8

Sedimentary Innovation: Responding to Incremental Change

WHAT IS "SEDIMENTARY INNOVATION?"

For all their splashiness, seismic innovations as described in the last chapter are not actually that commonplace. Incremental improvements on new inventions, arising through collaboration or knowledge networks and based on imitation, tweaking, translating, and diffusion, are the main means through which innovation happens. Innovation scholar Christopher Freeman describes the shift in emphasis in regulatory and policy work from radical innovations to "incremental" or sedimentary innovations:

> [R]adical innovations … tended to overshadow incremental innovations, both in policy making and in descriptive analysis for a long time … an important change in emphasis in policy making [has been] the recognition that the vast majority of firms do not make radical innovations, but all can and should make incremental innovations and adopt new products processes first made by others.[1]

A simple, one-move example of an incremental innovation would be Apple Corporation's iPad. Unlike the obvious, seismic potential that smartphone technology was immediately recognized to have, the iPad's launch was accompanied by debate about whether it was an innovation at all, or just a scaled-up version of an iPhone.[2] With the smartphone as a cognitive anchoring device, it was difficult to imagine that an iPad might be something different, yet what seemed like just a difference in physical size altered the user experience in considerable ways, and gave rise to follow-on innovations and functions.[3] (Both phone and tablet also of course generated imitators.)

Or, more subtly perhaps, consider rail safety: in July 2013, an unattended freight train carrying 72 cars of crude oil derailed and exploded in Lac Mégantic, Québec, causing forty-seven deaths.[4] It produced one of the largest

oil spills in Canadian history. Freight trains are not new, of course, and nor are oil spills. Yet the Lac Mégantic derailment serves as an example of the risks and unpredictability of sedimentary innovation. The sedimentary innovation here was a process one, of major rail shipment of crude oil products, stemming from increased oil prices and political pressures not to build pipelines, combined with railway deregulation,[5] and inadequate enforcement[6] to create serious gaps in rail safety. Leading up to the disaster, shale oil and bitumen transported by rail in Canada had increased from 500 carloads in 2009 to an estimated 140,000 carloads in 2013, in an effort by oil companies to reap profits from the increase in oil prices then occurring.[7] As Tim Shufelt writes, "For the Canadian oil patch, railways were an inelegant – if necessary – substitute for highly controversial pipelines."[8]

Another recent train derailment, in Oregon, introduces another element: the sheer weight of heavy crude oil versus its lighter variety. In June 2016, a train carrying heavy crude derailed in Oregon's Columbia River Gorge, when a number of the bolts that fastened the tracks together were sheared off.[9] Since 2001, US freight railways have only seen a 12 percent increase in the number of cars they transport, but after taking into account the weight and mileage that the system is subjected to, railroads have actually experienced a 24 percent increase in "ton-miles."[10] Like the Lac Mégantic disaster, the derailment in Oregon was a multi-causal phenomenon. It was not caused solely by technological advances in oil extraction, or process innovations in transporting oil by rail, or because the properties of heavy crude undermine the safety of tank cars, or because of a lack of sufficient regulation. It was caused by each of these phenomena converging to intensify the strain on the system, making the track as a whole more prone to failure.

In these examples are the hallmarks of the phenomenon I want to consider: "sedimentary" layers of innovation, each perhaps unremarkable on its own and not flashy in technological terms and yet, collectively, highly consequential. In contrast to seismic innovations, "sedimentary" (or incremental) innovations are built up through multiple small modifications to equipment or organization or use, made by engineers (including financial engineers), technicians, managers, salespeople, product users, and others.[11] In high-risk, technologically complex environments like nuclear power plants, the accretion of small operator errors can produce catastrophic accidents, which are nevertheless "normal" in the sense that their causes are so common, unremarkable, and ultimately inevitable.[12] As we know from Chapter 6, important sedimentary innovations may not always be underpinned by a significant technological change, or a clearly visible trajectory from specific technology to innovative outcome. Changes in business processes or in how and where a tool is deployed

count too. The move to rely on rail to transport crude oil in these quantities is a process innovation, and produces manufactured risk, but its incremental development and multifactorial causes make it hard to detect until a focusing event, like a large oil spill, arises. By then much damage has been done.

Our language and our literature are full of allegories for the problems posed by the small drip-drip of incremental change: one can suffer death by a thousand cuts, Gulliver was tied down by Lilliputians, there is a last straw that can break a camel's back, and (apocryphally) frogs can be boiled alive if the water in a pot is heated gradually enough.[13] While the concept of sedimentary innovation is in some ways analogous to the more familiar idea of incremental innovation, the metaphor of *sedimentary* innovation also helps emphasize the dangers of gradually increasing, piling-up innovation in a way that the word incremental does not. Sedimentary innovation can bury the structures designed to contain it, and can fundamentally shift the landscape even while not appearing to be doing much at all.

Alongside these darker images, we also have a romantic account of sedimentary innovation, just as we have a romantic account of seismic innovation. The image of vision-plus-perseverance as the basis of innovation, or the eccentric who, in the fullness of time (and perhaps posthumously) was proved right, is a familiar cultural stock figure whose existence affirms the idea that imagination and hard work should ultimately pay off. Sedimentary innovations may be less magical in the popular imagination than the seismic form, but they too occupy a space in our normative, and narrative, universes. Sedimentary innovation also occupies a space in the flexible regulation literature, which we need to understand before we can delve more deeply into the ways in which sedimentary innovation not only intersects with but also represents a challenge for that literature.

In this chapter, we go a bit deeper into the influence of networks, the first-mover advantage, and the problem of innovative bricolage ("making do") as each one affects our understanding of sedimentary innovation as a regulatory challenge. Thereafter, we can consider the particular cognitive barriers that human beings encounter when trying to recognize sedimentary innovation accreting in real time. Finally, we turn to some possible regulatory responses to the challenges associated with dealing with sedimentary innovation in particular.

SEDIMENTARY INNOVATION AS REGULATORY OPPORTUNITY AND REGULATORY CHALLENGE

The image of sedimentary innovation, and progress, underpins a range of pragmatist, experimentalist, and evidence-based regulatory prescriptions. In fact,

the idea of incremental, step-by-step progress underlies important regulatory touchstones such as the "race to the top," and the use of decentralization and competition to foster productive innovation. Because flexible regulation so often emphasizes the value of bottom-up learning, former US Supreme Court Justice Louis Brandeis's notion of multiple "laboratories" for democracy is a recurrent theme in flexible regulation scholarship. As Brandeis famously said,

> The discoveries in physical science, the triumphs in invention, attest the value of the process of trial and error. In large measure, these advances have been due to experimentation …
>
> It is one of the happy incidents of the federal system that a single courageous State may, if its citizens choose, serve as a laboratory; and try novel social and economic experiments without risk to the rest of the country.[14]

Brandeis's famous claim that federalism permits multiple laboratories for democracy in fact *assumes sedimentary innovation*: it establishes a legal architecture for running parallel experiments, with a view to increasing the rate of beneficial discoveries and innovations. Focusing on the upside potential of sedimentary innovation, Charles Sabel and his colleagues in particular have described developments in hospitals, prisons, schools, and other public institutions in terms of the benefits that can arise from multiple laboratories.[15] The experimentalists adopt the term "bootstrapping" to describe the process in which incremental innovations in different jurisdictions create a structure conducive to experimentalism, arguing that it is a positive self-reinforcing process. Outside the federalism context, the same faith in permitting regulatory improvement by fostering private sector experimentation underpins the "regulatory sandbox" initiatives around fintech, which were launched in multiple jurisdictions in 2016.[16]

Laboratory and sandbox initiatives can have many virtues in improving regulation, including by helping to develop best practices and giving regulators access to more detailed and up-to-date information about the ways in which industry actors are innovating. At the same time, we should remember that innovators may innovate not only to make markets more efficient, but also to avoid regulation; that there may not be external market backstops that can quickly assess and reflect back the social welfare benefits (or detriments) associated with financial innovations; that innovations will both develop and diffuse in hard-to-predict ways; and that even the bounds of a regulatory sandbox are not likely to be immune from the undermining effects of innovation. A regulatory sandbox focused on fintech innovations could find itself expanding its definition of what fintech is, or what kind of play is permitted in the sandbox. Especially in the context of growing inter-jurisdictional regulatory

competition for fintech business – a factor that is influencing all this interest in sandboxes in the first place – we should be mindful of the possibility that private sector innovation could become the driver of the experiment to such a degree that public regulatory priorities are undermined.

Regulatory competition for innovative financial work between London and New York has often been blamed for a general lowering of regulatory standards in the lead-up to the financial crisis. Regulatory competition within the United States also provoked increased innovativeness by American banks, but not without a price. As Art Wilmarth has noted, prior to the financial crisis, competition among US state banking regulators and between state and federal regulators promoted further instances of cooperative innovation between the private and public sectors. Competition helped generate a reflexive loop of regulatory innovation, ultimately producing very significant change. On the upside, Wilmarth points to private sector innovations that go on to achieve success once they are embraced and championed by regulatory actors, operating in competition with each other:

> [T]he dual banking system has permitted states to act as "laboratories" in experimenting with new banking products, structures, and supervisory approaches, and Congress has subsequently incorporated many of the states' successful innovations into federal legislation. In addition to the examples … of checking accounts, bank branches, real estate loans, trust services, and NOW accounts, the state banking system originated reserve requirements, deposit insurance, adjustable-rate mortgages, automated teller machines ("ATMs"), bank sales of insurance products, interstate electronic funds transfer systems, interstate bank holding companies, and supervisory agreements that promote cooperative oversight of multistate banking organizations by state bank regulators, the FRB, and the FDIC.[17]

Ultimately, however, the downside revealed itself. Increasing competition between state and federal bank regulators then spurred further innovation, eventually in ways that threatened regulatory standards. The result of competition and innovation was pressure on regulators to adopt a more innovation-friendly and flexible stance:

> During the 1980s and early 1990s, the [US Office of the Comptroller of the Currency]'s success in obtaining court decisions expanding intrastate branching opportunities for national banks forced many states to adopt laws granting statewide branching privileges to state banks. During the same period, state initiatives allowing state banks to offer securities and insurance products encouraged federal regulators to take similar steps. These state and federal regulatory innovations helped persuade Congress to enact [the

> Gramm-Leach-Bliley Act] in 1999, which removed legal barriers separating the banking industry from the securities and insurance businesses. Thus, the regulatory competition for bank charters has placed continuing pressure on state officials and the OCC to demonstrate that they can provide innovative, responsive, and cost-effective supervision to their regulated constituents.[18]

Saule Omarova has also tracked how the business of banking changed over time. She looked at the way in which, from the mid-1980s onward, the OCC gradually broadened its statutory interpretation of what a bank does, using first the "look-through," then the "functional equivalency," and finally the "elastic definition" approach. Omarova emphasizes how, at each stage, decisions by regulators precipitated the growth of financial innovation, allowing financial institutions to take greater and more complex risks. The relationship is a reciprocal and reflexive one. Moreover, like the innovations to which they contributed, the regulatory innovations were subtle, incremental, and operated "under the radar" in a way whose consequence could only be recognized in retrospect. As Omarova says,

> Contrary to an implicit assumption underlying most conventional explanations, the financial innovation of recent decades did not happen "naturally"; it was not some generalized evolutionary force but, to great extent, a product of policy choices and decisions by regulatory agencies. Moreover, some of the most influential of those decisions escaped public scrutiny because they were made in the subterranean world of administrative action invisible to the public, through agency interpretation and policy guidance.
>
> . . . It was not the highly visible acts of Congress but the seemingly mundane and often nontransparent actions of regulatory agencies that empowered the great transformation of the U.S. commercial banks from traditionally conservative deposit-taking and lending businesses into providers of wholesale financial risk management and intermediation services.[19]

The banking story illustrates the nature of sedimentary innovation, as well as the relationship between regulatory innovation and private sector innovation: these are series of incremental changes, which collectively lay down a markedly different landscape than existed prior – even while a clean, coherent account may readily present itself only after the fact. In similar fashion, the broad-scale securitization of residential mortgages did not happen overnight. It took place, as did other moves toward maturity transformation, the speculative use of derivatives, and the growth of leverage, in incremental steps.[20]

The point is not that sedimentary innovation, laboratories for democracy, or regulatory sandboxes are bad; far from it, they can in fact be very positive, especially if their promise is measured relative to easily-gamed bright-line

regulatory rules. The point is simply that sedimentary innovation, like innovation generally, can exert powerful undermining forces on regulation itself across time. The fact that it is incremental change, which proceeds by degrees, can make it seem more benign in terms of its effects on regulation than it ultimately turns out to be.

The Impact of Network Effects: Brandeis and the "Swarm"

Examples like the railway oil spills, the evolution of banking, or the ABCP Crisis in Canada show how inputs from multiple different arenas – (a) increased oil prices plus political pressure not to build pipelines plus the sheer weight of heavy crude oil, for example; or (b) regulatory competition plus an evolving banking business model; or (c) the development of structured financial products and a new banking model, plus a global "savings glut" and low interest rates, plus a looming mortgage crisis next door – can together accrete into a new set of practices or conditions on the ground, which profoundly alter, in unexpected ways, the conditions with which regulation must grapple. Sedimentary innovation is a multifactorial phenomenon. What is more, the process by which sedimentary innovation accretes is an organic, contingent, somewhat unpredictable one that bears little resemblance to the clear, linear, mission-oriented innovative process we sometimes imagine.

The experimentalist account of regulatory bootstrapping, and the deep potential of incremental change, is important. At the same time, managing sedimentary innovation – having the presence of mind to bootstrap the "right" things and curtail the "wrong" things – is a challenging prospect. Sedimentary innovation holds out the possibility of meaningful benefits, certainly; as an object of regulation, however, it can also be hard to see, and hard to handle. The first problem is our own human fallibility as identifiers of relevant information and as rational decision-makers. Beyond that lie further problems that relate to the nature of innovation itself.

Claude Lévi-Strauss coined the term bricolage in its current usage. The bricoleur, in Lévi-Strauss's elegant twentieth-century formulation, is someone who works with his or her hands. However, what distinguishes bricoleurs from other craftspeople is that while they are skilled in many diverse tasks, their projects do not depend on having particular materials or tools on hand. They make do. In Lévi-Strauss's words, the bricoleur's

> Universe of instruments is closed and the rules of his game are always to make do with "whatever is at hand," that is to say with a set of tools and materials which is always finite and is also heterogeneous because what it contains

> bears no relation to the current project, or indeed to any particular project, but is the contingent result of all the occasions there have been to renew or enrich the stock or to maintain it with the remains of previous constructions or destructions. The set of the "bricoleur's" means… is to be defined only by its potential use or … because the elements are collected or retained on the principle that "they may always come in handy."[21]

Sedimentary innovation can be marked by bricolage, whether one works with one's hands or in more intangible realms like finance. In the financial context, Engelen et al. suggest that the idea of bricolage "has a double relevance to the process of financial innovation because it both describes the result of innovation, which … has become a series of fragile long chains and it also characterizes the activity of innovation by the bricoleur at one nodal point in a chain."[22] That is, the fragile long chains of innovation they describe are the product of financial intermediaries fashioning retail-ready financial products out of the wholesale material available, rent-seeking at each juncture along the way. Bricolage is also occurring at each discrete nodal point, since "financial innovation does not correspond one-on-one with specific knowledge or technology."[23] Engelen et al. challenge the dominant accounts of financial innovation "in mainstream finance, social studies of finance and Marxist political economy which, all in different ways, argue or imply that science (represented by finance theory) or some other form of rationality (like class interest calculation) either is financial innovation or drives financial innovation." Instead, they argue, bricolage undertaken under changing, unstable circumstances will produce, inherently, unstable long chain innovations like the complex structured products we saw in the run-up to the financial crisis.[24]

The idea of bricolage is consistent with what we know about how innovation, including financial innovation, develops. Robert Merton once famously described what he called the "financial innovation spiral effect" – the idea that particularly useful or versatile financial innovations can spawn multiple knock-on financial innovations and collateral agreements. Once developed, a custom-made financial innovation can serve as a baseline for other commoditized agreements that ostensibly further fine-tune risk allocation between other parties. In Merton's words, the "synthesizing of custom financial contracts and securities is for financial services what the assembly-line production process is for the manufacturing sector. Options, futures, and other exchange-traded securities are the raw 'inputs' applied in prescribed combinations."[25]

The spiral effect makes the path of financial innovation more complex and more unpredictable, and that complexity is then multiplied by its deployment within the complex, varied, and interconnected financial system. The

financial system is a complex network of institutions such as domestic banks, overseas banks, central banks, insurance companies, and investment firms, and they are linked together in multiple ways: through transactions, through products and services, through markets, and through the financial infrastructure of clearing, settlement, and trade depository functions. This is not a sea urchin-like "spike" of activity; it is a progressive spread.

From a regulatory perspective, the complex network characterizing the financial sector also means that certain hubs, like Wall Street or the City of London, should attract particular scrutiny. So should financial institutions that by virtue of their size, relationships, or influence are key vectors for transmitting risk, and therefore are important to systemic stability.[26] However, understanding the importance of networks to innovation is one thing, and defining relevant networks in a useful way is quite another. Financial system networks are multiple, variable, dynamic, and overlapping, and they can gain purchase at several different levels, as described below. They transmit innovations, as well as their effects (including risk), but the innovations are also altered, tweaked and repurposed as they diffuse. Financial network analysis is still in its early stages, though the US Treasury's Office of Financial Research (OFR) considers it a "promising new tool."[27] In furtherance of this project, however, we cannot forget that institutional network connections are only one, and the most formal, of the kinds of networks that bind the financial system together. As the innovation literature points out, network ties can be formal or informal, and strong or weak. While formal contractual relationships may be the most important elements for purposes of transmitting risk, understanding how innovation is transmitted will be more complicated. Along with institutional network analysis, we will also want to consider social and financial geography. As well, we will want to understand the precise nature of the products in question: it turns out that as a function of weak property rights and strong competition, financial innovations may diffuse through networks in particular ways.

Networks as Institutional and Social Phenomena

In the years since the financial crisis, network analysis based on computer simulations has begun to provide new insight into global financial interconnectedness and how such networks can or cannot absorb stress. Network analysis can help us develop a better image of the relationships through which goods, information, and risk all travel (even if any analysis will only provide a snapshot of a discrete moment in time). For example, when Sheri Markose and her colleagues modeled the US CDS market as of late 2007 and early 2008, they found J.P. Morgan to be the dominant bank in the network,

followed by European banks, and then other US banks like Goldman Sachs and Citibank.[28] Figure 8.1 reproduces their model of this network.

Recent work by Richard Bookstaber and Dror Y. Kenett for the OFR breaks interbank relationships down in a more granular, if less visually networked, way. Focusing on former US investment bank Bear Stearns's and two of its hedge funds during the financial crisis, their map, reproduced as Figure 8.2,

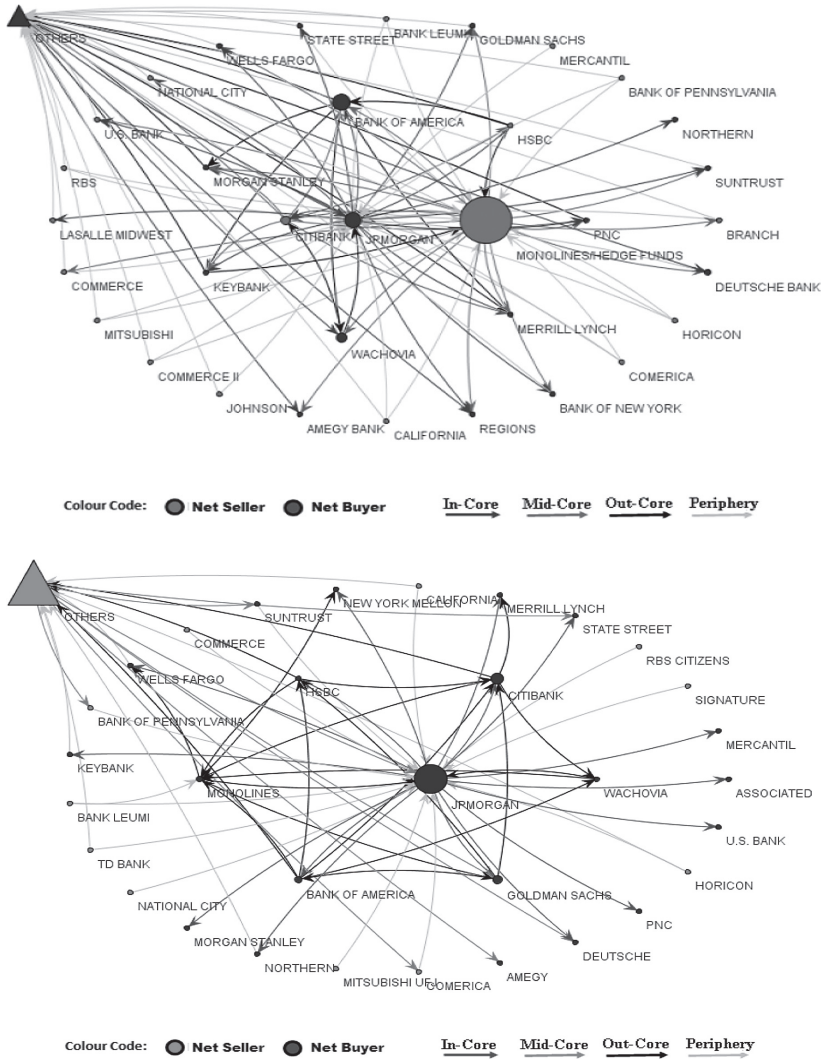

FIGURE 8.1. CDS network (Markose, "Too interconnected to fail," 640, note 28 above).

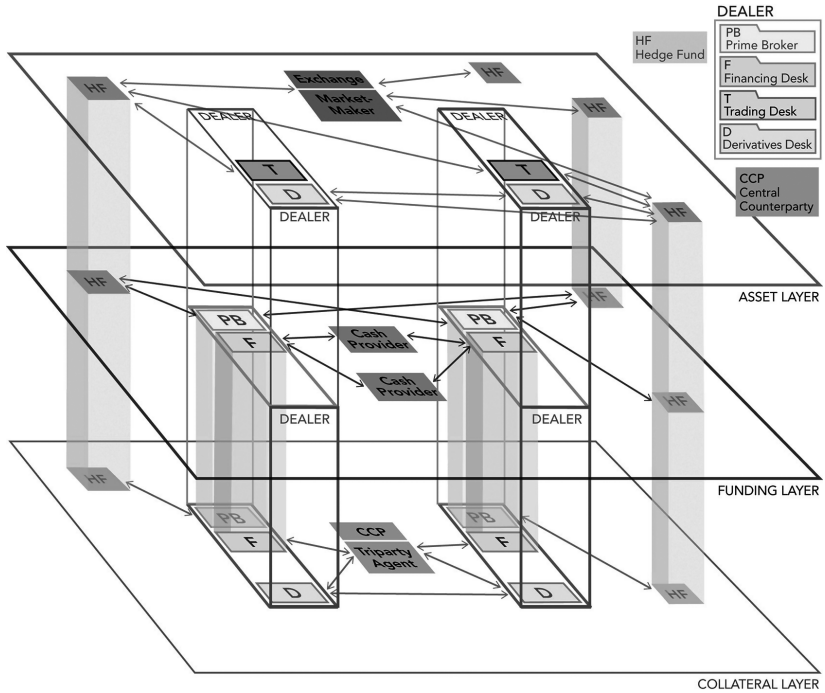

FIGURE 8.2. US Office of Financial Research, three-dimensional multilayer network map of the financial system (Source: Richard Bookstaber & Dror Y. Kenett, "Looking deeper, seeing more: a multilayer map of the financial system," OFR Brief Series (July 14, 2016) at p. 7).

identifies three layers of connections (across short-term funding, assets, and collateral flows) through which risk was transmitted across the financial system:

Schemas like these are helpful in understanding vectors along which risk may be transmitted. While there may be some overlap, financial *innovation* networks probably look somewhat different. If mapped, they could be equally useful in understanding how particular innovations are being transmitted. Yet, as valuable as these institutional network maps may prove to be, mapping institutional connections for purposes of tracking innovation must incorporate insights from social geography as well.

Within networks, geography – including social geography and cognitive geography – influences how innovative ideas diffuse, and how they evolve through diffusion. In some cases, physical geography may affect economic activity. Geographical proximity is a component that contributes to how and where network hubs develop, and isolation can have effects as well: for example, Hampton and Christensen have argued that small island economies can

become locked into dependence on offshore finance, and therefore into tax haven activities.[29] The rate of diffusion of consumer-facing financial innovations like ATMs, debit cards, and direct deposits can also depend heavily on the demographics of the market, including education, race/ethnicity, and age.[30] Even despite heavy supply-side pressure to adopt innovations, the demand-side can be resistant to adopting innovations in certain contexts as a result of geography.

But perhaps the most interesting aspect of the social geography of financial innovation, when considering innovation as a regulatory challenge, is the way in which "supply-side" social networks seemingly influence the incremental development, diffusion and evolution of new technology, products, and practices. Sociologist Donald MacKenzie has described the famous 1998 downfall of the hedge fund Long-Term Capital Management (LTCM) in social network terms.[31] Salomon Brothers, headed by John Meriwether, reputedly "the most talented bond trader of his generation," developed LCTMs, with Nobel laureate partners Robert Merton and Myron Scholes (both instrumental to developing and perfecting the Black-Scholes option pricing model discussed earlier).[32] The fund was so successful that other investors started imitating it, and the result was something of a "super-portfolio" of overlapping arbitrage positions. Network effects thus created unanticipated homogeneity, which in turn decreased the entire system's stability and increased contagion effects.[33]

What may have been especially important in the globalization of securitization is what we might call "cognitive geography," or even the geography of professional social hierarchy: this is the sense that innovations diffuse out from knowledge or practice hubs, much in the way that Boaventura de Sousa Santos describes "focal objects" in his analogy of law to cartography.[34] De Sousa Santos refers to the distortions that are unavoidable aspects of map-making as *projection*. Projection and distortion happen outward from a focal object determined by the context surrounding the creation of that particular map. De Sousa Santos applies the concept of "focal objects" to law, and argues that the legal accounts that are created with a particular focal object at their center will be distorted in various ways when moving out from that point. Financial innovation, too, seemingly rippled outward from financial network hubs in a way that demonstrated the intellectual and reputational sway of centers like London and New York.

Reflecting on how local or regional crises beginning in the US subprime mortgage market could have turned into a global one, Roger Lee expresses surprise at:

> [T]he geographical spread of the CDO market from New York to London, and then on to continental Europe ('contra' home bias and the historical

> significance of local markets). At that distance, decisions appear to have been made on the 'reputations' of offering banks, the claimed superior innovativeness of Anglo-American markets and the rumour-mill of actions taken by competing banks in other jurisdictions. Whereas institutions involved in currency trading have had to develop rigorous checks on cross-market positions on a 24/7/365 basis, this type of discipline was apparently not applied to participation in exotic products.[35]

Lee notes that by taking on the known and unknown risks associated with the CDO market, institutions were effectively gambling on the stability of the Anglo-American markets. These institutions "joined (perhaps unwittingly) the leverage applied to those markets by agents who stood most to gain, at least in the short-term from the leverage game."[36] In other words, network hubs were not only better able to transmit their innovations, but the reputational sway they wielded – their status as focal objects, in prestige terms using de Sousa Santos's cartographical metaphor – meant that other, more peripheral network players may also have been *less likely to scrutinize* those innovations. Diffusion took a particular form, which was the product not only of law and regulation, particular innovations, and network centrality, but of subjective reputational factors as well.

Of course, social geography also meant that the crisis, like economic shocks generally, imposed a differential effect on the poor. Where unemployment rose in the US and UK, levels of malnutrition and even death were expected to rise in the poorest parts of the global economy. As Minouche Shafik, then the permanent Secretary of the UK's Department for International Development, noted:

> [T]hose consequences are far more severe, frankly than anything we will experience as a result of this crisis … And if this crisis is unfolding in poor countries more slowly more quietly and perhaps a bit less dramatically – it's because the families who are having to cut back on the quality of food they eat are poor and isolated and in rural areas and so we don't see them on the front page of the Financial Times or the Wall Street Journal, but that doesn't make the effect any less real.[37]

Herding and the First-Mover Advantage

Along with institutional relationships and the impact of cognitive and social geography, a third consideration that can help us to understand sedimentary financial innovation is the nature of financial products themselves. As we discussed in Chapter 6, financial innovation is particularly susceptible to herding because financial innovations are characterized by weak property rights, meaning first-movers have a considerable advantage.[38] In addition, common

incentive systems across financial institutions – a short-term profit orientation and the bonus structure, for example – gave each bank an incentive to evade capital requirements and take risks so long as its competitors were doing the same, generating a collective action problem.[39]

This was not the case back in 1931, when John Maynard Keynes famously observed that "[a] 'sound' banker, alas! is not one who foresees danger and avoids it, but one who, when he is ruined, is ruined in a conventional and orthodox way along with his fellows, so that no one can really blame him."[40] Banking has changed utterly, and is now an innovative industry where once it was a sleepy one. And yet based on a different set of economic drivers, Chuck Prince, Citigroup CEO, uttered a strikingly similar conformist sentiment in 2007. Dismissing concerns about liquidity in the credit-fueled economy, he just as famously said, "[w]hen the music stops, in terms of liquidity, things will be complicated. But as long as the music is playing, you've got to get up and dance."[41]

Consider that the following factors operate simultaneously and can reinforce each other: the pre-crisis environment was innovative in part because of the first-mover advantage. It was susceptible to collective action problems because of the additional incentive structures that operated within its institutions. Regulators who were seeking to be nimble and flexible in a competitive regulatory environment endorsed innovative activity. Innovations diffused in complicated and hard-to-track ways through institutional interconnections, but also as a result of the social and reputational sway that particular hubs enjoyed. And, the innovations in question were often the product of a process of bricolage that gave the impression that each incremental evolution was relatively unremarkable. Even while regulators were working to be receptive to financial innovation, they were not in a position to really understand how far from safety those innovations had taken them.

MAKING SENSE OF SEDIMENTARY INNOVATION

Humans Struggle to See Sedimentary Change

We probably all know, by now, that humans are not terribly good decision-makers under all conditions. For example, we tend overall to read too much into things that make a forceful impression on us, particularly where we have personal experience with them, and we read too little into things that do not make such an impression. Thanks to the availability heuristic, we also tend to confuse how easy it is to bring an example of something to mind with the probability it will occur (e.g., my friend lost money to a pump-and-dump scheme,

so losing money in pump-and-dump schemes must be more common than I thought).[42] Perhaps for this reason, when making inter-temporal choices, we tend to value the present more than the future.[43] When calibrating the costs of low-probability, high-impact events – something else we struggle with, and which affects our thinking about seismic innovations too – we tend to discount future events even more. Thanks to anchoring and adjustment, we are also liable to judge future probabilities by reference to pre-existing starting points, which may or may not be reasonable or even relevant to the question at hand. Then, we tend to see what we want (or expect) to see. Confirmation bias, meaning the tendency to interpret evidence in a way that confirms existing beliefs and expectations,[44] distorts our perception of risk and inhibits our ability to see the unexpected, including the kinds of unexpected developments that may arise from sedimentary innovation.[45] Nor are we especially numerate. Anything above basic numeracy, like the complex probabilities that characterize risk, is challenging for most of us.[46]

Humans' familiar and predictable cognitive limitations take a particular form when it comes to sedimentary innovation. Put bluntly, we do a poor job of registering more incremental phenomena. We are simply not wired to detect gradual change very well.[47] In psychology, Weber's Law says that humans' ability to detect differences in the magnitude of a stimulus will depend on how large it is relative to the background situation. For example, while most people can hear a whispered voice in a quiet room, they may not notice someone shouting in their ear at a rock concert if the shouting is not louder, by a certain minimum proportion, than the background concert noise.[48] We acclimatize; we habituate; we become "change blind." How we respond to risk will be a function of how much risk we are already taking (as anyone who has ever traded a large debt in for a larger one knows). How much we register change, meaning innovation, will also be a function of how much change and innovation we are used to. Thus, sedimentary innovation can escape notice and, absent a focusing event, we seem able to become accustomed to very high levels of risk so long as it accretes slowly.

There is more. We may over-extrapolate from our own experience, and assume too much about what we do not know. We may anchor our perception of risk to something that has proven not to be risky for us individually (statistics notwithstanding), or not risky at our particular *scale*. For example, we may imagine that a financial innovation that seemingly presents low risk to the firm that developed it also poses a low level of risk to an entire sector, to systemic stability, or to society generally. Or, because a past financial innovation was considered to be low-risk, a newer and similar but in fact much riskier financial innovation may be judged to be lower risk than it is because we mentally

characterize it as only an adjustment to, and recognizable in the terms of, the earlier low-risk innovation.

On the other hand, we tend to jump to conclusions about significance when confronted with striking events. They cause us to see patterns and discern pressing, widespread problems. As Rajeev Gowda says,

> [P]eople can be readily persuaded that a few examples of unfortunate results are an adequate representation of a policy's overall performance. Presenting a sequence of inferences which seem believable may persuade people towards such conclusions. This could lead to support for an unwarranted overhaul of the policy. The representativeness heuristic could also affect people's willingness to support risk management policies, e.g., flood risk-reduction measures, if the adduced sequence of future events leading to such disasters does not seem believable.[49]

This suggests, as already discussed, that the decision to frame an identified innovation as seismic can open windows of opportunity for regulatory action. By contrast, sedimentary innovations do not register with the same significance. In the regulatory context, this means that (to the extent we think about regulation at all when things seem to be going fine), even if we understand that sedimentary innovation is more common and often more influential, we may still respond rather too listlessly to it, because of the absence of a striking event.

The biases and heuristics above are only some of the reasons why our rationality is bounded.[50] Humans do not always even *try* to operate on a rational plane. We are also emotional beings, and our decision-making process can be influenced, or even dominated, by emotion.[51] Fear and anxiety can be strong emotional drivers of regulation and risk-related decision-making. Consider the heavy regulatory burden imposed on nuclear power compared to conventional fossil fuels. As journalist William Saletan noted when writing on the Fukushima crisis, there have only been 31 direct fatalities from nuclear power in the last 40 years, but over 20,000 in the oil supply chain and 15,000 in the coal supply chain. The ratio of fatalities per unit of energy produced is 18 times greater for oil than for nuclear energy.[52] Yet the fear of nuclear disaster provokes dread in a way that a steady stream of conventional fatalities does not, and to a substantial degree we regulate in response to our dread.[53]

We also experience anxiety where we perceive something as unknown, and where we cannot (rightly or mistakenly) slot it into a pre-existing narrative. Therefore, phenomena that seem new or different inspire more regulation than phenomena that seem like an extension of the familiar.[54] How vivid the imagery associated with a bad event, and how far into the future it

may occur, also influence its emotional valence.[55] Sedimentary innovation is less unfamiliar and less emotionally evocative. In contrast to seismic innovation events, where particularly after a disaster risk is salient and people may over-estimate risk and over-regulate, when it comes to sedimentary innovation people may persistently under-estimate risk and under-regulate. This may be even more the case for financial risk, because it tends to be counterbalanced by the glittering promise of financial return. As well, financial risk tends not to generate the same imagery as, for example, environmental risk. The media-ready images of physical destruction, tar-covered shore birds or children being tested for toxin-related illnesses are absent.

Finally, the status quo bias also contributes to our passivity in the fact of sedimentary innovation. Given the choice, humans generally tend to prefer to maintain the status quo or to refrain from acting.[56] The status quo and confirmation biases may make us unwilling to recognize, in the absence of a striking event, that facts on the ground have changed and demand a response. Coupled with the prospect theory – that we tend to value avoiding potential losses over having potential gains – these biases may help explain why regulators may be more inclined to act aggressively *ex post* than comprehensively *ex ante*. Why change anything if there is no salient risk? Why "take the punch bowl away" when everyone is enjoying the party and nothing bad has happened?[57]

This presents a form of slippery slope problem as well, for both regulators and firms, in terms of accountability. Let us imagine that early on in the trajectory of some financial innovation, matters seem stable. There is risk associated with the innovation, but it seems to be operating within a tolerable range. With every day that sedimentary innovation accretes, the regulator (and the firm's compliance personnel) will have to consider afresh not one, but two questions: the first is whether the risk has now exceeded tolerable levels. The second, equally difficult one, is: why intervene today when we did not intervene yesterday? The regulator must not only justify its present intervention, but somehow establish the difficult claim that some *de minimis* change suddenly justifies acting, even though yesterday the regulator had judged in all its wisdom that things were fine. In settings such as this, the human mind opts for consistency, rejecting a potentially awkward change in posture, until disaster ensues.[58]

Epistemological Problems and Awareness Problems

One other cognitive bias hints at the larger epistemological problem that underlies sedimentary innovation as a regulatory challenge: the hindsight bias. The hindsight bias causes us to imagine, after viewing an outcome, that

that outcome was always clear.[59] The hindsight bias influences policy evaluation. As Gowda says,

> When faced with negative outcomes, the hindsight bias may lead people to criticize the decisions leading to failure as if the negative outcome should have been foreseen as inevitable rather than merely probable. Closely related to the hindsight bias, the outcome bias leads people to judge the goodness of risk-related decisions on the basis of their outcomes … The hindsight and outcome biases could generate charges of incompetence or corruption to explain the failures of policies which may have failed by chance.[60]

These biases also make it simpler for us to conclude after the fact that we were mistaken to ever have run the risks we did. For example, while in view of the retrofitting costs we may honestly have imagined in 2010 that we were willing to run the tiny risk of an enormous tsunami flooding a major nuclear power plant in central Japan, it feels quite impossible to sustain that view in mid-2011, after a disaster has occurred. But the fact that the terrible thing happened does not mean that we had not measured the risk, and (even if not in this case, then in others) been willing to run it earlier. Our societies could not function without running some risks. Our after-the-fact assessment of which risks have been worth running is heavily skewed by which risks actually came, perhaps just by chance, to pass.

The hindsight and outcome biases are a problem for policy analysis regardless of the subject matter or innovation in question. However, the particular way in which they manifest in regard to sedimentary innovation is that they imposes *ex post* a level of certainty that simply was not present *ex ante*. They suggest not only that damage could and should have been avoided, but also that we can do better in avoiding it next time. In other words, when it comes to sedimentary innovation, the hindsight bias blinds us to the persistence of uncertainty itself. Every effort to improve regulation and avoid future harms – including the one we are engaged in here – is based on the idea that we can avoid regret later, if only we improve our risk management processes enough.

In fact, we are hampered by our inability to see, in the moment, precisely what is going on. Anticipating problems or identifying key turning points, in a complex world full of noisy signals, is extraordinarily difficult.[61] Moreover, it is impossible to predict which of multiple possible or probable outcomes will actually come to pass. This is not necessarily (or not only) a function of our limited ability to think clearly, to separate the causal wheat from the epiphenomenal chaff. It is also a function of the complex nature of causation. So, while there is a behavioral component to the challenge of regulating,

including regulating sedimentary innovation, there is also a more fundamental epistemological one.

What may be less immediately obvious is how fragile any such coherent explanation is bound to be. Though it is no less true of the seismic innovation story, it is especially with respect to sedimentary innovation that we can *see* the contingency and subjectivity in the causal account. The causal account of the relationship between regulation and sedimentary innovation is a complex one. Like determining proximate cause of injury in a complex tort situation, determining (or predicting) how technological change and sedimentary innovation will co-evolve is an indeterminate process. Understanding financial innovation as most often a form of sedimentary, rather than seismic, innovation may be a useful analytical lens, because it yields a different interpretation of the problem at hand and generates different prescriptions for its resolution. At the same time, we need to be alive to the ways in which this account, like any other, cannot be more than partial and imperfect in its *ex post* explanations.

Regulatory Boundaries and Coordination Problems

Another aspect of the phenomenon of sedimentary innovation is that in complex, multipart systems, sometimes very consequential events happen in the interstices between existing regulatory regimes, or regulatory moments, or regulatory objects. Each component of regulation may focus on the "main effect," from its vantage point, and miss developments in the cracks in between. The anchoring effect of existing regulatory structures makes it harder to see interstitial phenomena with the color and depth that more central objects have. The legibility of a new innovation is a challenge for sedimentary innovations just as it is for seismic ones.

Entities operate within a complex factual and regulatory matrix, with layers of rules. Regulators may not see the connections between how public and private regulations interact, or how transnational and domestic regulations interact.[62] Transnational governance does not overpower domestic legal regimes, but rather intersects with domestic and customary systems to generate elaborate combinations of regulations.[63] Even leaving aside the impact of complexities such as private ordering and transnational regimes, it seems difficult to coordinate formal regulatory regimes.[64]

Moreover, interactions may not be obvious because different regulators may interact in unanticipated ways. Consider the relationship between bankruptcy law, the capital requirements imposed on financial institutions, and housing policy in the United States pre-crisis. Presumably the size and robustness of

the subprime mortgage market was not the main concern of the Recourse Rule in the United States, which allowed financial institutions to keep only one-fifth as much capital on hand to cover triple-A rated mortgage-backed securities as for business and consumer loans.[65] Capital adequacy, not housing policy or access to credit, was the Rule's concern. Similarly, 2005 amendments to American bankruptcy provisions in 2005[66] expanded the definitions of a "repurchase agreement" (a "repo" agreement) to include mortgage loans, and interest on mortgage loans.[67] These amendments had the effect of facilitating the expansion of short-term repo financing. However, they also distorted creditor behavior and increased systemic risk.[68] The amendments essentially subsidized derivative financial activity with bankruptcy benefits, thus increasing the use of derivatives and reducing market discipline.[69] Of course, neither the derivative markets nor housing and mortgage policy was the Bankruptcy Code's main concern. The same is true of the relationship between capital adequacy rules and macroeconomics – they interacted in unexpected ways, effectively increasing the money supply and fueling an asset price bubble in housing.[70]

It is difficult in the abstract to do enough systematic comparison of the interactions between different regulatory regimes or strategies, and this is a problem that exacerbates and is exacerbated by sedimentary innovation. Coordination failure between regulators is a familiar problem, not limited to the innovation context, but it is a problem that is particularly relevant to the regulatory challenge that sedimentary innovation presents. These, too, are incorporated into the technical roadmap in this book's concluding chapter.

Sedimentary Innovation and Flexible Regulation

As we know by now, bright-line rules' rigidity in the face of incremental innovation makes it likely that the rules will be out of step almost by the time they are promulgated. Flexible regulation, which lays out a more nuanced and variable set of regulatory options, has been in part a response to that problem. Among the regulatory options it lays out is the idea of having a regulator set high-level principles or outcomes that regulated entities must meet, while leaving the details of implementation to the regulated actors themselves. In principle, this is the kind of system that should be able to adapt to sedimentary innovations while keeping sight of "big picture" regulatory objectives.

However, as the Volcker Rule account in Chapter 1 pointed out, moving the discussion of details to the technocratic plane can neutralize public participation, and it allocates substantial influence to those still in the room after the public moment has passed. Worse yet, if an agreement on principles or

high-level outcomes is in fact masking the regulatory incapacity to understand or work with the actual firm-driven innovations being developed – as was the case in the UK around principles-based prudential regulation,[71] or in the US around the CSE Program[72] – then the regulator will simply have ceded the regulatory field to private actors. The crucial difference between what Ayres and Braithwaite call "enforced self-regulation"[73] on the one hand, and outright deregulation on the other, is precisely there. It matters very much what back-end processes are in place, exactly, through which indeterminacy will be resolved and the spaces in regulatory scaffolding filled in. Sedimentary innovation can undermine flexible regulatory structures, like other regulatory structures, if the regulator is not possessed of considerable capacity to register change across time, including effects outside the discrete regulatory moment at issue, and to appreciate its potential impact and the necessary responses to it.

We should flag two other potential problems that might be particularly associated with flexible regulation and sedimentary innovation. The first is that, as the Basel II capital adequacy account, or Omarova's description of the changing nature of the "business of banking" makes clear, flexible regulatory structures can actually *increase* the speed and prevalence of sedimentary innovation. Jeffrey Gordon has engagingly demonstrated that in a "constructed system" like financial regulation, any new, non-trivial change to the regulatory regime alters the context in which it operates.[74] Regulation changes behavior. In Gordon's words, "regulatory benchmarks inevitably become a management target; the exogenous becomes endogenous."[75] In such a reflexive system, a regime that puts private sector innovation-embracing strategies at the core of its own standards, as Basel II or banking regulation did, can expect one of its outputs to be more private sector innovation.

Second, we should be aware of the ways in which the particular structure of regulation may not be well situated to deal with sedimentary innovation. Risk-based regulation, one of the touchstone concepts within flexible regulation, may be such a structure. Specifically, Julia Black and Robert Baldwin have pointed out that, in risk-based regulation, "the tendency is for regulators' gaze to be drawn to their highest risks and for regulators to be encouraged to pull back resources from lower risks."[76] Risks that individually look low may never trip the alarm in such a system, notwithstanding that collectively they may be very significant. Nor do we understand the interactions between them in a complex system. Sedimentary innovation, too, can appear innocuous to a risk-based regulator until it has progressed well down the road, and – because it develops incrementally, through the actions of multiple parties and in response to multiple stimuli – by that time it can be very difficult to unwind.

As difficult a task as it may be, developing viable regulatory responses to extensive and continuous private sector innovation requires careful attention to these interactions, and an appreciation for just how much regulatory structure interacts with and is affected by private sector innovation taking place within its bounds.

POTENTIAL REGULATORY RESPONSES TO SEDIMENTARY INNOVATION

In terms of potential regulatory responses, first should be the recognition that loopholes and disconnects will be exploited. Innovation presents a clear and persistent risk – perhaps the single most significant and under-analyzed risk – to regulation itself. We can and should improve on the quality of information we have about just how sedimentary innovation works its way through, and in the process expands, the spaces and arbitrage opportunities within the regulatory fabric. Better harmonization and collaboration between financial regulatory regimes domestically and transnationally (including around accounting rules, prudential regulation, bankruptcy, and living wills) would also help reduce opportunities for regulatory arbitrage.[77] In the run-up to the financial crisis, private parties engaged in regulatory arbitrage between overlapping US regulators.[78] Transnational arbitrage, prominently between New York and London, also played a role. Gaps such as these can be addressed, and we can design incentives that reward better decision-making by banks and seek to limit herding behavior.[79]

But all of that is familiar ground. While useful, these suggestions do not respond to the question of how better to understand sedimentary innovation and its effects; nor do they address the epistemological and awareness problems that dog our efforts. There is no regulatory silver bullet. Yet promising options exist that can help to augment regulatory capacity to track and respond to sedimentary innovation.

As we have noted, developing a better understanding for how financial innovation develops – considering market structure, incentives, transmission vectors, and the presence or absence of "off" switches – is key to being able to understand innovative phenomena as they grow and to appreciate some of the ways in which they may be undermining, circumventing, or swamping regulatory structures. It may be useful to draw on experience about the parts of the financial system that seemed to remain stable or enforceable while others did not.[80] It may be useful to consider, as well, taking steps to identify those areas where financial institutions already have some incentive to self-regulate, for self-interested reasons, and those where they do not.[81] Without relying too heavily, or at all, on assumptions about the reliability of self-regulation, this

may provide the opposite piece of information: a preliminary indication of what priorities most urgently need to have regulatory resources allocated to them.

Second, there is value in more explicitly considering the ways in which regulators, along with the rest of us, struggle to make sense of sedimentary innovation as it is developing. Are there ways that we might improve this capacity? The first way would be to take intentional steps to build better analytical capacity of the kind needed not just to understand the industry (though that is obviously essential), but also to identify behavioral cascades earlier, and to track "creep" in industry assumptions or standard practices over time. In the United States, the OFR has a mandate that can encompass these kinds of efforts.[82] A compatible suggestion would be Chuck Whitehead's, that regulators adopt a "Goldilocks Approach," meaning an approach whereby regulators are authorized to roll out, suspend or forgo regulatory steps over time, as information and experience improve understanding.[83]

It may also make sense to build an "institutional contrarian" role into the regulatory environment, particularly where regulators may be participating in sandbox exercises or other semi-collaborative engagements with private innovators. Regulatory contrarians as Brett McDonnell and Daniel Schwarcz describe them are "devil's advocates," with three key characteristics: 1) they are in a position of persuasive authority with access to media and officials (or, here, decision makers within the regulator), 2) they are affiliated with a regulatory entity but independent, and 3) they study the regulatory process to suggest improvements and point out flaws (or, as modified here, to point out assumptions or misperceptions about innovation that could undermine regulation).[84] Including a diversity of voices within a regulatory structure, combined with a formal structural role for presenting alternative views, may help increase the chances that a regulator will be able to identify, make sense of, and respond to sedimentary innovation in a timely and well-calibrated manner.

Third, regulators will want to understand sedimentary financial innovation as the network-based phenomenon that indeed it seems to be. This approach counsels treating the industry ecosystem as a network and focusing on its hubs rather than on specific instruments or institutions.[85] It would mean recognizing that, in regulatory terms, diffusion and herd behavior based on overall social and geographical networks can be just as problematic, in the aggregate, as any one institution that is considered "too big to fail" or "too interconnected to fail" on its own. Risk-based regulation that relies on bright-line matrices, like threshold asset size, risks missing important aggregate effects.

In addition, regulation could focus on breaking the connections through which sedimentary innovation diffuses, in the way that systemic risk

management tries to do with respect to systemic risk. Using an engineering-based approach as Steven Schwarz has suggested to manage systemic risk, regulators could also choose to implement modularity within innovation networks – for example, by closing off some components and only allowing them to interact with others in certain ways, to make it possible to repair the component before the entire system fails.[86] No doubt, this idea will be less popular with respect to the prospect of cabining innovation than it is for cabining risk. Whether it is a tool worth deploying would depend on the regulator's (and perhaps the broader policy-maker's) assessment of how many other safeguards were in place to manage the disadvantages associated with a particular sedimentary innovation, and whether it made sense to try to close off the innovation, rather than *ex ante* to try to close off the risks associated with it. Yet for innovations that, in policy-makers' estimation, seem over time to have lost their social value – such as financial innovations that a policy maker has determined have no function other than rent-seeking – it is an approach that should not be dismissed out of hand.

Each of these options, and combinations of them, may make sense as responses to sedimentary innovation. The challenge will be to develop regulatory capacity and to implement these measures in a much more thorough and effective way than has been attempted so far, in keeping with the magnitude of the challenge that innovation presents for regulation's ability to meet its other, substantive, goals.