue in TN Board 1. To synthesize all of these points, the instructor can open the floor for a debate about overall prioritization:

We've touched on all of FIA's potential priorities. Now, let's finish our discussion with an open debate on how we should rank them; remembering that what is important to the industry may or may not be something that is important to any individual firm.

Q: *Where should Holland and the FIA focus their efforts right "now" (the time of the case)?*

During this debate, the instructor should be sure to press students to clarify why their proposed priority involves large (positive or negative) externalities and, therefore, warrants FIA's focus and is not something that firms will engage with for the benefit of the industry regardless of whether Holland directs FIA resources to the issue or not. Depending on board space, the instructor could keep track of students' responses on the board.

8. Summary (5 minutes)

To begin to summarize the class, the instructor can revisit each of the issues discussed (from TN Board 1) while highlighting how different types of externalities appear. Then, one way the instructor can summarily emphasize the challenges and opportunities of managing an industry association is by drawing an analogy to managing a government, where an appreciation of externalities is crucial and the potential for value-generating coordination are large:

Wrap: *I think we can all agree that Andrew has quite a challenge facing him, but he and the FIA are in an exciting position to help coordinate progress within an industry that, without exaggerating too much, has the potential to change how our society is powered. But, running an industry is hard—in fact, it's quite a bit like running a country. You are reliant on your constituents' support, and you need to be very mindful of what is and what isn't legal. You need to keep an eye out for externalities and ask questions like "Is nobody going to do this great thing that would help everyone?". This may relate to issues such as lobbying regulators, conducting high-risk research, or attracting large-scale capital investments. But you should be able to do better than the penguins, who just shuffle around until someone gets pushed into the water. The key is understanding how to identify and manage externalities, especially in the context of emerging technologies. And if during this class you found yourself thinking "that sounds like a similar version of a problem we faced when trying to coordinate teams or individuals inside our organization" you're right! Externalities arise almost everywhere, especially when people are trying to innovate. So as the manager, whether you're trying to coordinate individuals, teams, multiple businesses in an industry, or multiple industries, it is imperative that you identify where the most important externalities are and try to find ways of "internalizing" them. Sometimes that could mean paying someone more to help them generate a positive externality; sometimes it might*

mean restricting what someone to keep them from generating a negative externality. Either way, it is no longer about debating just the private costs and private benefits of activities—it's about debating the full "triple product," to include the externalities of those activities because in the realm of innovation, they can be very large.

TN Appendix A—Board Plan

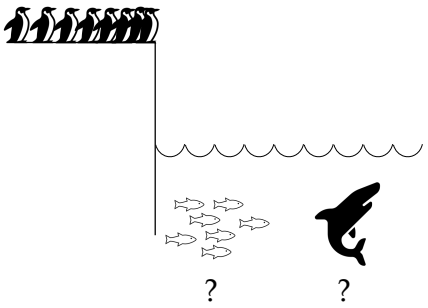
Board 1

Industry Priorities

Issue	(private) Benefits	(private) Costs	Externalities
Regulations	✓✓✓	✓✓✓	✓✓✓✓
Consumers	✓	✓✓	✓✓✓✓
Gov't Financing	✓	✓	✓✓✓
Industry: Horizontal	✓	✓	✓
Industry: Vertical	✓✓	✓	✓✓
Geo-politics	✓	✓✓✓	✓✓✓
Private Financing	✓✓✓	✓✓	✓✓

Board 2

First Mover



Cons

- Uncertain:
  - regulations
  - customer preferences
  - competition

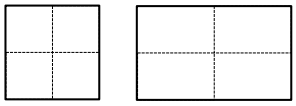
Pros

- "Un-captured" demand (esp. if high customer switching costs)
- Influence:
  - customers
  - industry standards
  - regulations

Board 3

Externalities

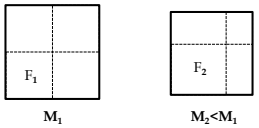
positive externality 1 firm pays **C** to increase total market (**M**) by **B**



4 equal firms' decisions

Competition: Pay if **B/4 > C**
Coordination: Pay if **B > C**

negative externality firm F pays **C** to capture more of smaller market



firm F's decision

Competition: Pay if **$(F_2 - F_1) > C$**
Coordination: Never pay since **$M_2<M_1$**

Board 4

Regulation Tradeoffs

Ex-ante (approvals, trials)		**Ex-post** (inspection, liability)
←less	Financing constraints	more→
←less	Risk appetite	more→
←more	Safety by fixed costs (pre-entry)	less→
←less	Safety by variable costs (post-entry)	more→
←*Concerned about adverse selection*		*Concerned about* → *moral hazard*

Board 5

Innovation Externalities

Externality		**Lever**
1. ⊕ **Hard to capture value: Customers** (imperfect price discrimination)		Thicker markets for technology
		Establish R&D consortium
2. ⊕ **Knowledge spillovers: Other firms** (imperfect price discrimination)		Agree on technology standards
		Promote a diversity of technologies
3. ⊖ **Creative destruction** (business stealing)	hurt	Encourage vertical integration
		Increase competition
4. ⊖ **Congestion** (duplicative efforts)	help	Encourage new, young entrants

\+ a *positive* externality ⇒ *under*-investment in innovation
− a *negative* externality ⇒ *over*-investment in innovation

help: amplify/reduce externality in a way that leads to *more* investment in innovation
hurt: amplify/reduce externality in a way that leads to *less* investment in innovation

Board 6

Innovation Incentives

Push ($ → work) "supply side"		**Pull** (work → $) "demand side"
←more	Financing constraints of innovators	less→
←less	Risk appetite of innovators	more→
←more	Can specify "good" innovators ex-ante	less→
←less	Can specify "good" technology ex-ante	more→
←*Concerned about adverse selection*		*Concerned about moral hazard*→

Board 7

Risk Pooling

A gamble: roll a 6-sided die

- *Rules: 1–5=you pay me $1M 6=I pay you $1B*
  Chance you win = $\frac{1}{6} \approx 16.7\%$
  Expected value = $\frac{1}{6} \times \$1B - \frac{5}{6} \times \$1M \approx \$166M$
- *Pool and split with 9 friends?*
  Expected value still $166M (per person)
  Chance ≥ 1 winner: $(1\text{-}p^n) = (1-(\frac{5}{6})^{10}) \approx 84\%$
  Payoff with 1 winner: $\frac{\$1B - \$9M}{10} = \$99.1M$ (per person)
- *Pool and split with 19 friends?*
  Chance ≥ 1 winner ≈ 97%
  Payoff with 1 winner = $98.1M (per person)
- *If rolls are correlated, e.g., ρ=0.5?*
  Chance ≥ 1 winner with 10 friends ≈ 57%
  Chance ≥ 1 winner with 20 friends ≈ 74%

Mega-fund

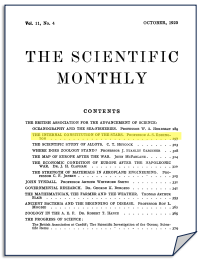
Pros
- Diversifies risk to increase capital access
- Can tailor risk

Cons
- Hard to know true probabilities and correlations
- Potentially reduce competition
- Fragility from concentrated holdings

Why?
- High fixed costs
- Long timelines
- Low individual success prob.
- High payoff if successful
- Risk-averse investors
  = positive externalities of coordinated fundraising

TN Appendix B—Slides (see Supplementary PowerPoint file)

A New (in 1920) Theory: Fusion Powers the Stars


Vol. 11, No. 4 OCTOBER, 1920

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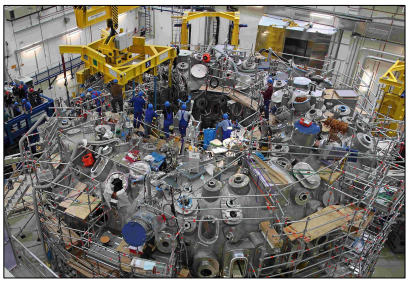
mass can not be annihilated, and the deficit can only represent the mass of the electrical energy set free in the transmutation. We can therefore at once calculate the quantity of energy liberated when helium is made out of hydrogen. If 5 per cent. of a star's mass consists initially of hydrogen atoms, which are gradually being combined to form more complex elements, the total heat liberated will more than suffice for our demands, and we need look no further for the source of a star's energy.

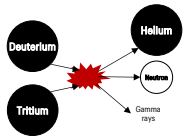
Source: The Scientific Monthly (1920), Vol. 11, No. 4 1

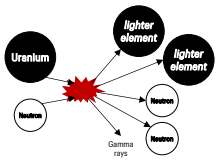
Bottling a Star



Source: Wendelstein 7-X Stellerator at the Max-Planck-Institut für Plasmaphysik (https://en.wikipedia.org/wiki/Fusion_power#/media/File:Wendelstein7-X_Torushall-2011.jpg) 2

Fusion vs. Fission





fusion

light elements fuse → heavy element + energy

hard to maintain

less radioactivity

fission

heavy element splits → light elements + energy

hard to stop

more radioactivity

Source: Case authors. 3

Fusion as a Power Source

Energy efficiency

$$Q = \frac{\text{energy produced}}{\text{energy used}}$$

net gain: $Q > 1$

Energy produced

$$n\,T\,\tau$$

closer — hotter — longer

"Lawson criterion" or "triple product"

Sources: Case authors and Philippe Laflochelle, Breakthrough Energy Ventures. 4

Legal Boundaries of Coordination

e.g., price fixing, anti-competitive hiring

Samsung Exec Gets Jail Time For Role In DRAM Price-Fixing Scandal

By Sharon Gaudin • December 22, 2006, 09:23 AM EST

Young Hwan Park, president of Samsung Semiconductor, Samsung's U.S.-based subsidiary, will serve 10 months in prison and pay a $250,000 fine. According to a written statement from the Department of Justice, he also has agreed to assist the government in its ongoing investigation.

This is the fifth Samsung executive to agree to a prison sentence in the dynamic random access memory, or DRAM, price-fixing investigation. Three foreign-based executives and one U.S. executive from the company have already pleaded guilty and agreed to serve prison terms ranging from seven to eight months. Each will pay a fine of $250,000.

Four companies and 18 people have been charged in the Justice Department's investigation into a price-fixing conspiracy surrounding DRAM. Criminal fines totaling more than $730 million also have been levied. According to the government, this represents the second-largest total amount of fines ever imposed in a U.S. criminal antitrust investigation into one price-fixing conspiracy.

Justice Department Requires Six High Tech Companies to Stop Entering into Anticompetitive Employee Solicitation Agreements

Friday, September 24, 2010

For Immediate Release

Office of Public Affairs

WASHINGTON — The Department of Justice announced today that it has reached a settlement with six high technology companies – Adobe Systems Inc., Apple Inc., Google Inc., Intel Corp., Intuit Inc. and Pixar – that prevents them from entering into no solicitation agreements for employees. The department said that the agreements eliminated a significant form of competition to attract highly skilled employees, and overall diminished competition to the detriment of affected employees who were likely deprived of competitively important information and access to better job opportunities.

Sources: Gaudin, S., "Samsung Exec Gets Jail Time For Role In DRAM Price-Fixing Scandal." CRN, Dec. 22, 2006.
US Department of Justice, "Justice Department Requires Six High Tech Companies to Stop Entering into Anticompetitive Employee Solicitation Agreements," Sep. 24, 2010.

5

Industry Associations: Regulation

National Community Television Association

Gus Pahoulis (Plaintiff) v. United States of America (Defendant)
United States Court of Appeals, Third Circuit
Mar 22, 1957

The problem is whether the service charge for a community television antenna is within the intendment of Section 3465(a) (2)(B) which provides:

'A tax equivalent to 8 per centum of the amount paid for any wire and equipment service.'

There must be some reasonable limitation of the phrase 'any wire and equipment service' otherwise rentals of televisions, radios, record players, public address systems and a host of other electrical gadgets would be swept under the levy; a result clearly not intended.

Judgment is entered in favor of the plaintiff.

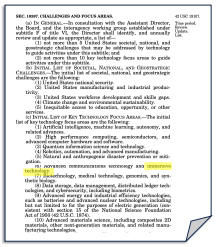
NCTA gets cable exempt from 8% tax on "wired communications"

Sources: Case authors' abbreviation of *Pahoulis v. US* (1957);

6

Industry Associations: Funding

XR Association



SEC. 10707. CHALLENGES AND FOCUS AREAS.

(a) IN GENERAL.—The Director, acting through the Assistant Director, the Board, and the subcommittee working group established under subtitle F of title VI, the Director shall identify, and annually review and update as appropriate, a list of—

(1) societal, national, and geostrategic challenges that may be addressed by technology to guide activities under this subtitle; and

(2) not more than 10 key technology focus areas to guide activities under this subtitle.

(b) INITIAL LIST OF SOCIETAL, NATIONAL, AND GEOSTRATEGIC CHALLENGES.—The initial list of societal, national, and geostrategic challenges shall include—

(1) United States national security;

(2) United States manufacturing and industrial productivity;

(3) United States workforce development and skills gaps;

(4) Climate change and environmental sustainability;

(5) Inequitable access to education, opportunity, or other services.

(c) INITIAL LIST OF KEY TECHNOLOGY FOCUS AREAS.—The initial list of key technology focus areas are the following:

(1) Artificial intelligence, machine learning, autonomy, and related technologies.

(2) High performance computing, semiconductors, and advanced computer hardware and software.

(3) Quantum computing and related technology.

(4) Robotics, automation, and advanced manufacturing.

(5) Natural and anthropogenic disaster prevention or mitigation.

(6) advanced communications technology and innovative technologies.

(7) Biotechnology, medical technology, genomics, and synthetic biology.

(8) Data storage, data management, distributed ledger technology, and cybersecurity, including biometrics.

(9) Advanced energy and industrial efficiency technologies, such as batteries and advanced nuclear technologies, including but not limited to technologies described in section 951(b)(2)(A) of the Energy Policy Act of 2005 (42 U.S.C. 16231(b)(2)(A)).

(10) Advanced materials science, including composites 2D materials, other next-generation materials, and related manufacturing technologies.

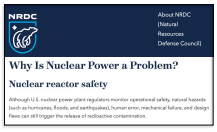
XRA gets "immersive technologies" on priority list in CHIPS Act

Sources: XR Association; H.R.4346—CHIPS and Science Act of the 117th Congress (2021–2022).

7

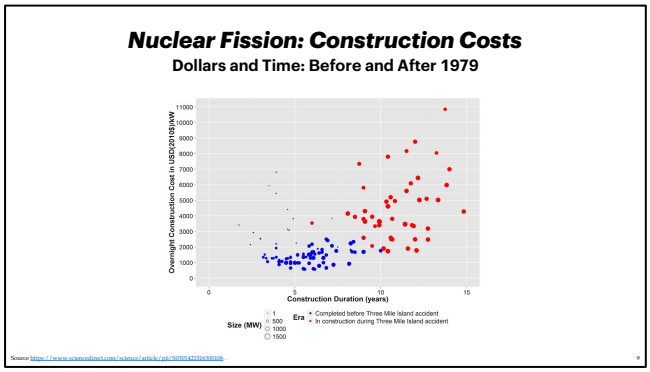
Nuclear Fission: Consumer Opposition

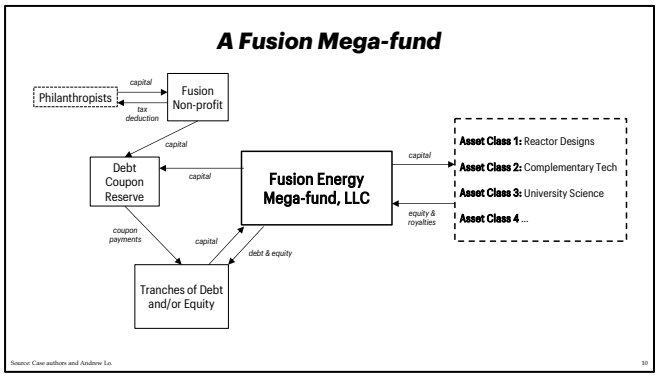
Sierra Club, Natural Resources Defense Council, World Wildlife Fund



Sources: https://www.sierraclub.org/nuclear-free; https://www.nrdc.org/stories/nuclear-power-101#problems; https://wwfeu.awsassets.panda.org/downloads/external_briefing_gas_nuclear_ _insld.pdf .

8


Nuclear Fission: Construction Costs
Dollars and Time: Before and After 1979
Overnight Construction Cost in USD(2015)/kW
Construction Duration (years)
Size (MW)
Era
Completed before Three Mile Island accident
In construction during Three Mile Island accident


A Fusion Mega-fund
Philanthropists
capital
tax deduction
Fusion Non-profit
capital
Debt Coupon Reserve
capital
Fusion Energy Mega-fund, LLC
capital
equity & royalties
Asset Class 1: Reactor Designs
Asset Class 2: Complementary Tech
Asset Class 3: University Science
Asset Class 4 ...
coupon payments
capital
debt & equity
Tranches of Debt and/or Equity

Endnotes

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