What can nuclear power teach us about the institutional adoption of clean meat?

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Abstract

Studies on clean meat adoption have mostly focused on consumer acceptance, but institutional choices by governments, industries, and news media can also delay or accelerate the adoption of new technologies. This report examines the factors that contributed to nuclear power's widespread adoption in France and applies those findings to the question of how to advance the adoption of clean meat. Among other conclusions, this report finds that supply constraints on a competing good can accelerate the adoption of a new technology, that technical explanations about why a new product is safe are likely to backfire, that safety incidents that appear to confirm preexisting concerns are especially damaging to a new technology, and that states reliant on imports to meet their needs for a good or service are more promising targets for the early adoption of substitute technologies than states that are more self-reliant.

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>
> — Frank Baumgartner and Bryan Jones, "Agenda Dynamics and Policy Subsystems"

Introduction

This case study examines the rise of nuclear power in France. Beginning in the 1970s, France underwent far-reaching energy nuclearization. The country went from drawing over half of its power from oil-burning plants in the early 1970s to drawing 75% of its electricity from nuclear plants by 1990.[1] Every other high-income country failed to undergo similar levels of nuclearization. In the United States, nuclear power has never exceeded 21% of electricity generation. Nuclear power and its uptake maps one future possibility space for clean meat (also known as cultured meat, i.e. meat grown from animal cells outside of animal bodies): a nascent technology, developed in laboratories for decades, must transition into the technology stack used to produce electricity or food for the general public and in large institutional settings.

Many studies in the area of clean meat adoption have focused on consumer acceptance.[2] Relying on consumer choice (i.e. individuals choosing to buy products associated with the new

[1] Nuclear Power in France, World Nuclear Association, accessed October 27, 2017, http://www.world-nuclear.org/information-library/current-and-future-generation/world-energy-needs-and-nuclear-power.aspx; Electricité de France History, Funding Universe, accessed October 27, 2017, http://www.fundinguniverse.com/company-histories/electricit%C3%A9-de-france-history/; Andrew Holmes, *Electricity in Europe: Power and Profit* (London: Financial Times Business Information Ltd., 1990).

[2] E.g., Aurélie Hocquette et al., "Educated consumers don't believe artificial meat is the solution to the problems with the meat industry," *Journal of Integrative Agriculture* 14 (2015): 273–284; Gerben A. Bekker et al., "Explicit and Implicit Attitude Toward an Emerging Food Technology: The Case of Cultured Meat," *Appetite* 108 (2017): 245–254; Wim Verbeke et al., "'Would you eat cultured meat?': Consumers' Reactions and Attitude Formation in Belgium, Portugal and the United Kingdom," *Meat Science* 102 (2015): 49–58.

technology, such as at a grocery store or restaurant) as a method of social or technical change, however, has shortcomings.[3] Though consumer acceptance or resistance is almost certain to play a role in the adoption of clean meat, institutional uptake (e.g. institutions like college cafeterias and ready-to-eat meal producers switching their supply chain to the new technology) remains an understudied phenomenon that accounts for a significant amount of food production and can itself hasten or delay consumer acceptance, such as by accustoming consumers to the new technology.

In the case of animal-free meat,[4] accelerating widespread adoption by one year could avoid the killing of approximately 907 billion animals. The U.N. Food and Agriculture Organization estimates that 56 billion farmed land animals are killed every year for human consumption. Mood and Brooke estimate that between 37 and 120 billion farmed fish and between 970 and 2,700 billion wild fish are killed yearly. An additional 448 to 1,025 billion fish are used to produce fishmeal and fish oil (mostly for aquaculture feed). Using the most conservative estimates available and assuming a 60% reduction in deaths brought about by animal-free meat indicates that 906.6 billion animal deaths would be averted by clean meat in one year. Assuming middle-range numbers and a 90% reduction from clean meat suggests that 2.44 trillion animal lives would be spared per year. (These estimates do not include bait fish, bycatch, or illegal and unreported catch and are therefore probably undercounts.)[5]

Clean meat could function as a substitute good for animal protein in the industrial-scale supply chains that feed schools, hospitals, militaries, refugee camps, large corporations, and provide foreign food aid. The institutional uptake of clean meat could avert a large amount of animal

[3] See Jacy Reese, "Confrontation, Consumer Action, and Triggering Event," Animal Charity Evaluators paper, July 15, 2014, https://www.academia.edu/13749264/Confrontation_Consumer_Action_and_Triggering_Events; Consumer Action, The Abolition Project, available at http://abolition.e2bn.org/campaign_17.html; and Kelly Witwicki, "Social Movement Lessons From the British Antislavery Movement: With a Focus on Applications to the Movement Against Animal Farming," Sentience Institute, forthcoming, December 1, 2017, www.sentienceinstitute.org/lessons-from-the-british-antislavery-movement.

[4] While this report focuses on cell-cultured meat, the discussion can also apply to sophisticated plant-based foods like the Impossible and Beyond Burgers, including animal-free dairy and egg products.

[5] See U.N. Food and Agriculture Organization, FAOSTAT Statistical Database, apps.fao.org; A. Mood and P. Brooke, "Estimating the Number of Fish Caught in Global Fishing Each Year," fishcount.co.uk, July 2010; and A. Mood and P. Brooke, "Estimating the Number of Farmed Fish Killed in Global Aquaculture Each Year," fishcount.co.uk, July 2012. For one reason to exercise caution when estimating what percentage of animal products will be replaced by clean meat, see *Clean meat might not function as a straightforward substitute good for animal meat* below.

suffering while establishing the infrastructural groundwork for food-production supply chains that do not depend upon animal farming.

Studying how the institutional uptake of emergent technologies occurs, therefore, is relatively important and relatively neglected for those who aim to facilitate the adoption of clean meat to reduce animal meat consumption.

Overall, this report provides evidence for the following claims:

- Reductions in the supply of a good tend to raise prices for that good and open a critical window for the adoption of a competitive good. Nuclear energy benefited from this dynamic when oil was subject to price shocks in the 1970s. Clean meat adoption could be accelerated by supply shocks for animal products.

- Some factors that influence the available supply of a good, like weather events, are out the control of activists and advocates. Others, like regulation, can be influenced by focused campaigns. Focusing on regulation, corporate campaigns, welfare improvements, labor activism, supply chain disruption, and other factors that can constrict the supply of a target good is an effective way of increasing the price of that good, decreasing quantity consumed, and accelerating the adoption of replacement goods like clean meat.

- Different types of supply shocks have different dimensions that can make them more or less potent. Activist campaigns should be attentive to how fears over food supply reliability evoke national security concerns, how *E. coli* or bovine spongiform encephalopathy recalls heighten public worry about the uncleanliness of factory-farmed meat, and how extreme weather events both threaten food supply chains and bring the connection between climate change and animal farming to the fore.

- There are good reasons to be cautious of relying on technically-informed, scientifically-sound explanations for why clean meat is safe to shift public sentiment in a positive direction. Public discourse tends to be both mercurial and suspicious about technical arguments for the safety of a new technology. There is even evidence for a backlash effect in which increased discussion of technical safety issues, even if these discussions explain why a new product is safe, tends to increase rather than decrease negative sentiment around a new technology.

- For an emerging technology, the tone and content of media coverage matters a great deal. There is evidence that positive or negative coverage is a leading rather than lagging indicator of public sentiment.

- Clean meat developers should be especially wary of risking safety incidents that would confirm or appear to confirm preexisting concerns or narratives about clean meat. This dynamic was especially damaging to nuclear power.

- Government centralization and technocracy shape the adoption of new technologies. For example, a closed, highly centralized decision-making process is generally better able to insulate itself from opposition, especially site-specific opposition, than is a relatively open, decentralized process. Perceptions among high-level bureaucrats about the way a new technology complements or conflicts with their vision of the state also influences institutional adoption. Because utility-scale power is regulated, built, and purchased differently from food products, it is hard to know how these factors will affect the adoption of clean meat.

- Technically-adept states that depend on food imports are likely to be more receptive to the institutional adoption of clean meat than states that do not have these characteristics. So far, most clean meat companies have focused on the US market. States like Singapore remain underrated as potential early adopters of clean meat.

Why did France adopt nuclear power?

Starting in the mid-1950s, the possibility of using nuclear fission to generate power transitioned from laboratories in the United States and the Soviet Union to power-producing public works projects. From 1957 to 1966, France installed seven gas-cooled nuclear reactors. From 1971 to

1991, the country brought 59 light-water reactors online.[6] Nuclear power grew from 3.9% of energy generation in 1970 to 77.7% in 2015.[7]

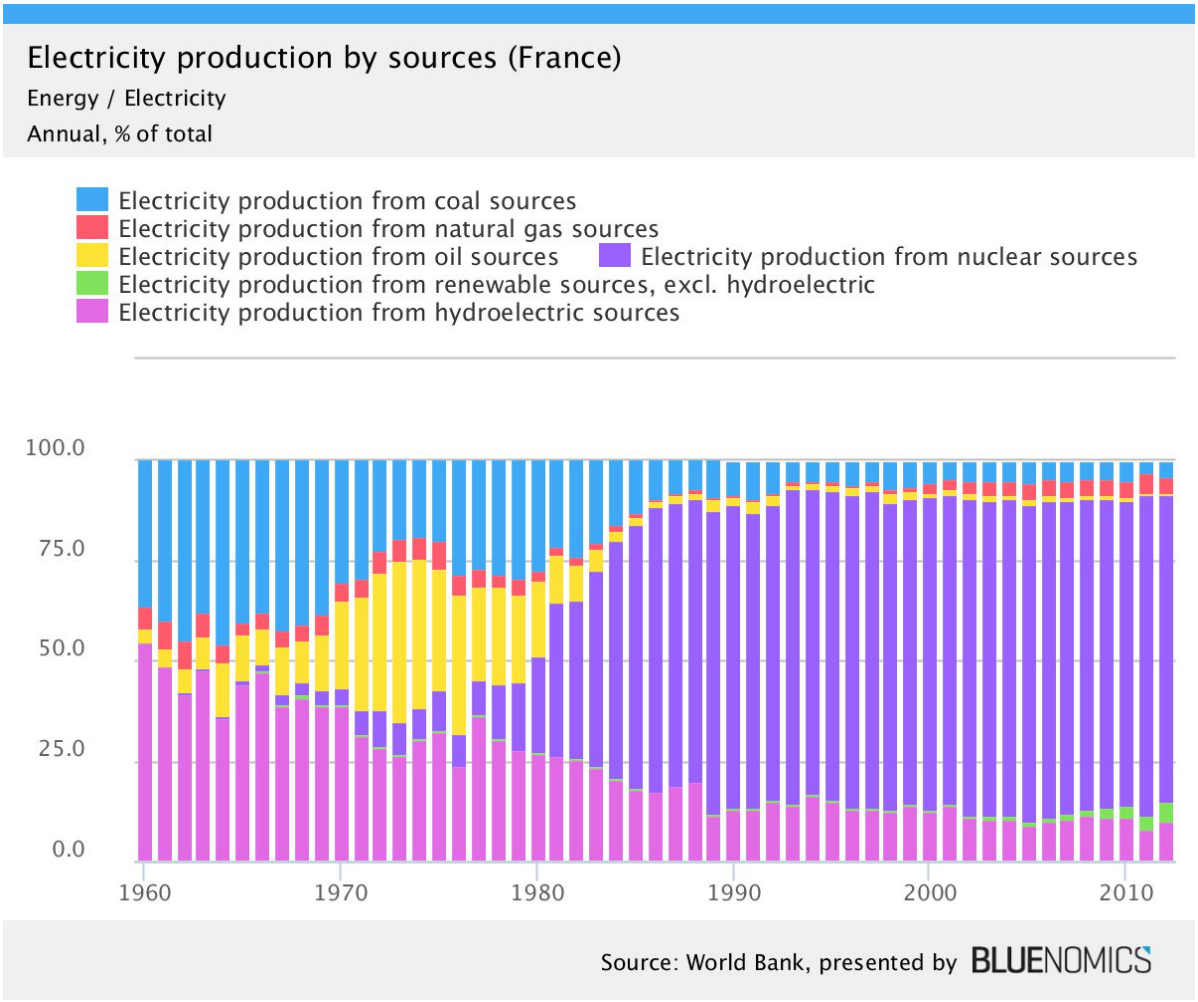

Figure 1. Bluenomics with data from Electricity production tables, IEA Statistics, World Bank, https://data.worldbank.org/indicator/EG.ELC.NUCL.ZS?locations=FR.

No other government, before or since, has undertaken a comparable effort to build out its nuclear capacity. Today, France's reliance on nuclear power stands alone among all states, rich or

[6] Jessica R. Lovering Arthur Yip, Ted Nordhaus, "Historical construction costs of global nuclear power reactors," *Energy Policy* 91 (2016): 378.

[7] Electricity production from nuclear sources (% of total), IEA Statistics, World Bank, accessed November 24, 2017, https://data.worldbank.org/indicator/EG.ELC.NUCL.ZS?locations=FR.

poor. Why was nuclear power taken up rapidly in France, and why did other states not do the same?

The academic literature gives us this basic roadmap:

- Through the 1950s, France largely burned oil for electricity.[8] This oil supply was 99% imported and therefore subject to disruption.[9] The oil shock of 1973 more than tripled the price of imported oil for France.[10]

- Nuclear was seen by French engineers and policymakers as reliable and less volatile than oil.[11] Pierre Messmer, in a top-down decision, announced a plan in March of 1974 to build 80 new reactors over the following 22 years.

- France largely carried out the Messmer plan. The antinuclear movement grew alongside nuclear power, as in other European countries, but remained mostly ineffective.

If nuclear was a top-down decision, how did French citizens react? French support for nuclear plants has remained relatively positive from the 1970s on. Most public opinion polling in the years following the Messmer plan shows French support in the 60% range.[12] Approval dipped to 46% in the immediate aftermath of the Chernobyl disaster, but resumed a slow rise in polls taken just six months later.[13] The OECD Nuclear Energy Agency reports that confidence in a nuclear regulators and operators is significantly higher in countries with active nuclear programs. See this

[8] Electricité de France History, Funding Universe, accessed October 27, 2017, http://www.fundinguniverse.com/company-histories/electricit%C3%A9-de-france-history/; Andrew Holmes, *Electricity in Europe: Power and Profit* (London: Financial Times Business Information Ltd., 1990).

[9] Aurélie Élisa Gfeller, *Building a European Identity: France, the United States, and the Oil Shock, 1973-74* (New York: Berghahn Books, 2012), 116.

[10] Ibid., 115-117.

[11] James Jasper, *Nuclear Politics: Energy and the State in the United States, Sweden, and France* (Princeton: Princeton University Press, 2014), 148-77.

[12] Jean-Pierre Chaussade, "Public confidence and nuclear energy," IAEA bulletin, 1990, 7-9 and David Lewis Feldman, "Public Choice Theory Nuclear Power Applied to France" *Journal of Public Policy* 6, no. 2 (1986): 137-158.

[13] Ibid.

NEA graph, in which the dark circles denote countries with nuclear programs and lighter circles those without:

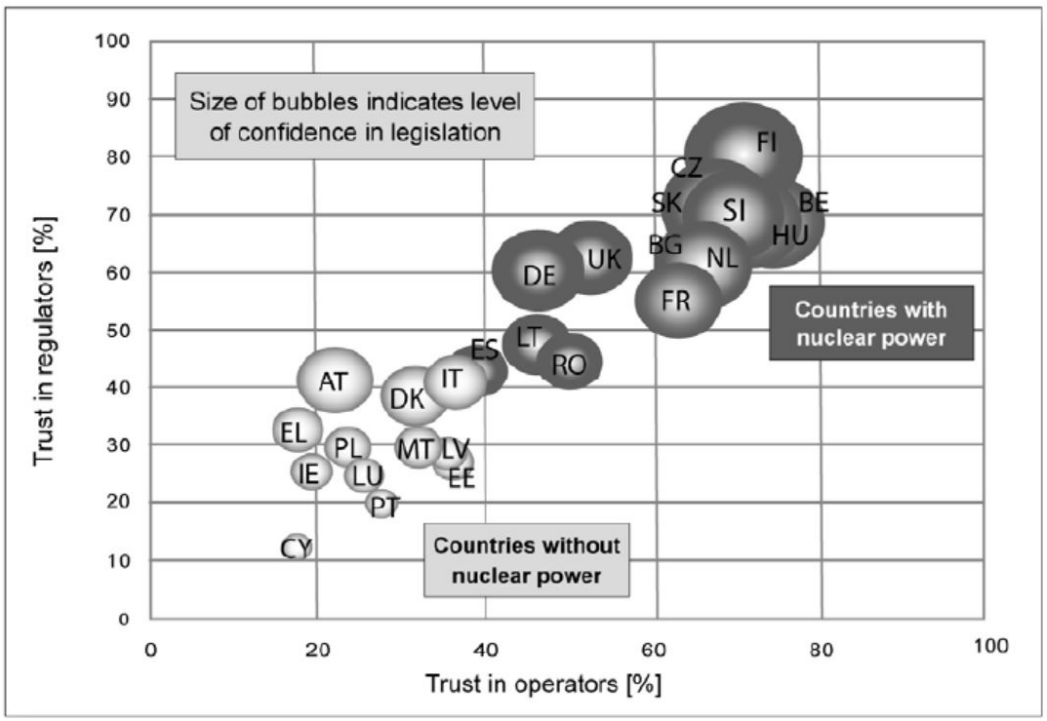

Figure 2. "Confidence in nuclear regulators, operators, and legislation." See Nuclear Energy Agency, "Public Attitudes toward Nuclear Power," OECD, 2010, https://www.oecd-nea.org/ndd/pubs/2010/6859-public-attitudes.pdf.

In general, it appears that the top-down decision to build French nuclear electricity capability did not provoke a fatal backlash among the French public. True, the Messmer Plan inspired protest, and anti-nuclear groups grew up in France as they did in other countries experimenting with nuclear power at the time.[14] However, public opinion toward nuclear in non-nuclear countries

[14] See, e.g., Alain Touraine, *Anti-Nuclear Protest: The Opposition to Nuclear Energy in France* (Cambridge, MA: Cambridge University Press, 1983); Jerome Price, *The Antinuclear Movement* (Boston: Twayne Publishers, 1990); and John Surrey and Charlotte Huggett, "Opposition to Nuclear Power," *Energy Policy* (1976): 286-307.

remained far frostier than in countries with nuclear power programs. If there was a backlash effect, it appears to have been outweighed by a familiarity effect of some kind.[15]

Claude Mandil, the former Executive Director of the International Energy Agency, suggests three reasons for French support of nuclear power:

- Fear of dependence on foreign powers for energy: a "popular French riposte to the question of why they have so much nuclear energy is 'no oil, no gas, no coal, no choice'";

- "France has a tradition of large, centrally managed technological projects…. 'French people like large projects. They like nuclear for the same reasons they like high speed trains and supersonic jets'"; and

- "the French authorities have worked hard to get people to think of the benefits of nuclear energy as well as the risks. Glossy television advertising campaigns reinforce the link between nuclear power and the electricity that makes modern life possible. Nuclear plants solicit people to take tours—an offer that six million French people have taken up."[16]

It is likely that the widespread adoption of nuclear power generated its own kind of momentum and support in France within and beyond elite circles. Frank Baumgartner and Bryan Jones write (as in the epigraph of this report) that "public discourse when traced over long periods of time tends to show a fascination with one aspect of the issue to the exclusion of the other, at any given time. While individuals might be able to recognize that the same issue has both good and bad sides, public attention as it is reflected in media coverage tends to focus on one or the other. Over time, attention may shift from virtual euphoria to an equally one-sided preoccupation with negative aspects of the same policy or industry."[17] In France, interlocking narratives about nuclear power emphasized its reliability, its status as a monument to French engineering, and its necessity in the face of scarce domestic sources of energy. This pro-nuclear image was durable against a number of safety incidents in the early decades of French nuclear power, including the

[15] For more evidence of the link between having a nuclear program and approving of nuclear power, see NEA, "Public Attitudes toward Nuclear Power," OECD, 2010, https://www.oecd-nea.org/ndd/pubs/2010/6859-public-attitudes.pdf.

[16] Interview and report by Jon Palfreman, "Why The French Like Nuclear Power," *PBS*, accessed November 20, 2017, http://www.pbs.org/wgbh/pages/frontline/shows/reaction/readings/french.html.

[17] Frank R. Baumgartner and Bryan D. Jones, "Agenda Dynamics and Policy Subsystems," *The Journal of Politics* 53, no. 4 (1991): 1046.

partial meltdown of a gas-graphite reactor at Saint-Laurent in late 1969.[18] The triggering event for widespread French uptake of nuclear power was almost certainly the oil shock of 1973.

The oil shock of 1973

In October 1973, as a result of US support for Israel in the Yom Kippur War, the Organization of Arab Petroleum Exporting Countries began to cut oil production. From October 1973 to January 1974, the price of a barrel of oil went from $2.90 to $11.65.[19] This exposed states dependent upon imported oil to significant risk. Western Europe as a whole imported 99% of its oil in 1972. France was more dependent still: vulnerability to supply constraints was "particularly high in France and much lower in the United States. French oil imports as a share of total energy consumption rose from 69 percent in 1971 to 75 percent in 1973." Oil's share of total energy consumption in Western Europe generally was 50%. The United States, long an oil producer, "relied on foreign oil to meet only 35 percent of its energy needs."[20]

In response to the oil shock, French PM Pierre Messmer announced (unexpectedly, and with no open deliberation) in March 1974 that France would embark on a program of energy independence via nuclear power. Messmer announced that France would build 80 nuclear reactors over the next twenty years. The government eventually built 59 nuclear reactors and today meets 75% of its electricity needs with nuclear power.

Peering inside the decision to enact the Messmer Plan is difficult in part because the plan seems to have been formulated with so little debate inside or outside of government. Even the best-sourced accounts generally rely at some point on rumor or innuendo. Near the peak of the oil crisis, James Jasper writes, France's top nuclear advisory committee (the *commission pour la Production d'Électricité d'Origine Nucléaire*, or simply the PEON commission) "was again asked to make recommendations concerning the growth of nuclear energy. It quickly developed the 13,000 MWe figure, as opposed to 8,000 MWe for the same two years in the earlier plan. The 13,000 MWe plan was chosen because it seemed to be the maximum effort French industry could

[18] Gabrielle Hecht, *The Radiance of France* (Cambridge, MA: MIT Press, 2009), 271. Interestingly, the meltdown at Saint-Laurent *did* have the effect of contributing to the demise of gas-graphite reactors in favor of a light-water design that paved the way for the French reactor program we know today.

[19] Michael Corbett, "Oil Shock of 1973-74," Federal Reserve History, accessed October 19, 2017, https://www.federalreservehistory.org/essays/oil_shock_of_1973_74 and Gfeller, *European Identity*, 120-21.

[20] Gfeller, *European Identity*, 116-17.

make toward nuclear energy. The government adopted the new recommendations in their entirety, after only three days of consideration—at least according to a popular rumor."[21] In the end, Jasper argues, the decision resulted from a contingent combination of technological enthusiasm among French elites, individual discretion, political expedience, and personality:

> Nuclear power had the allure of a dramatic and modern technology, much like the Apollo missions or the Concorde. Messmer jumped at it, while [US President] Ford retreated. First, Messmer faced a possible election in two months, and Ford in two years. Second, the moves that would be needed to support nuclear energy in the two countries were quite different. In France it was an elegant announcement releasing certain institutional energies. In the United States it would have been a complex scheme involving utility financing and rate relief for something called CWIP (construction work in progress), hardly the stuff of myth. But in the end, we find choices made by top political leaders on the basis of their own preferences and policy styles. They had to choose which argument to believe.[22]

Interestingly, the US also announced its own Messmer-style plan during the 1973 oil shock. Project Independence, announced by Richard Nixon, aimed to build 1,000 nuclear reactors in the US by the end of the 20th century. In 1991, the US reached a high-water mark of 112 functioning reactors. US nuclear power has never risen above 21% of total electricity generation. Why was the Messmer Plan mostly carried out and Project Independence (and other proposals like it) mostly not carried out? In other words, why was the 1973 oil shock a successful trigger for the adoption of nuclear in France and a mostly-unsuccessful trigger in the US?

The first salient reason has to do with France's heavy reliance on imported oil and the US's relative abundance of domestic sources of oil. The second main reason has to do with the fact that opposition to nuclear power in the United States was able to translate itself into meaningful political opposition while in France it was not.[23] This difference in translation had to do with

[21] Jasper, *Nuclear Politics*, 157.

[22] Ibid., 158.

[23] For a similar two-phase approach to explaining the difference in nuclearization between France, the US, and West Germany, see Dieter Rucht, "The impact of anti-nuclear power movements in international comparison," *Resistance to New Technology*, ed. Martin Bauer (New York: Cambridge University Press, 1995), 288-90. (Rucht actually uses a

French attitudes about technical expertise and centralized decision-making and with American decentralization and the meltdown at Three Mile Island in Pennsylvania. In short, the US had more affordable and secure alternatives to nuclear power and an opposition movement that had its fears confirmed by a well-publicized accident and that was not frozen out by an insular bureaucracy.

State centralization and technocracy

France's centralized administrative state was guided at high levels by technocratic administrators insulated from low-level opposition. Gabrielle Hecht writes that these technocrats are "trained in the elite schools known as grandes écoles [and] make many of the nation's industrial and financial policy decisions" and that "the means through which this elite exerts power remain murky." Naturally, French technocrats aver that they're in high places for a reason: their power flows from the fact that "only they are qualified to make certain decisions." Critics of French technocracy describe instead "a system of social privilege that enables [this elite] to create a closed community" in which the "language of technical rationality and professional competence serves as a tool of exclusion and a cover for raw power."[24] Both views capture different true aspects of the French technical bureaucracy. The system is exclusionary, technically-skilled, centralized, and insulated from popular opinion and lower levels of government.

Alain Touraine recounts how government centralization in France contributed to insulating pro-nuclear technocrats from local opposition and protest movements. Unlike the US system, in which elected representatives understand themselves as communicating their constituents' views *to* Washington, "the job of local representatives in France was to communicate the desires of the national government to the citizens."[25] Influence radiated from Paris. The French geography of power was especially important in the case of nuclear development because, as John Surrey and Charlotte Huggett note, opposition to nuclear plants is often *site-specific*. Opposition grows at potential nuclear plant sites and extends from there, establishing links with other sites, gathering

three-pronged approach, but the third prong is something of a fudge factor that includes e.g. "contingent events." His first two phases are broadly similar to the two main reasons I've offered here.)

[24] Hecht, *Radiance*, 10-11.

[25] Touraine, *Anti-Nuclear Protest*, 62. Moreover, Touraine notes, French political discourse at the time emphasized civility and deemphasized conflict as an aspect of legitimate political discourse in a way that, e.g., the US system did not. (See Touraine, 64.)

momentum and credibility, and attempting to move up the political chain.[26] In large part because of governmental centralization and technocracy, French protest movements against nuclear were unable to translate themselves into effective political opposition.

The centralization and technocracy of the French government also contributed to government intervention in and operation of French nuclear plants: "The French government now holds 90 percent of shares in Areva, the firm that builds nuclear reactors, and 85 percent of Electricité de France (EDF), the utility that operates them."[27] This engendered standardization: "the French selected just one American reactor model and charged one agency, EDF, to run the system for the nation." By contrast, "America's decentralized system meant that from the start it was a messy and expensive free-for-all, many different designs managed by many different utilities."[28]

Clean meat is likely to be less centralized than nuclear power. However, what was "a messy and expensive free-for-all" with respect to permitting and the economics of power generation could lead to a diversity of products and approaches that contribute to the eventual attractiveness and competitiveness of clean meat products. I remain uncertain about what role standardization and centralization, necessities for power plants, will play in the scaling and adoption of clean meat.

French nuclear decline?

Most experts predict that nuclear's share of French electricity generation will shrink in the 2020s, mostly due to knowledge obsolescence, aging plants, and political demands for renewable energy.[29] This decline scenario suggests reassuring and worrying scenarios for how clean meat could decline after it had become popular. Consider one analogous clean meat scenario: cultured meat has been dominant for the middle decades of the 21st century. However, the first major

[26] Surrey and Huggett, "Opposition," 288-89.

[27] Umair Irfan, "France Loses Enthusiasm for Nuclear Power," *Scientific American*, June 29, 2015, https://www.scientificamerican.com/article/france-loses-enthusiasm-for-nuclear-power/.

[28] Jon Palfreman, "Tapes and Transcripts | Nuclear Reaction," *PBS*, accessed November 7, 2017, http://www.pbs.org/wgbh/pages/frontline/shows/reaction/etc/script.html. Note that several post-Soviet states have unusually high nuclear electricity generation (Slovakia and the Ukraine are the highest outside of France at about 50% of electricity), possibly for similar reasons.

[29] "France's nuclear-energy champion is in turmoil," *The Economist*, December 1, 2016, https://www.economist.com/news/business/21711087-electricit-de-france-has-had-shut-down-18-its-58-nuclear-reactors-frances-nuclear-energy and "French energy transition bill adopted," *World Nuclear News*, July 23, 2015, http://www.world-nuclear-news.org/NP-French-energy-transition-bill-adopted-2307155.html.

generation of clean meat scientists is aging out and clean meat is now being challenged by newer food production techniques that are safer, cleaner, decentralized, still involve little animal suffering, and (although still more expensive in most scenarios) falling in price—perhaps sophisticated plant-based substitutes similar to the Impossible Burger. This scenario presents little worry. It is broadly analogous to, say, advanced and inexpensive solar photovoltaic power versus nuclear power.

There is, however, a closely related scenario that is concerning: cultured meat has been dominant for the middle decades of the 21st century. However, the first major generation of clean meat scientists is aging out and clean meat is now being challenged by newer food production techniques that are safer, cleaner, slightly more centralized, involve relatively more animal suffering, and (although still more expensive in most scenarios) falling in price—perhaps some form of insect agriculture that meets these criteria. This scenario is more akin to, say, a resurgence of cheap natural gas (extracted and transported by novel methods) as a replacement for nuclear power. On long time horizons, technological development tends to be radically unpredictable. It is certainly possible that economic or ecological shifts (e.g., food price shocks brought on by global declines in arable land in the second half of the 21st century) could push future food production technology toward exploiting animals in ways heretofore unanticipated.

Lessons

Resource availability

French officials were convinced to nuclearize the French electricity system in large part because France lacked domestic sources of coal and oil.[30] As imported oil became expensive and unreliable, concerns about national security and economics alike made nuclear power seem increasingly necessary. If France had possessed domestic sources of energy, it is likely its transition to nuclear power would have resembled that of the US: slower, shallower, and more incomplete.

[30] For an account of how resource availability is braided with and depends upon institutional worldviews and bureaucratic interpretations of available technologies and resources, see Jasper, *Nuclear Politics*.

There are two lessons to draw from resource availability. First, countries with weak or nonexistent domestic production of animal products present overlooked opportunities for a clean meat market that has mostly focused on the US. Second, making animal products more difficult to produce domestically is likely to render clean meat more competitive sooner. For an exploration of the first lesson, see *The case for Singapore* below. I'll unpack the second lesson here.

The French case indicates that switching to clean meat can be accelerated by advocacy and regulations that increase the price, difficulty, and unreliability of producing animal meat. A "meat shock" could precipitate a large institutional transition to clean meat, as did an oil shock in the French context, but only if clean meat technology is ready to scale (or can be made ready) at the time of the shock. Note that shocks don't necessarily need to involve an immediate break: imagine a "slow meat shock"[31] in which concern for animals/repeated *E. coli* and mad cow scares/rising prices gather weight over time. Possible sources of a meat shock include:

Supply constraints

In economics parlance, this involves the supply curve for animal products shifting to the left. The 1973 oil shock is itself a famous example of the effects of the supply of a good being constrained. Expanding demand coupled with flat, declining, or slowly-rising supply is the traditional recipe for rapid increases in price. The idea of price shocks for food have been of continuing concern to economists. Take this 2010 USDA report on food commodity prices as an example: "World market prices for major food commodities such as grain and vegetables have risen sharply to historic highs of more than 60 percent above levels just 2 years ago. Many factors have contributed to a tightening of world balances of grains and oilseeds over the last decade [including] increased demand for biofuels[,] feedstocks[,] and adverse weather conditions in 2006 and 2007 in some major grain- and oilseed-producing areas [as well as] rising energy prices [and] increasing agricultural costs of production."[32] Clearly, a variety of different factors can generate supply constraints. Some of these factors, like increasing production costs by way of regulation, can be influenced by focused activism.

[31] Though I'm using the term "meat shock" (for its brevity and directness if nothing else), these observations apply to animal products generally. Also, please note that although the term "shock" in economics traditionally refers to the sudden and unpredictable effect of an exogenous variable, not all the points I'll discuss here fit neatly under that heading.

[32] Ronald Trostle, "Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Commodity Prices," USDA Economic Research Service, 2010.

Conner Mullally and Jayson Lusk have found that animal welfare reforms passed by California in 2008 have constricted supply and raised egg prices in that state. After the laws went into effect in January 2015, "by July 2016, both egg production and the number of egg-laying hens were about 35% lower than they would have been in the absence of the new regulations."[33] The sticker price for a dozen eggs was "about 22% higher from December 2014 through September 2016 than it would have been in the absence of the hen housing restrictions." While animal advocates will cheer 35% fewer egg-laying hens in the short term,[34] the more important long-term dynamic involves the setting of a higher equilibrium price for eggs at which quantity consumed is lower. This higher price point doesn't just discourage consumption: it makes cultured egg products (e.g. "hen-free egg whites" like those being developed by Clara Foods) price competitive months or years before they otherwise would be, setting in place a major condition for accelerated adoption. Note that a supply crunch and resulting higher prices can be triggered by any number of variables: welfare reforms, increases in animal feed prices, weather, transportation costs, sickness among hens, new food safety regulations, labor market conditions, and so forth.

Lewis Bollard, for example, uses the Sierra Club's campaign against coal to suggest that animal advocates "focus national efforts on integrating negative and positive externalities into prices [of factory-farmed animal products]." He points out that the Sierra Club campaign, Beyond Coal, "started 15 years ago with a strategy to enact both tougher rules on coal and larger subsidies for renewables, so that the prices of each would better reflect their social value. Similarly, we can push for animal welfare, environmental, and labor regulation of factory farms, while also pushing for subsidies for more humane alternatives, like plant-based and clean meat." Bollard also suggests "focus[ing] local efforts on bottlenecks for the industry," like critical infrastructure construction, in an attempt to shift supply curves leftward.[35]

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[33] Conner Mullally and Jayson L. Lusk, "The Impact Of Farm Animal Housing Restrictions on Egg Prices, Consumer Welfare, and Production in California," *American Journal of Agricultural Economics* (2017), https://doi.org/10.1093/ajae/aax049.

[34] Short term, of course, because Mullally and Lusk find evidence that, as expected, egg prices began to creep downward after their initial sharp rise and consumption began to recover after its initial fall, in part because egg imports began to make up for California's domestic shortfalls. The overall effect, however, is still higher prices (just not 22% higher) and fewer eggs consumed (just not 35% fewer).

[35] Lewis Bollard, "We're Going Beyond Coal. Could We Go Beyond Factory Farming?" Open Philanthropy Project Farm Animal Welfare Newsletter, accessed November 25, 2017, http://mailchi.mp/3bdc58236098/could-we-go-beyond-factory-farming.

(In fact, Martin Bauer posits that a similar dynamic has changed the nuclear industry: "The industry, by complying with safety standards to render nuclear power more acceptable, incurs increasing costs. Safety expectations in the public have increased the costs of building, running and waste disposal for nuclear power plants to an extent that makes its economic viability doubtful in competition with other energy sources. In 1980 the unit costs of nuclear power generated electricity had risen to 571% of the 1968 level. The recalculation of the economic rationale of nuclear power is at least in part due to the public scrutiny of anti-nuclear movements and its effects on public expectations and government regulations.")[36]

Public fears over unsafe meat

Tainted or unsafe meat is a form of supply constraint, but also contains additional dimensions of public perception and fear. Recall Baumgartner and Jones's point that "public discourse when traced over long periods of time tends to show a fascination with one aspect of the issue to the exclusion of the other, at any given time."[37] US and European beef supply chains in particular have seen periodic bovine spongiform encephalopathy ("mad cow disease") and *E. coli* recalls. A typical year in sees dozens of EU and US recalls for beef, chicken, and pork each. In 2016, for example, the USDA reported 26 beef recalls, 30 pork recalls, and 39 poultry recalls. Recall reasons include *Listeria*, *E. coli*, *Salmonella*, "Extraneous Material," "Undeclared Allergen," and so on.[38] Work by Sorenson et al. on mad cow revelations in Switzerland suggests that large scares depress beef consumption more severely than would be expected from price increases or supply constraints alone.[39]

Supply chain reliability and national independence

As before, this concern expresses an additional dimension of a few other causes here (e.g. supply constraints, unsafe meat). The US maintains a large amount of domestic meat production and is therefore partially insulated from import supply shocks, but countries that import >80% of their food remain sensitive to the prospect of supply disruption. A reliability shock in the form of

[36] Bauer, *Resistance*, 29-30.

[37] Baumgartner and Jones, "Agenda Dynamics," 1046.

[38] Recall Summaries 2016, USDA, accessed November 10, 2017, https://www.fsis.usda.gov/wps/portal/fsis/topics/recalls-and-public-health-alerts/recall-summaries/recall-summaries-2016.

[39] A. W. Sorenson et al., "Impact of 'Mad Cow Disease' publicity on trends in meat and total vitamin A consumption in Geneva between 1993 and 2000," *European Journal of Clinical Nutrition* 57, no. 1 (2003): 177-85.

political instability, conflict, trade war, regular war, or one of the other causes listed here could spur a domestic supply crunch spiked with additional fears about dependence on foreign powers to keep bellies full. (Recall how intensely French leaders were concerned about relying on oil imports to keep the lights on.) If clean meat can offer relatively more certainty than imported farmed animal products, adoption may well come sooner, even if a price gap persists.

Concern for animals increases rapidly and nonlinearly

It may already be true that concern for animals is increasing at a rate that feels slow to living humans but is historically speaking quite fast. For example, in 1948, eight percent of Americans reported that they opposed "the use of live animals in medical teaching and research." By 1999, 37.5% said that medical tests on animals were unacceptable.[40]

Two factors may explain this resistance: a general expansion of humanity's moral circle[41] and increases in the scale and severity of factory farming. In short, the ethical issues become larger and more salient as moral concern becomes broader and more sensitive. Increases in concern for animals and opposition to factory farming would plausibly create an environment favorable to new restrictions, outright bans on factory farming practices, or widespread abstention from animal meat.

Major climate events

Climate change threatens food production in several ways, including extreme weather events, declines in usable agricultural land, desertification, and changes in precipitation patterns.[42] These changes can affect animal product prices directly (e.g. a hog farm is destroyed by floods) or indirectly (e.g. animal feed prices rise because of declines in arable land). They represent another supply-constraint scenario with additional dimensions. If extreme weather events, for example, are well publicized, affect agricultural production directly, and are seen to be linked to animal

[40] Harold Herzog et al., "Social Attitudes and Animals," in *The state of the animals*, ed. D.J. Salem and A.N. Rowan (Washington, D.C.: Human Society Press, 2001), 55-69.

[41] Outlined (albeit controversially) in Peter Singer, *The Expanding Circle* (Princeton, NJ: Princeton University Press, 2011) and Steven Pinker, *The Better Angels of Our Nature* (New York: Penguin, 2011).

[42] See, e.g., Tim Wheeler and Joachim von Braun, "Climate Change Impacts on Global Food Security," *Science* 341 (2013): 508-513 and Marco Springmann et al., "Global and regional health effects of future food production under climate change: a modelling study," *The Lancet* 387 (2016): 1937-46.

agriculture, they could plausibly engender moves—by necessity or choice—away from animal meat.

Involvement of current players

Tyson Foods' recent investment in Beyond Meat and Cargill's recent investment in Memphis Meats indicate lower likelihood of meat industry opposition to clean meat. If established food producers see clean meat as economical and scalable—if they can cut costs and expand production by using it—they're more likely to adopt it than they would be a technology that can't be coopted, put into their own supply chains, and scaled up. (See, for example, oil and coal companies' failure to meaningfully invest in e.g. solar and wind power, which leaves many committed as a matter of financial survival to blocking or delaying the uptake of these technologies.)[43]

Public narrative

Popular perceptions of emerging technologies are both important and fickle. Key here is Baumgartner and Jones' point that public discourse tends to focus on one facet of an issue at a time, often swinging from euphoria to dread.[44] There may be reasons to be cautious of advancing even scientifically-sound explanations for why clean meat is safe, especially if these explanations are overly technical. As Hans Mathias Kepplinger notes,

> the reduction of the negative side effects of technology—or the risks of technology—does not necessarily lead to a decrease in fears and concern. Instead, even small dangers become the occasion for great concern due to increased interest in remote events and potential incidents. It can therefore hardly be supposed that an increase in safety of nuclear power plants or genetic engineering automatically increases acceptance. Making increased safety a theme of topical interest would presumably rather add to the

[43] Wood Mackenzie, "Renewables on the rise: are the Majors ready to invest?" accessed November 19, 2017, https://www.woodmac.com/news/feature/renewables-on-the-rise-are-the-majors-ready-to-invest/.

[44] "Images [of new technologies] are based on facts, of course, but public attention tends to focus strongly on one set of facts at a time, and exhibits a remarkable ability to dwell on the positives while ignoring the negatives during one period; only a small change in environment can later cause the attention of nonspecialists to swing to the opposite extreme." See Baumgartner and Jones, "Agenda Dynamics," 1046-47.

> concern than reduce it, because it brings facts found to be threatening into people's consciousness without the population being able to understand the arguments.[45]

Kepplinger cites as an example water fluoridation experiments in which researchers found that "acceptance [of fluoridation] dropped due solely to the subject being made a theme of popular interest. This was still the case even if the arguments in favour of fluoridation were presented in a suitable way."[46] Ralph Nader and engineer-turned-activist John Abbotts relate a story in which the US Atomic Energy Commission released "Theoretical Possibilities and Consequences of Major Accidents in Large Nuclear Plants," a 1957 report intended, at least in part, to show in detail how unlikely such accidents were. The effort backfired when activists and the public focused on projected casualty numbers included in the report (e.g. 3,400 deaths and upwards of 40,000 injuries in one scenario).[47]

Additionally, public debates tend not to focus on a specific chain of well-established technical claims (which is often necessary for arguing why a given technology is safe) but instead glide from concern to concern: "As the opposition [to nuclear power] developed, its basis broadened out to reveal successive layers or facets of concern. This made it difficult to identify a set of cogent issues and provided scope for the debate to shift from one concern to another."[48] This type of shifting concern-cloud is difficult to dissipate with focused arguments, no matter how well-grounded.

Kepplinger further notes that the increasingly critical role played by journalists since the middle of the 20th century tends to complicate public perceptions of new technology. Kepplinger documents how much more critical (or less credulous) journalists have become in the last century, writing that "from the beginning of the century until the mid-1960s, about 7% of all contributions in the Swedish press contained references to criticism of persons, organizations or conditions," but that by the end of the 1960s "the share of contributions containing criticism

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[45] Hans Mathias Kepplinger, "Individual and institutional impacts upon press coverage of sciences: the case of nuclear power and genetic engineering in Germany," in *Resistance*, ed. Bauer, 359.

[46] Ibid., 360.

[47] Ralph Nader and John Abbotts, *The Menace of Atomic Energy* (New York: Norton and Company, 1977), 27 and Rosemary Klapac, "Two Roads Diverge, and France Took the One Less Traveled," unpublished seminar paper, December 16, 2010.

[48] Surrey and Huggett, "Opposition," 305.

rose… to nearly 30%." In Germany, meanwhile, "the share of contributions containing criticism of technology rose between 1965 and 1986 from 15-20% to 30-50%." He argues that these changes had four main consequences:

> First, criticism of persons, institutions and circumstances received more publicity. Secondly, the intensified publicity increased the readiness for public criticism. Thirdly, it became more likely that negative events, among them the unintentional results of science and technology, received news coverage. Fourthly, the subjective points of view of journalists increasingly shaped the contents of news coverage. This takes place, among other things, through 'instrumental actualization', that is, the preferred news coverage of events and opinions which confirm journalists' own views.[49]

The views of journalists matter. Kepplinger reports that coverage by prominent newspapers was a *leading*, not lagging, indicator for public sentiment during nuclear debates in Germany in the 1970s and '80s: "The time-lag correlations show that—taking the entire period from 1975 to 1986—the coverage by Stern (0.66), Der Spiegel (0.71) and Frankfurter Rundschau (0.47) anticipated the views of the population by three, two or one years respectively." (Numbers in parentheses are the time-lag correlations.) He concludes: "we may rule out the idea that the coverage simply reflected the views of the majority of the population on nuclear energy…. the coverage of the mass media did not primarily reflect but shaped the opinions of the majority."[50]

As will be discussed in the next section, nuclear power in the US stalled in large part because activist pushback translated into political action. The main grist for activist pushback came about when preexisting fears (nuclear power is dangerous) met real safety incidents (Three Mile Island, Chernobyl). This implies that, in addition to doing everything possible to reduce the possibility of safety incidents with clean meat, it is sound strategy to avoid dwelling on safety risks with clean meat, even in an effort to rebut them, and to focus instead on positive aspects of clean meat rather than preexisting fears and to be especially wary of risking incidents that would confirm preexisting concerns. The Three Mile Island meltdown in the US killed no one but appeared to vindicate the public fear and uncertainty surrounding nuclear power.[51]

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[49] Kepplinger, "Individual and institutional," 362-63.

[50] Ibid., 373-75.

[51] See James Jasper on Three Mile Island's effects in *Nuclear Politics*, 210-215.

What can the US case teach us?

Like France, the US undergoes a similar nuclear-electricity bump in the 1970s (also revolving around the oil shock of 1973). Unlike France, US nuclear never accounts for more than 21% of electricity generation. Why?

As mentioned previously, the US case differs from the French case in two important ways: different conditions for adoption (resource availability and institutional culture) and for anti-nuclear resistance (US anti-nuclear activism was able to translate itself into effective political opposition because of differences between French/US governance and the meltdown at Three Mile Island). Both of these conditions have appeared in this report (see previous discussion of resource availability and centralization and technocracy), but I'd like to add a few numbers that reinforce the strength of US energy and meat production.

The US enjoyed cheaper and more reliable access to domestic reserves of coal and oil than did France. Though US domestic oil production had peaked in 1970 at 9.6 million barrels of oil per day, it was still quite high—9.2 million barrels per day—when the oil price shock hit in 1973. France, by contrast, had almost no domestically-produced oil.[52]

US meat production resembles US oil production. For example, in 2015, Americans consumed 11.25 billion kilograms (24.8 billion pounds) of beef against production of 10.75 billion kg (23.7 billion pounds).[53] The US is the world's largest poultry producer and the second-largest exporter of pork. Therefore, for the US, fears of food dependence are unlikely to play nearly the role fears of energy dependence played in precipitating the French switch to nuclear. However, states and regions that import most of their food may be more susceptible to institutional adoption of clean meat (see *The case for Singapore* below).

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[52] US Energy Information Administration, US Field Production of Crude Oil, accessed November 19, 2017, https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=mcrfpus2&f=a. For a sense of scale, French oil production in barrels per day is typically counted in the low five figures, e.g. 20,000 to 30,000 barrels per day. The US and other major producers are counted in the millions.

[53] USDA Economic Research Service, Cattle & Beef Statistics & Information, accessed November 19, 2017, https://www.ers.usda.gov/topics/animal-products/cattle-beef/statistics-information.aspx. Even in years where production and consumption match near-perfectly, it is not the case that all US beef is eaten by US consumers. Most years, 8-12% of US beef is produced for export, and the US imports a similar amount (three to four billion pounds) from countries like Australia, Canada, New Zealand, Mexico, Brazil, Uruguay, and Nicaragua.

Early adopters often pay a price

Jasper, writing on the adoption of nuclear power, suggests that

> there are penalties for taking the lead in many technological innovations and merits to borrowing from other countries. The United States lacked the regulatory structure to reshape nuclear energy and recover from the shocks of leaping on the nuclear bandwagon before the technology was fully developed. Likewise France benefited from borrowing light water technology almost intact from the United States. By the time of the Messmer Plan, light water technology was developed enough so that standardization was a reasonable option. Whether a country adopts a technology early or late influences its costs, even though the ultimate effect of costs on policies depends in turn on organizational arrangements.[54]

It is plausible that clean meat technology could enter a scenario in which high-income countries who are able to produce it in the nearer future, like the US, pay higher initial costs (we can already see the outlines of this in the consumer market, where animal-free products of different kinds often enter the market from the top, as a high-end good) and later entrants benefit from cheaper, more efficient, second-generation technology.

The case for Singapore (and places like it)

The French adoption of nuclear power indicates that a country's domestic supply of a good can affect its adoption of a replacement good. Most clean meat projects are based in the US and focus on the US market. As mentioned above, the US has achieved a high degree of "meat independence." The US imported just 14% of beef consumed in 2014.[55] Poultry imports are even lower, accounting for ~0.3% of consumption from 2006 to 2012.[56]

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[54] Jasper, *Nuclear Politics*, 275.

[55] Note, however, that US beef production has declined in recent years, leading to something of a demand squeeze and a rise in imports. See USDA FAS, "A Review of U.S. Tariff Rate Quotas for Beef Imports," International Agricultural Trade Reports, April 25, 2016, https://www.fas.usda.gov/data/review-us-tariff-rate-quotas-beef-imports. For now, this trend appears to be relatively short-term and could reverse itself in the future.

[56] Marin Weaver et al., "Poultry: Industry and Trade Summary," United States International Trade Commission, January 2014, https://www.usitc.gov/publications/332/poultry1.pdf

What about countries in which the reverse is true? It is likely that states and regions that import large percentages of their food and see science and engineering as national strengths may be receptive to the institutional adoption of clean meat earlier than other markets.

Singapore, for example, imports around 90% of its food and invests heavily in its science and engineering capability.[57] The Singaporean government has shown itself willing to initiate top-down projects that rely on emerging technology. For example, Singapore's Changi General Hospital hosts a variety of trials for emerging medical technology, including autonomous delivery robots and bandage systems that detect blood.[58] Singapore's flagship university, National University of Singapore (NUS), operates a robust Food Science & Technology Programme that conducts work on, e.g., the "development of functional bakery products with tea antioxidants," "high intensity ultrasound aided yogurt fermentation," and, of course, "modeling and control system design of frozen dough process."[59] It is, in short, a place unafraid of food technology. The Agri-Food & Veterinary Authority of Singapore reports that local food production is a policy priority and aims to supply 30% of the island's egg consumption domestically.[60] The Singaporean government is notoriously centralized, authoritarian, and technocratic, all elements which have contributed to faster-than-usual adoption of emerging technologies that are perceived as meeting a national interest like food security.

Other regions, city-states, or nation-states with some elements of this dynamic include Slovenia, Hong Kong, the UAE, Israel, China, both Koreas, Japan, Ireland, the Netherlands,[61] Algeria, Qatar, Lebanon, and Taiwan. The dynamic of differing susceptibility to clean meat across states is probably understudied.

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[57] Cecilia Tortajada and Thinesh Kumar Paramasilvam, "Singapore's Impressive Food Security," *The Diplomat*, September 6, 2015, https://thediplomat.com/2015/09/singapores-impressive-food-security/.

[58] Salma Khalik, "Hospitals turn to cutting-edge robots and technology for healthcare assistance," The Straits Times, July 23, 2015, http://www.straitstimes.com/singapore/health/hospitals-turn-to-cutting-edge-robots-and-technology-for-healthcare-assistance.

[59] See NUS Food Science & Technology Programme, National University of Singapore, accessed November 19, 2017, http://www.fst.nus.edu.sg/research/ResearchGroup/FoodProcessingnEngineering.html.

[60] The Food We Eat, AVA, accessed November 6, 2017, http://www.ava.gov.sg/explore-by-sections/food/singapore-food-supply/the-food-we-eat.

[61] The Netherlands is a major food exporter, true, but this is in large part due to to heavy investment in agricultural research and development.

Reasons you might want to doubt this analysis or clean meat adoption in general

Clean meat might not function as a straightforward substitute good for animal meat

This study has largely proceeded on the assumption that clean meat, once scalable, will function as a substitute good for animal meat. That is, as clean meat consumption rises, it will displace animal meat. I think this is a reasonable assumption absent strong evidence either way, given the obvious similarities between the two product categories. There are a few complicating points to consider, however: even similar goods are usually less-than-perfect substitutes for each other, clean meat could in fact become a complementary good to animal meat, or no clear relationship of substitution or complementarity could be established between the two.

Ferenc Toth and Hans-Holger Rogner offer an example of this complexity in their analysis of the relationship between nuclear and oil in energy markets in the 20th century. They find, for example, that "[s]ince 1973 nuclear power expanded its market share in electricity generation essentially at the cost of oil. In absolute terms, however, oil sales to power generation did not decline—[they] rather increased slightly."[62] This fact implies that if the market for meat continues to grow globally (as the market for power did), clean meat could be introduced and take significant market share from animal meat, but that total animal meat consumed could continue to rise. This outcome has probably been understudied relative to its likelihood.

Social processes like the adoption of new technology are highly unpredictable

The adoption of a new technology occurs within multiple overlapping complex systems, each of which contains many interacting variables and is difficult or impossible to model well. Even nonmathematical or narrative attempts at understanding evince frustration with the arbitrary nature of the social circumstances braided into technological change. Dorothy Nelkin notes with an air of mystification: "Exploring the public resistance to technology in America, one is

[62] Ferenc L. Toth and Hans-Holger Rogner, "Oil and nuclear power: Past, present, and future," *Energy Economics* 28 (2006): 5. This paper is rife with examples of complicated substitution effects at work between nuclear and oil.

immediately struck with a paradox. Some technologies provoke organized opposition; others, no less invasive, no more benign, are welcomed, or, at the least, they are accepted with comparatively little debate."[63] James Jasper adds that not only do worldviews and institutional culture complicate economic or functional explanations of the adoption of new technologies, but also entire industries can hang on the biographies and predilections of individual bureaucrats.[64] One wants very much to avoid being overly deductive or giving a false sense of precision in this area. Humility and intelligently navigating large possibility spaces remain essential.

Future food production techniques are also highly unpredictable

The radical unpredictability of future technologies appeared in the brief discussion of the projected decline of French nuclear power in the 2020s. Beyond a ten or fifteen year time horizon, there is little evidence of successful prediction of food technology. It is possible that clean meat could be part of an evolution in food production that leads to worse outcomes for animals in the medium and far future. However, it seems likely that given present knowledge and evidence available to us, working to introduce clean meat is likely to reduce animal suffering a large amount for the foreseeable future.

Nuclear could be highly disanalogous to clean meat

Nuclear energy and meat production are two different technology stacks in different markets. Consumer choice is more important in food than in energy markets. It is rare, although not unheard of, to go to your utility company and select what kind of power you want to consume the way you might select dinner. Although this study has been primarily interested in how institutional uptake works, popular views and consumer choice matter.

Martin Bauer, when comparing opposition movements against nuclear, biological, and and information technology, notes that the scale and type of risk differs across domains and can affect the likelihood and strength of resistance. "Comparisons," Bauer writes, "are furthermore complicated by the fact that public risk perception is not cumulative; it does not add up many small risks to give one large risk. Risk perception feeds on the size and controllability of danger, and less on its probability…. This difference may explain the presence or absence of large-scale

[63] Dorothy Nelkin, "Forms of intrusion: comparing resistance to information technology and biotechnology in the USA" in *Resistance*, ed. Bauer, 379.

[64] Jasper, *Nuclear Politics*, 13-15.

organized resistance."[65] When it comes to scaling the technology, clean meat is likely to face fewer obstacles than nuclear power. The potential scope of disaster is smaller and less cinematic. However, when it comes to *type* of risk, uncertainty persists around consumed products like clean meat. "Type of risk," Bauer suggests, "makes a difference for public perception. The health risks of [nuclear, bio, and info] technologies vary. Radiation touches the problem of physical well-being of individuals and society. Leukaemia, cancer and malformations at birth are issues central to people's life concerns. By contrast the problems of information technology are more abstract," and biotech remains uncertain in its own way: "In new areas of biotechnology and genetic engineering health risks are an open question, and more of a diffuse but widespread concern than well defined."[66]

The risk landscape of clean meat seems to resemble other biotech in certain ways. Biotech research, unlike nuclear power, has not seen the kind of focused opposition that could be translated into real political curtailment.[67] Gene therapy and new drug development continue apace. Joachim Radkau notes that opponents of biotech "suspected that with the advent of AIDS the biotechnical equivalent of Chernobyl had already happened. However... the practical significance of several hypothetical risks of genetic engineering has not become clear. Perhaps it is the wrong way to look for a risk of the Chernobyl type—the search for an over-exact analogy may be misleading!—and perhaps it may be erroneous, too, to look for the kind of risk which is specific to genetic engineering alone."[68] Indeed, searching different case histories for highly specific risk analogies is probably not an effective research strategy. It is likely more useful to understand, even in some limited way, broader dynamics of resistance and adoption.

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[65] Bauer, *Resistance*, 9. See the broader chapter for a discussion about how the differences between technologies (centralization, public/private, Cold War or not) affects their corresponding resistance movements (1-19).

[66] Ibid., 9-10.

[67] GMOs have certainly attracted a non-negligible amount of opposition. However, Joachim Radkau's observation that "criticism of genetic engineering has appeared during the last few years rather incoherent and diffuse" and that it lacks the "certain concentration of critical energy [that the history of nuclear resistance shows] is useful for getting practical results" rings true. Diffuse criticism that is not rooted in one central fear-image has difficulty digging in, gaining brain-traction.

[68] Joachim Radkau, "Learning from Chernobyl for the fight against genetics? Stages and stimuli of German protest movements—a comparative synopsis" in *Resistance*, ed. Bauer, 352-54.

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