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Technology of Cultural Transmission I: The Printing Press

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Abstract

Existing theories of the effects of the printing press treat it as speeding up the transmission of technical knowledge. This cannot explain why a large proportion of both manuscripts and early printed books was religious. We argue that books transmit prudential and moral rules as well as technical information. These culturally transmitted rules provide a foundation for economic rationality, and solve problems of trust in large markets. In Europe, cheaper book production stimulated not only scientific progress, but also new forms of religion, which used book reading to inculcate rules appropriate to the emerging modern economy. We model the effect of the printing press on economic growth. Initially religious works dominate, but as the stock of technical knowledge grows, the proportion of technical works increases.

The conventional theory of the invention of printing is that it sped up the transmission of technical knowledge. In the long run this theory is surely true. Empirically though, it faces a puzzle. For a long period, the most common topic of printed books appears to be not technical, but religious. 45% of Italian incunabula – the earliest printed books – were on religious topics (Hirsch, 1974). In England, about 40% of the editions published from 1480-1640 were religious – by far the largest category (Klotz, 1938). Across Europe, 35% of all editions between 1454 and 1600 were on religious topics (Dittmar and Seabold, 2017). This data does not fit well with the theory that the press exists to spread technique.

There is also a theoretical issue. There is a complementarity between the production and distribution of technical knowledge. As long as distribution is limited, for example by the expense of handwritten manuscripts, the market for knowledge is limited. This lowers the

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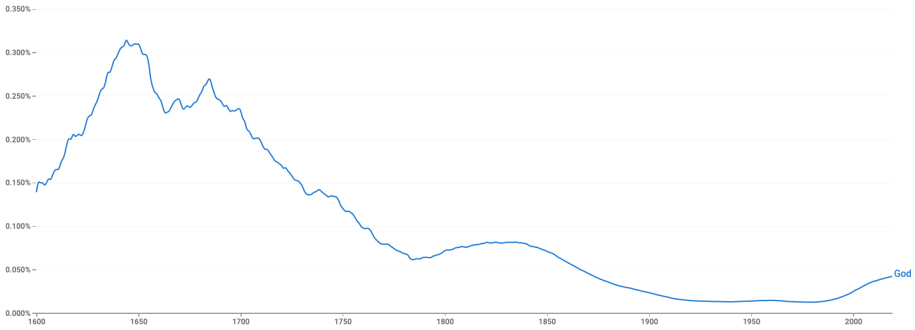

Figure 1: Occurrences of ”God” in Google ngrams database, 1600-2019. Smoothing 10.

incentive to produce scientific and technical discoveries. In turn, when the stock of knowledge is low, the demand for technical literature will be limited. Also, technical innovation is a slow process. So, we would expect that when the printing press was invented, and for some time afterwards, there was relatively little technical knowledge to transmit. But then it is unclear what would make the press a profitable innovation in the first place.

We suggest an alternative theory. The written word is a technology of cultural transmission, as well as information transmission. Cultural norms are rules of behaviour that benefit the individual, or those around him. The early modern economy increased the demand for a set of cultural norms including disciplined work effort, self-control, saving and foresight, and honesty and cooperation with business partners and employers. Printing lowered the cost of transmitting these norms. This was the initial driver of demand for books. Only later, with the gradual development of scientific and technical knowledge, did technical works come to dominate the book market. Figure 1 pictures this change: it shows occurrences of the word ”God”, as a proportion of all words, among works in English in the Google ngrams database. The peak is about 1650, or two centuries after the invention of print. After that there is a slow decline. Put simply, we explain why Gutenberg’s first major printed work was a Bible.

We formalize this theory by modelling the demand for both technical and religious literature in an economy with a modern sector and a traditional sector. The model organizes the stylized facts, including the link between Protestantism, education and urbanization; and the change in composition of printed editions over time. First, we develop our argument in greater detail, and provide evidence on how books worked to transmit norms in early modern Europe.

The argument

The invention of the printing press has long been acknowledged as a key step in European development. The press dramatically lowered the cost of books, allowing information to spread faster (Baten and Van Zanden, 2008). This in turn increased the rate of innovation and/or the level of human capital, leading to faster growth, and perhaps contributing to the Great Divergence between Europe and the rest of the world (Romer, 1986; Becker, Murphy and Tamura, 1990). This view was put by Condorcet (1795):

> These multiplied copies, spreading themselves with greater rapidity, facts and discoveries not only acquire a more extensive publicity, but acquire it also in a shorter space of time. Knowledge has become the object of an active and universal commerce.

A modern historian makes the same argument (Ferguson, 2017):

> The best explanation for [the economic impact of the printing press] is the role of printing in disseminating hitherto unavailable knowledge fundamental to the functioning of a modern economy. The first known printed mathematics text was the Treviso Arithmetic (1478).... Books on manufacturing techniques such as brewing and glass-blowing soon followed....

At the broadest level, this story is highly plausible, since technical progress and new ideas are central to modern economic development, and (until very recently) ideas were communicated overwhelmingly via books.

However, one fact seems not to fit the narrative: a very substantial proportion of book sales consisted of religious works. The numbers given above probably underestimate the proportion of physical printed matter that was religious, for two reasons. First, religious works probably had more copies per edition. Certainly, the bestsellers of the early modern period were overwhelmingly religious – most obviously the Bible, but also classics of piety like Thomas à Kempis's *The Imitation of Christ* and the *Ars Moriendi* (Art of Dying); Luther's polemical works; and later Puritan and Pietist works such as the *Whole Duty of Man*, *Pilgrim's Progress*, or Johann Arndt's *Wahres Christentum* (True Christianity). Second, a large mass of cheap printed matter including broadsides and pamphlets is not recorded in book databases, and much has probably been lost; a high proportion of this may have been religious (Watt, 1994).

While some early religious publications were bought in bulk by Church authorities, much publication was driven by consumer demand. In 1530, there were 64,000 clandestine copies of Tyndale's New Testament in England, at a time when owning it was illegal

(Zaret, 1985). The demand in Huguenot Lyon for Protestant works was supplied by smugglers (Watson, 2002). By contrast, Galileo's epoch-making *New Science* was only of interest to a tiny group of specialists.

A second problem for the mainstream theory is that the link between scientific progress and economic growth developed only slowly. Investments in knowledge *creation*, and in (innovations in) knowledge *transmission*, are complements: ideas are more valuable if you can sell them to many people, and printed books are more valuable when there are many new ideas to put into them. If so, we might expect the added value of a discrete improvement in communications technology (the invention of the printing press) to be small initially, and to grow over time as new scientific and technical innovations are discovered. In the extreme case, there might be a static equilibrium, in which there is little or no scientific progress, hence little demand for technical books, and therefore no incentive to invest in new communications technology.

Indeed, the evidence suggests that, while skilled workers were important in the early modern economy, the majority of their knowledge was "tacit" – knowledge that could be learned by practice, or direct transmission from master to apprentice, but not from books (Cipolla, 1972). This knowledge was jealously guarded by craftsmen's guilds, and early modern authorities encouraged the migration of entire communities of skilled workers so as to reap the benefits of their expertise (Belfanti, 2004). Books and patents played a relatively marginal role (Epstein, 2013). Some tacit knowledge was first codified by the eighteenth century *encyclopédistes*. The "second industrial revolution", beginning in the 1870s, was the first wave of innovations to be underpinned by theoretical science (Mokyr, 2005; Allen, 2009). This is long after English productivity began to grow at around 1600 (Bouscasse, Nakamura and Steinsson, 2021).

These facts motivate us to modify the traditional story of the printing press' effects. Writing is a technology not just for information transmission, but for cultural transmission. That is, written communication not only provides information about how to achieve one's preferences; it can also alter those preferences. The early modern economy opened up opportunities for people with particular preferences, specifically hard work, patience and cooperation. This made it advantageous for people to change their own preferences, or for parents to seek to change their children's preferences, in this direction. A large part of the early market for books was for works that could do this. So, this theory addresses the two issues above. The demand for books-as-cultural-transmission provides an initial market that motivates entrepreneurs to invest in printing press technology, even before scientific progress has got going. And it explains the empirical evidence that religious works make up a large proportion of early printed material, which then declines over time as more valuable scientific ideas are transmitted in print.

The simplest competing hypothesis is that religious books were consumption goods, with economic effects no different from any other consumption good. Much early modern literature was certainly bought for entertainment, from cheap ballads and romances to the first European novels. Religious work also often strove to be entertaining, from the sumptuous Books of Hours printed in Paris, to religious versions of popular ballads. However, there are two kinds of evidence against this "consumption hypothesis". First, many early modern reading practices seem to be aimed at changing preferences. We describe these in detail below. Second, the printing press did not just increase the level of consumption of religious books, but also changed the nature of religion itself. Cities with more printers (hence lower prices) before 1517 saw more Protestant publications (Dittmar and Seabold, 2017). This in itself is compatible with the consumption hypothesis: new production technology can easily bring new "firms" into the market. But in turn, Protestantism had substantive economic effects, increasing long-run literacy, especially women's literacy and possibly affecting economic growth (Becker and Woessmann, 2008, 2009; Becker, Pfaff and Rubin, 2016). These empirical results suggest that religion is not only a consumption good, but also affects the economy more broadly. If so, then it is plausible that religious reading is also more than just an act of consumption.

Our argument is linked to the literature on cultural transmission and evolution (Cavalli-Sforza and Feldman, 1981; Boyd and Richerson, 1988; Bisin and Verdier, 2001). On this account, human preferences, i.e. rationalizable choice patterns, are not inborn but are the result of "enculturation" – learning cultural rules, transmitted from parents, peers and others in society. These rules, rather than explicit calculation, allows human behaviour to be well-adapted to its environment, even when that environment is "causally opaque" (Henrich, 2015). Indeed, according to the theory of cultural evolution, in the long run human rules will evolve to increase individuals' fitness, similarly to biological genes, driven by the same forces of mutation and selection (Boyd and Richerson, 1988). However, some "moral" rules or "social norms" may increase the fitness not of the individual, but of their social group. Because on average it is fitness-enhancing to learn from parents and others, humans are "docile": they tend to accept what they are told.[1] This allows teachers to teach not only fitness-enhancing rules that benefit the child himself, but also moral rules that benefit those around him (Simon, 1990; Gintis, 2003). For example, a mother may encourage her children to share fairly with each other. Rules may be transmitted vertically from parents to children, obliquely from non-parents in the previous generation, or horizontally among peers of the same generation.

[1]Evidence from developmental psychology supports the idea of docility (Clément, Koenig and Harris, 2004; Harris and Koenig, 2006; Jaswal et al., 2010). For the credibility of written material, see Eyden et al. (2013); Einav, Robinson and Fox (2013).

The emergence of the early modern economy created a new environment where existing rule sets, perhaps transmitted within rural communities, and tightly tied to specific agricultural and social contexts, were no longer optimal. Instead, thriving in the economy required more general principles including foresight, planning, thrift and saving; trustworthiness and reliability in economic relations such as employment; later, resistance to the new temptations of the urban economy, including alcoholism, gambling and prostitution (Rorabaugh, 1991; Evans, 1976).

Theories of cultural transmission usually treat the transmission process as fixed. However, there may be innovations in cultural transmission just as in information transmission.[2] The printing press lowered the cost of books and pamphlets, which could be used for both information transmission and cultural transmission.

We next describe the process of cultural transmission via reading at this period. We detail the contexts in which reading took place; list some relevant formats of printed material; finally, we discuss the content of the norms which were being transmitted.

Contexts of reading as cultural transmission

Early modern reading was different from reading today. Apart from a small cultured elite, people had fewer books. They read them "intensively" (Engelsing, 1974), or as a contemporary marginal note in a work of Ramus put it: "This whole book... continually, and perpetually to be meditated, practiced and incorporated into my boddy & souwle.... by perpetual meditations, recapitulations, reiterations... sounde and deepe imprinting as well in ye memory as in the understanding" (Sherman, 2010). A single book might be studied for a year. A tailor's apprentice staying in Coventry found a history of Britain in his master's house; over three months, he learnt most of it by heart (Spufford, 1979*b*).

Protestantism in particular made intensive reading, especially of the Bible, central to religious practice. "To reade the word, and to meditate thereon, is a daily part of a Christian holy life," said the New England Puritan John Cotton (Hambrick-Stowe, 2013). The Bible was supplemented by a whole literature on self-improvement. Some works were on nearly as many bookshelves as the Bible itself, and remained there for centuries: in English, *Foxe's Book of Martyrs*, the *Whole Duty of Man*, *Plain Man's Pathway to Heaven*, and later *Pilgrim's Progress*; in Germany, the anonymous *Theologia Germanica*, and Jo-

[2]We can distinguish these within a microeconomic framework: information transmission changes people's beliefs, while cultural transmission changes their preferences. From the perspective of cultural evolution, the distinction is unimportant, since humans do not maximize their expected utility given their beliefs, but simply follow transmitted norms and rules. But the distinction helps us clarify our differences with previous theories.

hann Arndt's *Das Wahre Christentum* ("True Christianity"), which was popular throughout Protestant Europe.

The private reading encouraged by Protestants could be highly methodical and intellectual. In his text for preachers *The Art of Prophesying*, the Puritan William Perkins (1996) recommended cataloguing-style techniques for Bible study, using a commonplace book: "divide the right-hand pages of your book into columns... Head each of these pages with a major topic...". He also suggested creating an alphabetical index for ease of reference. Devotional manuals laid down rules for reading, including making it part of one's daily routine and avoiding wandering thoughts, and provided model prayers to be said before reading. But reading was not just an intellectual activity: the Bible was to be read and meditated upon, and manuals suggested visualization techniques like imagining Christ on the cross to bring the message home (Hambrick-Stowe, 2013).

Many works of English Puritanism focused on the government of children, in particular on how to teach children to read; as the preachers Dod and Cleaver put it, "we are changed and become good not by birth but by education" (Walzer, 1965). Families prayed together, read the Bible together, and catechized each other. These practices aimed at *vertical* or *oblique transmission* of norms across the generations. Teaching servants was part of this: many servants and apprentices were literally children, and the master-apprentice relationship was an institution for education as much as for employment (Cambers, 2011). The development of print led to further innovations which were specifically aimed at the enculturation of children: Puritans developed the first books aimed specifically at children, along with specialized catechisms for young children (Sommerville, 1992).

Print was not solely used for private reading of the kind that we are most familiar with today. A literate person might read works to his illiterate peers. Householders were expected to read aloud to their families, including servants. An early English protestant encouraged people to "take the Scripture in their hands" at the alehouse and to "talk, commune and reason of it" (Collinson and Murphy, 1988). 16th century French peasants and Huguenot artisans held similar Bible discussions (Davis, 1991). A visiting Jesuit priest described a Puritan meeting in 1580s England (Spufford, 1979*a*, via Fulbrook, 1983):

> Each of them had his own Bible, and sedulously turned the pages and looked up the texts cited by the preachers, discussing the passages among themselves to see whether they had quoted them to the point.... Also they would start arguing among themselves about the meaning of passages from the Scriptures – men, women, boys, girls, rustics, labourers and idiots....

This is an example of *horizontal transmission* among peers of the same age cohort. Later, Puritan groups would hire lecturers in order to expound the Bible to them (Seaver,

1970). Readers might follow the text, take notes on the sermon, and afterwards discuss it in the household. The sermon in turn might subsequently be printed. In economic terms, then, reading was often a complement to verbal transmission, rather than a substitute.

The use of books for cultural transmission was not limited to Protestantism, nor did it only happen after the invention of print. The Brethren of the Common Life, founded in the fourteenth century by the Dutch mystic Geert Groote, emphasized religious reading, including of the Bible in vernacular translation, as a means to a holy life. Brethren themselves copied books as a means to earn a living, moving into printing after 1454. The order also established public schools, and its ideas on education influenced both humanists and Protestants. There is evidence that cities with a BCL order saw higher literacy, and greater economic growth, as a result (Akçomak, Webbink and Ter Weel, 2016). Similarly in 17th century Rome, the Order of the Pious Schools was founded by St Joseph of Calasanz, in order to provide free tuition to the children of the poor, with instruction books translated into the vernacular. Calasanz's central focus was on moral education, although Piarist schools also provided optional technical training in Latin and mathematics (Tanturri, 2011). Lastly, the most famous Catholic example of a book as a vehicle for cultural transmission is the the *Spiritual Exercises* of Ignatius Loyola.

Print formats of enculturation

In Protestant Europe, the most widespread and important single source of enculturation was the Bible itself. This did not necessarily mean the canonical single text. Summaries, verse-a-day collections, or children's stories extracted from the Bible were all common alternatives (Bottigheimer, 1993). Stories from the Old and New Testaments were used as illustrations of vice and its punishment. Solomon's Proverbs and Paul's epistles were widely referred to for life advice. Catholics read Bibles, including vernacular Bibles, as well, despite the opposition of the church hierarchy (François, 2018).

Probably the best-known format designed for cultural transmission is the conduct manual. These originated among Christian humanists and were developed over the 16th and 17th centuries, culminating in England in Puritan manuals such as the *Whole Duty of Man*, the *Plain Man's Pathway to Heaven*, or *Goldengrove*. A further subgenre was the manual of household government, such as Whitforde's *Werke for Housholders* (1533); Batty's *Christian Man's Closet*; Griffith's *Bethel: A Forme for Families* (1633); Perkins' *Oeconomia Christiana* ; Gouge's *Of Domestical Duties;* Rogers' *Matrimonial Honour*; or Dod and Cleaver's *Godly Form of Household Government.* These tended to specify separately the duties of husbands, wives, parents, children, masters and servants. They combined religious exhortation with practical advice. Still more specific were mothers' manuals, which were

typically framed as deathbed advice or a legacy to children, continuing the advice given in life.

Printed work could even reach the illiterate. The early Lutherans used woodcuts extensively to get their message across (Scribner, 1994); a third of German woodcuts were on religious topics (Houston, 2014). Swedish *skillingtryck*, French *fatras* and Russian *lubki* were similar formats. Texts might be read out by one literate person to an illiterate audience. In England, a large proportion of the very cheapest printed work contained religious or moral precepts (Watt, 1994). These works included religious ballads, sold for singing and often reusing secular tunes, and printed posters which would be hung on the walls of taverns or private houses. In one eighteenth-century catalogue of cheap woodcuts, about a quarter were on religious subjects. Among chapbooks (sold by travelling pedlars or "chapmen"), the cheapest "penny godlies" were available for 2 pence. Subjects included polemics against drunkenness; life advice handed down by a parent on their deathbed; and ABCs of religion and morality, which used the alphabet as a mnemonic device. By one estimate, a third of chapbooks were "godly" in the 1680s. A 24-page abridgment of the *Plain Man's Pathway to Heaven* went through 17 editions in three years. These works catered to the desire for entertainment as well as for moral improvement: the most popular and longest-lasting forms often included elements of narrative or dramatic interest, such as the biblical tale of the Prodigal Son.

Catechisms were another key format. These were short, self-contained texts, often in question-and-answer format, designed to be learned by heart, and meant to be taught by clergy as well as by householders to their children and servants. The 16th century saw an explosion of catechisms; later, many countries settled on a single catechism, often mandated by law to be taught in schools and/or churches. This uniformity allowed cheaper and larger print runs, and could also make the norms they contained common knowledge. ("Common knowledge" means that everyone in a given group knows the norm, knows that everyone else in the group knows it, et cetera. This is advantageous for rules governing interpersonal interactions, since it helps coordinate people's expectations that everybody will follow the norm.) The Anglican catechism, learned by children in the Church of England from the 16th to the early 20th century, ran in part:

> My duty towards my neighbour is to love him as myself, and to do all men as I would they should do unto me: to love, honour, and succour my father and mother: to honour and obey the King and all that are put in authority under him: to submit myself to all my governors, teachers, spiritual pastors and masters: to order myself lowly and reverently to all my betters: to hurt nobody by word nor deed: to be true and just in all my dealings: to bear no malice nor hatred in my heart: to keep my hands from picking and stealing, and my tongue from

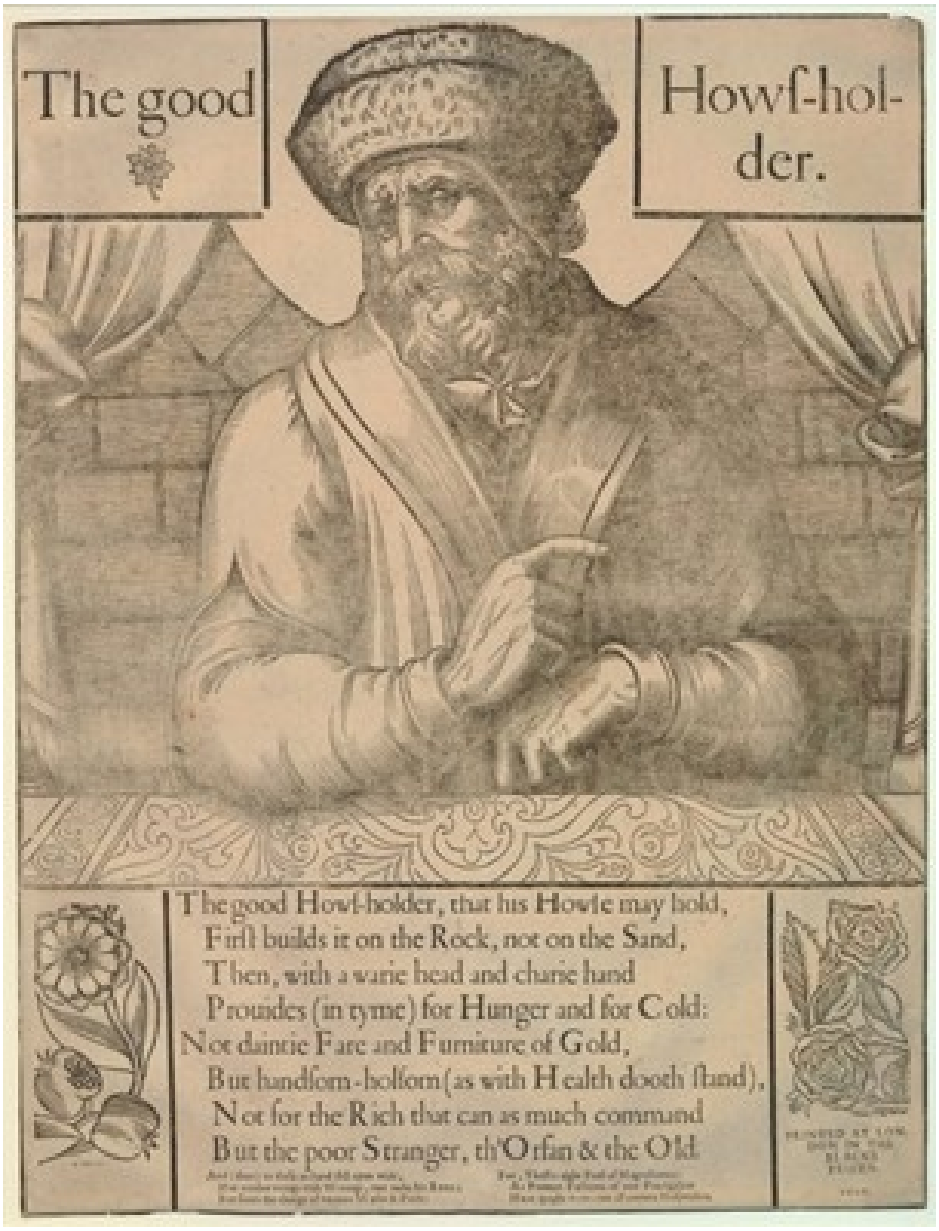

Figure 2: The Good Howsholder. Sixteenth-century woodcut from Watt (1994).

> evil-speaking, lying and slandering; to keep my body in temperance, soberness, and chastity: not to covet nor desire other men's goods; but to learn and labour truly to get mine own living, and to do my duty in that state of life unto which it shall please God to call me.

Despite the authoritarian elements in this, catechisms were not merely imposed on the population by central authorities. A large number of "unofficial" catechisms were published in Elizabethan England (Green, 1986). These were not always aimed at children: many were explicitly designed for adults who were new to religion – "novices in the schoole of Christ". Perhaps a million copies of catechisms, official and unofficial, circulated in early seventeenth-century England.

The content of enculturation

These formats transmitted various messages to the reader. We can distinguish between advice that would benefit the individual, and social norms that would benefit those around him. The former included *hard work* and *self-control*. The latter included *cooperation* and *trustworthiness*. The content also included *social roles*, which set the terms of cooperation, not necessarily in an equal way.

Hard work: *Bethel, or a Forme for Families* commended "getting our substance by honest labour". The *Whole Duty of Man* described "honest industry and labour" as "the means by which God... gives us the necessaries of this life"; "the sluggish person shall never thrive". The *Plain Man's Pathway to Heaven* included a chapter condemning idleness, and gave four reasons for hard work in one's calling: "First, to bear the yoke laid upon mankind; by the Lord; secondly, to get the necessaries of this life ; thirdly, to live unto the profit of human society; lastly, to avoid evil thoughts and actions." *Of Domestical Duties* said that slothfulness led to ""poverty, servitude...hunger, beggary and death", and warned of the habit-forming nature of laziness. Well-known Bible quotes included Proverbs 6.6 ("Go to the ant, o sluggard, behold her ways, and be wise...") and Proverbs 24.33 ("Yet a little sleep, a little slumber, a little folding of the hands to sleep...").

Conduct manuals enjoined *self-control* with respect to several specific, widespread temptations, including food, drink, sex and violence. *Bethel* advised young people to be sober-minded and "fly the lusts of youth" (2 Timothy 2.22). *Domestical Duties*, the *Whole Duty* and *Plain Man's Pathway* all warned against "whoredom". The *Whole Duty* also included a chapter on temperance in drinking. The *Pathway* and others treated anger as a forerunner to murder, and therefore as a breach of the Sixth Commandment.

Truth-telling was praised, and lying condemned, in general and specifically in the context of trade. *Bethel* said "shun lying and equivocation"; honesty for sellers included giving prices appropriate to the true quality of goods. *Domestical Duties* recommended "preferring honesty before commodity". The *Whole Duty* called speaking truth "a common debt we owe to all mankind". The *Pathway* described lying as a sign of damnation, especially to be found in "shopkeepers and servants".

The social roles defined in conduct manuals included masters and servants, husbands and wives, and parents and children. Regarding *servants*, the manuals could build on a large body of New Testament parables concerning the employment relation, including the Parables of the Faithful Servant (Luke 12.35-48), the Master and Servant (Luke 17.7-10) the Wedding Feast (Matthew 22.1-14), the Unforgiving Servant (Matthew 18.21-35) and the Wicked Husbandmen (Matthew 21.33-46). Servants should be obedient to their master's commands; this specifically included when monitoring was absent, as distinct from "eye-service". Cleaver's *Godly Form of Household Government* made the same point: unless servants "serve God in their labours,... their obedience can never be constant, but will be by fits and starts, and hang only on the master's eye." Of course this was also a reason for masters to hire Godly servants. *Bethel* and *Domestical Duties* gave servants a broad duty to increase their master's profit. Servants were expected not to answer back, and not to leave their employment before the end of the contract. The context would typically be an apprenticeship lasting several years. Early exit was a problem for masters, because the costs of educating apprentices were front-loaded (De la Croix, Doepke and Mokyr, 2017). Servants also shouldn't marry without their master's consent. Luther's *Small Catechism* made similar points.

The books also laid out the corresponding duties of *masters*, including paying wages on time, not imposing excessive working hours (especially on Sundays, when time should be allowed for religious observance) and supporting servants when they fell ill.

A similar set of mutual duties governed husbands and wives, not, of course, on equal terms. The *Godly Form of Household Government* laid out the division of labour in the household:

> The duty of the husband is to get goods: and of the wife to gather them together, and save them. The duty of the husband is to travel abroad to seek living: and the wife's duty is to keep the house. The duty of the husband is to get money and provision: and of the wife, not vainly to spend it. The duty of the husband is, to be a giver; and of the wife to be a saver. The duty of the husband is, to be Lord of all: and of the wife, to give account of all. The duty of the

> husband is, to dispatch all things without door; and of the wife, to oversee and give order for all things within the house.

Not all this printed material was intended to increase people's success in the early modern economy. Much was purely religious, such as the literature on "dying well". Other content was quite anti-capitalistic. For example, many books condemned greed strongly, and some, like the *Plain Man's Pathway to Heaven* saw it as pervasive in contemporary society. In other words, the transmitted content was not optimized so as to maximize one's long-run earnings. Instead, we should think of a slow process by which economically advantageous messages spread and won out over other material. At the endpoint of this process are works like Benjamin Franklin's *Autobiography*, where economic advantage plays a much more explicit role.

Although many of our citations come from English Puritan conduct manuals, we do not argue that these norms were unique to Puritanism. In fact, many Catholics and non-Puritan Anglicans had made similar points (Todd, 1980).

The demand for enculturation

The preferences transmitted by print could be valuable commodities in the early modern labour market. Modern employers value "soft skills" as much as technical skills (Heckman, Stixrud and Urzua, 2006). This is likely to have been even more in an earlier era, when human behaviour was markedly less polished than it is today. The sociologist Norbert Elias (1994) argues that from the Renaissance, humans went through a "civilizing process" in which previously acceptable forms of behaviour became unacceptable. The History of Myddle is a seventeenth-century record of life in a small Shropshire town (Gough, 1981). Its index begins:

> Absenteeism
>
> Abusive language towards parents
>
> Accident, death due to
>
> Adoption
>
> Adultery
>
> Aggression (see Fighting, Quarrelling, Homicide)
>
> Alcoholism (see also Drunkenness)

... and that's just the A's. Quantitative data indeed suggests that alcohol consumption (Spring and Buss, 1977), child abandonment (Cunningham, 2005) and violence (Eisner, 2003) were

more common than today. At the same time, formal controls on behaviour were rarer. In communities, there were no police forces. Employers lacked clocks for timekeeping, and the telephone to keep in touch with remote agents. Contract enforcement in court might be prohibitively expensive, and courts might be corrupt in any case.

So, in this period, employers faced serious principal-agent problems, with little monitoring ability. They therefore urgently needed reliable, sober, trustworthy apprentices. A recurrent concern is that servants might provide "eye-service" – working when they were under observation, but shirking otherwise. The apprenticeship relation, which involved masters exchanging work for training (typically in "tacit" knowledge), involved a risky gamble that the apprentice might break off the contract before he had repaid the cost of his training. This could be to take a more attractive position, but perhaps also because of an apprentice's low discount rate between present toil and future rewards (Wallis, 2008). Masters were also consistently apprehensive that their apprentices might drink, visit brothels, seduce their daughters, steal from them, get into fights, or riot (Smith, 1973, 1981). Apprentices, in turn, needed to save money in order to open a workshop or to pay for admission to mastership.

For these reasons, high discount factors, a preference for work, and a cooperative personality were advantageous traits in the early modern labour market. Adults often paid to purchase these things themselves, just as people now buy self-help books. Parents often paid for vertical transmission of values to their children. Most education was privately funded by parents, and it was widely agreed that the purpose of education was character formation, at least as much as technical skills (Cunningham, 2005). As well as paying for employees' soft skills via wages, masters might also find it worthwhile to provide enculturation themselves, just as they provided technical training. This was particularly true since apprenticeship typically started at a young age. As Archbishop Tillotson put it: "it is really of our service and advantage that those that belong to us should serve and fear God; Religion being the best and surest Foundation of the Duties of all Relations" (quoted in Schücking, 1970). Or Bullinger: "the good man of the house, by planting godliness in his family, doth not a little advance and set forward his private profit...; for wicked servants are for the most part pickers and deceitful; whereas, on the other side, the godly are faithful."

Because it transmits social norms of cooperation, enculturation is in part a public good. Furthermore, if a community benefits when individuals coordinate on the *same* norm, then it will wish to encourage or enforce uniformity of moral teaching. Indeed, schools were not always set up in response to private demand. Instead many were established by religious reformers, sometimes in partnership with the secular authorities. Examples before the invention of printing include the Brethren of the Common Life mentioned above. After the printing press, Lutheran reformers in Germany made a century-long effort to develop teaching throughout their areas of influence (Strauss, 1978). In doing so they appealed to secular

as well as religious motivations (though they would probably have rejected this distinction). Luther wrote "A city's prosperity does not consist alone in the accumulation of treasure... but its greatest wealth, its health and power, does consist in [...] sensible, honest, and well-disciplined citizens" (cited inKemp, 1912). Similarly, Sweden's very early development of widespread literacy was mandated by the Protestant monarch, but put into practice by local communities (Johansson, 2009). There were similar literacy drives in Calvinist Scotland and Geneva (Watt, 2002). English mass education was provided predominantly by churches until the late 19th century (Bowen, 1981).

Publicly-provided curricula typically included Bible-reading and the memorization of religious texts; catechisms played a central role (Laqueur, 1976; Wrightson, 2002). Writing was less important than reading. In Utrecht primary schools, reading and learning the catechism each took up ten times more space in the curriculum than writing, and twenty times more space than either arithmetic or history (Benedict, 2004).

Some emergent nation-states started national literacy campaigns, although these were often limited in scope and effect. State authorities worked with religious reformers to develop curricula. The stated purpose of these campaigns was not technical education but citizenship, social order and political obedience (Houston, 2014). Indeed, these public goods provided a stronger rationale for state intervention than the benefits of technical training, which mostly fell to the student. However, much of the support for publicly-provided education came from the local community, rather than the nation-state (Schmidt, 1995); in England, Puritan lectureships were funded by town notables (Seaver, 1970). This suggests that the primary public good being produced was local-level social order, rather than political indoctrination.

Both Protestants and Catholics tried to enforce uniform teaching according to their religion, wherever they could do so (Watt, 2002). As the Lutheran Dietrich Reinkingk wrote, "One religion in one country and state connects the minds of the subjects among themselves and with their superiors" (cited in Reinhard, 1989). Later, in the 19th century, there were regular conflicts between religious denominations over the content of education in both Britain and Holland.

A last piece of evidence for the "enculturation" view of print is the increase in female literacy. In the early modern period, women played a role in the economy as part of the household, which was both a site of childrearing, and the basic unit of economic activity. However, they did not typically perform skilled labour. If the only purpose of literacy were to learn skills for use in the labour market, then we would not expect female literacy to be affected by the availability of print. On the other hand, if reading transmits values that affect work effort, irrespective of skill, then these could be valuable for both men and women. In fact, though men's literacy increases more, there are substantial increases in female literacy

in many countries. In Sweden, for instance, female literacy equalled male literacy in the 18th century, and even surpassed it in some areas (Johansson, 2009).

Related literature

Our topic is at the intersection of three literatures: the history of print and reading; the economics of cultural transmission; and growth economics, specifically the role of knowledge. We mention just some key works from each.

There is a vast literature on the history of books and print. Eisenstein (1980) and Febvre and Martin (1997) are key contributions. More specific work is cited above. Within economics, Baten and Van Zanden (2008) and Buringh and Van Zanden (2009) measure per capita book production in the long run and relate it to economic growth.

Bisin and Verdier (2001) developed a microeconomic framework to study cultural transmission. Doepke and Zilibotti (2008) argue that parent-child cultural transmission can explain the development of the "spirit of capitalism", and why aristocratic landowners eventually fell behind the middle class during the industrial revolution. They don't model the mechanism of cultural transmission. Here, we use a reduced form in which books can increase productivity, implicitly by the mechanisms detailed above: altering preferences towards cooperation, leisure, savings and time discounting.

In terms of model we use a combination of the Diamond model (Diamond, 1965) and the Lucas model (Lucas Jr, 1988) of endogenous growth to obtain a model of unified growth (Galor and Weil, 2000). In the Diamond model output per consumer is constant in the long run so there is stagnation. In the Lucas model output per consumer grows in the long run so there is perpetual growth. Unified growth theory aims at explaining the transition from stagnation to perpetual growth. In the Lucas model the source growth is accumulation of knowledge. We enrich our model compared to the Diamond and Lucas models in that we consider transmission of enculturation and knowledge, where enculturation influences productivity and knowledge influences human capital.

Introduction to the model

We formalize our argument in an overlapping generations model where at every date a new generation of consumers enters the economy and an old generation of consumers leaves the economy.

There are two different production technologies: in what we denote *traditional* production firms use capital and *unskilled* labour are used to produce output; and, in what we

denote *modern* production firms use capital and *skilled* labour are used to produce output. For both technologies labour productivity matters and for modern production, but not for traditional production, human capital matters. Even though productivity matters for both traditional and modern production the choice of technology depends on productivity. For low productivity traditional production is chosen and for high productivity modern production is chosen. Both forms of production are available at every date, so a transition from traditional production to modern production happens because consumers choose to change form supplying unskilled labour to supplying skilled labour and firms choose to change technology traditional to modern and not because a new technology becomes available.

Unskilled labour used in traditional production is simply productivity times hours worked and skilled labour is simply human capital times productivity times hours worked. Therefore the difference between the two forms of labour is that human capital matters for skilled labour but not for unskilled labour. To formalize how productivity and human capital come about, we assume consumers can use their time on four different activities, namely leisure, enculturation, education and work. Leisure matters for consumer welfare, education contributes to human capital and work generates income. We innovate by letting consumers spend time on *enculturation*. This does not increase human capital in the conventional sense of technical skills, but it makes people more productive by increasing their non-cognitive skills, for example by making them more honest, cooperative and hardworking. Enculturation is time spent on becoming more productive, possible by consuming material like that described above. We model this simply by making productivity an increasing function of enculturation.

Society matters for economic agents both in form of institutions and culture. Institutionally, we assume that exchanges between agents take place on perfectly competitive markets. Culture is captured in two variables: the level of technical *knowledge* and the level of *industriousness*, both in society. These assumptions are huge simplifications of complex aspects of society, but they allow us to make our main argument clear and precise.

Knowledge is a state variable which increases when individuals spend time on education so it is a byproduct of education. Moreover, the level of knowledge affects how effective time spent on education converts into human capital. Consequently, the interaction between knowledge and education provides a reduced-form summary of a cultural transmission process. Industriousness is a state variable which measures how widespread the support for values like hard work and cooperation is, and increases when people spent time on enculturation so industriousness is a byproduct of enculturation. Moreover, since individuals take their values from the surrounding culture, the level of industriousness affects how effective time spent on enculturation converts into productivity. So, the interaction between industriousness and enculturation provides a very reduced-form summary of a cultural transmission

process. A major difference between knowledge and industriousness in our model is that knowledge cannot disappears while industriousness can depreciate.

We implicitly assume the invention of the printing press led to lower prices for books, which in turn led to higher demand for books. Indeed the invention of the printing press moved books from being out of reach to being within reach for most individuals. Moreover, we implicitly assume the demand of books depends on the time devoted to education and enculturation as well as the levels of knowledge and industriousness. A reason why the levels of knowledge and industriousness matter for the demand for books is that the levels of these state variables indicate how education and productivity are valued and consequently indirectly the incentives to use the time allocated to education and enculturation effectively. To illustrate what we have in mind we imagine the invention of the printing press had a short-run effect and a long-run effect. The short-run effect is that invention of the printing price led to a downward jump in the prices for books, which in turn led up an upward in the demand for books. The long-run effect is that as education and industriousness increase gradually over time, the demand for books increases gradually over time.

For traditional production, the minimum capital per worker needed to produce is low like a stick to poke holes in the ground for seeds or a quill pen for producing handwritten manuscripts. For simplicity we assume there is no minimum capital requirement for traditional production. Consequently, it is possible to produce with any ratio between capital and number of workers. However, for modern production there is a minimum capital requirement per worker. The requirement reflects that letting two workers instead of one worker use the same spinning jenny or laptop simultaneously will not increase productivity noticeable. Independently of how productive and educated workers are, there must be at least one unit of capital per worker. Naturally, in case workers are productive and educated the capital requirement is without importance, but in case workers are less productive or less educated the capital requirement matters. Hence, the requirement matters for whether there is a transition from traditional to modern production.

With traditional production perpetual growth is not possible because perpetual growth in productivity is not possible. Suppose the transmissions of enculturation and industriousness at one date into productivity and industriousness on the next date, and of education and knowledge at one date into human capital and knowledge at the next date, both become more effective. Then there can be a transition from traditional production to modern production because the rewards from modern production involving skilled labour are larger than the rewards for traditional production involving unskilled labour. With modern production perpetual growth is possible because perpetual growth in knowledge is possible.

Setup

We introduce our setup and consider the problems of consumers and firms.

Consider the overlapping generation model with time extending from minus infinity to plus infinity, $t \in \mathbb{Z}$. There are three standard goods, namely a consumption good, capital and labour, and two non-standard goods, namely industriousness in society and knowledge in society. Let $Z_t > 0$ be industriousness in society and $E_t > 0$ be knowledge in society, both at date t.

Consumers are identical within and across generations, except for their date of birth. They have one unit of time when young and care about leisure when young and consumption when old. Time can be consumed as leisure or spent on education, enculturation and work. Consumers care about leisure, while enculturation and education can be used to improve productivity and human capital respectively. Let o_t be time spent on leisure, n_t enculturation, e_t education, ℓ_t work and c_{t+1} consumption of a consumer in generation t with $o_t, c_{t+1} > 0$ and $n_t, e_t, \ell_t \geq 0$. The utility function is

$$U(o_t, c_{t+1}) \;=\; \alpha \ln(o_t) + \ln(c_{t+1})$$

with $\alpha > 0$.

Consumers can work as unskilled or skilled workers. For unskilled workers the labour supply is productivity times time spent on work. Productivity depends on the individual's level of enculturation and society's level of industriousness. The supply of unskilled labour is

$$\lambda_t^u \;=\; B n_t^\beta Z_t^\beta \; \ell_t \tag{1}$$

with $B > 0$ and $\beta \in]0,1[$. The expression $n_t^\beta Z_t^\beta$ can be interpreted as effective level of enculturation and it is increasing in both time spent on enculturation and society's level of industriousness. The constant B measures the efficiency of the transmission of enculturation into individual productivity, or more briefly the efficiency of the enculturation process. Use of religious books is assumed to be increasing in effective consumption of enculturation.

For skilled workers the labour supply is productivity times human capital times time spent on work. Human capital depends on time spent on education and knowledge in society, with the supply of skilled labour being

$$\lambda_t^s \;=\; C e_t^\gamma E_t \; B n_t^\beta Z_t^\beta \; \ell_t. \tag{2}$$

with C and $\gamma \in]0,1[$. The expression $e_t^\gamma E_t$ can be interpreted as effective education and it is increasing in both education and knowledge in society. The constant C measures the efficiency of the transmission of effective consumption of education into individual human capital. Use of technical books is assumed to be increasing in effective education.

Availability of books has an impact on the efficiency of the transmissions of both effective consumption of busy leisure into productivity and effective consumption of education into human capital. Specifically, increased availability of religious books would increase B and of scientific books would increase C.

Consumers transform consumption good at date t into capital at date $t+1$ by putting the consumption good under their pillows at date t and bringing out capital from under their pillows at date $t+1$.

Firms are identical and have access to two different constant returns to scale technologies at every date to focus on other changes than technical innovations. The traditional technology transforms capital and unskilled labour into the consumption good,

$$F^u(K_t, L_t^u) \;=\; A(K_t)^\sigma (L_t^u)^{1-\sigma}$$

with $A > 0$ and $\sigma \in]0,1[$. The modern technology transforms capital and skilled labour into the consumption good,

$$F^s(K_t, L_t^s) \;=\; A(K_t)^\sigma (L_t^s)^{1-\sigma}$$

with $A > 0$ and $\sigma \in]0,1[$. For the second technology there must be at least one unit of capital per worker. The capital requirement reflects that every worker occupies at least one unit of capital independent of how effective they are. Capital depreciates completely for both technologies. The two production functions are assumed to be identical to focus on how supplies of unskilled and skilled labour and the capital requirement influence the transition from traditional production to modern production.

The consumption good is the numeraire, the price of capital is $1+r_t$ with $r_t > -1$ and the wages for unskilled and skilled labour are $w_t^u, w_t^s > 0$. Therefore r_t is the real interest rate and w_t^u and w_t^s are the real wages. However, the wages are per unit of effective labour and not per unit of time of labour. Indeed, the wages per unit of time are $w_t^u B_t n_t^\beta Z_t^\beta$ for unskilled labour and $w_t^s C e_t^\gamma E_t B n_t^\beta Z_t^\beta$ for skilled labour. Consequently, the wage per unit of time can be higher for skilled labour than for unskilled labour even though the wage per unit of effective labour is lower for skilled labour than for skilled labour and vice versa.

The consumer problem

Consumers decide to supply their labour as unskilled or skilled in order to maximize their utilities. First the consumer problems for the two cases are stated and solved. Second utilities in the two cases are compared.

Suppose a consumer in generation t decides to work as an unskilled worker. Then the consumer problem is:

$$\max_{(o_t,n_t,e_t,\ell_t,\lambda_t^u,c_{t+1})} \quad \alpha\ln(o_t)+\ln(c_{t+1})$$

$$\text{s.t.} \quad \begin{cases} c_{t+1} &= (1+r_{t+1})w_t^u\lambda_t^u \\ \lambda_t^u &= Bn_t^\beta Z_t^\beta\ \ell_t \\ o_t+n_t+e_t+\ell_t &= 1. \end{cases}$$

The solution is:

$$\begin{cases} o_t^u &= \dfrac{\alpha}{1+\alpha+\beta} \\ n_t^u &= \dfrac{\beta}{1+\alpha+\beta} \\ e_t^u &= 0 \\ \ell_t^u &= \dfrac{1}{1+\alpha+\beta} \\ c_{t+1}^u &= (1+r_{t+1})w_t^u\dfrac{\beta^\beta}{(1+\alpha+\beta)^{1+\beta}}\ BZ_t^\beta \end{cases}$$

and the savings are $s_t^u = w_t^u\lambda_t^u$,

$$s_t^u \ = \ w_t^u\frac{\beta^\beta}{(1+\alpha+\beta)^{1+\beta}}\ BZ_t^\beta.$$

Since the use of time is constant across dates, the time index is dropped, (o^u,n^u,e^u,ℓ^u). The supply of unskilled labour is $\lambda_t^u = B(n^u)^\beta Z_t^\beta\ \ell^u$ which is increasing in the efficiency of the enculturation process B, and in industriousness Z_t.

Suppose a consumer in generation t decides to work as a skilled worker. Then the consumer problem is:

$$\max_{(o_t,n_t,e_t,\ell_t,\lambda_t^s,c_{t+1})} \quad \alpha\ln(o_t)+\ln(c_{t+1})$$

$$\text{s.t.} \quad \begin{cases} c_{t+1} &= (1+r_{t+1})w_t^s\lambda_t^s \\ \lambda_t^s &= Ce_t^\gamma E_t\ Bn_t^\beta Z_t^\beta\ \ell_t \\ o_t+n_t+e_t+\ell_t &= 1. \end{cases}$$

The solution is:

$$\begin{cases} o_t^s &= \dfrac{\alpha}{1+\alpha+\beta+\gamma} \\ n_t^s &= \dfrac{\beta}{1+\alpha+\beta+\gamma} \\ e_t^s &= \dfrac{\gamma}{1+\alpha+\beta+\gamma} \\ \ell_t^s &= \dfrac{1}{1+\alpha+\beta+\gamma} \\ c_{t+1}^s &= (1+r_{t+1})w_t^s \dfrac{\beta^\beta \gamma^\gamma}{(1+\alpha+\beta+\gamma)^{1+\beta+\gamma}} CE_t\, BZ_t^\beta \end{cases}$$

and the savings are $s_t^s = w_t^s \lambda_t^s$,

$$s_t^s \;=\; w_t^s \frac{\beta^\beta \gamma^\gamma}{(1+\alpha+\beta+\gamma)^{1+\beta+\gamma}}\, CE_t\; BZ_t^\beta\,.$$

Since the use of time is constant across dates the time index is dropped, (o^s, n^s, e^s, ℓ^s). The supply of skilled labour is $\lambda_t^s = C(e^s)^\gamma E_t\; B(n^s)^\beta Z_t^\beta\;\; \ell^s$ which is increasing in the efficiency of the transmission of effective enculturation into productivity B, industriousness Z_t, the efficiency of transmission of effective education into human capital C, and, knowledge E_t.

Let U^u (U^s) be the indirect utility of working as an unskilled (skilled) worker. Then

$$e^{U^s - U^u} \;=\; \left(\frac{1+\alpha+\beta}{1+\alpha+\beta+\gamma}\right)^{1+\alpha+\beta} \left(\frac{\gamma}{1+\alpha+\beta+\gamma}\right)^{\gamma} CE_t\; \frac{w_t^s}{w_t^u}.$$

The consumer will be unskilled (skilled) if and only if $e^{U^s-U^u} \leq 1$ ($e^{U^s-U^u} \geq 1$). For $\phi \in]0,1[$ defined by

$$\phi \;=\; \left(\frac{1+\alpha+\beta}{1+\alpha+\beta+\gamma}\right)^{1+\alpha+\beta} \left(\frac{\gamma}{1+\alpha+\beta+\gamma}\right)^{\gamma},$$

consumers will supply unskilled (skilled) labour if and only if $w_t^u \geq \phi CE_t w_t^s$ ($w_t^u \leq \phi CE_t w_t^s$). The decision to supply unskilled or skilled labour is independent of industriousness in society, but depends on knowledge in society.

The firm problem

Naturally, firms decide to use the traditional or the modern technology to maximize their profits subject to technological constraints. First, the firm problems for the two scenarios are stated and solved. Second, we consider the decision to use the traditional or the modern technology.

For firms using the traditional technology the technological constraint is that output is determined by the amounts of capital and unskilled labour. Therefore the firm problem is:

$$\begin{array}{ll} \max\limits_{(Y_t,K_t,L_t^u)} & Y_t-(1+r_t)K_t-w_t^uL_t^u \\ \text{s.t.} & Y_t = A(K_t)^\sigma(L_t^u)^{1-\sigma}. \end{array}$$

For $k_t^u = K_t/L_t^u$ being the capital intensity the first-order conditions are:

$$\left\{\begin{array}{rcl} \sigma A(k_t^u)^{\sigma-1} &=& 1+r_t \\ (1-\sigma)A(k_t^u)^\sigma &=& w_t^u. \end{array}\right.$$

Clearly, there is a non-trivial solution $k_t^u > 0$ to the firm problem for the firm using unskilled labour if and only if

$$w_t^u = (1-\sigma)A\left(\frac{\sigma A}{1+r_t}\right)^{\sigma/(1-\sigma)}.$$

For firms using the modern technology the technological constraints are that output is determined by the amounts of capital and skilled labour used by the firm and that there has to be at least one unit of capital per worker. Hence the firm problem is:

$$\begin{array}{ll} \max\limits_{(Y_t,K_t,L_t^s)} & Y_t-(1+r_t)K_t-w_t^sL_t^s \\ \text{s.t.} & \left\{\begin{array}{rcl} Y_t &=& A(K_t)^\sigma(L_t^s)^{1-\sigma} \\ K_t &\geq& \dfrac{L_t^s}{\lambda_t^s}. \end{array}\right. \end{array}$$

For $k_t^s = K_t/L_t^s$ being the capital intensity there is a non-trivial solution $k_t^s > 0$ to the firm problem if and only if the maximal profit is zero and either the capital requirement is not binding or the capital requirement is binding.

In case the capital requirement is binding, $\sigma A k^{\sigma-1} = 1+r_t$ implies $k < 1/\lambda_t^s$, $k_t^s > 0$ is a solution if and only if:

$$\left\{\begin{array}{rcl} \sigma A(k_t^s)^{\sigma-1} &<& 1+r_t \\ A(k_t^s)^\sigma-(1+r_t)k_t^s &=& w_t^s \\ k_t^s &=& \dfrac{1}{\lambda_t^s}. \end{array}\right.$$

The wage w_t^s is increasing in λ_t^s in case the capital requirement is binding, because

$$\frac{dw_t^s}{d\lambda_t^s} = (\sigma A(k_t^s)^{\sigma-1}-(1+r_t))\frac{dk_t^s}{d\lambda_t^s}$$

where $dk_t^s/d\lambda_t^s = -1/(\lambda_t^s)^2$.

In case the capital requirement is not binding, $\sigma A k^{\sigma-1} = 1+r_t$ implies $k \geq 1/\lambda_t^s$, $k_t^s > 0$ is a solution if and only if:

$$\begin{cases} \sigma A (k_t^s)^{\sigma-1} &= 1+r_t \\ (1-\sigma) A (k_t^s)^{\sigma} &= w_t^s \\ k_t^s &\geq \dfrac{1}{\lambda_t^s}. \end{cases}$$

The wage w_t^s is constant in λ_t^s in case the capital requirement is not binding.

Consequently: the wage for skilled labour is increasing labour supplied $dw_t^s/d\lambda_t^s > 0$ in case the capital requirement is binding $\lambda_t^s > ((1+r_t)/(\sigma A))^{1/(1-\sigma)}$; and, the wage for skilled labour is independent of labour supplied $dw_t^s/d\lambda_t^s = 0$ in case the capital requirement is not binding $\lambda_t^s \leq ((1+r_t)/(\sigma A))^{1/(1-\sigma)}$. Since there is constant returns to scale in production independently of whether the firms use unskilled or skilled labour, profits are zero.

Industriousness and knowledge formation

Industriousness in society at date $t+1$ is formed by industriousness in society at date t and average individual productivity at date t with $Z_{t+1} = (1-\delta)Z_t + \tau B n_t^{\beta} Z_t^{\beta}$ where $\delta \in]0,1[$ and $\tau > 0$. The parameter δ is the depreciation rate of industriousness and the parameter τ measures the impact of average effective individual enculturation average on industriousness. Lowering the printing cost for religious books corresponds to increasing B, which makes the enculturation process more effective, which again increases future industriousness.

Knowledge in society at date $t+1$ is formed by knowledge in society at date t and average time spent on education at date t with $E_{t+1} = E_t + \tau C e_t^{\gamma} E_t$ where $\tau > 0$ measures the strength of the impact of average human capital on knowledge. There is no depreciation in knowledge – old ideas never die, they just become obsolete. Lowering the printing cost for technical books corresponds to increasing C, which makes the transmission of effective education into human capital more effective, which again increases knowledge at the next date.

Equilibrium

Two scenarios are considered. In the first, consumers and firm are restricted to unskilled labour; and, in the second, consumers and firms are restricted to skilled labour.

Equilibrium with traditional production

In an equilibrium with traditional production, consumers maximize utility, firms maximize profits, both subject to the constraint that labour has to be unskilled, and markets clear.

Definition 1 *An **equilibrium** is prices, consumption plans and production plans,*

$$((\bar{r}_t, \bar{w}_t^u)_{t\in\mathbb{Z}}, (\bar{o}_t^u, \bar{n}_t^u, \bar{e}_t^u, \bar{\ell}_t^u, \bar{\lambda}_t^u, \bar{c}_{t+1}^u)_{t\in\mathbb{Z}}, (\bar{y}_t^u, \bar{k}_t^u)_{t\in\mathbb{Z}}, (\bar{Z}_t^u, \bar{E}_t^u)_{t\in\mathbb{Z}}),$$

such that

- *Consumers maximize utilities:* $(\bar{o}_t^u, \bar{n}_t^u, \bar{e}_t^u, \bar{\ell}_t^u, \bar{\lambda}_t^u, \bar{c}_{t+1}^u)$ *is a solution to the consumer problem for every* t.
- *Firms maximize profits:* $(\bar{y}_t^u, \bar{k}_t^u)$ *is a solution to the firm problem for every* t.
- *Markets clear: for every* t,

$$\begin{cases} \bar{c}_t^u + \bar{w}_t^u \bar{\lambda}_t^u &= \bar{y}_t^u \bar{\lambda}_t^u \\ \bar{k}_{t+1}^u \bar{\lambda}_{t+1}^u &= \bar{w}_t^u \bar{\lambda}_t^u. \end{cases}$$

- $\bar{Z}_{t+1}^u = (1-\delta)\bar{Z}_t^u + \tau B(\bar{n}_t^u)^\beta (\bar{Z}_t^u)^\beta$ *and* $\bar{E}_{t+1}^u = \bar{E}_t^u + \tau C(\bar{e}_t^u)^\gamma \bar{E}_t^u$ *for every* t.

The dynamical system describing equilibria is

$$\begin{cases} k_{t+1}^u \lambda_{t+1}^u &= (1-\sigma)A(k_t^u)^\sigma \lambda_t^u \\ Z_{t+1}^u &= (1-\delta)Z_t^u + \tau B(n^u)^\beta (Z_t^u)^\beta \\ E_{t+1}^u &= E_t^u + \tau C(e^u)^\gamma E_t^u \\ \lambda_t^u &= B(n^u)^\beta (Z_t^u)^\beta \, \ell^u \end{cases} \tag{3}$$

Hence, if $(k_t^u, \lambda_t^u, Z_t^u, E_t^u)_{t\in\mathbb{Z}}$ is a solution to the dynamical system, then

$$\begin{cases} \lim_{t\to\infty} k_t^u &= ((1-\sigma)A)^{1/(1-\sigma)} \\ \lim_{t\to\infty} Z_t^u &= (\tau B(n^u)^\beta/\delta)^{1/(1-\beta)} \\ E_t^u &= E_0^u \\ \lim_{t\to\infty} \lambda_t^u &= (B(\tau n^u/\delta)^\beta)^{1/(1-\beta)} \, \ell^u. \end{cases}$$

Since consumers use no time on education $e^u = 0$, knowledge is constant over time.

Definition 2 *A **steady state** is an equilibrium at which every variable is time independent.*

There is a unique steady state at which

$$\begin{cases} k^u &= ((1-\sigma)A)^{1/(1-\sigma)} \\ Z^u &= (\tau B(n^u)^\beta/\delta)^{1/(1-\beta)} \\ E^u &= E_0^u \\ \lambda^u &= (B(\tau n^u/\delta)^\beta)^{1/(1-\beta)}\,\ell^u. \end{cases}$$

Equilibrium with modern production

In an equilibrium with modern production, consumers maximize utility, firms maximize profits, both subject to the constraint that labour has to be skilled, and markets clear.

Definition 3 *An equilibrium is prices, consumption plans and production plans,*

$$((\bar{r}_t^s,\bar{w}_t^s)_{t\in\mathbb{Z}},(\bar{o}_t^s,\bar{n}_t^s,\bar{e}_t^s,\bar{\ell}_t^s,\bar{\lambda}_t^s,\bar{c}_{t+1}^s)_{t\in\mathbb{Z}},(\bar{y}_t^s,\bar{k}_t^s)_{t\in\mathbb{Z}},(\bar{Z}_t^s,\bar{E}_t^s)_{t\in\mathbb{Z}}),$$

such that

- *Consumers maximize utilities:* $(\bar{o}_t^s,\bar{n}_t^s,\bar{e}_t^s,\bar{\ell}_t,\bar{\lambda}_t^s,\bar{c}_{t+1}^s)_{t\in\mathbb{Z}}$ *is a solution to the consumer problem for every* t.
- *Firms maximize profits:* $(\bar{y}_t^s,\bar{k}_t^s)$ *is a solution to the firm problem for every* t.
- *Markets clear: for every* t,

$$\begin{cases} \bar{c}_t+\bar{w}_t^s\bar{\lambda}_t^s &= \bar{y}_t^s\bar{\lambda}_t^s \\ \bar{k}_{t+1}^s\bar{\lambda}_{t+1}^s &= \bar{w}_t^s\bar{\lambda}_t^s. \end{cases}$$

- $\bar{Z}_{t+1}^s=(1-\delta)\bar{Z}_t^s+\tau B(\bar{n}_t^s)^\beta(\bar{Z}_t^s)^\beta$ *and* $\bar{E}_{t+1}^s=\bar{E}_t^s+\tau C(\bar{e}_t^s)^\gamma\bar{E}_t^s$ *for every* t.

Suppose the capital constraint is binding, $\sigma Ak^{\sigma-1}=1+r_t$ implies $k<1/\lambda_t^s$. Then the dynamical system describing equilibria is

$$\begin{cases} \lambda_t^s k_t^s &= 1 \\ Z_{t+1}^s &= (1-\delta)Z_t^s+\tau B(n^s)^\beta(Z_t^s)^\beta \\ E_{t+1}^s &= E_t^s+\tau C(e^s)^\gamma E_t^s \\ \lambda_t^s &= C(e^s)^\gamma E_t\,B(n^s)^\beta(Z_t^s)^\beta\,\ell^s. \end{cases} \tag{4}$$

Suppose the capital constraint is not binding, $\sigma A k^{\sigma-1} = 1+r_t$ implies $k \geq 1/\lambda_t^s$ for every t. Then the dynamical system describing equilibria is

$$\begin{cases} \lambda_{t+1}^s k_{t+1}^s &= (1-\sigma)A(k_t^s)^\sigma \lambda_t^s \\ Z_{t+1}^s &= (1-\delta)Z_t^s + \tau B(n^s)^\beta (Z_t^s)^\beta \\ E_{t+1}^s &= E_t^s + \tau C(e^s)^\gamma E_t^s \\ \lambda_t^s &= C(e^s)^\gamma E_t B(n^s)^\beta (Z_t^s)^\beta \ell^s. \end{cases} \tag{5}$$

Hence, if $(k_t^s, Z_t^s, E_t^s)_{t\in\mathbb{Z}}$ is a solution to the dynamical system, then

$$\begin{cases} \lim_{t\to\infty} k_t^s &= ((1-\sigma)A)^{1/(1-\sigma)} \\ \lim_{t\to\infty} Z_t &= (\tau B(n^s)^\beta/\delta)^{1/(1-\beta)} \\ E_{t+1}^s/E_t^s &= (1+\tau B(e^s)^\gamma) \\ \lim_{t\to\infty} \lambda_{t+1}^s/\lambda_t^s &= (1+\tau B(e^s)^\gamma)\,\ell^s. \end{cases}$$

Since consumers use time on education $e^s > 0$, knowledge grows over time and consequently the economy grows over time.

Definition 4 *A **steady state** is an equilibrium at which every variable either is constant or has a constant growth rate.*

There is a unique steady state in case the capital constraint is not binding at which

$$\begin{cases} k^s &= ((1-\sigma)A)^{1/(1-\sigma)} \\ Z^s &= (\tau B(n^s)^\beta/\delta)^{1/(1-\beta)} \\ E_{t+1}^s/E_t^s &= (1+\tau B(e^s)^\gamma) \\ \lambda_{t+1}^s/\lambda_t^s &= (1+\tau B(e^s)^\gamma)\,\ell^s. \end{cases}$$

There is no steady state in case the capital constraint is binding because knowledge grows over time and consequently at some point of time the constraint will not bind.

Dynamics

Consider an unanticipated change from (B,C) to (B',C') where $B' \geq B$ and $C' \geq C$ between dates $t=0$ and $t=1$. Assume the economy is at the steady state with traditional production up to date $t=0$. Then for the steady state with traditional production the change in (B,C)

has no influence on capital intensity, interest rate and wage, but increases industriousness. However, the change in (B,C) can induce the economy to switch from traditional production to modern production. If the capital requirement is not binding, then the change in B is without importance for whether the switch happens or not. However, if the capital requirement is binding, then the change in B is important.

Binding capital requirement

Two corollaries provide sufficient conditions for production to change from traditional to modern in the capital requirement is binding. The main difference between the cases where the capital requirement is not binding and where the capital requirement is binding is that if the capital requirement is binding, then a change in B leads to industriousness to increase over time and as industriousness increases, the potential supply of skilled labour increases. And as potential supply of skilled labour increases, the wage of skilled labour increases too. Hence, it is possible that consumers switch from supplying unskilled labour to supplying skilled labour at some point of time. The switch is induced by the change in B and the change in C can be without importance.

In case the capital requirement is binding for (B',C') and therefore also for (B,C), the switch can be induced by the change in B.

Theorem 1 *Consider an unanticipated change from (B,C) to (B',C'), where $B' \geq B$ and $C' \geq C$, between dates $t=0$ and $t=1$. Suppose*

- *The economy is at the steady state with traditional production for $t \leq 0$.*
- *The capital requirement is binding at the steady state for (B',C').*

Let

$$\begin{cases} k^{u\prime} &= ((1-\sigma)A)^{1/(1-\sigma)} \\ Z^{u\prime} &= (\tau B'(n^u)^{\beta}/\delta)^{1/(1-\beta)} \\ w^{u\prime} &= (1-\sigma)A(k^{u\prime})^{\sigma} \\ \lambda^{s\prime} &= C'(e^s)^{\gamma}E_0 B'(n^s)^{\beta}(Z^{u\prime})^{\beta}\,\ell^s \\ w^{s\prime} &= A(\lambda^{s\prime})^{-\sigma} - \sigma A(k^{u\prime})^{\sigma-1}(\lambda^{s\prime})^{-1}. \end{cases}$$

If $\phi C'E_0 w^{s\prime} > w^{u\prime}$, then the economy switches to modern production. Eventually the switch becomes permanent.

Proof: Since the capital requirement is binding at the steady state with traditional production for (B',C'), it is binding at the steady state with traditional production for (B,C). For (B,C)

the wage for unskilled labour is $w^u = w^{u\prime}$ and the potential wage for skilled labour $w^s = A(\lambda^s)^{-\sigma} - \sigma A(k^u)^{\sigma-1}(\lambda^s)^{-1}$ where $k^u = ((1-\sigma)A)^{1/(1-\sigma)}$, $\lambda^s = C(e^s)^{\gamma} E_0 B(n^s)^{\beta}(Z^u)^{\beta}\,\ell^s$ and $Z^u = (\tau B(n^u)^{\beta}/\delta)^{1/(1-\beta)}$. Since the economy is at the steady state with traditional production for $t \leq 0$, $\phi C E_0 w^s < w^u$ so consumer supply unskilled labour instead of skilled labour.

The expressions for $k^{u\prime}$, $Z^{u\prime}$ and $w^{u\prime}$ are these variables at the steady state with traditional production for (B',C') and the expressions for $\lambda^{s\prime}$ and $w^{s\prime}$ are the potential supply of skilled labour and the wage for skilled labour at the steady state with traditional production for (B',C'). From the increase in (B,C) and forward production continues to be traditional as long as $\phi C' E_0 w_t^s < w_t^u$ production is traditional and the economy evolves as described in Equations (3). However, production is bound to switch to become modern at some date because at the steady state with traditional production after the increase in (B,C) consumers will switch to supply skilled labour by assumption $\phi C' E_0 w^{s\prime} > w^{u\prime}$.

After the switch to modern production, industriousness decreases monotonically and knowledge increases monotonically as described in Equations (4). Hence, it is possible that the capital requirement becomes binding at some date and the economy switches back to traditional production at some date. From that date the economy converges to the steady state with traditional production, but with more knowledge, so it is not a steady state of the economy. At some subsequent date, the economy switches back to modern production. Again, industriousness is monotonically decreasing and knowledge is monotonically increasing. Again, it is possible that the capital requirement becomes binding and the economy switches back to traditional production at some date. From that date converges to the steady state with traditional production, but with more knowledge. After finitely many cycles between traditional production and modern production there is so much knowledge that the capital requirement will not becomes binding anymore and the switch to modern production is permanent. □

Up to the increase in (B,C) industriousness is constant. From the increase in (B,C) to the switch from traditional production to modern production, industriousness increases. From the switch to modern production industriousness decreases. Therefore, the evolution of industriousness in the model fits qualitatively with the evolution of the relative occurence of the word "God" in Figure 1. As explained in the proof of Theorem 1 the economy can cycle between modern production and traditional production for some finite period of time. As long as the economy cycles between modern production and traditional production, industriousness cycles too. However, knowledge accumulates in the phases with modern production and eventually modern production becomes permanent.

In case the capital requirement is binding for (B,C), but not for (B',C'), there is a switch from traditional production to modern production provided the change in C is large enough, but it can be induced by the change in B.

Corollary 1 *Consider an unanticipated change from (B,C) to (B',C'), where $B' \geq B$ and $C' \geq C$, between dates $t = 0$ and $t = 1$. Assume*

- *The economy is at the steady state with traditional production for (B,C) for $t \leq 0$.*
- *The capital requirement is binding at the steady state for (B,C).*
- *The capital requirement is not binding at the steady state for (B',C').*

If $\phi C' E_0 > 1$, then the economy switches to modern production. Eventually the switch becomes permanent.

Proof: Since wages for unskilled labour and skilled labour are identical at every date in case the capital requirement is not binding, if $\phi C' E_0 > 1$, then consumers want to supply skilled labour at the steady state with traditional production after the increase in (B,C). The rest of the proof follows the proof of Theorem 1 □

For both Theorem 1 and Corollary 1, as long as production is traditional the increase in (B,C) increases industriousness, the increase in industriousness increases in the supply of unskilled labour and the potential supply of skilled labour. Since the capital requirement is binding for (B,C), the increase in the potential supply of skilled labour leads to an increase in the wage for skilled labour. Eventually, the increase in the wage for skilled labour leads consumers to supply skilled labour instead of unskilled labour so the economy switches from traditional production to modern production.

Non-binding capital requirement

In case the capital requirement is not binding, there is a switch from traditional production to modern production if and only if the change in C is large enough. Specifically, the change in B is without importance.

Corollary 2 *Consider an unanticipated change from (B,C) to (B',C'), where $B' \geq B$ and $C' \geq C$, between dates $t = 0$ and $t = 1$. Assume*

- *The economy is at the steady state with traditional production for (B,C).*
- *The capital requirement is not binding at the steady state for (B,C).*

The economy switches to modern production if and only if $\phi C' E_0 > 1$. Eventually the switch becomes permanent.

Proof: Since wages for unskilled labour and skilled labour are identical at every date in case the capital requirement is not binding, if the economy is at the steady state with traditional production for (B,C), then $\phi C E_0 < 1$.

First to show that the capital requirement is not binding it should be noted that $k'\lambda' \geq k\lambda$ and $\lambda' \geq \lambda$ implies $(1-\sigma)A(k')^{\sigma}\lambda' \geq (1-\sigma)Ak^{\sigma}\lambda$. Let $(k^u, \lambda^u, Z^u, E^u)$ be part of the steady state with traditional production for (B,C). Since $(\lambda_t^u)_{t\in\mathbb{N}}$ is monotonically increasing and $k_1^u\lambda_1 = k^u\lambda^u$, it follows from induction that $(k_t^u\lambda_t^u)_{t\in\mathbb{N}}$ is non-decreasing so the capital requirement is not binding at any date as long as production is traditional.

Second to show the economy switches to modern production at date $t = 1$, if the capital requirement is not binding, then the wage for unskilled labour and the potential wage for skilled labour are identical at every date as long as production is traditional. However, production is bound to switch to become modern at the increase in (B,C) because $\phi C' E_0 > 1$ so consumers want to supply skilled labour instead of unskilled labour.

Third after the switch to modern production, industriousness is monotonically decreasing and knowledge is monotonically increasing. Therefore it is possible that the capital requirement becomes binding at some date and the economy switches back to traditional production. From that date the economy converges to the steady state with traditional production, but with more knowledge. At some subsequent date, the economy switches back to modern production. Again, industriousness is monotonically decreasing and knowledge is monotonically increasing. Again, it is possible that the capital requirement becomes binding and the economy switches back to traditional production at some date. Again, from that date converges to the steady state with traditional production, but with more knowledge. After finitely many cycles between modern production and traditional production there is so much knowledge that the capital requirement will not becomes binding anymore and the switch to modern production is permanent. □

Up to the increase in (B,C) industriousness is constant. The production switches from traditional to modern with the increase in (B,C) and industriousness decreases monotonically and knowledge increases monotonically. As explained in the proof of Corollary 2 the economy can cycle between modern production and traditional production for some period of time with industriousness decreasing in periods with modern production and increasing in periods with traditional production. However, eventually the switch to modern production becomes permanent. In this case, then, the evolution of industriousness up to the last switch to modern production does not fit the evolution of the occurence of the word "God".

Comments on the model

In our model, the shift from traditional production to modern production is not inevitable. Indeed, if the level of knowledge is low, then the invention of printing press would not be the spark that led to the shift from no growth to growth.

Suppose the transition from traditional production to modern production happens in two phases as described above. In the first phase the demand for religious books would increase, while the demand for technical books would be stable and small, because in that phase consumers spend time on enculturation but not education, so knowledge is fixed. In the second phase the demand for religious books would decrease and the demand for technical books would increase, because both average enculturation and industriousness in society decrease, and both average education and knowledge in society increase. The development in the demand for religious books is observed in Figure 1.

The capital requirement for firms using skilled labour is the reason why the transition from traditional production to modern production can take time in that the increases in B and C happen at a date and the transition can happen at a subsequent date. Indeed, without the capital requirement for firms using skilled labour the wages for the two forms of production would be identical so consumers choose to supply unskilled (skilled) labour if and only if $\phi CE_t < 1$ ($\phi CE_t > 1$). Therefore the transition would be instant.

To keep the analysis simple we have assumed representative agents: all consumers are identical and behave identically and all firms are identical and behave identically. Consequently, the transition from traditional production to modern production is bang-bang as all agents switch simultaneously. Naturally, outside the model these transitions were and are gradual. An obvious next step would be to expand the model to include multiple production sectors, perhaps agriculture, manufacturing and service, and heterogeneity of consumers within generations. Depending on individual characteristics agents need different incentives to switch from a production sector to another production sector.

Again to keep the analysis simple we have assumed there is no interaction between productivity and human capital. Outside the model there could very well be externalities between enculturation and industriousness on the one side, and education and knowledge on the other side. Indeed a side product of an increase in productivity could be new knowledge and a side product of an increase in human capital could be productivity. With these externalities the increase in productivity caused by the invention of the printing press would lead to new knowledge and the new knowledge could lead to the transition from traditional production to modern production. The relation between productivity and human capital remains an empirical question. Dittmar and Meisenzahl (2020) provide evidence for a link

between Protestantism and upper tail human capital in German cities, with the mechanism being political change as indexed by religious printing.

Further topics

Our motivating evidence is the pattern of religious content in books over time. Here we discuss some aspects which are not explicitly captured in our model.

The relationship between print and Protestantism. In the model, print is a technology of cultural transmission for practical and moral rules, and religion plays no explicit role. In fact, however, moral rules were justified by reference to the Christian belief system, which provided an overarching framework encompassing both ethical rules of behaviour, and truth claims about the nature of reality. Fifteenth-century Europe already had an extensive infrastructure for transmitting these beliefs – the Catholic church, which spread its beliefs by preaching, written works in manuscript, visual art such as that of the great cathedrals, and institutions like the monasteries and universities (in which the church played a major role). One possible interpretation of the Reformation is as follows. The Catholic church was an incumbent which extracted profit from belief transmission, not necessarily directly, but by transmitting beliefs that favoured the incumbent, such as the doctrine of Purgatory which supported a profitable trade in indulgences (Ekelund et al., 1996). Print was a disruptive technology which threatened the incumbent by lowering the cost of cultural transmission, allowing consumers to "cut out the middleman". The reformed denominations provided a form of religion which was complementary to print, since they placed individual Bible-reading at the centre of religious practice. The Catholic church was initially handicapped by its traditional opposition to lay reading, especially of religious work in the vernacular. It was caught in an "innovator's dilemma" (Christensen, 1997), since the new techniques of enculturation threatened its existing infrastructure. Nevertheless, under the pressure of competition, Catholicism developed its own traditions of reading as cultural transmission. Not surprisingly, the competition between religious "firms" spilled over into political conflict and violence.

The failure of the printing press in the Ottoman empire. It is well known that the Ottomans banned the printing press initially, only allowing printed work among religious minorities. In 1729, the press was reintroduced, but throughout the 18th century, only 33 books were printed. Since eighteenth-century Ottoman Empire was considerably behind the technological frontier, in a conventional framework we would expect printed matter to be highly in demand. However, in our model, if time preferences are sufficiently low, most people prefer to work in the traditional sector and there is no demand for technology. Indeed, after

the printing of religious works was allowed in 1802, the rate of publication increased, with a substantial minority of books being on religious subjects (Coşgel, Miceli and Rubin, 2012).

Conclusion

The "Great Divergence" of Western economies is usually thought of in terms of economic growth and technical innovation, not preference change. But a strand of the literature has always emphasized changes in human values, from Weber's (1904) "spirit of capitalism" to Mokyr's (2009; 2016) "enlightened economy" and "culture of growth". Indeed, there is growing evidence that "WEIRD" people – those in Western, Educated, Industrialized Rich Democracies – are different from others (Henrich, Heine and Norenzayan, 2010). We suggest that a specific technology, the printing press, may have contributed to shaping human values by lowering the cost of the written word.

In this paper we have modelled endogenous preferences within the framework of a growth model. There are multiple equilibria. Increases in productivity, such as those caused by a reduction in the cost of books, can induce a transition from the steady state into the modern regime of economic growth. In particular, the role of books in increasing productivity in unskilled labour can be crucial. This role can provide a bridge, allowing productivity to increase even before the economy transitions. We also provide motivating qualitative evidence for how early modern reading practices might increase individuals' productivity, by altering their preferences towards cooperation, leisure, savings and time discounting.

A key part of our argument is that book reading is associated with preference change. Testing this in the early modern context is a challenge. While evidence on the effects of Protestantism could be compatible with our story, we really want more direct empirical tests. New techniques for quantitative text analysis could help. A first step in this direction is the recent evidence that cooperation-related content in plays increased before the English civil war and the Glorious Revolution (Martins and Baumard, 2020).

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