Transnational Diffusion of Ideas and Technologies

MJ Peterson

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Diffusion of New Ideas, Practices, and Technological Innovations

I. The Basic Model of Diffusion

Most historians of ideas and technological change agree that the spread of ideas, practices, or innovations from the originators to others can be described by a hazard model. Hazard models, first developed in epidemiology and now used in many fields of social science, are mathematical formulations used to predict the likelihood that an individual will actually experience an event (such as developing a disease) within a particular time period given some risk (probability) that the event will happen to her or him. Whatever the level of risk of developing the particular disease, its cumulative spread through the population can be summarized with an S-curve plotted by placing time along the x axis and the number of new cases occurring in each time interval along the y axis. At first the disease spreads slowly because there are few sources of infection that trigger uninfected individuals in the process of exposure to germs, their incubation, and their overwhelming of immune system that culminates in disease. Even if the disease has a 75% transmission rate (three-fourths of those exposed to the germs causing to develop the disease themselves), each individual is unlikely to encounter someone who is contagious. Thus, the number of new cases increases slowly. As more people come down with the disease, however, a threshold is reached at which each individual's likelihood of encountering a source of infection increases significantly. In this second phase, indicated by the steeply rising portion of the S-curve, spread of the disease speeds up and the number of new cases per time interval increases exponentially. Spread enters a third phase once most people have been exposed to the disease, indicated by the slowly rising (or even flat) upper portion of the S-curve. With most people already exposed to the disease and only a few left who have not encountered it, the number of new cases per time interval drops. While the exact shape of the S-curve depends on the rate of transmission of the disease and the period of time needed for it to incubate in a newly-exposed person, the basic shape holds true for the spread of any disease that is not inhibited by effective preventive measures.

Studies of the diffusion of ideas, practices, and technological innovations substitute them for the germs of the disease model, and treat learning about their existence and content as the equivalent of exposure to a source of infection. Similarly, the rate of adoption of the new idea, practice, or technological innovation is

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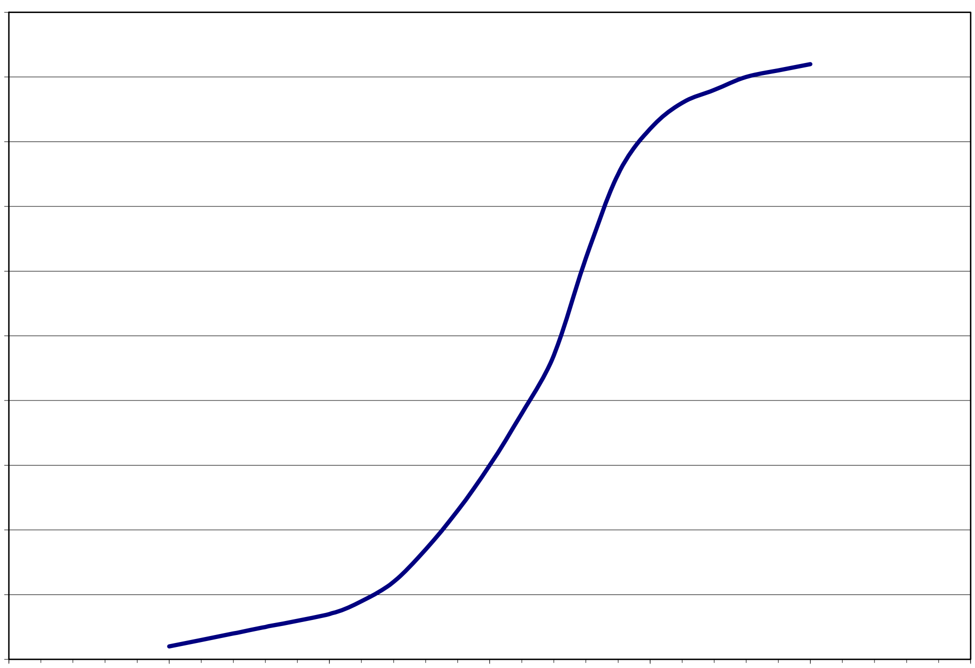
the parallel to the transmission rate of a disease, and the amount of time between learning about the idea, practice, or technology and deciding to whether adopt it is the parallel to the incubation period for a disease. Some analysts of innovation argue that the upward inflection point separating the first phase from the second occurs when somewhere between 10 and 25% of the population had adopted the new technology because that is when interpersonal "word of mouth" communication about it accelerates.[1] Yet, this is a wide interval and not particularly helpful for making predictions. In addition, many ideas, practices, technological innovations never diffuse beyond the circle of inventors and innovators. Others may diffuse a bit further, but never to the point where the S-curve moves from slow to exponential rise; for a variety of reasons most people decide against adopting them and using them.

Quantifying the adoption rate and the time between initial learning and the adopt/reject decision is harder than quantifying the transmission rate and incubation period of a disease. These obstacles to easy quantification mean that S-curve graphs work better for tracing past patterns of spread than for predicting future ones. Even so, the hazard model is a useful heuristic device because it alerts us to recurrent patterns and sensitizes us to the need for paying attention to phase transitions. In particular, it warns enthusiastic proselytizers of ideas or sellers of new technologies that explosive growth in the number of converts or buyers will not last forever.



An S-curve (hypothetical data)

The elements of the hazard model also direct attention to questions of what influences the likelihood that people will first learn about a new idea or technological advance and then choose to adopt it. Prior learning is necessary to (though not sufficient for) adoption, so anything that reduces the likelihood of learning about an idea, practice or technology (such as expression in an unfamiliar language, garbled messages in a familiar language, or censorship) or blocks access to a device or object embodying a technological

[1] E.g., Everett Rogers, *Diffusion of Innovations* (3rd edition. New York; Free Press, 1983), p.11.

innovation for trial use (such as distance from the makers, high cost of the device or object, or regulations limiting access to the device or object) automatically inhibits adoption.

Just as diseases spread from some initial source of infection to persons nearby, and then from them to a wider set of others, and so on, new ideas, practices and technologies originate with some individual or small group and then spread to successively larger circles of others. Diseases can make long geographic leaps if carried from one part of the world to another by infected travelers; learning about ideas, practices, and technologies can also span long distances through telecommunications and geographically dispersed social, professional, or business networks.

Yet, it is important to remember that learning about the new idea, practice, or technology does not automatically lead to its adoption. Amish communities are quite familiar with motor vehicles and telephones, but have chosen to restrict their use to a few very particular occasions and do not keep them within individual households. Japanese warriors became familiar with and used firearms in the early 17th century, but made and maintained a collective decision to avoid their use during Japan's era of isolation under the Tokugawa Shoguns between 1630 and 1854.

Both examples point up the importance of users' own evaluation of new ideas and technologies. Unlike germs, which are unwanted but can get past all of a person's hygienic precautions and immune system defenses, adoption requires willing acceptance. Analysis of the diffusion of technology typically distinguish among:

1.) "inventors" who come up with the initial version of the new technology;

2.) "innovators" who modify the initial version in ways that make the technology more attractive to potential users by increasing its reliability, simplifying the process of making it, or simplifying its use;

3.) "early adopters" who start using the new technology soon after it appears;

4.) "adopters" (sometimes divided into "early majority" and "late majority") who take it up after seeing a number of others use it;

5.) "late adopters" who take it up only after the vast majority of others have; and

6.) "nonadopters" who never use it although they know that it exists and that other people in their area are using it.

An individual or organization considering the adoption of a new idea, practice, or technology needs to be convinced that adoption will improve its overall situation. Sometimes the individual or organization considers its own situation in isolation from what others are doing. Such a focus clearly shaped the choice of the apocryphal Vermont farmer whose phone rings while a neighbor is visiting. The neighbor asks if he is going to answer it, and the farmer says "Nope; I put that thing in for *my* convenience." More often, however, the fact others are using a particular idea, practice, or technology strongly influences the decision. This is particularly true in competitive situations – such as prevail between armies, business firms, or sports teams – where any new idea, practice or technology that gives its users any advantage must either be adopted or understood well enough to develop effective defenses against it. Others' use also affects decisions about whether and when to adopt any technology with "network effects" – increasing value to users as larger number of others also adopt it.

Studies of diffusion have identified several factors that affect the rate of adoption of a new technology in a single country or community:

1.) Characteristics of the technology itself or in comparison to competing technologies;

2.) Economic benefit/cost ratio of using the new technology;

3.) Mode of social decision about adopting new technologies;

4.) Communication channels used to promote the new technology;

5.) Social and material conditions in which the technology will be used; and

6.) Extent of promotion by trusted persons;[2]

Characteristics of the technology include its own features, its functionality as compared to other technologies for accomplishing the same task, and its feasibility within current technological attainments. The important features of the technology itself include ease and convenience of use, compatibility with technologies already in use, fit with prevailing social expectations, and the extent to which users can try it out temporarily or on a small scale before having to commit to adoption or non-adoption. Cost and ease of use as compared with other technologies is also important, though users will accept a short period of inconvenience as they master the new device if they believe gains in convenience or effectiveness will repay that effort. Feasibility within the limits of current technological attainments determines whether the idea for the technology gets expressed in a physical device. Many inventors get good ideas before fabrication technologies are well enough developed to permit making devices based on them. Sir George Cayley, a prosperous landowner in Yorkshire, England worked out the basic design for airplanes – a wing to get lift from moving air, a propulsion device to get the moving air by moving the wing through it, and tail rudders for steering – in 1809. However, his design was not realized until 1903 when internal combustion engines proved capable of supplying the right combination of sufficiently lightweight and strong power.[3] Sometimes the state of complementary or related technologies – technologies that need to be used together with the new invention for it to work well – are insufficient. A working fax machine was exhibited at the Crystal Palace Exposition of 1851, but it was not until the transmission speed of phone lines got up above 3000 bits/second in the 1970s that fax connections convenient and affordable for users in small offices or stores became available.

Cost-benefit ratios of use also influences adoption rates. Though high cost directly limits adoption, most economic calculations affecting acquisition involve comparison with the cost of other ways of doing the

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[2] Everett Rogers, *Diffusion of Innovations* (3rd edition. New York; Free Press, 1983).

[3]J.A. Bagley, "Aeronautics" in Ian McNeil, editor, *An Encyclopedia of the History of Technology* (London: Routledge, 1990), 619-624.

same task. High cost did help confine telephones to upper and upper middle class homes in Europe and North America in the 1920s. In Sweden households within 1 kilometer of a large telephone exchange were more likely to have phones than others because the more distant households had to pay the National Telecommunications Administration the cost of running wires to their houses before service would be installed.[4] This initial cost dampened their enthusiasm considerably. Yet, relative benefits-cost ratios are typically more important. Many businesses that might have opted for telephones found that by careful phrasing or use of any of the many published abbreviation systems ("commercial codes") available, telegrams were cheaper than telephone calls for urgent long distance business communications until well into the 20th century. City dwellers in the 1920s found it cheaper to garage and run a modest-price automobile than to house, feed, and equip a horse.

The *mode of decision-making* used to select new technologies also affect the rate and extent of adoption. Societies in which individual persons, households, or firms are allowed to choose on their own have different diffusion patterns than those where the adoption process involves collective decisions among all members of an extended social group or decision for a large group by a small leadership. In the collective decision situation, individual limited trials may occur, but general use develops only after a social consensus in favor. Until that consensus emerges, the graph of adoptions over time will be flat and close to 0 on the y-axis. Afterward, the rate of adoption will rise, but how steeply depends on whether the consensus is a decision that everyone most adopts the technology or a decision permitting adopters to go ahead and nonadopters to persist in their choice. Similar patterns mark centralized decision, though in this situation trials are controlled by the leadership and debate about whether to adopt is confined to a few. Even where decisions are made individually or by local communities, government regulations and taxes can encourage or hinder adoption of new technologies. Many governments promoted aviation in the 1920s and 1930s through subsidies. The contemporary US dependence on motor vehicles can be traced partly to policies favoring road and highway construction; conversely, high fuel taxes helped constrain household possession of automobiles in Western Europe.

Two *communication channels*, mass media and person-to-person contact can spread ideas about new technologies. Mass media are most effective for disseminating information that a new technology has been incorporated into devices very quickly, person-to-person communication between users and non-users among their family, friends, or occupational networks have the most impact on adoption decisions.

Social and material conditions also affect diffusion. Political and social stability encourages longer-term projects by promoting confidence that they can be finished and their results enjoyed. Technologies may intertwine with social factors that encourage or inhibit use. In the 1960s and 1970s fax technology was more popular in Japan than telex. Telex is a character-based system, an automated telegram system in which the sender types characters on a keyboard and the machine converts them into the Morse dot-and-dash code used on the wire and the receiving machine converts the Morse code back into characters and prints them out on paper while fax technology reveals characters as output of line-by-line scanning of light and dark areas. Japanese users liked fax because it is much easier to scan than to type out the 4000 characters of Chinese ideograph-based *kanji* and additional syllabic characters of *kana* script used in written Japanese. Desire to "keep up" with the neighbors means that households in neighborhoods where most others have acquired a particular new device – say a color television in the 1960s – will be more likely

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[4] Torsten Hagerstrand, *Innovation Diffusion as a Spatial Process* (Allan Paul, trans. Chicago: University of Chicago Press, 1967), 53.

to buy one than households in neighborhoods where few others have them. Adoption of technologies incorporated into obviously expensive devices may be hindered by social beliefs that possession inspires envy and the envious respond by invoking witchcraft against the envied person.[5] Studies of farmers' adoption of new irrigation technologies have shown that soil quality and depth of the water table are major determinants of farmers' choices regarding irrigation.[6]

Individuals trusted by others in the community can foster or hinder adoption of a new technology. In every community others look to certain people for guidance because of some role they occupy or a reputation for wisdom. In many countries farmers' technology choices are strongly influenced by what government-employed agricultural agents recommend or warn against in the course of their work. The Nestlé campaign to promote use of baby formula in developing countries succeeded as well as it did (and attracted as much vehement objection as it did) because the women hired to promote it often dressed in a manner similar to medical clinic staff.

The existence of so many influences on technology choice mean that the route from learning about a technology to using it regularly is more complex than the route from encountering germs to coming down with a disease. Unlike the pathway from germs to disease, the pathway from learning about a technology to using it regularly involves physical, social, and individual factors. Yet, the hazard model does capture broad patterns. The answer to the puzzle about how something influenced by many factors can be expressed in similar patterns has two parts: a) the pattern has considerable variation in the timing and speed of its phases and b) innovators and other advocates of a technology pay attention to potential users' reactions and often modify the devices embodying the technology or their explanations of what the technology can do to fit their audience. It is frequently the case that the early devices using a particular technology bear little resemblance to the later ones; the vacuum tubes and mechanical card readers of the Univacs of the 1950s bear scant resemblance to the silicon chips and magnetic hard drives of contemporary computers.

II. The Impact of National Differences on Diffusion

The simplest hazard models assume an undifferentiated population in which each individual has about the same likelihood of encountering any other nearby individual and influences pass freely between them. More sophisticated ones are able to accommodate differentiated or segmented populations in which the likelihood of encounter is high within a subgroup and low between subgroups. The transnational diffusion of ideas, practices and technologies involves segmented populations because national boundaries and cultural differences insert additional filters through which learning about new ideas, practices, or technologies must pass.

Though national borders do not form as strong a barrier to communication as they did in the past, some countries still succeed in walling off their populations from global information flows. North Korea is the most successful today, but most dictatorships limit local access to foreign-origin information. To the extent that a

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[5] Liliana Goldin, "Work and ideology in the Maya highlands of Guatemala," *Economic Development and Cultural Change* 41/#1: 103-4 (Oct. 1992) notes such beliefs were common among Maya in Guatemala.

[6] E.g., M. Caswell and D. Zilberman, "The effects of well depth and land quality on the choice of irrigation and technology," *American Journal of Agricultural Economics* 68: 798-811 (1986) and G. Feder, R.E. Just, and D. Zilberman, "Adoption of agricultural innovations in developing countries: A survey," *Economic Development and Cultural Change* 33: 255-298 (1985).

government can make national boundaries into barriers excluding communications from outside, they prevent learning about inventions and innovations and keep adoption decisions from arising at all. Even when borders are permeable language differences channel the direction of information flows. Translation can widen the flows, but it only occurs when someone (perhaps the originator of an idea or invention; perhaps an early adopter who wants to spread it) decides that a particular piece of information is important enough to justify the work involved. The spread of English as a second language around the world has reduced some of the barriers between countries, though may accentuate the differences of information open to the more privileged and to the less privileged within countries because the former are much more likely to have opportunities to learn English.

When communication succeeds, cross-national differences in adoption reflect different conjunctures of the same six factors that influence adoption in a single country.

While the *characteristics of the technology itself* may remain constant, the comparisons to competing technologies can differ considerably because they depend on what else is available. Where batteries are easily obtained, a wind-up flashlight will be a distant second choice after a battery-powered flashlight; households will not acquire them, or will only have them for emergencies in case all batteries on hand are run down. Where batteries are scarce, a wind-up may be the only choice.

The *economic cost-benefit ratios* of new technologies may be radically different in various places because of differences in physical environment, factor endowments, local operating skills, or cost of infrastructure and supplies needed to keep the technology running. The economics of using solar cells are very different in the Sahara than in rainy Seattle or the dark Arctic winter. A constant national labor shortage greatly reinforced 19th Americans' efforts substitute machines for humans in as many areas of production and housework as possible; plentiful labor meant the need to invent or acquire labor-saving machinery was much lower in China or India. Local skill levels can increase, and governments use policy devices like expedited residence permits for skilled immigrants, requirements that foreign firms allowed to operate in the country train locals for skilled jobs, or hiring foreign instructors to staff technical schools and colleges to increase the local skilled labor pool. However, technology choices do depend on current and near-future skill attainments rather than long-term potentials. Extending a national electric grid is much easier in countries where most people live in large cities and concentrated villages than in countries where most of the population is spread thinly across vast deserts, and absence of reliable electricity constrains many technology choices. One can cook food in the Gobi Desert, but using an electric stove is usually not an option.

Differences in the *mode of social decision* about adopting new technologies may or may not yield differences. Advocates of participatory decision-making tend to assume that an open process leading to collective consensus decision will result in using technologies that are less centralizing and less risky than those chosen in either an elite-run decision processes or a system of individual choice (because the wealthiest will be able to operate at a scale overshadowing everyone else), but that is a proposition that needs further testing. In a world of open communication, it may be harder for elites than for cohesive social groups to exclude unapproved technologies or unapproved uses of approved technologies. In a cohesive social group, mutual regard and respect for the tradition of consensus provide effective barriers against individual technology wandering. Elites may enjoy comparable legitimacy but when they do not they are likely to face the sorts of individual wandering in which Iranians put sermons and revolutionary messages

from Ayatollah Khomeini into their cassette recorders and residents of the Baltic republics connected to the Swedish cell phone system rather than use Soviet landlines.
Differences in communication channels can have an impact. Fewer mass media outlets that reach a smaller segment of the population appear by definition to be less effective at disseminating information about ideas, practices, and technologies. Though paucity of mass media does not necessarily mean people cannot get information[7] but informal oral networks are not the best ways to circulate detailed technical information. Without ways to secure more detail, the discussions between users and family, friends, or occupational contacts that most influence adoption decisions may not be as effective.

Social and material conditions in which the technology will be used have an impact, but many technologies can be used in under a variety of conditions. Minnesotans need down parkas while Nigerian villagers do not; but both can wear tee shirts. Some technologies are perceived as culturally relevant, and adopted or resisted on cultural grounds; others are perceived as culturally neutral. Cassette tape recorders, initially developed with the idea that people would use them to have a portable source of musical entertainment, were quickly adopted by political dissidents ranging from Marxist guerillas to Islamicist imams for spreading their message.

Culturally based reactions to foreign origin technologies depend very much on the *extent of promotion by trusted persons*. Many studies of the cross-border spread of ideas and technologies acknowledge that their reception depends on their fit with already prevailing local models. Those that can be presented as consistent with local norms are more likely to be accepted than those that cannot. Colonial units in India willingly accepted new rifles in the 1850s since weapons are central to soldiering. Suggestions that the grease on the cartridges that had to be bitten before loading them into the rifles came from pigs or cows fanned the preexisting discontent among some Moslem and Hindu soldiers into mutiny because the grease was now seen as violating religious dietary laws. Even the name given to a device can affect the likelihood of adoption if locals interpret it in different ways. The most famous commercial example is the marketing fiasco of Chevrolet's attempts to sell its Nova model in Latin America. Chevrolet had named it with the Latin word for "new," but locals read the name as "no va" ("doesn't go") instead. Community influentials who dislike a foreign idea, practice, or technological innovation can discourage adoption by castigating it as contrary to local morals, likely to destroy local ways, or creating unwanted dependence on outsiders. Those who like it can promote adoption through both talking about it and by using it; their words and deeds indicate how it can be incorporated into local culture without severe negative consequences. People who are unhappy with local ways might even adopt a foreign idea, practice, or technological innovation as a way of expressing their unhappiness with and desire for change in the current situation.

The strong differences of climate, topography, economic factor endowments, and cultural heritages between industrial and developing countries around the world have inspired concern that many countries, particularly smaller and poorer ones, end up with technology that fails to meet their real needs. This is often attributed to the influence of multinational corporations, but there are actually three reasons why persons, groups, local business firms, or the government in a country acquire inappropriate technology:

1.) the whole set of currently known and used technologies is inappropriate to a particular country or activity within it,

[7] In many African countries the rumor flows known in francophone countries as *radio trottoir* (pavement radio) often make up for scanty broadcast media. See Stephen Ellis, "Tuning in to pavement radio," *African Affairs* 88 (#352): 321-330 (1989).

2.) inappropriate technology is acquired because no one in the country providing information to the choosers knows about the appropriate technologies that exist, or

3.) the choosers know about appropriate technologies but choose inappropriate ones.[8]

Since multinational corporations are not the only source of technology in the world, they are not solely responsible for instances of the first problem. They could be the source of the second and third problems through selective presentation of information or hard bargaining, but as governments, locally owned firms, and others in developing countries acquire greater awareness of available technologies and greater ability to compare them knowledgeably the bargaining balance is shifting. In the meantime a significant "appropriate technology" movement,[9] given more impetus by rising concern for ecological sustainability, seeks to remedy all three problems through developing technologies designed specifically for conditions in poor countries, publicizing all technologies they regard as appropriate, and developing contacts with technology choosers.

In cross-border as well as within country situations, the hazard model is a summary of patterns that result from the aggregate of technology choices. In so doing, they obscure the activities of promoters and discouragers of new technologies, innovators, firms, governments, and others often seek to influence the cross-border spread of ideas and technologies. Innovators generally want to see their innovations adopted widely. Some business firms prosper by encouraging use; both cellphone network providers and cellphone manufacturers prosper when usage spreads. Other firms prosper through patents and licensing; they want licensees but not unauthorized copiers. Governments both encourage diffusion of particular technologies through their foreign aid programs or other subsidies, and constrain diffusion through export controls. Private "non-profits" (foundations, institutes, advocacy organizations) have been strong supporters of programs to develop and distribute higher-yielding varieties of plants commonly grown for food in developing areas; they also helped disseminate birth control drugs and devices. Others have campaigned against the use of certain technologies, particularly the products of nuclear engineering, genetic modification, and animal cloning.

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[8] Frances Stewart, *Technology and Underdevelopment* (Boulder, CO: Westview Press, 1977), page 3.

[9] Inspired initially by E.F. Schumacher, *Small is Beautiful* (New York: Harper and Row, 1973).