Modelling the Spread of Moveable-Type Printing in Europe

Moveable-type printing with a printing press and metal type was developed by Johann Gutenberg of Mainz and his employees around 1450, although experiments may have begun around 1430 (Pettegree 2010, ch. 2); it came to wide public notice in 1455, when Bishop Eneo Silvio Piccolomini, later Pope Pius II, saw sections of "Gutenberg's Bible" at the Frankfurt Fair, and reported his astonished admiration (Raven and Proot 2020). It did not come out of nowhere: it was preceded in Europe by the printing of trademarks, religious images and playing cards from woodcuts or copperplate engravings. Moreover moveable-type printing with metal type had been developed in the 13th century in Korea, and earlier still (for paper money) in China (Pan 1998) although there is currently no clear evidence news of this had reached Europe. There seems no doubt that such a technology would have emerged in late medieval or early modern Europe, but the exact time and place appear highly contingent: Gutenberg and his collaborators devised an intergrated system including the press itself, new alloys and inks, and highly-skilled, coordinated working practices.

By 1400 manuscript book production in western and central Europe was already in part a quasi-industrial process involving complex networks of individuals and institutions. There were three main types of book being produced, associated with three corresponding classes of buyer (Pettegree 2010, ch.1):

- Luxury items, primarily religious in content, but including an increasing number of classical works, bought for prestige and display by royal and aristocratic families, and increasingly by rich commoners. Such a book, richly illustrated and bound, could cost as much as or more than the annual income of a skilled worker.
- Books produced for the use of churchmen, monks and nuns. By this date, the demand for bibles had slackened off, as every religious establishment needing bibles already had them, so replacement was the only source of demand. But missals, prayerbooks, and calendars of religious festivals as well as one-page religious texts such as indulgences were being produced in large numbers.
- Textbooks for children (mostly but not entirely boys), and for students (effectively all young men) studying at the growing number of universities. The latter covered the "arts", which included grammar, music, mathematics and logic, as well as theology, medicine and law for advanced students. Typically, university students would hire successive parts of a text they needed to study from an approved bookseller (the manuscript would have been checked for quality by the university), and either copy it themselves or pay someone else to do so. To avoid the fee, they might illicitly borrow and copy a text from another student, but this risked copying that student's errors.

The third type of book, and increasingly the second, would be written on paper rather than the more expensive parchment. Parchment, derived from the skins of animals, was a limited resource; paper, derived from linen rags, was readily available in southern Europe - although in the north, where most clothing was of wool, paper or the rags to make it had to be imported (Monro 2014, ch.13). There is no reason to suppose there was a shortage either of writing materials or of labour to produce all the books and other written items required, although demand continued to grow. Hence while there was an obvious business opportunity in devising ways to speed up the production of multiple copies of a text, the system could have continued without one for decades at least - indeed, manuscript production on a large scale continued alongside printing well into the 17th century, while early printed books required considerable "hand-finishing" (illumination, page headings) before sale (Pettegree 2010, ch. 2). How revolutionary the introduction of moveable metal-type printing in itself was, is disputed (Eisenstein 1979, 2002a,b, Johns 1998, 2002).

The technology of the printing press spread rapidly across western and central Europe through networks of knowledge transfer and commerce, although many of the early printers, including Gutenberg, went bankrupt: considerable capital outlay on parchment or paper, and wages to skilled workers, might be required months or even years before most of an edition was sold, and a rival printer might get an edition printed first, or produce a superior product. Printers generally relied on printing texts other than books for much of their income (Stallybrass 2007). The centre of printing shifted, first to northern Italy and then to cities such as

Paris, Basel and Antwerp. But printing interacted in complex ways with other socio-technical transitions in the area of communication and scholarship: that from parchment to paper (Monro 2014, ch. 13); the increased use of vernacular languages in texts; the spread of universities; the building and stocking of libraries (Jardine 1996, ch.3, Pettegree and Der Weduwen 2021, ch.5); the revival of Greek scholarship and the spread of that in Hebrew, Arabic, and other languages (Eisenstein 1979, Part 2); and the increase in literacy. All these changes had begun before 1450, but how far and in what ways did the printing press accelerate and modify them? How did they reciprocally affect the spread of printing, chronologically, geographically, and in terms of what was printed? How would they have been affected if Gutenberg's innovation had been developed a few decades earlier or later, or in somewhere other than Mainz, such as Venice, Paris, Florence, Basel or Prague? Simulation – specifically, agent-based simulation – could address these complex questions in ways no other methodology can.

The provisionally planned stages of this research are as follows (these stages may overlap considerably):

1. Literature survey and data collection. There are online databases of known medieval and early modern manuscripts and early printed books (e.g Johns Hopkins Sheridan Libraries 2026, Folgerpedia 2026, British Library 2026, Staatsbibliothek zu Berlin 2026). Relevant academic papers are widely scattered.
2. Construction of a guiding ontology, covering individuals, institutions (businesses, religious institutions, universities, and governmental, religious, commercial and educational authorities), texts and other materials in manucript and printed form, technical and commercial processes, technological changes (these were in fact relatively limited after the initial experiments carried out by Gutenberg and his associates), geographical locations of centres of manuscript production and printing presses, places where books were sold, and trade routes. The construction of such an ontology is an important check on the subsequent model design, making explicit what is being left out as well as what is being included (Gotts et al. 2019).
3. Construction of an initial, relatively simple model or more likely models (on different scales e.g. of a single printing house or bookseller as against the book trade as a whole) based on this ontology.
4. Publication of one or more papers based on these models, and of the models themselves and acompanying documentation in the CoMSES model library (CoMSES Net 2026).
5. Decisions on the time period, geographical extent and range of texts to be covered.
6. Decisions on the related changes and transitions to be included in the modelling.
7. Construction of a model or models, based as closely as possible on what is known about the spread of printing from its origins in Mainz around 1450, and about whichever related historical transitions are to be included. The model(s) will include stochastic elements, as any complex historical process must be affected by unrepeatable and idiosyncratic events – which may or may not be important in determining overall outcomes. Currently, it is intended to use the Mesa agent-based modelling package (Project Mesa Team 2026) for the model.
8. Choice of a statistical methodology to identify the most important model aspects which cannot be well-constrained by empirical evidence, select output measures, and assess the similarity of output from model runs to what is known of the historical course of events. Possibilities include Approximate Bayesian Computation (Castro 2026), and the EMA Workbench (Kwakkel 2026).
9. Multiple model runs to determine input parameter values giving the closest match to the historical course of events. As noted at (7), stochastic elements will be included in the model(s), so outputs can be expected to vary even with all input parameters fixed. The methodology adopted in (8) will need to be capable of determining the best parameter values.
10. Publication of one or more papers based on the model(s) and the model runs; and of the documented model(s) in the CoMSES model library.
11. Multiple model runs with the time and place of the development of a technology similar to Gutenberg's altered, covering a range of time and space to be determined in earlier stages of the research, but provisionally covering the period 1400-1500, and the main urban areas of economic activity and technical innovation in western and central Europe over that period.
12. Publication of one or more papers based on these model runs.

Stages (1) and (2) are underway. Anyone interested in collaboration is welcome to get in touch.

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