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A Numerical Revolution: The diffusion of practical mathematics and the growth of pre-modern European economies

Raffaele Danna, Martina Iori, Andrea Mina

New knowledge, especially knowledge of scientific and technological nature, is a fundamental engine of growth. The accumulation of knowledge and its application to a variety of human needs is a discontinuous process and involves complex social and economic interactions. While much has been written on major discontinuities associated, for instance, with the rise of new technologies during industrial revolutions, other phases of economic development are less well understood, even though they might bring into even sharper focus the mechanisms through which growth is generated by the systematic application of human knowledge to practical problems. Following a stream of literature on the role of human capital and useful knowledge accumulation in the industrial revolution, a recent debate is exploring the contribution of knowledge and ideas in European growth also during the pre-modern period (de Pleijt & van Zanden 2016; Dittmar 2011; Epstein 2013).

In this paper, we investigate the transmission of new mathematical knowledge from the 13th to the end of the 16th century in Europe. Using an original dataset of over 1050 manuals of practical arithmetic, both manuscript and printed, and written in more than 90 European cities, we produce new evidence on how the transition from Roman to Hindu-Arabic numerals (0, 1, 2, 3, 4, 5, 6, 7, 8, 9) improved the economic performance of cities. The dataset was constructed from existing catalogues as well as from extensive archival research. Contrary to previous studies, this dataset includes both manuscript and printed sources, making it possible to extend the period of analysis, as well as to control for the effects of the introduction of the printing press. The spread of these manuals makes it possible to document the transition of European economic agents from Roman to Hindu-Arabic numerals (0, 1, 2, 3, 4, 5, 6, 7, 8, 9). Moreover, it makes it possible to identify a continuous process of transmission of useful knowledge which linked the commercial revolution of the 13th century to the so-called 'little divergence' of northern Europe.

The inherent properties of the new mathematical symbolism as well as extensive historical evidence suggest that the spread of Hindu-Arabic numerals had transformative effects on European commercial practices. Case study evidence suggests that the diffusion of these techniques had a positive impact on economic performance. In documenting the economic relevance of this new knowledge, we illustrate the characteristics of the texts and how their diffusion took place through organised learning in dedicated institutions, i.e. practical arithmetic schools. These were vernacular schools which progressively spread throughout western-Latin Europe, and provided economic agents with the fundamental tools to handle advanced commercial techniques. We complement this qualitative evidence by estimating the effects of the diffusion of practical arithmetic on European growth at the city-level, relying on population data on more than 820 cities. We test the economic impact of this mathematics with regression analysis of log city growth in the period 1300-1700. We use pooled OLS and fixed-effects panel estimations

and we control for a rich set of geographic and institutional variables (presence of universities, capital cities, presence of printing presses, Roman roads, ports, navigable rivers).

We argue that, by transforming commercial practices, Hindu-Arabic numerals were a relevant factor for the development of the commercial revolution of the 13th century, and we show that their diffusion through organised learning (i.e. practical arithmetic schools) is positively and significantly associated with the growth of pre-modern European economies. We provide both qualitative (historiographical) evidence and quantitative (econometric) analyses of the effects of Hindu-Arabic numerals on city-level growth. Both OLS and panel fixed effects estimates show a positive and significant effect of the publication of practical arithmetic manuals on city growth. Where we do not have a causal framework of estimation, we have strong historiographical methods that help us to shed light on the underlying economic mechanisms of the phenomenon. We discuss the results in the context of the debate on the role of human capital accumulation in pre-modern European growth.

References

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