Property Rights to Technical Knowledge in Premodern Europe, 1300–1800

By STEPHAN R. EPSTEIN*

The role of technology in the transition from premodern, "Malthusian" to modern economies in late 18th- and 19th-century Europe is among the major questions in economic history, but it is still poorly understood. In particular, the view that premodern societies experienced low labor productivity and stagnant living standards, and that technological change before ca. 1800 was close to zero due to pervasive guild rent-seeking and poorly specified property rights to knowledge (Douglass C. North, 1981; Joel Mokyr, 2002), is hard to square with the fact that the surge of technological innovation in the 18th century occurred within institutional frameworks not too dissimilar to those of 1300.

It is well known that the technical knowledge of premodern craftsmen and engineers was largely experience-based. However, the implications of the fact that there were basic cognitive limitations to how technical knowledge could be expressed, processed, and transmitted have yet to be examined in detail (Arthur S. Reber, 1993; Epstein, 2003). What follows elaborates on this point, spells out the main implications for property rights to knowledge, and suggests that the principal, endogenous bottleneck to premodern technical diffusion and innovation was the cost of person-to-person teaching and demonstration.

† *Discussants:* Philip Hoffman, California Institute of Technology; Bhaven Sampat, Georgia Institute of Technology; Gavin Wright, Stanford University.

* Department of Economic History, London School of Economics and Political Science, Houghton Street, London WC2 2AE, United Kingdom. I thank Philip Hoffman for his insightful comments.

I. Transmission of Technical Knowledge

Experience-based knowledge is a good, and its exchange and diffusion demand that those who have it take deliberate action to share it through face-to-face communication. These operations are costly to implement and have relied historically on a variety of solutions. Analytically, it is useful to break down the question of how technical knowledge was taught into the distinct issues of intergenerational transmission and transmission between skilled peers.

The first and most important stage in acquiring technical knowledge was through apprenticeship. Since future human capital cannot act as collateral, resource-poor but potentially able workers may be incapable of bearing the costs of their investment in skills, leading to a socially suboptimal supply of skilled workers. Apprenticeship allowed trainees to exchange subsidized training for below-market wages after training was concluded. However, firms would have still supplied suboptimal amounts of training if the trainee had been able to quit before contract expiry. Craft guilds played a dominant (though not unique) role in overcoming training externalities in human-capital formation. Craft guilds supervised job performance, work conditions, and quality of instruction; enforced contracts through compulsory membership, statutory penalties, and blackballing; and protected apprentices against poor training in craft-specific skills within oligopsonistic labor markets. These functions explain the extraordinary longevity of European craft guilds from the late 11th century to the early 19th (Epstein, 1998).

Apprenticeship training was costly, for two reasons. First, skills and expertise take time and

effort to acquire. Although experts do not think in fundamentally different ways from nonexperts, experts have substantially more knowledge about the task at hand and display qualitative differences in the way they organize and represent that knowledge. Experts use specialized recognition processes to achieve unusual feats of memory, reorganize knowledge into complex hierarchical systems, and develop complex networks of causally related information. The knowledge of less-skilled individuals, in contrast, is encoded using everyday concepts that make the retrieval of even their limited knowledge difficult and unreliable. It consequently takes about ten years of dedicated training to achieve top-level expertise (K. Anders Ericsson et al., 1993), a fact that is plausibly reflected in the length of premodern apprenticeships.

Secondly, apprenticeship was costly because most craft knowledge was implicit or hard to codify. The importance of implicit knowledge and experience placed a premium on employing family members, who had been socialized early into the craft and generated higher levels of trust, particularly in the most technically advanced industries like mining and metalworking, ship- and high-quality edifice-building, and clock and instrument-making. Nevertheless, apprenticeship and guild membership in Europe were non-ascriptive and individualistic—there was no cultural, kin, or other noncontractual obligation to remain tied to one's master, birth group, or community, a fact that probably lowered the costs of mobility considerably by comparison with other premodern societies.

Much premodern craft and engineering knowledge appears to have been shared or "distributed" within industrial districts (Epstein, 2003; see also Robert C. Allen, 1983). Sharing was more likely in ship- and edifice-building, mining and metalworking, and in the production of clocks and scientific instruments, which displayed strong division of labor and advanced levels of coordination and where cooperation provided clear economies of scale and scope—sectors that are also notable for having played the most technologically innovative role in the Industrial Revolution. Sharing was probably less common in industries like glassmaking and in some of the luxury-goods sectors, where experimental knowledge whose scientific basis was poorly understood gave individual craftsmen a competitive edge.

The existence of strong externalities in many industries defined an environment characterized by low appropriability. Low appropriability will in principle reduce incentives for innovation within individual firms and would help explain the craft guilds' reputation for technological conservatism. Nonetheless, empirical evidence of guild conservatism is weak, and there is good evidence to the contrary, even though innovation that drew prevalently on tacit knowledge is hard to identify (Epstein and Maarten Prak, 2004). The craft guild also enabled individual members to capture a share of consumer surplus from their invention, by forbidding the poaching of skilled labor employed by the inventor, and by raising the costs of exit for other members through a combination of penalties and club goods. The interval between invention and copying provided inventors with a first-mover advantage and a reasonable rate of return.

II. Texts and Patents

In theory, technical knowledge could be disseminated across space in three ways: through publicly available texts, through patents, and through migrating individuals. In practice, published, "disembodied" technical knowledge did not disseminate well. Premodern scientists and savants typically overestimated the role played by explicit, propositional knowledge in craft and engineering practice. Written manuals were incomplete and sometimes misleading; they might contain technical details not actually applied in solving the problem; and they left out crucial practicing "tricks." These problems were compounded by the fact that experts frequently had difficulty describing what cues they responded to and what factors contributed to decisions they made, which explains why equally skilled experts in the same field disagreed on how to do their job (Eric H. Ash, 2000). The large tacit and nonlinear component of experience-based knowledge explains why not a single premodern innovation was transferred simply through the printed word.

Premodern patents faced similar technical and cognitive problems. Patent law was first established in late 15th-century Venice and spread rapidly to the rest of Italy and northward, first to the German principalities, then to France, Spain, and the Low Countries, and subsequently

to England (Malcolm Frumkin, 1947–49). By contrast with their modern counterparts, however, premodern patent laws did not normally request novelty and originality; most patent descriptions were generic and did not remotely approximate a modern blueprint; and innovations were seldom examined before the 18th century. Although some administrations, like Venice from the early 16th century, demanded a working model of patented machinery, it is unclear to what extent the models could overcome problems of scaling when reproducing the original. In practice, patents were a means for towns or rulers to encourage the introduction of a new machine or process in their jurisdiction, by conceding a contingent monopoly over exploitation. Patents were granted mainly for mechanical inventions in power production (milling, hydraulics, heating), which had high sunk costs and indivisibilities and low reproduction costs; patents were also used as a means of commercial advertisement. Since patents tended to require costly lobbying and upfront fees, and placed the entire burden of proof and investment risk on the inventor's shoulders, barriers to entry to the technology market via patents were high. The propensity to patent was also influenced by other factors. Many product and process innovations were never patented because they were better protected as trade secrets or because they were part of the collective knowledge of a craft; for example, the makers of watches, clocks, and astronomical and other scientific instruments, most of whom were organized in guilds, opposed patents that tried to privatize knowledge that was already in the craft's domain or that were perceived to restrain trade (Epstein and Prak, 2004). Consequently, premodern patent rights did not play a major role in innovation before 1800 (Christine MacLeod, 1988).

III. Technological Transfer

The assumption that patent rights to invention were necessary for premodern technological innovation rests on the view that intellectual creation is nonrivalrous, and that once in the public domain, it can be copied at no additional cost. This fact may be true but is economically irrelevant, since what matters is the application of the new idea, which has learning and physical costs. In premodern manufacture, the costs of application arose from the largely implicit nature of technical knowledge, which created the need for one-on-one training and meant that technological innovations had to be transferred by traveling craftsmen and engineers.

Between ca. 1300 and ca. 1550, European craft guilds and polities devised institutional arrangements that sustained craft mobility and raised the *potential* rate of technological innovation. Skilled migrant workers were temporary and seasonal, made up mainly of apprentices and journeymen, or permanent, made up mostly of established masters (Epstein, 2004a). Organized apprentice and journeyman tramping grew out of the temporary skills shortages following the plague epidemics of 1348–1350. By 1550, tramping was common in much of western Europe, although it was only fully institutionalized in German-speaking central Europe and less extensively in France. In England, independent journeyman organizations were formed after the decline of London as a national training center from the 1680's. Since the main purpose of organized tramping was to coordinate information and allocate skilled labor more efficiently across regions, formal organizations never arose in densely urbanized regions like northern Italy and the Low Countries where information costs were low.

Apprentice and journeyman mobility helped develop and diffuse technical knowledge within areas that were institutionally, economically, and culturally similar. Nascent monarchies and territorial states, however, made it a point to attract new skills and technology from outside such zones. Competition for skilled workers, for example, for master cathedral-builders, existed already during the Middle Ages, but it increased markedly during the early Renaissance (ca. 1450–1550) in the eastern Mediterranean, and after the Reformation in north-central Europe, when European rulers made it policy to attract displaced craftsmen from enemy lands. The Huguenot migrations to Geneva and England and the wholesale transfer of artisan skills from Brabant to the Netherlands after the sack of Antwerp in 1585 are just some threads in a complex web of politically driven technical diffusion (W. C. Scoville, 1951). From the mid-17th century, mercantilist states promoted domestic industry and engaged in industrial espionage more systematically; attempts by guilds and

political authorities to stop ski
migrating were hindered by
tions and state competition
1998).

There were four major obs
cessful transfer of technical
long distances. The most ofte
crecy and guild opposition to
the least important. Rent-seek
position did not create insup
change because guilds were
tion to enforce their wishes, a
ship was often divided (E
2004). Strong evidence to thi
that technological leadership
from southern to northweste
Italy (1200–1450), to the so
and southern Netherlands (ca
the Dutch Republic (1570–16
Britain after ca. 1675, largely
migrants trained by guilds.
technological torch set in m
rapid innovation in the nev
Britain, for example, was a o
ical debtor up to the late 17th
Hollister-Short, 1976); betwe
it imported from the Contir
vanced techniques in metal s
ing, in the making of gla
watches, scientific instrument
silk cloth, and in hydraulic
agriculture, and it integrated
largely under the aegis of the
tion of dependence began to
ca. 1675, and already by
Parliament had become so w
national competitors, and so
technical prowess, that it pas
the emigration of resident te

The two main obstacles
transfer were information a
which restricted labor mobili
of a local skills base that
integrate new techniques. A
only absorb outside innovati
trained technicians who cou
and repair new machinery. A
transferring British coal-bas
non-coal-based Continental
18th century, for example,
bility of the associated interm
and skills (Harris, 1998). Kr

political authorities to stop skilled workers from migrating were hindered by weak administrations and state competition (John R. Harris, 1998).

There were four major obstacles to the successful transfer of technical knowledge over long distances. The most often cited, trade secrecy and guild opposition to innovation, were the least important. Rent-seeking and guild opposition did not create insuperable barriers to change because guilds were seldom in a position to enforce their wishes, and guild membership was often divided (Epstein and Prak, 2004). Strong evidence to this effect is the fact that technological leadership moved over time from southern to northwestern Europe, from Italy (1200–1450), to the southern Rhineland and southern Netherlands (ca. 1450–1570), to the Dutch Republic (1570–1675), and finally to Britain after ca. 1675, largely thanks to skilled migrants trained by guilds. Each relay of the technological torch set in motion a period of rapid innovation in the new regional leader. Britain, for example, was a one-way technological debtor up to the late 17th century (Graham Hollister-Short, 1976); between 1600 and 1675 it imported from the Continent the most advanced techniques in metal smelting and forging, in the making of glass, pottery, guns, watches, scientific instruments, wool, linen, and silk cloth, and in hydraulic engineering and agriculture, and it integrated these innovations largely under the aegis of the guilds. This position of dependence began to be reversed after ca. 1675, and already by 1720, the English Parliament had become so worried about international competitors, and so confident in native technical prowess, that it passed a law banning the emigration of resident technicians.

The two main obstacles to technological transfer were information and transport costs, which restricted labor mobility, and the absence of a local skills base that could successfully integrate new techniques. An economy could only absorb outside innovation if it had enough trained technicians who could make, operate, and repair new machinery. A major hurdle with transferring British coal-based technologies to non-coal-based Continental economies in the 18th century, for example, was the incompatibility of the associated intermediate goods, parts, and skills (Harris, 1998). Knowledge transmission could therefore be excruciatingly slow. It took over a century to transfer Hollander paper beaters from the 17th-century Netherlands to 18th-century France because of a lack of good machine-makers and repairers; 18th-century French metalworkers had no knowledge of high-quality steelmaking that had been practiced in Germany, northern Italy, Sweden, and England for up to two centuries (Cyril S. Smith, 1956; Leonard N. Rosenbrand, 2000).

Bottlenecks to technical transfer were relaxed over time by falling information and transport costs, which can be proxied reasonably accurately by trends in urbanization (Paul Bairoch et al., 1988). The most salient example of the correlation between technological leadership and urbanization is premodern England, which was transformed between 1650 and 1750 from a technological and underurbanized semi-periphery to the most technologically innovative and urbanized country in the West. The most plausible reasons for the correlation are the standard Marshallian ones: economically successful towns attract skilled workers, whose pooling stimulates the growth of specialized intermediate-goods industries; knowledge spillovers among firms increase; and reliable knowledge improves and increases with use. This model fits well with the evidence that premodern regional technological leadership always followed commercial leadership, with a certain lag (Karel A. Davids, 1995).

IV. Concluding Remarks

In conclusion, the main causes of low rates of premodern innovation were the high information and reproduction costs related to experience-based knowledge. The principal source of diminishing returns to technicians' knowledge seems to have been the poor interactions between dispersed craftsmen and engineers, rather than the narrowness of the premodern crafts' epistemic base.

Although in principle tacit knowledge should have raised the appropriability of rent streams from invention, in practice appropriability was rather low, because the system of apprenticeship training and the use of a mobile skilled labor force made it difficult for individuals to protect technical secrets. Patent laws were commonplace but mostly ineffective. Technical knowledge within industrial regions or districts

with integrated skilled labor markets was largely shared, although only trained experts could understand it. Technological transfer across long distances, however, was inherently rivalrous, because it required nonlocal patterns of expertise to successfully apply a foreign invention.

A distinctively European technological system emerged from the late 11th century, based on craft-based apprenticeship training, nonascriptive membership of craft associations, and, increasingly, competition among states for skilled workers. These three elements defined a set of necessary and sufficient endogenous conditions for the accumulation, codification, and circulation of reliable technical knowledge (Epstein, 2004b). However, the main *direct* source of premodern technical innovation was the craft guild, for three reasons. First, it enforced the rules of apprenticeship against free-riding and exploitation. Second, it offered institutional, organizational, and practical support to the migrant apprentices, journeymen, and masters who transferred their technical knowledge from one town and region of Europe to another. Third, it supplied incentives to invention that the patent system did not by enforcing temporary property rights over members' innovations. Notably, only the first effect was the outcome of deliberate policy; the other two were unintended consequences of the club goods that the craft supplied its members.

Over time, the costs of technical dissemination fell in response to growing state competition and urbanization. Urbanization provided better opportunities for exchanging knowledge, higher average quality of labor, a greater likelihood of matching skills to demand, and stronger incentives for knowledge modeling and codification. Although it is not a priori clear whether high urbanization attracted skilled migrants, or whether migration (driven by exogenous factors like war) caused high urbanization, the evidence points to the primacy of the former, pull factors, specifically of urban commercial success. Thanks to migration by skilled workers, each new technological leader could draw on the accumulated knowledge of its predecessors, recombine it with the domestic knowledge pool, and develop it further. In these circumstances, it is plausible that it would be only a matter of time before a process analogous to the Industrial Revolution would take place.

REFERENCES

Allen, Robert C. "Collective Invention." *Journal of Economic Behavior and Organization*, March 1983, *4*(1), pp. 1–24.

Ash, Eric H. "'A Perfect and an Absolute Work,' Expertise, Authority, and the Rebuilding of Dover Harbour, 1579–1583." *Technology and Culture*, April 2000, *41*(2), pp. 239–68.

Bairoch, Paul; Batou, Jean and Chèvre, Pierre. *La population des villes européennes 800–1850: Banque de données et analyse sommaire des résultats*. Geneva, Switzerland: Droz, 1988.

Davids, Karel A. "Shifts of Technological Leadership in Early Modern Europe," in J. Lucassen and K. Davids, eds., *A miracle mirrored. The Dutch Republic in European perspective*. Cambridge, U.K.: Cambridge University Press, 1995, pp. 338–66.

Epstein, Stephan R. "Craft Guilds, Apprenticeship, and Technological Change in Preindustrial Europe." *Journal of Economic History*, September 1998, *53*(4), pp. 684–713.

______. "Transmitting Craft Knowledge in Premodern Europe." Mimeo, London School of Economics, 2003.

______. "Labour Mobility, Journeyman Organisations and Markets in Skilled Labour in Europe, 14th–18th Centuries," in L. Hilaire-Perez and A. Garçon, eds., *Pratiques historiques de l'innovation, historicité de l'économie des savoirs (12e–19e siècles)*. Paris: Comité des Travaux Historiques, 2004a, pp. 129–44.

______. "The Rise of the West," in J. Hall, ed., *An anatomy of power: The social theory of Michael Mann*. Cambridge, U.K.: Cambridge University Press, 2005 (forthcoming).

Epstein, Stephan R. and Prak, Maarten, eds., *Guilds, technology and economy in Europe 1400–1800*. London, U.K.: Routledge, 2004 (forthcoming).

Ericsson, K. Anders; Krampe, R. Th. and Tesch-Römer, C. "The Role of Deliberate Practice in the Acquisition of Expert Performance." *Psychological Review*, July 1993, *100*(3), pp. 363–406.

Frumkin, Malcolm. "Early History of Patents for Invention." *Transactions of the Newcomen Society*, 1947–49, *26*, pp. 48–56.

Harris, John R. *Industrial espionage and technology transfer. Britain and France in the*

Eighteenth Century. Alder
gate, 1998.

Hollister-Short, Graham. "Lead
Seventeenth-Century Engli
History of Technology, 1976

MacLeod, Christine. *Inventin
Revolution. The English
1660–1800*. Cambridge,
University Press, 1988.

Mokyr, Joel. *The gifts of Athe
igins of the knowledge eco*
NJ: Princeton University P

North, Douglass C. *Structure a
nomic history*. New York:

Reber, Arthur S. *Implicit le
knowledge. An essay on*

Eighteenth Century. Aldershot, U.K.: Ashgate, 1998.

Hollister-Short, Graham. "Leads and Lags in Late Seventeenth-Century English Technology." *History of Technology*, 1976, *1*, pp. 159–83.

MacLeod, Christine. *Inventing the Industrial Revolution. The English patent system, 1660–1800*. Cambridge, U.K.: Cambridge University Press, 1988.

Mokyr, Joel. *The gifts of Athena. Historical origins of the knowledge economy*. Princeton, NJ: Princeton University Press, 2002.

North, Douglass C. *Structure and change in economic history*. New York: Norton, 1981.

Reber, Arthur S. *Implicit learning and tacit knowledge. An essay on the cognitive unconscious*. Oxford, U.K.: Oxford University Press, 1993.

Rosenband, Leonard N. *Papermaking in eighteenth-century France. Management, labor, and revolution at the Montgolfier mill 1761–1805*. Baltimore, MD: Johns Hopkins University Press, 2000.

Scoville, W. C. "Spread of Techniques: Minority Migrations and the Diffusion of Technology." *Journal of Economic History*, Autumn 1951, *11*(4), pp. 347–60.

Smith, Cyril S. "Introduction," in *Réamur's memoirs on steel and iron. A translation from the original printed in 1722* [A. Grünhaldt Sisco, transl.]. Chicago: University of Chicago Press, 1956, pp. vii–xxxiv.