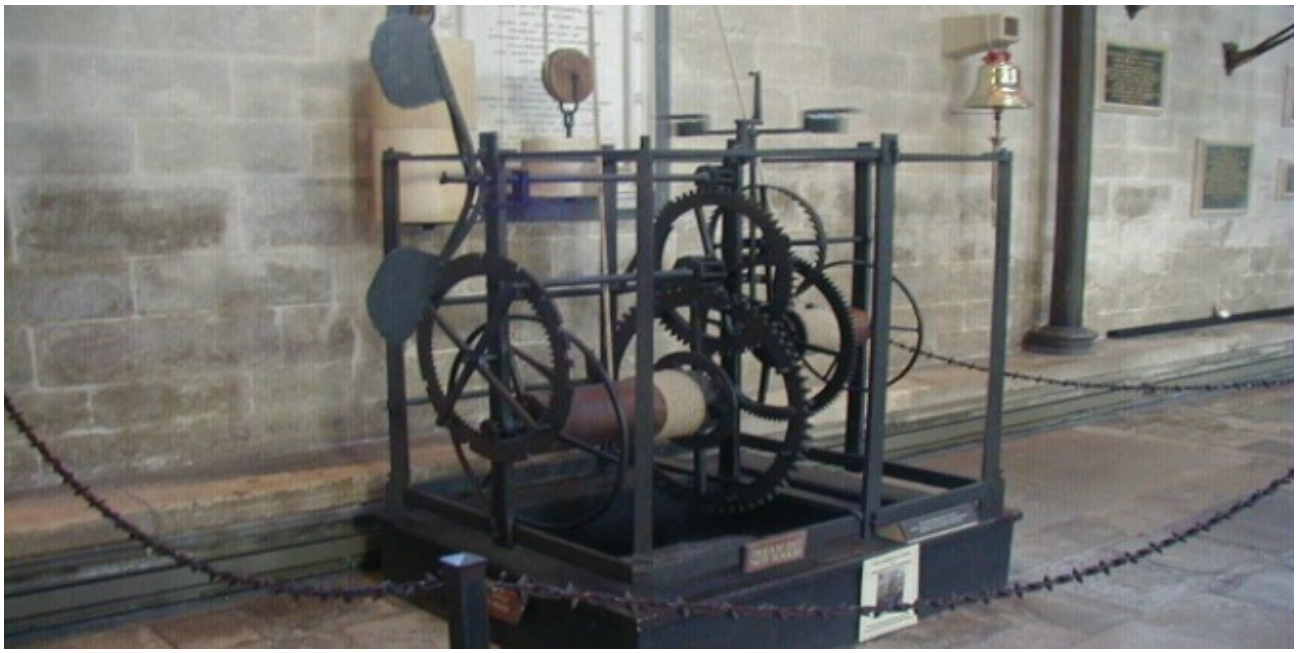
# Mechanical clocks prove the importance of technology for economic growth

blogs.lse.ac.uk/businessreview/2016/09/27/mechanical-clocks-prove-the-importance-of-technology-for-economic-growth/

9/27/2016



**Salisbury Cathedral clock (the oldest surviving functional mechanical clock in the world), © Copyright by Hywel Williams under a CC-BY-SA-2.0 licence**

“Remember that time is money.” Already in 1748 Benjamin Franklin underlined in a short contribution to a business manual that the temporal aspect is a pivotal variable for the economy. Such a statement is even more important for today’s business activities. Precise measurement of time is fundamental to schedule business meetings exactly on the minute and the hour, to have opening hours for retail business, to synchronise exchange activities on financial markets. The measurement of time allows monitoring and coordinating production processes and it is crucial to improve labor efficiency. Furthermore, improving coordination and reducing transaction costs are so basic and self-evident that the underlying need of a common precise time measurement gets almost forgotten.

However looking at the evolution of mankind, the concept of a precise measurement of time is surprisingly rather recent. Until the late Middle Ages people had to rely on sun or water clocks which did not play any role for basic life and business activities. Market openings and activities started with the sun rise and typically ended at noon when the sun was at its zenith, while a labor day was as long as the sun was up and pay by the hour did not exist.

Different attitudes on punctuality started by the late Middle Ages, when first public mechanical clocks were introduced and spread in European cities. These clocks were typically built on church towers or on the communal tower of the town, and they were mechanical devices that produced a weight-driven acoustic signal every hour. Thus, early mechanical clocks did not have a dial, but only worked with a bell. The day was typically divided into two units of twelve, and the bells rang accordingly as many times. In this way, the clocks were publicly accessible and easy for everyone to understand and the knowledge for enjoying this technology was very simple: a person only had to listen to the chime and have the ability to count.

In a recent paper we study the impact of the spread of these first public mechanical clocks on the economic growth and development of Western European cities and regions in the long run. This fundamental question is not new and has already been discussed by social scientists such as Marx, Sombart, and Weber, but it has never been analysed

quantitatively and empirically tested. The introduction of clocks and a precise way of measuring time is also linked to the impact of a new General Purpose Technology (henceforth GPT) for a society. This relationship has become highly relevant over the last decades in the Western World where growth mainly can be achieved by the accumulation of knowledge and the improvement or introduction of new technologies. Unfortunately, the answer is not that clear.

In a 1987 article published in the *New York Times*, Noble Prize winning economist Robert Solow described a 'productivity paradox' that highlights that the American productivity slowdown in the 1970s and 1980s coincides with the adoption of computers and he noted that "You can see the computer age everywhere but in the productivity statistics". This statement has in the meantime been known as the famous "Solow Paradox" and widely discussed by several world-class economists and also nowadays both sign and size of the contribution of hi-tech machine on economic growth is still unclear both at micro and macro level.

Our research shows that public mechanical clocks had a big impact on growth in the places that were early adopters of the new technology. The study finds significant growth effects based on the diffusion rate of mechanical clocks. The findings support the view that GPT's can have a strong impact on economic growth. But it takes time for such fundamental innovations to have an effect because the technology must be culturally and socially accepted and applied in related economic activities.

Clocks started spreading simultaneously in Italy, Germany, and England starting the late 13$^{th}$ century and then spread until 1450 in most Western and Central European Countries, beside Italy, England, Germany, also in Belgium, the Netherlands, France, Spain, Poland, the actual Czech Republic, and Scandinavia.(See figure 1) The spread followed a (for new technologies) typical s-shaped distribution curve. The distribution weighted by the total population size started slowly, then rose exponentially, and finally slowed down again, reaching in 1450 a saturation point with a relative decreasing adoption rate. (See figure 2)

### Figure 1: the diffusion of the mechanical clock (1450)

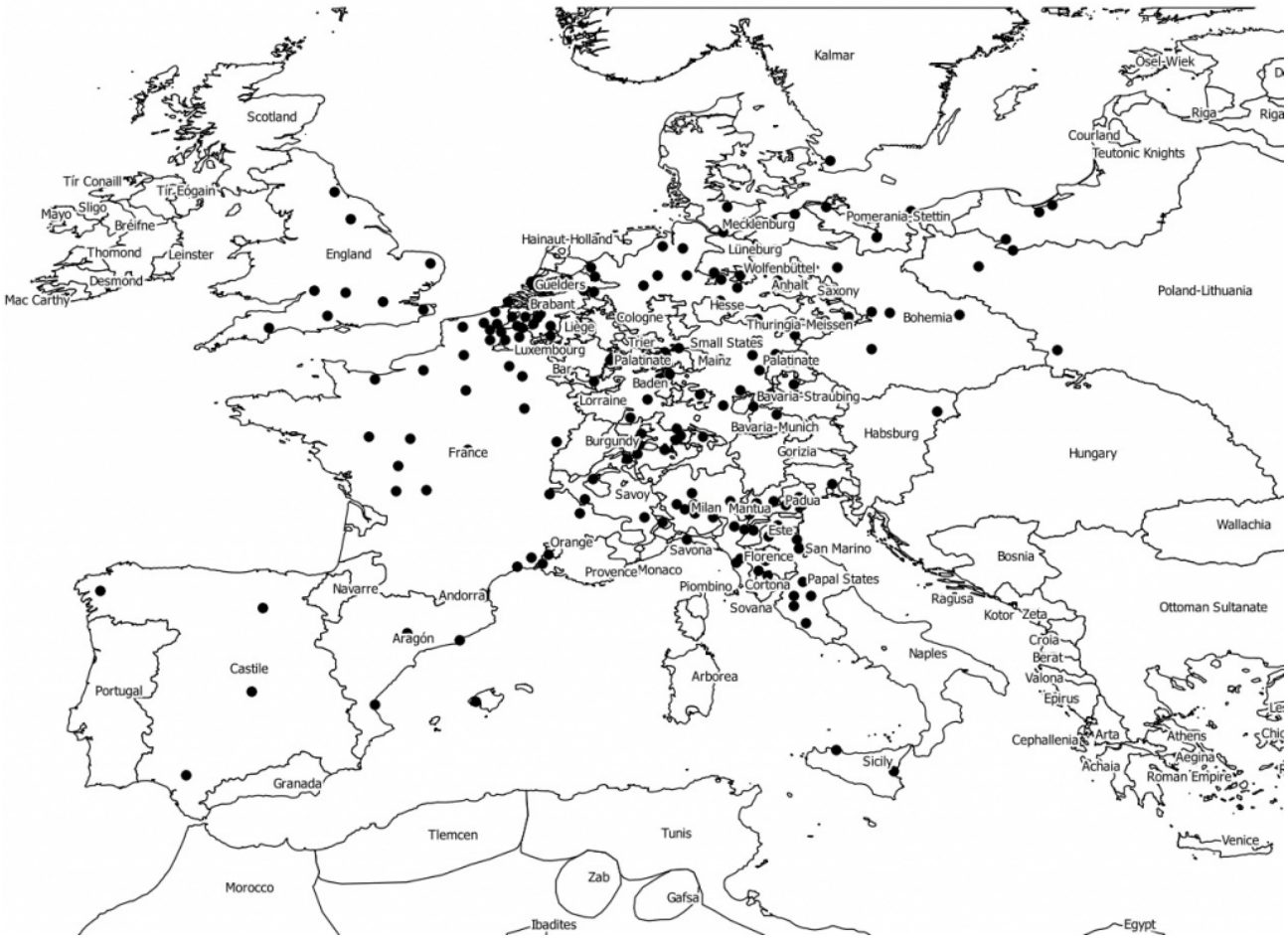
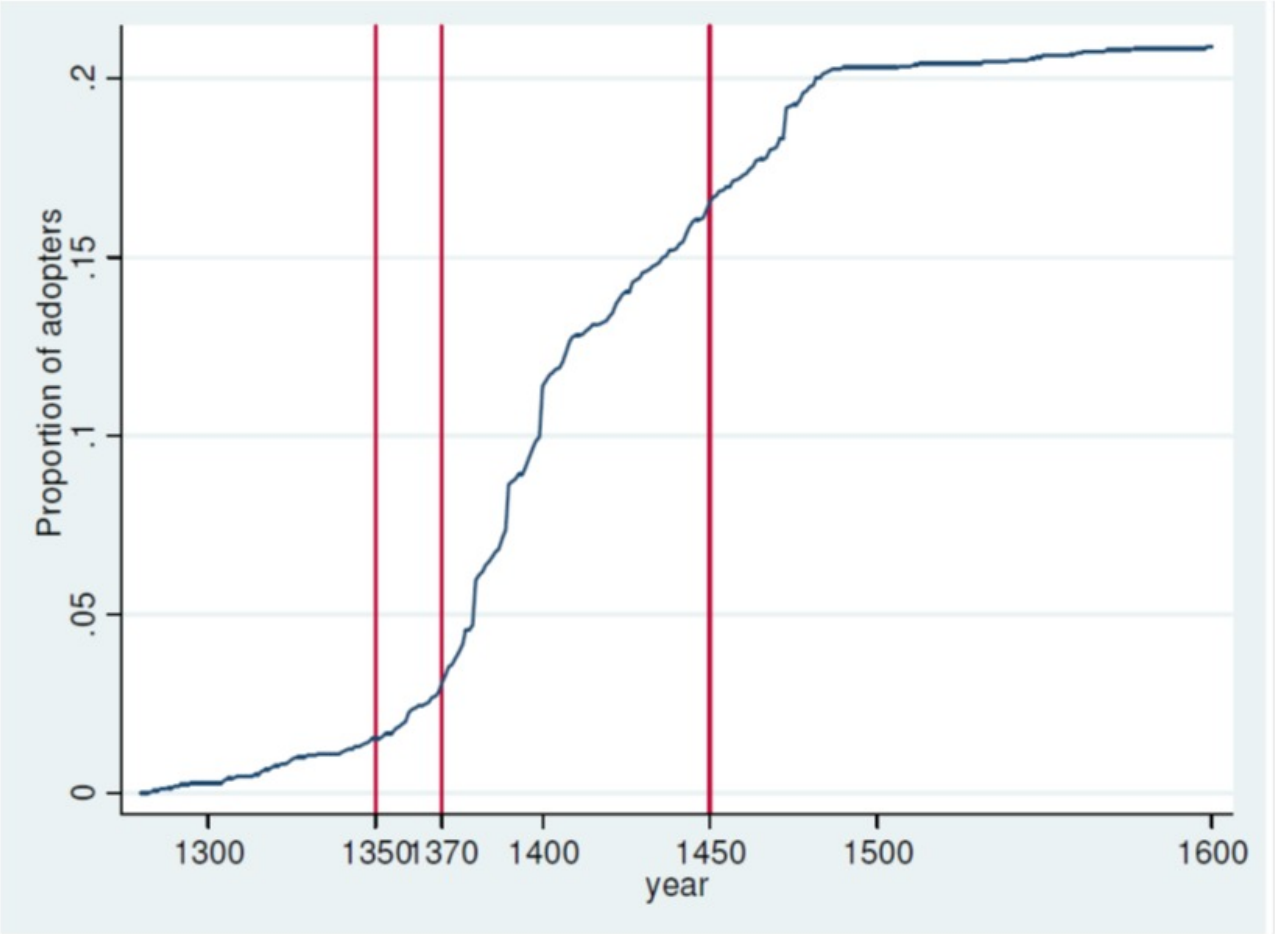



**Figure 2: The diffusion curve of the mechanical clock**




Building a clock in a town was motivated by prestige and not by economic needs, thus towns did not forecast any of the benefits clocks would bring in the long run or what can be seen ex post as an economically efficient application. Consequently the economic use was a slow process of adoption. Whereas the use of clocks for coordinating activities, such as market times or administrative town meetings, can already be observed during the 14$^{th}$ and 15$^{th}$ centuries, the use of clocks to monitor and coordinate labor processes evolved only slowly, in particular during the 16$^{th}$ century.

Finally, a cultural adoption reflected in the daily cultural and philosophical thinking of the time can be observed from the middle of the 16$^{th}$ century for instance with the Protestant movement, in particular with John Calvin's propagation of the concept of "scarce time". In addition the 17$^{th}$ century brought forth scientists and philosophers such as Robert Boyle and Thomas Hobbes who used the clock as a metaphor for the functioning of the world and to explain how institutions such as the state should work.

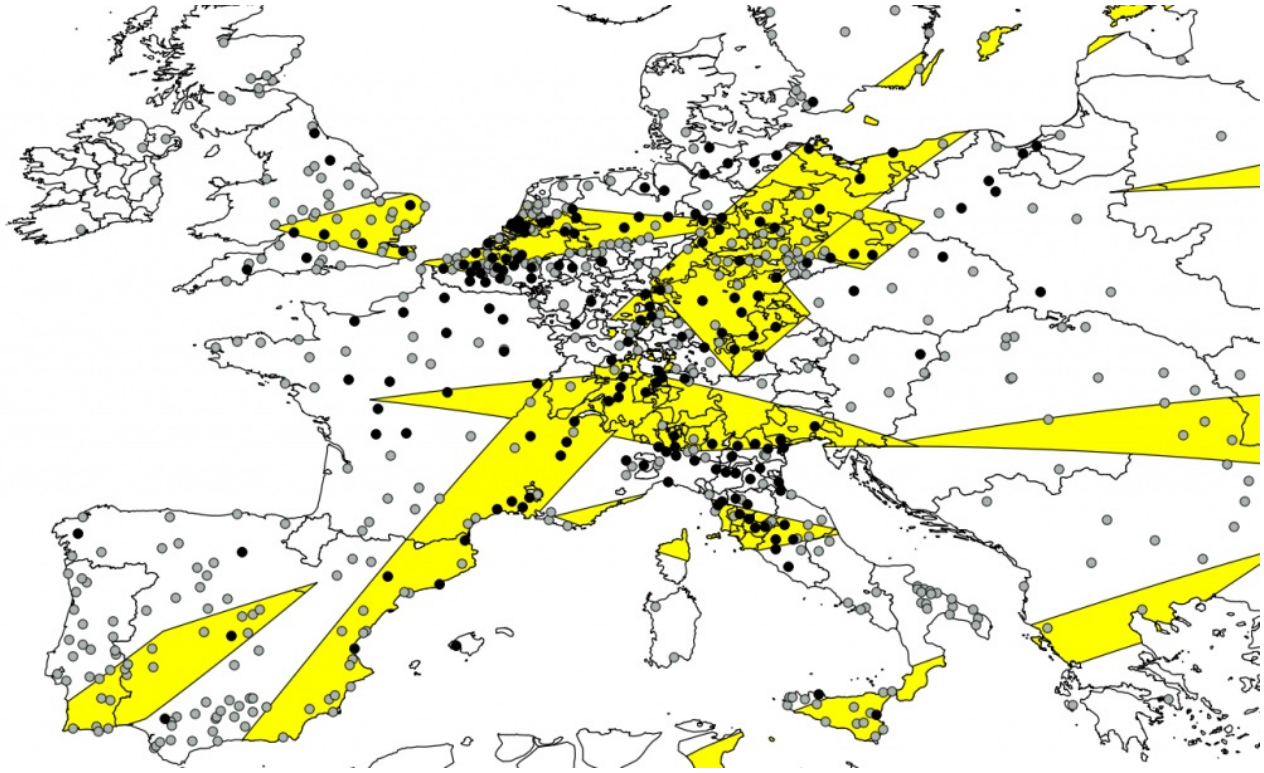
Looking at this slow process, it is not surprising that it took a while until the complementary organisational, procedural, and cultural behavioral innovations turned into economic growth rates. Based on empirical growth regressions, we find that earlier adopters (cities which adopted the clock before 1450), compared with other cities, display significant growth differences in the range of 30 percentage points for the period of 1500-1700. These results indicate that public clocks as a GPT indeed localised spillover effects on various economic and economy-supporting activities and led to higher city growth rates.

This approach explains economic growth from a micro perspective. As an extension and alternative approach, we study countries' GDP growth rates. This makes it possible to estimate comparative growth effects between countries and create a macroeconomic perspective. Again, we find significant growth effects based on the diffusion rate of mechanical clocks on economic growth.

To achieve our results we run empirical growth regressions. To differentiate between the cause (the introduction of the mechanical clock) and consequence (population growth) we apply a two-stage regression approach using in the first stage instrumental variables which are related to the adoption of the clock but not to the economic performance itself. We look in particular at different appearances of solar eclipses and use them as instrumental variables.

Historians have convincingly shown that the creation of astrolabes, which were the predecessors (and technological basis) of mechanical clocks, were triggered by solar eclipses. The study uses these insights and the geographical data provided by NASA of solar eclipses from 800 until the end of the thirteenth century. Figure 3 shows the area covered by total and annular solar eclipses and the cities adopting a mechanical clock at the early stage. Also considering this strategy, the importance of the mechanical clocks is confirmed.

**Figure 3: Area in Europe with more than one total or annular solar eclipse. Cities adopting a early public mechanical clock in black.**



To conclude, new GPTs can have a fundamental impact on economic growth, this is the good news and as a policy advice it is indeed important to implement new technologies and let societies learn to use and adapt to them. However it can take generations to reap the full benefits of new high tech machines. So quick gains might not be achievable.

♣♣♣

*Notes:*

- *This blog post is based on the author's paper Time for Growth, LSE Economic History Working Papers, N. 222/2015, presented at the 2016 Annual Congress of the European Economic Association in Geneva.*
- *The post gives the views of its author, not the position of LSE Business Review or the London School of Economics.*
- *Before commenting, please read our Comment Policy*

**Lars Boerner** is Assistant Professor at the London School of Economics and Political Science in the Department of Economic History. He holds a PhD from the Humboldt University Berlin. He has been in affiliated with the Free University Berlin, Stanford University, and the European University Institute. His main research interest is in pre-modern growth focusing on trade, technological innovations, and the evolution of market institutions.

**Battista Severgnini** (PhD Humboldt University Berlin, 2010) is Associate Professor of Economic Growth and Productivity in the Department of Economics at Copenhagen Business School. His primary areas of interest are economic growth, productivity, labour economics, sport economics and economic history.