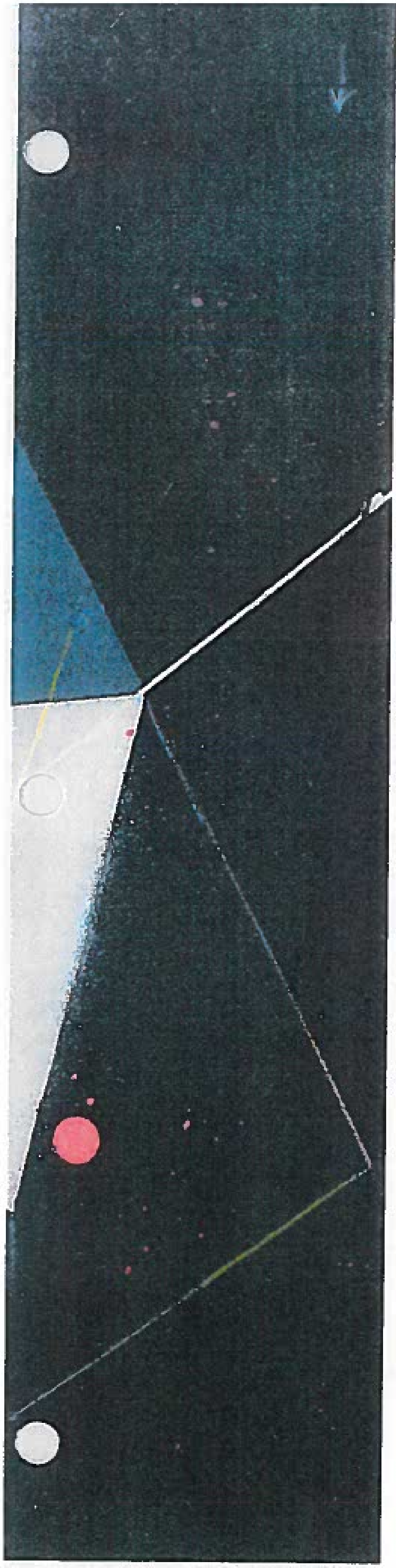


ARTWORK A. Ruiz Villar, *Casa Desestructurada I*, 2016
Acrylic, pencil, tape, and spray paint on wood

Right Tech, Wrong Time

How to make sure your ecosystem is ready for the newest technologies

BY RON ADNER AND RAHUL KAPOOR

For the past 30 years, "creative destruction" has been a source of fascination at top-tier business schools and in magazines like this one. The almost obsessive interest in this topic is unsurprising, given the ever-changing, never-ending list of transformative threats—which today include the internet of things, 3-D printing, cloud computing, personalized medicine, alternative energy, and virtual reality.

Our understanding of the shifts that disrupt businesses, industries, and sectors has profoundly improved over the past 20 years: We know far more about how to identify those shifts and what dangers they pose to incumbent firms. But the *timing* of technological change remains a mystery. Even as some technologies and enterprises seem to take off overnight (ride sharing and Uber; social networking and Twitter), others take decades to unfold (high-definition TV, cloud computing). For firms and their managers, this creates a problem: Although we have become quite savvy about determining *whether* a new innovation poses a threat, we have very poor tools for knowing *when* such a transition will happen.

The number-one fear is being ready too late and missing the revolution (consider Blockbuster, which failed because it ignored the shift from video rentals to streaming). But the number-two fear should probably be getting ready too soon and exhausting resources before the revolution begins (think of any dot-com firm that died in the 2001 technology crash, only to see its ideas reborn later as a profitable Web 2.0 venture). This fear of acting prematurely applies both to established incumbents being threatened by disruptive change and to innovating start-ups carrying the flag of disruption.

To understand why some new technologies quickly supplant their predecessors while others catch on only gradually, we need to think about two things differently. First, we must look not just at the technology itself but also at the broader *ecosystem* that supports it. Second, we need to understand that competition may take place *between the new and the old ecosystems,* rather than between the technologies themselves. This perspective can help managers better predict the timing of transitions, craft more-coherent strategies for prioritizing threats and opportunities, and ultimately make wiser decisions about when and where to allocate organizational resources.

You're Only as Good as Your Ecosystem

Both established and disruptive initiatives depend on an array of complementary elements—technologies, services, standards, regulations—to deliver on their value propositions. The strength and maturity of the elements that make up the ecosystem play a key role in the success of new technologies—and the continued relevance of old ones.

The new technology's ecosystem. In assessing an emerging technology's potential, the paramount concern is whether it can satisfy customer needs and deliver value in a better way. To answer that question, investors and executives tend to drill down to specifics: How much additional development will be required before the technology is ready for commercial prime time? What will its production economics look like? Will it be price-competitive?

If the answers suggest that the new technology can really deliver on its promise, the natural expectation is that it will take over the market. Crucially, however, this expectation will hold only if the new technology's dependence on other innovations is low. For example, a new lightbulb technology that can plug into an existing socket can deliver its promised performance right out of the box. In such cases, where the value proposition does not hinge on external factors, great product execution translates into great results.

However, many technologies do not fall into this plug-and-play mold. Rather, their ability to create value depends on the development and commercial deployment of other critical parts of the ecosystem. Consider HDTV, which could not gain traction until high-definition cameras, new broadcast standards, and updated production and postproduction processes also became commercially available. Until the entire ecosystem was ready, the technology revolution promised by HDTV was bound to be delayed, no matter how great its potential for a better viewing experience. For the pioneers who developed HDTV technology in the 1980s, being right about the vision brought little comfort during the 30 years it took for the rest of the ecosystem to emerge.

An improved lightbulb and an HDTV both depend on ecosystems of complementary elements. The difference is that the lightbulb plugs into an existing ecosystem (established power generation and distribution networks; wired homes), whereas the television requires the successful development of

Idea in Brief

THE PROBLEM
Over the past 20 years we've gotten very good at predicting whether a major new technology will supplant an older one—but we are still terrible at predicting when that substitution will take place.

THE INSIGHT
If the new technology doesn't need a new ecosystem to support it—if it is essentially plug-and-play—then adoption can be swift. But if other complements are needed, then the pace of substitution will slow until those challenges are resolved. Change takes even longer when the old technology gets a boost from improvements in its own ecosystem.

THE IMPLICATIONS
Start-ups need to consider not just when their innovation will be viable, but also what external bottlenecks will arise. Incumbents, meanwhile, should use the transition period to up their own game—and to figure out a strategy for long-term survival.

co-innovations. Improvements in the lightbulb will thus create immediate value for customers, but the TV's ability to create value is limited by the availability and progress of other elements in its ecosystem.

The old technology's ecosystem. Successful, established technologies—by definition—have overcome their emergence challenges and are embedded within successful, established ecosystems. Whereas new technologies can be held back by their ecosystems, incumbent technologies can be accelerated by improvements in theirs, even in the absence of progress in the core technology itself. For example, although the basic technology behind bar codes has not changed in decades, their utility improves every year as the IT infrastructure supporting them allows ever-more information to be extracted. Hence in the 1980s, bar codes allowed prices to be automatically scanned into cash registers; in the 1990s, aggregating the bar code data from daily or weekly transactions provided insight into general inventory; in the modern era, bar code data is used for real-time inventory management and supply chain restocking. Similarly, improvements in DSL (digital subscriber line) technology have extended the life of copper telephone lines, which can now offer download speeds of 15 megabytes per second, making copper-wire services competitive with newer cable and fiber networks.

The War Between Ecosystems

When a new technology isn't a simple plug-and-play substitution—when it requires significant developments in the ecosystem in order to be useful—then a race between the new- and the old-technology ecosystems begins.

What determines who wins? For the *new* technology, the key factor is how quickly its ecosystem becomes sufficiently developed for users to realize the technology's potential. In the case of cloud-based applications and storage, for example, success depended not just on figuring out how to manage data in server farms, but also on ensuring the satisfactory performance of critical complements such as broadband and online security. For the *old* technology, what's important is how its competitiveness can be increased by improvement in the established ecosystem. In the case of desktop storage systems (the technology that cloud-based applications would replace), extension

About the Research

We developed and explored the ideas described in this article during a five-year research project on the pace of substitution in the semiconductor-manufacturing ecosystem.

The semiconductor industry's remarkably robust progress over the past 60 years was made possible by innovations in the lithography technology that semiconductor manufacturers use. We studied the successive generations of lithography equipment and noticed a pattern: In some cases, the new technology dominated the market in a matter of two to five years, whereas in other cases it faced prolonged, unexpected delays in achieving market dominance—and sometimes never did. This was true despite the fact that each generation offered superior performance, even on a price-adjusted performance basis.

To test our hypotheses about how ecosystem emergence challenges and extension opportunities affect the pace of substitution, we first collected and analyzed detailed data on every product and firm involved in every generation of the technology. We supplemented that information with extensive interviews with executives from firms throughout the ecosystem.

Our statistical analysis showed that 48% of the variation in the pace of substitution was attributable to traditional factors: price-adjusted performance differences, the number of rivals in the market, and the tenure of the old technology. When we added consideration of the ecosystem dynamics discussed in the article, we were able to account for a remarkable 82% of the variance.

For more details on the research, see "Innovation Ecosystems and the Pace of Substitution: Re-examining Technology S-Curves," by Ron Adner and Rahul Kapoor, *Strategic Management Journal* (March 2015).

opportunities have historically included faster interfaces and more-robust components. As these opportunities become exhausted, we can expect substitution to accelerate.

Thus the pace of substitution is determined by the rate at which the new technology's ecosystem can overcome its emergence challenges relative to the rate at which the old technology's ecosystem can exploit its extension opportunities. To consider the interplay between these forces, we have developed a framework to help managers assess how quickly disruptive change is coming to their industry (see the chart "A Framework for Analyzing the Pace of Technology Substitution"). There are four possible scenarios: creative destruction, robust resilience, robust coexistence, and the illusion of resilience.

Creative destruction. When the ecosystem emergence challenge for the new technology is low and the ecosystem extension opportunity for the old technology is also low (quadrant 1 in the framework), the new technology can be expected to achieve market dominance in short order (see point A in the exhibit "How Fast Does New Technology Replace the Old?"). The new technology's ability to create value is not held back by bottlenecks elsewhere in the ecosystem, and the old technology has limited potential to improve in response to the threat. This quadrant aligns with concept of creative destruction—the idea that an innovative upstart can swiftly cause the demise of established competitors. While the old technology can continue serving niches for a long time (see "Bold Retreat," by Ron Adner and Daniel C. Snow, HBR, March 2010), the bulk of the market will abandon it relatively quickly in favor of the new technology. As an example, consider the rapid replacement of dot matrix printers by inkjet printers.

Robust resilience. When the balance is reversed—when the new technology's ecosystem confronts serious emergence challenges and the old technology's ecosystem has strong opportunities to improve (quadrant 4)—the pace of substitution will be very slow. The old technology can be expected to maintain a prosperous leadership position for an extended period. This quadrant is most consistent with technologies that seem revolutionary when they're first touted but appear overhyped in retrospect.

Bar codes and radio frequency identification (RFID) chips provide a good example. RFID chips hold the promise of storing far richer data than bar codes ever could, but their adoption has lagged because of the slow deployment of suitable IT infrastructure and nonuniform industry standards. Meanwhile, IT improvements have extended the usability of bar code data, as we've already discussed, relegating RFID to niche applications and keeping the RFID revolution at bay for the past two decades. It may well be that RFID does eventually overcome its challenges and that ecosystem extension opportunities dry up for bar codes. If this happens, the dynamics will shift from quadrant 4 to another quadrant, and the pace of substitution will quicken. But that will be small consolation to the firms and investors that committed to RFID decades ago. The opportunity cost of waiting for the rest of the system to catch up can mean that being in the right place 10 years too soon is more costly than missing the revolution completely.

When substitution is slow, there are also implications for the new technology's required performance levels (see point D in the exhibit). Every time IT improvements make bar codes more useful, for example, the quality threshold for the RFID technology is raised. Thus performance expectations for the innovation keep ratcheting upward, even as its wide adoption is held back by the underdeveloped state of its ecosystem.

Robust coexistence. When the ecosystem emergence challenge for the new technology is low and the ecosystem extension opportunity for the old technology is high (quadrant 2), competition will be robust. The new technology will make inroads into the market, but improvements in the old-technology ecosystem will allow the incumbent to defend its market share. There will be a prolonged period of coexistence. Although extension opportunities are unlikely to reverse the rise of the new technology, they will materially delay its dominance.

An instructive example is the competition between hybrid (gas-electric) automobile engines and traditional internal-combustion engines. Unlike fully electric engines, which need a supporting network of charging stations, hybrids were not held back by ecosystem emergence challenges. At the same time, however, traditional gas engines have become more fuel-efficient, and the ecosystem for the traditional technology has improved, too, as gas engines have become better integrated with other elements in the vehicle, such as heating and cooling systems.

A period of robust coexistence can be quite attractive from a consumer perspective. Performance of both ecosystems is improving—and the better the

FURTHER READING

For more insights into the relationship between technologies and their ecosystems, see the following:

"Match Your Innovation Strategy to Your Innovation Ecosystem"
Ron Adner
HBR, April 2006

"A Sad Lesson in Collaborative Innovation"
Ron Adner
HBR.org, May 9, 2012

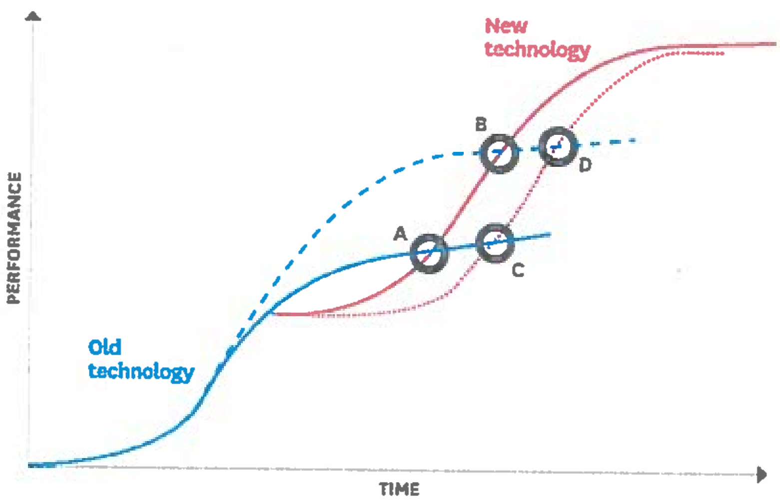
The Wide Lens: What Successful Innovators See That Others Miss
Ron Adner
Portfolio/Penguin 2013

"Beware of Old Technologies' Last Gasps"
Daniel Snow
HBR, January 2008

"Value Creation in Innovation Ecosystems: How the Structure of Technological Interdependence Affects Firm Performance in New Technology Generations"
Ron Adner and Rahul Kapoor
Strategic Management Journal
March 2010

HOW FAST DOES NEW TECHNOLOGY REPLACE THE OLD?

Traditionally the substitution of a new technology for an old one is shown with two S curves (the solid lines). A more holistic view adds two more dynamics. First, if the new technology depends on the emergence of a new ecosystem, it becomes dominant more slowly (dotted red line). Second, the old technology's competitiveness is extended if it can benefit from performance improvements in its surrounding ecosystem (dashed blue line).



CREATIVE DESTRUCTION
POINT A
The classic—and fastest—substitution takes place when the new technology's ecosystem is ready to go and the old technology's ecosystem can't be significantly improved.

ROBUST COEXISTENCE
POINT B
If the new technology is compatible with the existing ecosystem and the old technology's ecosystem can be significantly improved, substitution takes place later (relative to creative destruction) and at a higher performance level.

ILLUSION OF RESILIENCE
POINT C
If the new technology's ecosystem needs considerable development and the old technology's ecosystem has little room for improvement, the changeover occurs after time has passed without performance gains.

ROBUST RESILIENCE
POINT D
If the new technology's ecosystem needs considerable development and there are abundant opportunities to improve the old technology's ecosystem, the substitution occurs after the longest period of time and at the highest performance level.

NOTE THE EXACT POSITIONS OF B AND C WILL DEPEND ON THE SPECIFICS OF THE CASE, BUT THEY WILL REFLECT AN INTERMEDIATE PACE OF SUBSTITUTION (RELATIVE TO POINTS A AND D) AND INTERMEDIATE PERFORMANCE AT SUBSTITUTION.

old technology's ecosystem becomes, the higher the performance bar is for the new technology's ecosystem (point B in the exhibit).

The illusion of resilience. When the ecosystem emergence challenge is high for the new technology and the ecosystem extension opportunity is low for the old technology (quadrant 3), not much will change until the emergence challenge is resolved—but then substitution will be rapid (point C in the exhibit). Examples here are HDTVs versus traditional TVs, and e-books versus printed books. Both of those revolutions were delayed not by advances in the old technology's ecosystem but by ecosystem-emergence challenges in the new technology.

In scenarios in this quadrant, an industry analysis will most likely show that the old technology maintains high market share, but growth has stalled. Because rapid market-share inversion is to be expected once the new technology fulfills its value creation potential, the dominance of the old technology is fragile. It is maintained not by continued progress in the old technology but by setbacks for the new competitor.

Implications for Action

Once you understand that in the race to dominance, ecosystems are just as important as technologies, you will be better at thinking through how quickly change is going to occur—and deciding what level of performance you need to aim for in the meantime. We will consider how to tackle these questions shortly, but first let's review a few general truths that emerge from this perspective.

- If your company is introducing a potentially transformative innovation, the full value will not be realized until all bottlenecks in the ecosystem are resolved. It may pay to focus a little less on perfecting the technology itself and a little more on resolving the most pressing problems in the ecosystem.
- If you are a threatened incumbent, it pays to analyze not just the emerging technology itself but also the ecosystem that supports it. The greater the ecosystem-emergence challenge for the new technology, the more time you have to strengthen your own performance.
- Strengthening incumbent performance may mean improving the old technology—but it can just as easily mean improving aspects of the ecosystem that supports it.
- Every time the old technology's performance gets better, the performance threshold for the new technology goes up.

With that overview in mind, let's look at how to use this framework to analyze your own technology strategy. We recommend having executive conversations focused on two questions: Which quadrant is our industry in? and What are the implications for our resource allocation and other strategic choices?

Which quadrant are we in? Without the benefit of hindsight, your response to this question is clearly a matter of judgment. Some people would look at electric vehicles in 2016 and say they are still stuck in quadrant 4 (where we have placed them in our framework), pointing out that the charging infrastructure and battery performance are insufficient for mainstream adoption. Other people would position EVs on the cusp of quadrant 2, claiming that acceptance is growing and that better batteries make it possible to drive longer distances before recharging. Still others would place EVs solidly in quadrant 2, arguing that Tesla's success in selling its vehicles and populating its waiting lists is a sure sign that commercial potential is no longer constrained.

The sidebar "How Big a Threat Is the New Technology?" suggests issues to think through as you debate which quadrant you're in. Some questions pertain to the new technology and some to the old—but you will want to consider them all, regardless of whether you are an incumbent or a start-up. Don't expect all individual team members to agree on the answers to these questions. It is precisely by going through the process of articulating different views that teams can make the most of their collective insights.

What are the implications for resource allocation and other strategic choices? Each quadrant in the framework carries different implications for resource allocation decisions. And since markets are not transformed all at once, the quadrant also suggests possible ways to position yourself during the transition.

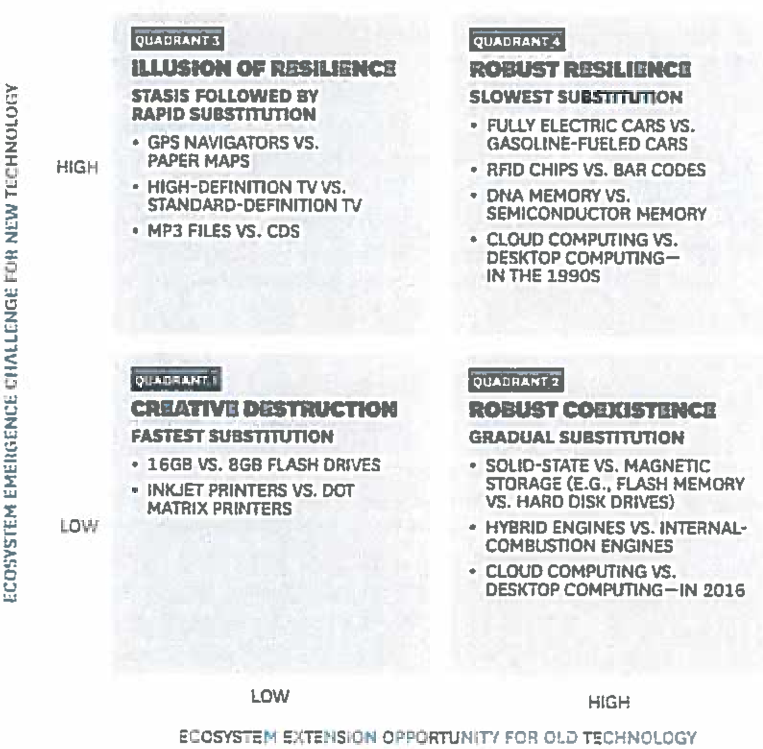
In quadrant 1 (creative destruction), with the old technology stagnant and the new technology unhampered, innovators should aggressively invest in the new technology. Incumbents should follow the familiar prescriptions for embracing change to withstand the winds of creative destruction. Part of that is looking for niche positions where they can survive in the long term with the old technology. For example, pagers were largely replaced by cell phones, but they are still used by emergency-service providers.

In quadrant 2 (robust coexistence), incumbent firms can continue to invest in the old technology and aggressively invest in improvements to the ecosystem, knowing that the new and the old technologies will coexist for an extended period. As in quadrant 1, they should also seek niche positions for the old technology for the long term, but there is less urgency to do so. New-technology innovators should move full speed ahead on perfecting the new technology along with its complements. That includes testing and refining the offering with early adopters and segments that are potentially receptive.

In quadrant 3 (the illusion of resilience), new-technology champions should direct resources toward resolving their ecosystem challenges and developing complementary elements, and resist overprioritizing further development of the technology itself. When the bottleneck to adoption is the ecosystem, not the technology, pushing technology progress is pushing the wrong lever. Incumbents, for their part, must guard against the false assumption that they are maintaining their market position because of the merits of their own technology. As publishers of road atlases will attest, this is probably a time to harvest and make only incremental improvements, with an eye toward sunset; it is not the time to redouble innovation efforts in the old technology.

A FRAMEWORK FOR ANALYZING THE PACE OF TECHNOLOGY SUBSTITUTION

The pace of substitution is determined by how quickly the new technology's ecosystem challenges are resolved and whether the old technology can exploit ecosystem opportunities for extension.



How Big a Threat Is the New Technology?

Predicting the pace of substitution requires analyzing the competition between the new- and the old-technology ecosystems. Six questions can help innovators and incumbents assess their positions and strategies.

NEW-TECHNOLOGY QUESTIONS

These questions (drawn from *The Wide Lens*, by coauthor Ron Adner) address the emergence challenges that confront the new technology. The answers should help innovators decide how to adjust their strategies.

1. What is the *execution risk*—the level of difficulty in delivering the focal innovation to the market on time and to spec?
2. What is the *co-innovation risk*—the extent to which the success of the new technology depends on the successful commercialization of other innovations?
3. What is the *adoption-chain risk*—the extent to which other partners need to adopt and adapt to the new technology before end consumers can fully assess its value proposition?

The greater the extent to which the new technology is facing any of these risks, the greater the challenge to be overcome, and the longer the expected delay in adoption of the technology.

OLD-TECHNOLOGY QUESTIONS

These questions address the prospects for improving the competitiveness of the incumbent technology. The answers should help incumbents identify opportunities they might exploit.

1. Can the competitiveness of the old technology be extended by further improvements to the technology itself?
2. Can it be extended by improvements to complementary elements in its ecosystem?
3. Can it be extended by borrowing from innovations in the new technology and its ecosystem?

The more positive the reply to each of these questions, the greater the extension opportunity for the old technology.

Finally, in quadrant 4 (robust resilience), incumbent firms should invest aggressively in upgrading their offerings and actively raising the bar that challengers need to cross. Obviously, new-technology innovators should be clear-eyed about working to resolve the ecosystem constraints they face. But at the same time they must recognize that the performance threshold for their core technology is rising. That necessitates both a significant level of resource investment and considerable patience regarding investment returns. Innovators are not likely to transform the sector in the foreseeable future, and therefore they will want to think through the economics of serving those customers they can succeed with.

One final note about the dynamics of change. Every innovator wants to end up in quadrant 1 so that it can play the classic creative-destruction game. But there are different paths for getting there. A hypothesis that predicts a transition path from Q4 to Q3 to Q1 is a bet on the exhaustion of the old technology. For an innovator, that would mean focusing on aligning the new-technology ecosystem without great concern for extending a performance advantage. In contrast, a predicted path of Q4 to Q2 to Q1 would mean competing against an improving incumbent-technology ecosystem. Here the innovator needs to continually elevate its performance while it simultaneously perfects the ecosystem.

FEW MODERN firms are untouched by the urgency of innovation. But when it comes to strategizing for a revolution, the question of "whether" often drowns out the question of "when." Unfortunately, getting the first right but not the second can be devastating. "Right tech, wrong time" syndrome is a nightmare for any innovating firm. Closer analysis of the enabling contexts of rival technologies—Is the new ecosystem ready to roll? Does the old ecosystem still hold potential for improvement?—sheds more light on the question of timing. And better timing, in turn, will improve the efficiency and effectiveness of the innovation efforts that are so critical for survival and success. ♉

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