

1 The Economics of Apprenticeship

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Introduction

The subject of apprenticeship, one of the more enduring of all economic arrangements, has received more attention from economic historians and the economics profession at large in recent years.¹ Yet, compared, say, with issues such as the economics of slave labor or the rise of formal human capital and literacy, apprenticeship – the mechanism through which practical skills were transferred from generation to generation – has not been the subject of much research before 2000. Even in the literature that has revised and criticized the old view of the guilds as a pure redistributive institution and an impediment to efficiency and technological progress, apprenticeship was often mentioned but was eclipsed by other issues such as exclusionary rent-seeking and allocative efficiency. There were some exceptions in specific cases, but in proportion to its importance and prevalence, the institution remained strangely under-researched until recently.² This is now changing, in large part through the pioneering work of a number of scholars on apprenticeship in Canada and Europe such as Gillian Hamilton, Bert De Munck, and Patrick Wallis, among others.³

¹ The comments and suggestions of David De la Croix, Morgan Kelly, Cormac Ó Gráda, Maarten Prak, and Patrick Wallis on an earlier draft are acknowledged with gratitude. A longer version of this essay with detailed footnotes can be found at www.faculty.econ.northwestern.edu/faculty/mokyr.

² O. J. Dunlop, 'Some aspects of early English apprenticeship', *Transactions of the Royal Historical Society*, third series, 5 (1911), 193–208; O. J. Dunlop, *English Apprenticeship and Child Labor* (New York: MacMillan, 1912); B. Elbaum, 'Why apprenticeship persisted in Britain but not in the United States', *Journal of Economic History* 49 (1989), 337–49; J. Lane, *Apprenticeship in England 1600–1914* (Boulder, CO: Westview Press, 1996); G. Hamilton, 'Enforcement in apprenticeship contracts: Were runaways a serious problem? Evidence from Montreal', *Journal of Economic History* 55 (1995), 551–74; G. Hamilton, 'The decline of apprenticeship in North America: Evidence from Montreal', *Journal of Economic History* 60 (2000), 627–64.

³ B. De Munck, *Technologies of Learning: Apprenticeship in Antwerp Guilds from the 15th Century to the End of the Ancien Régime* (Turnhout: Brepols, 2007); B. De Munck, 'From brotherhood community to civil society? Apprentices between guild, household and the

The new research has been directed primarily at economic and social historians; the important implications of apprenticeship for issues in economic growth, the economics of innovation and technological diffusion, labor economics, and the new institutional economics, need to be spelled out in some detail, which is what this chapter will attempt to do. As the other chapters in this volume amply attest, a great deal of new information has been unearthed in recent years about the actual workings of apprenticeship in the past. At the same time, economics provides a set of analytical tools that offer a theoretical framework to interpret the new data. These tools are both microeconomic and macroeconomic. In terms of microeconomics, one issue concerns contracts, that is, analyzing the transaction between the supplier of training (the master) and the customer (the apprentice and his family). Other microeconomic themes of interest connect directly to the organization of the industry and the use of apprenticeship as a barrier to entry and the structure of pre-modern urban labor markets, as apprentices and journeymen were a form of *unproletariat* before the Industrial Revolution.

Human capital theory suggests that investment in education is one of the most important human activities that determines lifetime outcomes on the microeconomic level and the economic performance of society on the macro level. An analysis of apprenticeship involves the intergenerational transmission of technical skills. These skills constituted a special form of human capital, a set of recipes often referred to as the “secrets of the trade,” a *savoir faire* that determined how goods and services were to be produced and who would be allowed to engage in it. The economics of knowledge stresses the important distinction between codifiable and tacit knowledge.⁴ Much of the knowledge imparted to apprentices was *tacit* knowledge, which could not be obtained from textbooks or encyclopedias and was not taught in schools. The only way for a young lad to become a barber, a cooper, or a cabinetmaker was through direct contact with, and imitation of, people who already possessed the requisite competence

freedom of contract in early modern Antwerp’, *Social History* 35 (2010), 1–20; B. De Munck, ‘Corpses, live models, and nature: Assessing skills and knowledge before the Industrial Revolution (case: Antwerp)’, *Technology and Culture* 51 (2010), 332–56; P. Wallis, ‘Apprenticeship and training in premodern England’, *Journal of Economic History* 68 (2008), 832–61; P. Wallis, ‘Labor, law, and training in early modern London: Apprenticeship and the City’s institutions’, *Journal of British Studies* 51 (2012), 791–819. Economists, too, are gradually recognizing its importance, e.g. W. Smits and Th. Stromback, *The Economics of the Apprenticeship System* (Cheltenham: Edward Elgar, 2001); D. De la Croix, M. Doepke and J. Mokyr, ‘Clans, guilds, and markets: Apprenticeship institutions and growth in the pre-industrial economy’, *Quarterly Journal of Economics* 133 (2018), 1–70.

⁴ D. Foray, *The Economics of Knowledge* (Cambridge, MA: MIT Press, 2004), especially 71–90.

and were willing and able to teach it.⁵ In terms of more aggregative analysis, apprenticeship was a major factor in the determination of the rate and quality of human capital formation. Beyond that, masters acted *in loco parentis* and apprenticeship was a major part of socialization and the intergenerational transmission of culture and norms, a topic that has recently become quite interesting to economists.⁶ Here the interests of the two disciplines clearly are conjoined, and interdisciplinary research is promising.⁷

Moreover, apprenticeship should also be analyzed through the prism of the new institutional economics pioneered by Douglass North. The market for apprenticeship, like all markets, depended on a set of institutions that determined how the contracts were enforced, how effective the training was, whether innovation was encouraged, and what it implied for the status of masters and apprentices. The institutions governing apprenticeship thus represent a prime example of a set of Northian “rules of the game” that determined economic outcomes. In its regulation, formal (that is to say, government) institutions coexisted and overlapped with private arrangements and corporate bodies and underlay pre-modern non-agricultural labor markets.

Finally, I will turn to the issue of economic growth and the Industrial Revolution, and argue that the work of economists implies a central role for apprenticeship in the questions regarding the sources of the “Great Enrichment” in Europe. An obvious reason for its significance in the growth literature is the observed differences in technological capabilities in different economies, with far-reaching consequences for economic performance. In the case of the British Industrial Revolution, for instance, it has been argued that the level of skills of British workers was higher than elsewhere largely due to its superior and flexible institutions of training youngsters.⁸

⁵ J. R. Harris, ‘Skills, coal and British industry in the eighteenth century’, in: Harris, *Essays in Industry and Technology in the Eighteenth Century* (Aldershot: Ashgate/Variorum, 1992), 33 called the tacit knowledge in the iron industries ‘unanalyzable pieces of expertise’ and ‘the knacks of the trade,’ but it was equally true in many service industries; see J. R. Farr, *Artisans in Europe, 1300–1914* (Cambridge: Cambridge University Press, 2000), 34.

⁶ A. Bisin and Th. Verdier, ‘The economics of cultural transmission and socialization’, in: J. Benhabib, A. Bisin and M. O. Jackson (eds.), *Handbook of Social Economics*, vol. 1A (Amsterdam: North-Holland, 2011), 339–416.

⁷ De Munck, *Technologies of Learning*, 4–5.

⁸ M. Kelly, J. Mokyr and C. Ó Gráda, ‘Precocious Albion: A new interpretation of the British Industrial Revolution’, *Annual Review of Economics* 6 (2014), 363–89; J. Humphries, ‘English apprenticeships: A neglected factor in the first Industrial Revolution’, in: P. A. David and M. Thomas (eds.), *The Economic Future in Historical Perspective* (Oxford: Oxford University Press, 2003), 73–102; N. Ben Zeev, J. Mokyr and K. van der Beek, ‘Flexible supply of apprenticeship in the British Industrial Revolution’, *Journal of Economic History* 77 (2017), 208–50.

The Industrial Revolution did not lead to the end of apprenticeship. In many economies one-on-one training is still very widely practiced. Despite the abolition of the English Statute of Apprentices and Artificers in 1814, apprenticeship remained of central importance in the British textile engineering sector, one of the high-tech sectors of the day.⁹ Moreover, while in our time apprenticeship has been partially supplanted by formal instruction in vocational and professional schools, the personal, one-to-one transmission of knowledge and hands-on experience is still felt to be of substantial importance, complementing rather than replacing more formal forms of instruction.¹⁰

Tacit Knowledge and Personal Teaching

One way to look at apprenticeship is as a personal and direct way of passing tacit skills and competence from master to pupil. Skills have been described by Michael Polanyi in his classic work on the topic as “the observance of a set of rules not known to the person following them.”¹¹ Tacit knowledge of any kind is likely to be transmitted through personal contact: by observation, memorization, and imitation. Hence, Polanyi argued, “An art which cannot be specified in detail cannot be transmitted by prescription, since no prescription for it exists. It can be passed on only by example from master to apprentice. This restricts the range of diffusion to that of personal contacts, and accordingly craftsmanship tends to survive in closely circumscribed local traditions.”¹² One corollary is that many high-skilled crafts were located in urban areas; rural manufacturing – while widespread – was mostly low-skill.¹³ In the modern age, it is common to think of codified and tacit knowledge as complements in which a hands-on personal relation supplements formal course work. Not so before the Industrial Revolution: formal instruction in the

⁹ G. Cookson, *The Age of Machinery: Engineering the Industrial Revolution, 1770–1850* (Woodbridge: Boydell Press, 2018), 236. As late as 1925, there were 315,000 apprentices and 110,000 ‘learners’ in Great Britain; see Smits and Stromback, *Economics*, 20.

¹⁰ In Germany today almost 60% of young people train as apprentices, compared with less than 5% in the United States. Apprenticeship occurs not just in manufacturing but in banking, IT, and hospitality. In experimental sciences, postdoctoral training – a form of apprenticeship – is still required; e.g. T. Jacoby, ‘Why Germany is so much better at training its workers,’ *The Atlantic*, 16 October 2014, www.theatlantic.com/business/archive/2014/10/why-germany-is-so-much-better-at-training-its-workers/381550/.

¹¹ M. Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1962), 49.

¹² *Ibid.*, 53.

¹³ P. Desrochers, ‘Geographical proximity and the transmission of tacit knowledge’, *Review of Austrian Economics* 14 (2001), 26 provides data for our time, but his argument holds *a fortiori* for medieval and early modern Europe.

majority of trades and occupations was rare. Only in law, medicine, and religion was there formal training in schools and universities. Artisans, both in manufacturing and in services, were taught the secrets of the trade by associating with a master with whom they spent their adolescent years.

How the transmission of knowledge took place exactly is not always easy to establish and was likely to depend on the idiosyncratic characteristics of individual masters and the special characteristics of the techniques taught. Most studies concede that little is known regarding the actual learning process, but Schalk speaks for the consensus when he surmises that skills were picked up primarily through imitation and learning by doing.¹⁴ The costs were the master's time as well as the raw materials used up in the less-than-successful products produced by the apprentice. An interesting formulation is suggested by Steffens suggesting that skill transmission took place through apprentices "stealing with their eyes" – meaning that they learned mostly through emulation, observation, and experimentation. Goody suggests that most learning comes from "monitored participation," a form of learning by doing in which the apprentice was allowed to carry out increasingly more complex tasks.¹⁵ Apprentices learned by being "inserted into the production process" from the start and in the absence of any serious epistemic base of the techniques in use, learning by doing and emulation were clearly central in the process.¹⁶ The tasks to which apprentices were put at first, insofar as they can be documented at all, seem to have consisted of menial assignments such as making deliveries, cleaning, and guarding the shop. Only at a later stage would an apprentice be trusted with more sensitive tasks involving valued customers and expensive raw materials.¹⁷

Contracts and the Nature of Apprenticeship

To start an apprenticeship, some kind of agreement had to be made between the two parties. In the absence of any formal and detailed description of what and how the youngster would be taught, the contract between him and his guardian on one side and the master on the other must be regarded as an archetypal incomplete contract. Unlike the standard incomplete contract model in economics, in which the main issue is the inability to specify all contingencies *ex ante*, in the case of

¹⁴ R. Schalk, 'Apprenticeships with and without Guilds', Chapter 7 in this volume.

¹⁵ S. Steffens, 'Le métier volé: Transmission des savoir-faire et socialization dans les métiers qualifiés au XIX^e siècle', *Revue du Nord* 15 (2001), 131; E. Goody, 'Learning, apprenticeship, and the division of labor', in: M. W. Coy (ed.), *Apprenticeship: From Theory to Method and Back Again* (Albany: SUNY Press, 2001), 289.

¹⁶ De Munck, *Technologies of Learning*, 4, 9. ¹⁷ Lane, *Apprenticeship in England*, 77.

apprentice indentures the exact nature of the service to be exchanged was itself vague. Even when some contracts were written by public notaries and contained details of the mutual expectations, the full details could not be specified *ex ante*, nor could they be observed with much accuracy *ex post*, due to the tacit nature of the service provided.¹⁸ Both the diligence and motivation of the pupil and the effort put in by the master were matters of discretion. The parents and guardians had to trust the master that he would teach properly; without such trust, the contract could not be viable. Moreover, the contract was normally concluded and signed by the parents, and when a tuition fee or “premium” was paid, this normally came out of their funds. Hence there was another agency problem, in that the main subject of the contract, the youngster himself, was usually not a party to the negotiation. In that regard an indenture contract between an apprentice and a master in early modern Europe was similar to the implicit contract between a student and a college in our time. The difference is that each apprentice–master relation was a non-repeated, personal, and unique interaction. Furthermore, the number of apprentices per master was small, so the informational difficulties were amplified and the possibilities for opportunistic behavior on either side were considerable.

Most of the economics literature on incomplete contracts is of little help here, since the solutions proposed there, such as the integration of firms to resolve hold-up situations or an ownership assignment that may incentivize both sides, seem irrelevant to this particular question. What is more, the information about the realized transaction was asymmetric in two ways. First, even if the two sides could observe the outcome perfectly themselves, it may have been impossible to convey this information to third parties asked to adjudicate disputes, that is, “incompleteness arises because states of the world, quality and actions are observable (to the contractual parties) but not verifiable (to outsiders)” – such as courts.¹⁹ But in this case one of the sides to the contract – the apprentice – was *by definition* underinformed about the material to be taught (and his parent or guardian, often the signatory on the contract, absent from the scene), and the incompleteness was compounded by an informational asymmetry between the contracting parties.²⁰ To make things worse, the apprenticeship contract was non-repeatable and had a clear-cut termination date after which the relationship was resolved, which made opportunistic behavior especially attractive as the contract came to an end.

¹⁸ De Munck, *Technologies of Learning*, 42.

¹⁹ O. Hart, ‘Incomplete contracts’, in: S. N. Durlauf and L. E. Blume (eds.), *The New Palgrave Dictionary of Economics*, 2nd edition, online version, unpaginated.

²⁰ Smits and Stromback, *Economics*, 41–2.

The contract between master and apprentice was subject to what is known as the credible commitment problem, which occurs widely in contract theory and political economy.²¹ The issue is basically this: if the apprentice or his guardian could advance the full cost of his training at the outset, this would be obviously desirable for the master. But when the apprentice was impecunious, and credit markets unavailable for this purpose, the best way to cover the master's cost was to have the apprentice commit to work for him when the training had advanced, thus securing a flow of cheap skilled labor for the master in compensation for his teaching efforts.²² From the point of view of incentivizing the master to teach properly, this makes sense: the productivity of the apprentice as employee depended on how skilled he was when the time came. The commitment problem, however, meant that while the apprentice or his guardian could promise from the outset to supply this work, when the time came he had no incentive to do so, and instead might shirk in his work or abscond carrying in his head the human capital he had accumulated.²³ As the master knew this, the apprentice could not credibly commit to providing the work and the entire apprenticeship system might unravel. The contract was therefore not self-enforcing. Smits and Stromback, after showing when the contract might be stable, note that neither the effort exerted by the apprentice nor the quality of instruction were contractable, and so the credible commitment problem remains.²⁴

The exchange between master and apprentice thus typically involved two bundled services: the master taught the apprentice the skills and secrets of the trade, which involved his time and the time of his employees, as well as the tools and raw materials that were used up in the instruction process. Moreover, in most documented cases, the apprentice was provided room and board by the master and in many cases he was socialized in other subjects, such as piety, literacy, and good manners.²⁵ As in most educational markets, the training involved not just the actual transmission of knowledge but also a formal stamp of approval at the end of the training that permitted the trainee to practice

²¹ For a good summary, see D. Acemoglu and J. Robinson, *Economic Origins of Dictatorship and Democracy* (Cambridge: Cambridge University Press, 2006), 133–36.

²² See e.g. S. A. Epstein, *Wage Labor and Guilds in Medieval Europe* (Chapel Hill: University of North Carolina Press, 1995), 143–44.

²³ The hard-to-observe effort exerted by the apprentice working for his master is at the core of the principal–agent models that analyze such contracts, as Adam Smith already noted: *The Wealth of Nations*, ed. E. Cannan (Chicago: University of Chicago Press, 1976), pt. I, 137.

²⁴ Smits and Stromback, *Economics*, 77, 88–89.

²⁵ For examples on the demand of apprentices for literacy skills, see M. Davies and A. Saunders, *The History of the Merchant Taylors Company* (Leeds: Maney Publishing, 2004), 109.

the trade, hopefully eventually as a master himself. It was thus a complex transaction on both sides, and it is easy to see what could go wrong.

An example from mid-thirteenth-century France serves as an illustration. In one contract, from Arras, a mother (probably a widow) apprenticed her son to a weaver for four years and basically guaranteed his good behavior.²⁶

Be it known to present and future aldermen that Ouede Ferconne apprentices Michael, her son, to Matthew Haimart on security of her house, her person, and her chattels, and the share that Michael ought to have in them, so that Matthew Haimart will teach him to weave in four years, and that he (Michael) will have shelter, and learn his trade there without board. And if there should be reason within two years for Michael to default she will return him, and Ouede Ferconne, his mother, guarantees this on the security of her person and goods. And if she should wish to purchase his freedom for the last two years she may do so for thirty-three solidi, and will pledge for that all that has been stated. And if he should not free himself of the last two years let him return, and Ouede Ferconne, his mother, pledges this with her person and her goods. And the said Ouede pledges that if Matthew Haimart suffers either loss or damage through Michael, her son, she will restore the loss and damage on the security of herself and all her goods, should Michael do wrong.

This example may create a mistaken idea of uniformity; in fact there was great variety in the nature of these contracts. In fourteenth-century Montpellier, for example, out of 126 surviving contracts, 48 were signed by the apprentice himself, so that nobody could vouchsafe or place a bond for their good behavior and ability to learn the trade.²⁷ In some cases, the apprentice had to pay a premium and separately for his room and board; in others, the money flowed in the other direction and he received a wage. In a way, the apprenticeship market resembled the marriage market: depending on the economic circumstances, traditions, and the way the matching operated, money could flow from the bride side to the groom side or the reverse.²⁸

From a purely theoretical point of view, it might thus have been logical for apprenticeship to take place within families, in which fathers taught their sons. The agency and enforcement problems would have been much reduced. In fact, in agriculture – that is, the majority of workers in pre-

²⁶ G. Espinas and H. Pirenne (eds.), *Recueil de Documents Relatifs à l'Histoire de l'Industrie Drapière en Flandre* (Brussels: Académie Royale de Belgique, 1906), vol. 1, 121. For earlier examples, see C. Hawkins, *Roman Artisans and the Urban Economy* (Cambridge: Cambridge University Press, 2016), 109–10.

²⁷ K. L. Reyerson, 'The adolescent apprentice/worker in medieval Montpellier', *Journal of Family History* 17 (1992), 358.

²⁸ G. Hamilton, 'The market for Montreal apprentices: Contract length and information', *Explorations in Economic History* 33 (1996), 505–07.

Industrial Revolution Europe – this was predominantly the case, and formal apprenticeship was rare (although teenage farm servants must have had some similar characteristics to apprentices). In urban occupations – both artisanal and commercial – fathers teaching their sons was fairly unusual, Alessandro Scarlatti, Johann Sebastian Bach, and Leopold Mozart notwithstanding.²⁹ By the seventeenth century, apprentices trained by relatives were a distinct minority, estimated in London to be somewhere between 7% and 28%.³⁰ Training within the extended family or clan was less common in Europe, because the nuclear family had become the norm from the early Middle Ages on, although relatives remained an option.³¹ It can be shown that if apprentices could select from a wide array of unrelated masters, technological progress was faster than if he was limited to family members.³²

Given that the contractual relation between master and apprentice can thus be seen as the mother of all incomplete contracts, one wonders how various past societies solved the threat of opportunistic behavior on both sides. There were countless margins at which things could go wrong, and they often did. The incentives simply did not line up. Even a competent teacher might skimp on the board and room, or humiliate and beat up his pupil.³³ The apprentice, as noted, might learn the secrets of the trade quickly and then abscond, or he might learn very slowly and thus be an unproductive worker. The relationship was by its nature asymmetric, but it became progressively more symmetric as the apprentice acquired the skills of the trade.³⁴ Yet it was in the interest of the master to keep the asymmetry as long as possible, since it was this asymmetry that allowed him to control his worker and thus draw rents from the apprentice's labor. It also delayed the appearance of another potential competitor in the local market.

²⁹ Reyerson, 'The adolescent apprentice', 357.

³⁰ T. Leunig, C. Minns and P. Wallis, 'Networks in the premodern economy: The market for London apprenticeships, 1600–1749', *Journal of Economic History* 71 (2011), 42; M. Prak, 'Mega-structures of the Middle Ages: The construction of religious buildings in Europe and Asia, c. 1000–1500', in: M. Prak and J. L. van Zanden (eds.), *Technology, Skills and the Pre-modern Economy* (Leiden: Brill, 2013), 153; see also Goody, 'Learning', 239. Fragmentary evidence for the Roman period indicates the likelihood that even in antiquity artisans commonly sent their sons to be trained with others: Hawkins, *Roman Artisans*, 198–202.

³¹ Epstein, *Wage Labor*, 105–06.

³² De la Croix, Doepke and Mokyr, 'Clans, guilds, and markets'.

³³ The awful experiences of the printer's apprentices in Paris in the later 1730s described in R. Darnton, *The Great Cat Massacre and other Episodes in French Cultural History* (New York: Basic Books, 1984), 75 may be an extreme example.

³⁴ H. Buechler, 'Apprenticeship and transmission of knowledge in La Paz, Bolivia', in: Coy (ed.), *Apprenticeship*, 44.

Institutions and Apprenticeship

It is thus perhaps surprising to the economist that apprenticeship worked at all, let alone its longevity and ubiquity. Some kind of institution was needed to enforce the contract between master and apprentice. In the absence of such an institution, opportunistic behavior would doom apprenticeship and limit it to the nuclear family. Over time, implicit and formal local institutions evolved that created conditions in which contractual relations for training could be carried out in an effective manner and resolve the threats of moral hazard and opportunistic behavior. Local governance was usually involved. After all, there was a collective interest at stake, since external economies and economies of agglomeration meant that the entire community had an interest in the preservation of certain specialized skills and the reputational rents that came with it.³⁵ However, this collective need does not, by itself, explain why certain institutions arose that made the institution work. Indeed, in the United States the absence of a guild tradition and high mobility made third party enforcement of apprenticeship contracts impracticable and the “market for apprenticeship” virtually disappeared.³⁶

Three types of institutions emerged that carried out the task of enforcing and supervising the apprentice–master relationship and made it work. Perhaps the most important one is the hardest to observe: personal reputation. In an urban environment, in which transactions were repeated and in which people knew one another through a variety of channels, maintaining one’s reputation as an honorable and trustworthy person was extraordinarily valuable. The economics of such network relations are well-understood.³⁷ The idea is fairly simple: Suppose two agents face one another in two spheres, for instance a master training an apprentice, whose father served with the master in a local institution or was socially connected to his customers. If the master cheated the apprentice by shirking in his teaching duties or mistreated him, it could entail reputational damage and thus punishment in the other spheres. Thus, the possibility of punishment in one game may be used to induce cooperation in the other. Knowing this, the master would be incentivized to refrain from opportunistic behavior. What was true for the master would be equally true for the apprentice: misbehavior might threaten to damage

³⁵ Reyerson, ‘The adolescent apprentice’, 360.

³⁶ Elbaum, ‘Why apprenticeship persisted’; B. Elbaum and N. Singh, ‘The economic rationale of apprenticeship training: Some lessons from British and US experience’, *Industrial Relations: A Journal of Economy and Society* 34 (1995), 593–622.

³⁷ G. Spagnolo, ‘Social relations and cooperations in organizations’, *Journal of Economic Behavior and Organizations* 38 (1995), 1–25.

his reputation as a trustworthy person as well as lead to sanctions on his family.

This insight is an example of how trust emerged through social networking and its effect on the efficiency of the apprenticeship market. When trust can be transferred from a social relationship into an economic one it can sustain cooperative outcomes in which exchange can take place and disputes are resolved even without strict contract enforcement by a third party such as courts or arbiters.³⁸ It is this kind of environment, whether or not one wants to refer to it as “social capital,” that created the possibility of cooperation even when standard behavior in finite games would suggest that opportunism and dishonest behavior might have been a dominant strategy. To work effectively, however, the environment needed to be stable and fairly limited in size and mobility low, so that information networks could operate effectively. The more dynamic and sophisticated the economy, the less these conditions obtained.³⁹

For that reason, more formal institutions involving third-party enforcement were needed to supervise the training and arbitrate between master and apprentice when disputes arose. There were many variations on the basic theme that some respectable local third party, such as a Justice of the Peace, was needed to arbitrate and settle out of court the frequent disputes that arose between master and apprentice.⁴⁰ Going to a formal court of law was possible in many countries, but given the cost and uncertainty of the outcome and the long duration of lawsuits, it must have been a *pis aller* (though some courts employed speedier and less costly arbitration and reconciliation procedures). Much of the negotiation between the master and the apprentice and his family must have taken place in the “shadow of the law” suggested by scholars in Law and Economics.⁴¹ In many cases, then, the combination of the fear of reputational damage and the possibility of legal action were often enough to make the apprenticeship system work. In some cases special organizations (such as the *neringen* in the Netherlands) set up by city government regulated the trade, including apprenticeship.⁴² In other cases, the

³⁸ See for example, E. A. Posner, *Law and Social Norms* (Cambridge, MA: Harvard University Press, 2000).

³⁹ Hamilton, ‘Decline’, especially 650–56.

⁴⁰ M. G. Davies, *The Enforcement of English Apprenticeship: A Study in Applied Mercantilism, 1563–1642* (Cambridge, MA: Harvard University Press, 1956), 207–08.

⁴¹ R. Cooter, S. Marks and R. Mnookin, ‘Bargaining in the shadow of the law: A testable model of strategic behavior’, *Journal of Legal Studies* 11 (1982), 225–51; also P. Rushton, ‘The matter in variance: Adolescents and domestic conflict in the pre-industrial economy of Northeast England, 1600–1800’, *Journal of Social History* 25 (1991), 102.

⁴² K. Davids, *The Rise and Decline of Dutch Technological Leadership* (Leiden: Brill, 2008), vol. 2, 385.

masters set up a number of clever contractual devices that made it less attractive for apprentices to abscond before fully serving their term. The up-front premium that would be forfeited and a promise of a cash payment upon completion were some of the contractual devices used to prevent the premature ending of the contract.⁴³

The third type of institution for making apprenticeship work is the best known: the craft guild. The history of apprenticeship and the history of the craft guild are intertwined and overlapping. Yet they are conceptually quite separate, and apprenticeship, being the more universal of the two, should be in a different category. While craft guilds of some kind existed all over the world, many – but not all – European guilds actively regulated and controlled apprenticeship.⁴⁴ When the guilds were abolished in France, many expressed concern about the future of apprenticeship.⁴⁵ More recent work casts some doubt on how widely guilds were engaged in explicitly enforcing the terms of the contract. In a conflict between a master (and thus a member of the guild) and an apprentice (who was not), it was unlikely that the apprentice would prevail if the guild was called on to arbitrate.⁴⁶ This asymmetry would explain why eventually local officials and courts became increasingly involved in contract enforcement, creating conditions in which the market for apprenticeship could operate relatively freely and effectively. In a study of eighteenth-century northern England conflicts between masters and apprentices and servants, it was found that in the cases that went before the courts, the apprentice was usually the plaintiff, “while the companies [guilds] offered the masters sufficient scope for correcting their apprentices, the latter had to appeal to the mercy of the more public forum of the quarter sessions to obtain justice.”⁴⁷

Yet there is too much evidence pointing to the guilds being closely associated with regulating apprenticeship to dismiss altogether their role in making the institution work properly. This was especially true when the effective power of local government, to say nothing of “the state,” was limited. In many cases, apprentices had to pay a special fee (known as *Lichtgeld* in Germany) to the guild to start their term, and it stands to reason that this fee was for the supervisory functions that the guild

⁴³ Hamilton, ‘Enforcement’.

⁴⁴ The canonical statement is by S. R. Epstein, ‘Transferring technical knowledge and innovating in Europe, c. 1200–c. 1800’, in: Prak and van Zanden (eds.), *Technology, Skills*, 31–32; also S. L. Kaplan, *The Bakers of Paris and the Bread Question* (Durham, NC: Duke University Press), 199.

⁴⁵ M. Fitzsimmons, *From Artisan to Worker: Guilds, the French State, and the Organization of Labor, 1776–1821* (Cambridge: Cambridge University Press, 2010), 46, 144–46.

⁴⁶ Summarized by M. Prak and P. Wallis, ‘Introduction’, in this volume.

⁴⁷ Rushton, ‘Matter in variance’, 92.

exerted.⁴⁸ A stylized version of the evolution of apprenticeship suggests that guilds were central in creating the institution in the first place in medieval Europe, and eventually the “market” (backed by the enforcement power of courts and similar third-party enforcement institutions) took over. In reality, the two systems overlapped, cooperated, and reinforced one another.⁴⁹

European guilds were a classic example of a “corporation” (which is the term used for guild in French) in that they consisted of people who shared a common economic interest and occupation, but who were typically not related.⁵⁰ Precisely because they were a form of social capital, in which people met and exchanged information, guilds created the networks that supported reputation mechanisms that may have been the most effective way in which most contracts were enforced. As in many models of collective action, each master had a strong incentive to free ride and “renege,” unless a penalty was likely. A master who systematically exploited and mistreated his apprentices might gain an advantage over his competitors. The same would be true for a master who poached the trained apprentices from a colleague before they had fully repaid their training cost. Improper training could lead to the production of shoddy goods and would create an externality by harming the reputation for quality of the entire town.⁵¹ The craft guild was one institution that curbed such opportunistic behaviors. The many social and professional joint activities bound up in the guild created the kind of phenomenon captured in Spagnolo’s model – the costs of opportunistic behavior could come from a very different corner than where the benefits were.⁵²

Guilds, Apprentices, and Markets

Did the role of craft guilds in regulating apprenticeship affect efficiency and the pace of innovation? The debate between those scholars who on balance see craft guilds as a positive force in the intergenerational transmission and accumulation of skills and those who see them primarily as an encumbrance to the development of human capital and well-functioning markets will not easily be decided. It concerns a three-dimensional

⁴⁸ R. Reith, ‘Apprentices in the German and Austrian crafts in early modern times: Apprentices as wage earners?’, in: B. De Munck, S. L. Kaplan and H. Soly (eds.), *Learning on the Shop Floor: Historical Perspectives on Apprenticeship* (New York: Berghahn Books, 2007), 182. Schalk, ‘Apprenticeships with and without Guilds’.

⁴⁹ For example, G. Colavizza, R. Cella and A. Bellavitis, ‘Apprenticeship in Early Modern Venice’, Chapter 4 in this volume.

⁵⁰ A. Greif, ‘Family structure, institutions, and growth: The origins and implications of Western corporations’, *American Economic Review* 96 (2006), 308–12.

⁵¹ Reyerson, ‘The adolescent apprentice’, 360. ⁵² Rushton, ‘Matter in variance’.

complex phenomenon that stretched over many centuries, a large number of different occupations, and countless localities.

As argued above, guilds were not the only mechanism to enforce and arbitrate apprenticeship contracts; and guilds, moreover, had many other functions unrelated to training. A guild system was thus neither necessary nor sufficient for the emergence of effective apprenticeship institutions.⁵³ When other methods of contract enforcement were effective, apprenticeship could function without them. Conversely, completing a guild-mandated apprenticeship did not guarantee a mastership.⁵⁴

Nonetheless, the guilds were an institution that could help overcome some inherent market failures that might have led to less and lower-quality human capital accumulation. They set rules to minimize the incentives for apprentices to engage in opportunistic behaviors. Perhaps the most obvious way was by solving the apprentice's commitment problem discussed above. With the power and authority of the guild behind him, the master could feel that the chances of opportunistic behavior were much lower, since an apprentice who departed before fulfilling the terms of his contract could be denied becoming a master or even employment altogether, or otherwise punished. The guilds had the power to enforce compliance with the contract through a variety of sanctions they could impose on wayward apprentices, including "compulsory membership, blackballing, and boycott."⁵⁵ Yet, as Adam Smith was the first to point out, guilds used limitations on apprenticeship as a way of generating rents for their members.⁵⁶ One complaint is that the uniform length of the apprenticeship term imposed by guilds was an inefficient one-size-fits-all kind of measure, and may have served more as a barrier to entry than as an efficient way of teaching youngsters.⁵⁷ That said, the specified duration of the term varied from skill to skill and they were a way of ensuring that the master could expect some labor services at the later stages of the apprentice's term. After all, all educational institutions have imposed some kind of uniform duration standard on students, including modern universities.

⁵³ S. Ogilvie, *The European Guilds: An Economic Analysis* (Princeton, NJ: Princeton University Press, 2019), ch. 7. See also, Hamilton, 'The market', 498.

⁵⁴ De Munck, *Technologies of Learning*, 41.

⁵⁵ S. R. Epstein, 'Craft guilds, apprenticeship and technological change in pre-industrial Europe', in: S. R. Epstein and M. Prak (eds.), *Guilds, Innovation and the European Economy, 1400–1800* (Cambridge: Cambridge University Press, 2008), 61.

⁵⁶ Smith, *Wealth of Nations*, pt. I, 133. U. Pfister, 'Craft guilds, the theory of the firm, and early modern proto-industry', in: Epstein and Prak (eds.), *Guilds, Innovation*, 27 has asserted that the exclusionary rents generated by guilds were necessary to correct for the underinvestment in human capital implied by the market failures in human capital formation.

⁵⁷ Ogilvie, *European Guilds*, ch. 7.

The advantage of a guild-enforced contract system was above all in supporting a system in which kinship was not the chief organizing principle of intergenerational transmission of skills. For one thing, innate abilities differed from father to son, and it seems obviously desirable that the son of a carpenter could become a notary and vice versa. More generally, however, what a non-kinship based system implies is that apprentices could choose a master able to teach them the best techniques extant, and that in principle they could learn from more than one master. De Munck refers to the custom of apprentices to roam from one workshop to the other as “shopping.”⁵⁸ A number of the chapters in this volume provide evidence of apprentices changing masters, and while it probably was not a very common phenomenon, it may have played a disproportionate role in diffusing best-practice techniques. In many documented cases apprentices were “turned over” to another master – according to one calculation this was true of 22% of all apprentices in England who did not complete their term.⁵⁹ Estimates for tailors’ apprentices in late medieval England who did not complete their terms have gone as high as two-thirds.⁶⁰ There could be many reasons for this, of course, including the master falling sick or becoming otherwise indisposed. But at least some apprentices might also have discovered midway through their training that their master did not teach them best-practice techniques or that the trade they were learning was not as suitable to them or as remunerative as some other and switched to a different master.⁶¹

Within the formal stipulations, however, apprenticeship systems could show surprising flexibility. In England, the formal length of the contract (stipulated by the 1563 Statute) was perhaps more of a guideline than a binding constraint.⁶² The flexibility of the guild system varied considerably across Europe, but nowhere in Europe was the institution as rigid as the written record suggests.⁶³ Still, it is no accident that economies in which such flexibility was more pronounced and apprenticeship was regarded as a “market” in which the terms between master and apprentice were negotiable were more dynamic and experienced more growth in productivity.

⁵⁸ De Munck, *Technologies of Learning*, 50.

⁵⁹ Wallis, ‘Apprenticeship and training’, 842–43.

⁶⁰ Davies and Saunders, *History of the Merchant*, 55; See also B. De Munck and H. Soly, ‘Learning on the shop floor in historical perspective’, in: De Munck, Kaplan and Soly (eds.), *Learning on the Shop Floor*, 9–10.

⁶¹ But see R. Schalk, ‘From orphan to artisan: Apprenticeship careers and contract enforcement in the Netherlands before and after the guild abolition’, *Economic History Review*, 70 (2017), 737.

⁶² Wallis, ‘Apprenticeship and training’. ⁶³ Prak and Wallis, ‘Introduction’.

The archetypical example for this kind of flexibility was the Northern Netherlands. In his authoritative work on Dutch technological progress, Karel Davids acknowledges that guilds “supplied facilities for the training and education of skilled workers.”⁶⁴ Yet he shows convincingly that many of the formal restrictions that guilds imposed on apprentices were enforced with a wink and a nod. An example is the “master piece,” a kind of proof of competence that apprentices who had completed their term were supposed to submit. These tests of competence, in Davids’s words, “were characterized by a certain “open-endedness”, which left room for innovation within the margins of a broad, liberal formula.”⁶⁵ Moreover, some of the craft guilds could force youngsters to take formal classes in drawing or mathematics if this was deemed a necessary complement to their proper training.⁶⁶

Apprenticeship, Labor Markets, and the Distribution of Income

Pre-Industrial Revolution economies differed from modern ones in many crucial ways, not least of them the way income was distributed between labor and non-labor and the blurry lines between firms and households. While in much of Europe land rents accrued largely to a well-defined class of landowners few of whom worked, in the non-agricultural economy the typical “firm” was a self-employed artisan in a workshop, often in or adjacent to his home. The distinction between household and firm, so fundamental to modern economics, was thus far from sharp. The main reason that so many of the apprentices received room and board was that it was natural for them to become part of the master’s production unit, which coincided with the household.

Master artisans produced two products jointly: the goods or services that they supplied, and the human capital of the youngsters that was created while being trained in his workshop. Training apprentices meant that the master artisan was producing his own replacement but also possibly his own future competitors.⁶⁷ In a large competitive industry, these direct effects are very small (since the apprentices trained by one single master competed with all craftsmen in that product line in the area), but he produced an externality for the entire industry. To be sure, as long as a master just replaced himself, the number of artisans remained the same. But given that the average apprenticeship length was

⁶⁴ Davids, *Rise and Decline*, vol. 2, 423.

⁶⁵ See also De Munck, *Technologies of Learning*, 78–79.

⁶⁶ Davids, *Rise and Decline*, vol. 2, 382, 486. ⁶⁷ Epstein, *Wage Labor*, 109.

perhaps four years plus two more years of journeymanhood, each artisan had the potential to train far more apprentices than was needed for his replacement even if he just had one at a time.⁶⁸ The much maligned restriction on the number of apprentices that each artisan was allowed to take could be seen as a collective-action mechanism to prevent such an outcome.

In some instances, such as the case of Utrecht documented by Schalk, only a small percentage of apprentices became masters, so the threat of more competition was dealt with in other ways.⁶⁹ What happened to those apprentices who did not become masters? Given urban mortality rates, it is certain that many of them died. Others never attained master status and found employment as long-term free journeymen, basically skilled laborers. Given that apprenticeship was an urban institution, it also seems plausible that urban training supplied some artisans to the countryside, where people could work in their trades without the restrictions – guild-driven or otherwise – that urban institutions imposed on them. In times of economic boom, masters had a strong incentive to take on a number of apprentices and journeymen.

Indeed, much evidence suggests that the work that apprentices and journeymen carried out for their master was not a corollary of a transaction in which the main exchange was the acquisition of human capital, but in many cases an indispensable source of wage labor in the artisanal economies of pre-Industrial Revolution European manufacturing. In large part this must have been because other forms of wage labor in much of urban Europe were hard to come by.⁷⁰ The obvious smoking guns here are that in many cases apprentices were paid in cash in addition to receiving instruction, room, and board. Moreover, in the early fourteenth century, when labor supply had increased due to population growth, masters were able to demand more from their trainees and give them less.⁷¹

In terms of economic analysis, the apprenticeship contract can be depicted as a continuum in the flows of resources between master and apprentice: on the one extreme it was purely a transaction involving the transmission of human capital, in which the master taught and the apprentice learned; in such cases a premium would be paid, or the

⁶⁸ Ogilvie, *European Guilds*, tables 7.4 and 7.5.

⁶⁹ Schalk, 'Apprenticeships with and without guilds'; J. Humphries, *Childhood and Child Labour in the British Industrial Revolution* (Cambridge: Cambridge University Press, 2010), 286.

⁷⁰ The pioneering paper that focused on apprenticeship as a labor market relation is Reith, 'Apprentices in the German and Austrian crafts'.

⁷¹ Epstein, *Labor Markets*, 216–20.

equivalent in labor services. On the other extreme, apprenticeship could be a pure wage-labor contract under a different name.⁷² In the latter cases, the worker learned little or nothing, and expected to be paid. Every apprentice in Europe found himself somewhere on this scale – most of course somewhere between the two extremes, when they learned and worked simultaneously, with the weights shifting toward the latter as the contract reached the end of the term. How important was the labor-market relation relative to knowledge transfer? Ogilvie's compilation of scores of disparate sources can be used to document this phenomenon. In a survey of sources taken from all over Europe, spanning over half a millennium, she shows that over half of all apprentices were paid a wage and that the phenomenon was widespread.⁷³ The bargaining position of apprentices and their chances of finding employment in their occupation in the same location varied over time depending on the conditions of demand and supply in the labor market.⁷⁴

In a competitive model, with well-informed agents, an equilibrium condition would be that both master and apprentice broke even, and that the condition of zero excess profit obtained. This kind of model is deployed by Hamilton for Montreal, but the assumptions she has to make for it to hold are rather strong, including free exit and entry into a market in which one side only bought the service once, and the other a small number of times. Still, the conditions imply that term length should have varied positively with the net payment to the apprentice (wages plus payment in kind) and training costs across contracts and negatively with the expected quality of the apprentice, which is what her empirical results show.⁷⁵ This labor market was affected by the growing division of labor: the finer the division of labor, the simpler the tasks and the easier it would be to get an untrained beginner to be productive (even though the master himself had to acquire supervisory and managerial skills).⁷⁶ As markets expanded, the division of labor became finer and the demand for unskilled labor increased even if the workers were termed "apprentices." The closer the relationship was to one of pure wage labor as opposed to training, the less reluctant the master was to take on more apprentices.

⁷² Colavizza, Cella and Bellavitis, 'Apprenticeship in Early Modern Venice', suggest outright that it is possible that masters were using apprenticeships as a form of labor contract.

⁷³ Ogilvie, *European Guilds*, table 7.10; also Schalk, 'Apprenticeships with and without guilds', and Humphries, *Childhood*, 235, 276–77.

⁷⁴ Reith, 'Apprentices in the German and Austrian crafts', 189.

⁷⁵ Hamilton, 'The market'.

⁷⁶ M. Kelly and C. Ó Gráda, 'Adam Smith, watch prices, and the Industrial Revolution', *Quarterly Journal of Economics* 131 (2016), 1727–52.

On the labor-supply side, it is worth pointing to the growth in the demand for market-purchased products associated with the Industrious Revolution in early modern Europe; while not much has been made of the growth of teenage labor in the seventeenth and eighteenth centuries in this literature, it stands to reason that once the emphasis shifts from individual income to household income, the demand for market-purchased goods created an impetus by parents to send their children to work and bring home their wages. In half the households surveyed in late-eighteenth-century England, children contributed to income.⁷⁷ This meant that in the process they acquired useful skills, through learning by doing and socialization by employers. For the textile workers who came under pressure due to mechanization, children often ended up as pauper apprentices, which may still have given them a chance to acquire valuable skills.⁷⁸

Apprenticeship, Skills, and the Great Enrichment

Human capital stories have not been central in the literature on the Great Divergence or the Great Enrichment.⁷⁹ In large part that is because much of the historical literature has focused on two indicators of human capital: literacy and years of schooling. Yet, before 1750, it is far from clear how valuable literacy was in the artisanal workplace outside some obvious service occupations such as clerks, notaries, teachers, and priests.⁸⁰ It is therefore not all that surprising that Britain could be the technological leader in the Industrial Revolution even when it scored somewhat in the middle of the pack as far as literacy is concerned.⁸¹ A more recent work on the Great Divergence surveys the literature and tends to be skeptical of most human capital measures that explain the difference between West

⁷⁷ J. de Vries, *The Industrious Revolution: Consumer Behavior and the Household Economy, 1650 to the Present* (Cambridge: Cambridge University Press, 2008), 217.

⁷⁸ Humphries, *Childhood*, 45–46; S. Horrell, J. Humphries and H.-J. Voth, 'Destined for deprivation: Human capital formation and intergenerational poverty in nineteenth-century England', *Explorations in Economic History* 38 (2001), 358–60.

⁷⁹ The notable exception is the economist O. Galor, *Unified Growth Theory* (Princeton, NJ: Princeton University Press, 2011), 30–46. For an introduction to this literature, see J. Mokyr, 'Human capital, useful knowledge, and long-term economic growth', *Economia Politica*, 30 (2013), 251–71.

⁸⁰ Economists have suggested that it was the commercial rather than the manufacturing aspect of artisanal work that required literacy and numeracy: M. Kelly and C. Ó Gráda, 'Artisanal skills, apprenticeship, and the English Industrial Revolution: Prescott and Beyond', unpublished working paper, 2017.

⁸¹ D. Mitch, 'The role of education and skill in the British Industrial Revolution', in: J. Mokyr (ed.), *The British Industrial Revolution: An Economic Perspective*, 2nd edition (Boulder, CO: Westview Press, 1999), 241–79; D. Mitch, *The Rise of Popular Literacy in Victorian England* (Philadelphia: University of Pennsylvania Press, 1992).

and East.⁸² All the same, many scholars have not only made that connection, but argued that artisanal competence was the main factor that drove the Great Enrichment. Epstein goes so far as to shrug off all formal learning as largely irrelevant before the Industrial Revolution and sees improvements in artisanal skills and their successful dissemination as the key to technological progress.⁸³

Skills and technological competence were crucial to economic progress. That does not mean that nothing else was; history does not live by one-line explanations. Artisans *by themselves* were limited in how much and how radically they could innovate, as they were taught a set of skills by their masters. Artisans were trained to make things that they had not invented and did not usually design, reproducing a given design over and over. Was innovation possible in such a system? In many cases the rules of the guilds or other ways in which resistance to innovation could show up imposed obstacles to craftsmen who thought out of the box. And yet many of the great inventors of the Industrial Revolution were trained as craftsmen and in some sectors learning by doing and a growing division of labor could lead to sustained productivity growth. Still, without a growing understanding of the natural laws and regularities that underlay the techniques (the epistemic base), the trial-and-error methods of artisanal innovation would inexorably have run into diminishing returns.⁸⁴ As early as the eighteenth century, scientific knowledge and methods were crucial to technological progress in a substantial number of areas.⁸⁵ The root of Europe's rapid technological progress was neither artisanal skills alone nor scientific advances by themselves, but the synergistic complementarity of the two.

⁸² K. Davids, *Religion, Technology and the Great and Little Divergences* (Leiden: Brill, 2012), 60–74.

⁸³ Epstein, 'Transferring,' especially 53, 67. D. McCloskey, *Bourgeois Dignity: Why Economics Can't Explain the Modern World* (Chicago: University of Chicago Press, 2010), 355–65; D. McCloskey, *Bourgeois Equality: How Ideas, Not Capital or Institutions, Enriched the World* (Chicago: University of Chicago Press, 2016), 505–06 also dismisses formal science as a major factor in economic growth before 1900. M. Berg, 'The genesis of useful knowledge', *History of Science* 45 (2007), 123–34 does not dismiss formal knowledge as Epstein does, but clearly feels that by stressing concepts like the Industrial Enlightenment, my book *Gifts of Athena* did not show a full appreciation for the role that artisanal knowledge played in bringing about the expansion of useful knowledge, and how the mobility of tacit knowledge through traveling craftsmen led to continuous improvement; J. Mokyr, *The Gifts of Athena* (Princeton, NJ: Princeton University Press, 2002).

⁸⁴ Mokyr, *Gifts of Athena*, 31–32.

⁸⁵ D. Wootton, *The Invention of Science: A New History of the Scientific Revolution* (London: Allen Lane, 2015), 476–508; J. Mokyr, *A Culture of Growth: The Origins of the Modern Economy* (Princeton, NJ: Princeton University Press, 2016), 270–73.

In terms of artisanal skills, Asia in 1500 was still in many ways ahead of Europe, and it was the fine work of Asian craftsmen that made Europeans desire Chinese ceramics, Indian cotton goods, Persian carpets, and similar high-end goods. Yet in the centuries that followed, European skills caught up, and they learned to make the Asian goods they desired, and then learned to make them better and cheaper than the Asians ever could. Without a flexible and open apprenticeship system that responded to demand and in which the high mobility of workers was normal, such a growth in prescriptive knowledge would not have happened. Footloose young apprentices and journeymen played an important role not only by disseminating best-practice techniques but also by creating a competitive environment in which creative artisans whose ideas were not welcome at home could move elsewhere.⁸⁶ In contrast, technology in Asia, with some exceptions, seemed to have been stuck in place, if often at a high level, and lacked the dynamism of Europe. Flexibility was key: “skilled” workers who were experts in the old technology would do little for a Watt, a Smeaton, or a Fairbairn, because innovation implied that the old competences were often outdated. New skills, or new combinations of old skills, were needed, and a rigid system of one master–one apprentice, teaching old and tried methods, would not do. Successful entrepreneurs, such as the Yorkshire textile-machine makers, were hiring well-trained artisans, and were able to make them do things they never did before.⁸⁷

What was it that led up to the Industrial Revolution and allowed it to become the starting point of sustained technological progress and economic growth instead of just another efflorescence? The cheek-by-jowl growth in *both* the competence of European artisans and insights of *savants* studying natural philosophy that laid out the rules and regularities that made their techniques work was key to Europe’s success. Brilliant technical ideas without the workmanship and materials to build them from blueprints would suffer the fate of Leonardo’s sketches. The apprenticeship system provided Europe with the mechanics, metalworkers, carpenters, instrument makers, and engineers that could execute and scale up the novel designs and turn them into reality. Mechanics trained as metalworkers, millwrights, carpenters, wheelwrights, and clockmakers were in high demand in the textile machinery sector during the Industrial Revolution (even if the skills did not always carry over easily). Skills acquired through apprenticeship in one industry were of great use elsewhere as long as the workers had the mental

⁸⁶ M. Belfanti, ‘Guilds, patents, and the circulation of technical knowledge’, *Technology and Culture* 45 (2004), 569–89; Berg, ‘The genesis’.

⁸⁷ Cookson, *Age of Machinery*.

agility to continue on-the-job learning after their apprenticeship was completed and to adapt to the needs of the new techniques.⁸⁸ The competitive and open system in Britain was more suited to such needs than the more rigid systems elsewhere.⁸⁹

Economies that had developed a flexible, mobile, and well-functioning system of apprenticeship could thus count on a higher quality of skill supply and experience greater technological dynamism. This was the case in seventeenth-century Netherlands, where in a host of industries, the Dutch developed technological leadership based on their widely acknowledged expertise.⁹⁰ By the eighteenth century, the advantage had shifted to Britain. The French chemist and politician, Jean-Antoine Chaptal was one of many who recognized the importance of tacit knowledge in Britain's precociousness when he pointed out that a central part of British know-how was what he called *tours de main* (tricks) and habits that were the soul of industry. Neither he nor his economist compatriot Jean-Baptiste Say ever spelled out how and why it was that Britain could count on the "superiority of its workmen" (as Say put it).⁹¹ But skills were learned, not transmitted genetically, and as Humphries has emphasized in her seminal paper on the topic, without a better recognition of the efficiency of the system that produced these skills, we will not fully understand Britain's leadership.⁹²

Can the difference between Britain and the Continent be generalized to the difference between Europe and Asia? We know all too little about how apprenticeship was organized in the East. Most of what we know supports the argument that elsewhere in the world the family still played a much larger role than it did in Europe.⁹³ One of Europe's unsung advantages recently stressed by economists was that professional and local corporations and organizations replaced kin-based cooperation.⁹⁴ There were

⁸⁸ *Ibid.*, 227. ⁸⁹ Ben Zeev, Mokyr and van der Beek, 'Flexible supply.'

⁹⁰ K. Davids, 'Guilds, guildsmen and technological innovation in early modern Europe: The case of the Dutch Republic', *Economy and Society in the Low Countries Working Papers*, no. 2, 2003; K. Davids, 'Apprenticeship and guild control in the Netherlands, c. 1450–1800', in: De Munck, Kaplan and Soly, (eds.), *Learning on the Shop Floor*, 65–84.

⁹¹ J.-A.-C. Chaptal, *De l'Industrie française* (Paris: chez Antoine-Augustin Renouard, 1819), vol. 2, 430; J.-B. Say, *A Treatise on Political Economy*, 4th edition (Boston: Wells and Lilly, 1821, orig. 1803), vol. 1, 32–33. Darnton, *Great Cat Massacre*, 114–15 has described Montpellier in the mid-eighteenth century as a place in which the products and the scale of production had been static for two centuries.

⁹² Humphries, 'English apprenticeships', 74.

⁹³ J. L. van Zanden, *The Long Road to the Industrial Revolution: The European Economy in a Global Perspective, 1000–1800* (Leiden: Brill, 2009), 165; M. Prak and J. L. van Zanden, 'Technology and human capital formation in the East and West before the Industrial Revolution', in: Prak and van Zanden (eds.), *Technology, Skills*, 15.

⁹⁴ Greif, 'Family structure'; A. Greif and G. Tabellini, 'The clan and the corporation: Sustaining cooperation in China and Europe', *Journal of Comparative Economics* 45 (2017), 1–35.

guilds in China, but much more than in Europe they were dominated by common ancestry. Chinese guild regulations often specifically postulated that only family members could learn the trade.⁹⁵ In contrast with Europe, the ancient tradition of a close association between kinship (common origin) and training remained intact. In early-twentieth-century southern China it was reported that “not only were the elders of the town the heads of the clan but the entire industry was organized and monopolized by the clan.”⁹⁶ Even fewer details are known about India, though one scholar assures us that “with few exceptions, the apprentices were members of the household and that the family was the main vehicle of training.”⁹⁷ While there was a noticeable gap between Britain and much of the Continent in the eighteenth century, this gap proved fairly easy to close in the years after 1815. The gap between western Europe and the rest of the world was much larger.

Recent arguments explaining the Great Enrichment through institutions and culture include the notions that the European state became somehow more inclusive or open access, that a bourgeois ethics arose, and the rise of the Republic of Letters created a more effective market for ideas.⁹⁸ What should not be left out is that a mixture of private-order and local government institutions were able to set up a system of professional training that provided the flexibility and the openness to new ideas that allowed Europe to develop a cadre of high-quality craftsmen who could turn blueprints into actual working models of machines and then scale them up and produce them with low levels of engineering tolerance. Once built, these mechanics could install, operate, and maintain the machinery that embodied the new technology. Apprenticeship in Europe, with all its flaws, worked well enough. One part of this success was because apprentices and journeymen had far more choice in whom to study with, because they were not limited to masters to whom they were related. As long as that choice was substantial, best-practice techniques could diffuse faster, and productivity grew.⁹⁹ To show this in formal models, economists have to make some rather

⁹⁵ C. Moll-Murata, ‘Guilds and apprenticeship in China and Europe: The Jingdezhen and European ceramics industries’, in: Prak and van Zanden (eds.), *Technology, Skills*, 234; H. B. Morse, *The Guilds of China: With an Account of the Gild Merchant or Co-hong of Canton* (London: Longmans, Green and Co., 1909), 33.

⁹⁶ D. Macgowan, ‘Chinese guilds or chambers of commerce and trades unions’, *Journal of the North-China Branch of the Royal Asiatic Society* 21 (1888–89), 181; J. S. Burgess *The Guilds of Peking* (New York: Columbia University Press, 1928), 71.

⁹⁷ T. Roy, ‘Apprenticeship and industrialization in India, 1600–1930’, in: Prak and van Zanden (eds.), *Technology, Skills*, 71, 77.

⁹⁸ These are but three hypotheses advanced by recent scholars: D. Acemoglu and J. Robinson, *Why Nations Fail: The Origins of Power, Prosperity, and Poverty* (New York: Crown, 2012); McCloskey, *Bourgeois Equality*; Mokyr, *Culture of Growth*.

⁹⁹ De la Croix, Doepke, and Mokyr, ‘Clans, guilds, and markets’.

strong assumptions to reach precise conclusions. Relaxing these assumptions, however, only makes the results stronger, if less tractable.

To sum up, the Great Enrichment or the onset of modern economic growth is by all accounts an over-determined phenomenon. It has been explained by many scholars, through geography, politics, culture, religion, demography, and luck. To that list we must add something prosaic and down to earth: technological competence, a practical *savoir faire* of making things through the right combination of materials, workmanship, and a drive to do things right. Techniques are “prescriptive knowledge,” that is, a set of recipes that describe how to produce a good or service. Because the recipe is always incomplete, to carry out these instructions requires competence, a specific form of tacit knowledge. This competence is not hardwired into humans, it has to be acquired at an early age under the right circumstances. It had little to do with schooling and literacy and most of the time it was independent of a theoretical understanding of why the techniques worked. Competence required a natural dexterity as well as learned tricks and procedures that were transmitted intergenerationally, that is, taught. The institution that took care of that was apprenticeship, and its crucial role in economic history merits the belated attention and research effort that it has received since 2000. Like all institutions, its form and functionality differed greatly among different societies, and these differences mattered to the outcomes.