CHURCH BUILDING AND THE ECONOMY DURING EUROPE'S 'AGE OF THE CATHEDRALS', 700–1500 CE[1]

Eltjo Buringh, Utrecht University

Bruce M. S. Campbell, The Queen's University of Belfast

Auke Rijpma, Utrecht University

Jan Luiten van Zanden, Utrecht University

This version: November 2019

Abstract: In a Christian age, churches reflected societies' material resources as well as their religious and cultural aspirations. Data on the construction history of 1,695 major churches in present-day Italy, France, Switzerland, Germany, the Low Countries, and Great Britain are used to infer the trend and pattern of economic activity between 700 and 1500 CE. Across this long and economically formative, but relatively poorly documented era, they are among the few artefacts that can be quantified consistently. This is the first attempt to resolve the methodological challenges entailed in systematically gathering, organising and analysing this information at a supra-national scale. The results imply a transformation in Western Europe from the end of the 10th century with steeply gathering momentum, culminating in the great boom of the 12th century. Fresh light is also shed on the long contraction that set in from the late-13th century. Rising agricultural production and feudal surplus extraction were important drivers early on, but over time construction activity was most vigorous at locations enjoying commercial and especially maritime advantages. By the 15th century, as the impetus of construction was faltering almost everywhere, it was in commercially resilient Brabant and the Netherlands that church building remained most buoyant.

Keywords: church building; medieval period; urbanisation; commercialisation; architecture; date heaping.

JEL codes: N63, N94, N33, L74.

---

[1] Duby (1977). Correspondence: a.rijpma@uu.nl. Stephen Rigby and participants at the World Congress of Cliometrics, the Economic History Society Annual Conference, and the Utrecht Economic and Social History Seminar are thanked for their helpful comments.

I INTRODUCTION — Church building as a proxy index of economic activity

Knowledge of the economic history of Europe in the centuries before the Industrial Revolution has advanced greatly in recent decades thanks to the systematic construction and analysis of time series of prices, daily wages, annual earnings, state finances and other indices of economic activity (Munro, ND; Allen 2009; Van Zanden 2009; Humphries and Weisdorf 2015 and forthcoming 2019; Bonney 1995). This includes pioneering work on the estimation of national incomes (Van Zanden and Van Leeuwen 2012; Álvarez-Nogal and Prados de la Escosura 2013; Bolt and Van Zanden 2014; Broadberry et al. 2015). Nevertheless, for reasons of documentary survival, few of these time series begin much before 1300 CE. The earliest are those for England and even these scarcely predate the economic slowdown that began in the second half of the 13th century. Accounts of the European economy as it entered a more dynamic phase sometime between the 10th and 12th centuries therefore lack temporal and spatial precision (Lopez 1971; Campbell 2016: 85–103).

To address this deficiency this paper presents a new time series based on the construction histories of 1,695 major episcopal, conventual, parochial and other churches across an area extending from the Mediterranean to the North Sea over the eight centuries from 700 CE to the Reformation. Construction of each church was, of course, the expression of many impulses: religious, economic, political, artistic and cultural. Construction work was normally sustained over periods of years and decades and hence was a manifestation of confidence in the future based on an assessment of the income streams required to bring such ambitious projects to completion. They required enterprise, planning and organisation of a high order, substantial inputs of capital and labour (both skilled and unskilled), and assemblage of impressive quantities of resources – stone, brick, lime and sand, timber, iron, lead, copper, glass and much else (Prak 2011). Each major project was an intrinsically economic undertaking with significant multiplier effects for the wider economy. Further, technological advance was as fundamental to church building as it was to economic progress. Thus, in the 1140s invention of the Gothic style opened up exciting new architectural possibilities which provided a significant boost to the construction industry by inviting the partial or wholesale replacement of existing structures (Simson and Levy 1956; Scott 2011).

Plainly, there are good reasons for connecting rising church building activity with growing economic prosperity and technological progress, and vice versa. Certainly, in Holland during the century after the Black Death an increase in GDP per capita of about 80 per cent (van Zanden and van Leeuwen 2012) was accompanied by a doubling of church-building activity per capita (figure 5 below): thereafter, the second half of the 15th century was much less dynamic on both counts. Evidently, Holland's churches were more likely to be built, rebuilt and enlarged when per capita economic resources were expanding than otherwise. England – for which there are good estimates from 1260 of population (Broadberry et al. 2015: 3-45), GDP per head (Broadberry et al. 2015: 227-33) and the annual earnings of unskilled labourers (Humphries and Weisdorf 2015 and forthcoming 2019), plus church-building per capita as presented in Section IV and plotted in figure 5 (below) – provides an even clearer example of the same phenomenon over a longer span of time (figure 1).

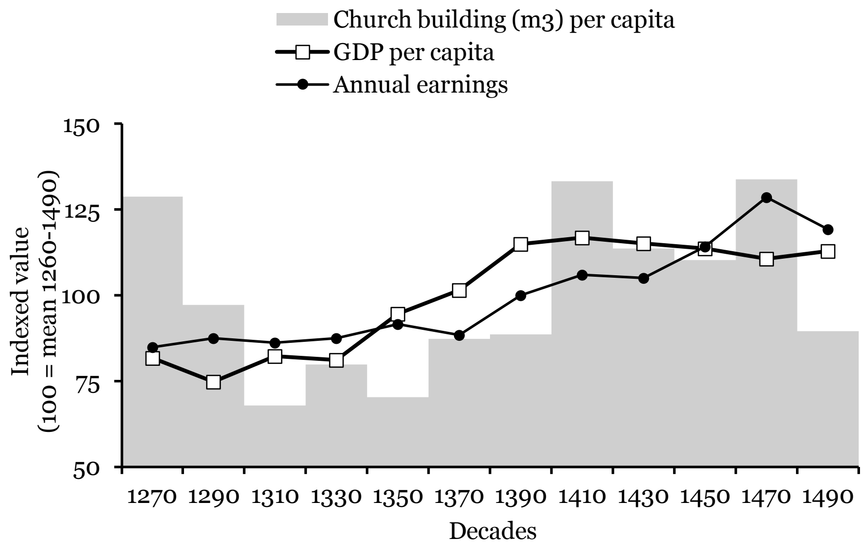

Figure 1. *English church building (cubic metres) per capita, GDP per capita and annual earnings (adult males and females combined in the ratio 70:30) per 20-year periods. Church-building estimates from figure 5 (below); GDP per capita from Broadberry et al. 2015: 227-33; annual earnings from Humphries and Weisdorf 2015 and forthcoming 2019.*

Across the period 1260-1500 trends in all three English per capita series – church building, GDP and annual earnings – are positively correlated (figure 1). The correlation between GDP per capita and annual earnings is an impressive +0.77. Correlations between church building per capita and GDP per capita and annual earnings are weaker but still positive, +0.38 and +0.49, and rise to +0.6 and +0.7 across the period 1280-1490. This is because the decline in church building during the final decades of the 13th century was more pronounced than the decline in GDP per capita and the erosion of annual earnings. Also, the recovery of church building per capita following the Black Death lagged behind the more spontaneous rises in GDP per capita and annual earnings. What stands out clearly, however, is the association between reduced church building per capita and low GDP per capita and low annual earnings during the impoverished first half of the 14th century and increased church building per capita and improved GDP per capita and annual earnings during the middle decades of the 15th century. Note, too, the decline in church building and annual earnings during the closing decades of the 15th century.

These results bear out the basic premise of this paper that prosperity and confidence in the future were good for church building, whereas recession and uncertainty tended to have the opposite effect. In a devout age, people built for the glory of God when times were good and the better that times became the more they built, and vice versa. Many of these great buildings still exist today and research by generations of architectural historians, archaeologists and others has established their detailed construction histories (Prak 2011: 383). These data are among the most precise and comprehensive records available for a period in which few written records were created and fewer survive (Clanchy 1979; Britnell 1997; Baten and Van Zanden 2008). Value is here added to this high-quality information by converting it into a consistent quantitative format capable of aggregation and analysis at regional, national and pan-national scales. Crucially, these data predate available estimates of GDP per head and real wages by many centuries; they also predate the onset of Europe's 'commercial revolution'. They can therefore help pinpoint the timing, location and circumstances of that notable acceleration in economic activity, track the pace and extent of its diffusion, reveal for how long the momentum of progress was sustained and highlight the course taken by the subsequent economic downturn.

The best and most accessible data on church building relate to a region comprising the present-day countries of Italy, France, Switzerland, Germany, the Low Countries (Luxembourg, Belgium and the Netherlands), and Great Britain, all of which, to varying degrees, were active participants in the commercial revolution of the 12th and 13th centuries. As this paper demonstrates, all were also active players in the concurrent church-building boom that characterised these centuries. Section II explains how the database of large churches has been assembled to yield regional, national and aggregate indices of church construction, and details how data issues were dealt with. Although data have been collected for the eight centuries from 700 to 1500, information on the dating and dimensions of individual building phases for the first four is less precise than for the last four. Less evidence survives from before c.1100 and a majority of the churches built in those years were replaced by larger structures after 1100, which not only are better preserved and understood but have often obliterated in whole or in part the footprint of their predecessors.

Temporal and spatial patterns in construction are discussed in Section III and per capita trends in Section IV. Attention here focuses upon the timing of the initial take off, the slackening of construction activity evident from the late-13th century, and the regional divergences that emerged following the Black Death between countries such as England, where ecclesiastical construction activity switched from major churches to parish churches, and others, most notably the Low Countries, where there was an intensification of major building projects after 1350. These findings bear upon the debate about the severity of the great slump of the fifteenth-century in Western Europe (Hatcher 1996) and the little divergence within Europe between the former vanguard economy of Italy and the newly energised economies of the Northern Low Countries. Section V discusses the factors that may account for these contrasting patterns and the nature of the association between church building and economic activity, including an analysis of the first-nature geography of the locations. Section VI summarises the key new historical insights that have emerged from analysis of these new data.

II MATERIALS AND METHODS — Quantifying the construction of major churches in Western Europe

Creating a database of the volume of church-building activity between 700 and c.1500 CE (start and end dates chosen to coincide with the onset of available national population series and the end of many established forms of worship that followed the Protestant Reformation) has entailed five stages.[2] First, within the eight sampled countries the churches themselves have been identified and geo-referenced. Second, their floor areas, nave heights and overall volumes in cubic metres have been estimated (appendix 1). Third, their respective building histories have been reconstructed and dated from an array of secondary sources. Fourth, correction has been made for the date heaping that results from the approximate dates allocated often on stylistic grounds to individual building phases. Fifth, the representativeness of the dataset and its results have been tested (appendices 2 and 3). To keep the task manageable the focus throughout has been on urban churches and upon the top 24 per cent of present-day churches with a completed floor area of at least 1,000 square metres, since their construction will have been of the greatest economic significance.[3] An estimate has nevertheless been made of the difference that including rural church building would make (appendix 2).

Initial identification of all churches potentially eligible for analysis was undertaken using OpenStreetMap (OSM), a collaborative project to create a free editable map of the world (OpenStreetMap contributors 2016). Using the Overpass API the maps were queried for all buildings marked as a place of worship in 10 by 10 kilometre rectangles around city centres.[4] These centres were taken from the Baghdad to London dataset (Bosker et al. 2013), which has been revised and expanded to include settlements with 5,000–10,000 inhabitants at any time between 800 and 1800 or with more than

[2] Replication files available at <https://github.com/rijpma/cathedrals> and Rijpma et al (2019): <https://doi.org/10.3886/E115381V1>.
[3] The initial database contained over 24,000 churches, more than 5,800 of which were larger than 1,000 square metres; 1,126 of these met all the required criteria and are contained in the final database. A further 569 churches were then added for Italy.
[4] Overpass API: <http://overpass-api.de/api/>.

Periods and countries	No. of sampled cities	% of cities with large church	Large churches per city	Building phases per church	% of building phases
700–1100					<= 900
Italy	320	49	2.1	2.6	59
France	264	70	1.7	3.3	48
Switzerland	14	86	1.4	3.0	57
Germany	165	56	1.7	2.8	36
Belgium	49	61	1.6	2.4	30
Netherlands	27	41	1.4	2.3	20
Great Britain	105	49	1.2	2.6	38
All	945	57	1.8	2.9	48
1100–1500					<= 1300
Italy	367	52	2.6	2.4	58
France	299	81	1.8	2.5	57
Switzerland	17	82	2.0	2.5	73
Germany	219	77	2.1	2.9	55
Belgium	59	78	2.1	2.5	60
Netherlands	47	79	1.7	3.3	38
Great Britain	135	57	1.3	2.8	53
All	1144	68	2.0	2.6	56
700–1500					<= 1100
Italy	367	55	2.8	3.7	41
France	299	83	1.8	5.0	48
Switzerland	17	82	2.0	4.4	41
Germany	219	79	2.2	4.2	32
Belgium	59	80	2.2	3.9	31
Netherlands	47	79	1.7	4.2	15
Great Britain	135	58	1.3	4.6	37
All	1144	70	2.1	4.3	40

Table 1. Overview of the dataset by present-day country: number of cities in expanded Baghdad-to-London data, percentage of cities with at least one large church (> 1,000 m^2*), total number of large churches per city, average building phases per church and percentages of building phases falling within stated periods. No churches in Luxembourg met the size criterion.*

100,000 inhabitants in the year 2000 (the original dataset contained only settlements with more than 10,000 inhabitants between 800 and 1800).[5]

The study area contained 1,144 settlements, of which 70 per cent (ranging from a minimum of 55 per cent in Italy to over 80 per cent in France, Switzerland and Belgium) contain churches that satisfy the basic selection criteria, most of them already by 1100 (table 1). Since the number of churches increased over time, the dataset contains more observations about building activity in the post-1100 period than before. More is also known in more reliable detail about the construction histories of churches built after, than before, *c.*1100. Nevertheless, 40 per cent of the available observations are in the 700–1100 period and enough is known about these earlier churches to provide an outline building chronology. Another concern about this dataset is that it has an inherent bias towards the most urbanised regions. It may also understate church building in those regions where extensive destruction of conventual churches followed the Reformation, as in the case of Great Britain. Coverage of regions such as the Netherlands, in contrast, where large-scale church building began relatively late and monastic foundation made only limited progress, is likely to be more comprehensive. Section IV and appendix 2 assess the possible effects of these sources of bias, while appendix 4 considers the extent to which the reconstruction and rebuilding of churches was a response to natural and human disasters.

The completed outline of each sampled church is represented by a spatial database of polygons, from which its overall floor area in 2016 has been calculated (Hijmans 2015). The next step was to gather building histories for those churches that existed in the medieval period and were larger than 1,000 m^2, taking account of both the actual building history of each church and details of any natural or man-made disasters that had struck the building. Each church was also classified into one of four broad types: cathedrals, conventual (both monastic and mendicant), parish churches, and other places of worship (including royal and collegiate chapels).

[5] The precise centres of cities were verified with Google's geocoding API: <http://maps.googleapis.com/maps/api/geocode/json?address=>.

Large churches were typically the product of successive construction phases (table 1), as documented by an extensive secondary literature. For many churches the descriptions given in *Wikipedia* provide a starting point for reconstructing the chronology of each building's erection.[6]. These were augmented, in the case of Italy, by reference to Buchowiecki (1967), Martinelli (1964), Gatti (1913), Vecchi (1982), Bota Varela and Kroesen (2016), and the *Enciclopedia Italiana* (1929–1961). For the French, Swiss, Luxembourg and Belgian churches the various volumes of the *Histoire générale des églises de France, Belgique, Luxembourg, Suisse* (1966–71), which describes the building history of thousands of churches, were consulted. Kubach and Verbeek (1976), Oswald et al. (1966, 1968, 1971) and Jacobsen et al. (1991) supplied additional information for German, Belgian and Dutch churches, as Binding (2000) does for French, British and German churches and Rijksdienst voor de Monumentenzorg (1977) for Dutch churches. Building histories of British churches have been found in Morris (1979), and the national heritage lists for England, Wales and Scotland.[7] It is because so much of this information is country specific that present-day countries have been retained in this paper as the basic framework within which results are presented.[8] Available medieval population estimates similarly make use of these modern national units.

In the year when the building of a church started from scratch (because either there was no predecessor or it had been demolished), its surface area was classified as zero square metres in the database. Additional building campaigns adding to an already existing place of worship begin with a year with a blank surface area and end with the final year of that specific building campaign in the database, which also contains the surface area in 100s of

---

[6] See <http://www.openstreetmap.org/way/28809723> for a typical example of the information about a church contained in the church-building database.

[7] <https://services.historicengland.org.uk/NMRDataDownload/default.aspx> was used to create links to listed buildings entries at <https://historicengland.org.uk/listing/the-list/>. For Scotland: the data provided by the Historic Environment Scotland Portal at <http://portal.historicenvironment.scot/spatialdownloads/listedbuildings> linked to <http://portal.historicenvironment.scot/designations>. For Wales no dataset was available for georeferencing, so links to maps have been created from the coordinates in the OpenStreetMaps data to the Historic Wales portal <http://historicwales.gov.uk/#zoom=7>.

[8] The data can be aggregated to smaller regions, but to prevent the series becoming volatile due to developments in one or a few churches, the aggregation window should not be too small. In densely populated regions like Flanders or the Île de France, 100 by 100 km would easily suffice, while in Southern France or Scotland, such a window would be too small.

square metres added to the church in question. The end result is a database of 7,225 church construction phases (an average of 4.3 per church – table 1), with the start and end year and how much surface area was added to the church.

Since OSM cannot provide the floor surface of predecessor churches, these had to be estimated, as described in appendix 1. The completed volume of a church was, of course, determined by more than its floor surface area. Were each church to be inspected and all the necessary measurements made (James 1972, 1989), the current total volume of the standing parts (nave, aisles, choir, chapels, towers, steeples, etc.) together forming a church could be measured with precision (appendix 3). For historical estimation of the sizes of preceding (and now often largely vanished) churches, such measurements are, however, not feasible. The procedure used to estimate the heights is described in appendix 1.

When precise dates are mentioned for the building history of a church these have been used. Nevertheless, sources are often vague about the dates involved and dating to the nearest century (*c*) is not unusual. In these instances, building dates have been coded as spanning the whole period, from (*c* - *1*)00 to (*c*)00. Building at the beginning of a century was coded as (*c* - *1*)20, at the end of a century as (*c* - *1*)80 and at the middle of century as (*c* - *1*)50. Because approximate dates are often assigned to construction phases, the data show considerable date heaping (figure 2, left panel). This has been corrected following the strategy for dealing with coarse data outlined by Heitjan and Rubin (1990), whereby heaped observations are treated as missing and a model of 'missingness' is set up to impute the values (Little and Rubin 1987).

The method used for de-heaping is simple. Observations are drawn from a truncated normal distribution centred on the original date, with a standard deviation so that 90 per cent of the draws are expected to be in a reasonable range for the type of heaping. For heaping on century (*c*)00 this range is ±50 years; for heaping early/late in a century (20/80), ±15 year; and for first half/middle/second half of century (25/50/75), ±20. The distribution is truncated by the previous and next date in the church's building history. Finally, heaping on years with multiples of 10 are imputed with a uniform distribution ±5 years (corrected for re-heaping on fives). This procedure is repeated multiple times and the data series this generates are averaged out to yield a final series. The overall trends in the resulting series (figure 2, right panel) are very similar to the uncorrected series, though the chronology is smoother, lower in amplitude and breaks at heaping dates are less pronounced. All figures reported below use this heaping-corrected series unless stated otherwise. Because uncertainty about the exact dates of construction phases remains, the final series are mostly aggregated to 20-year periods.

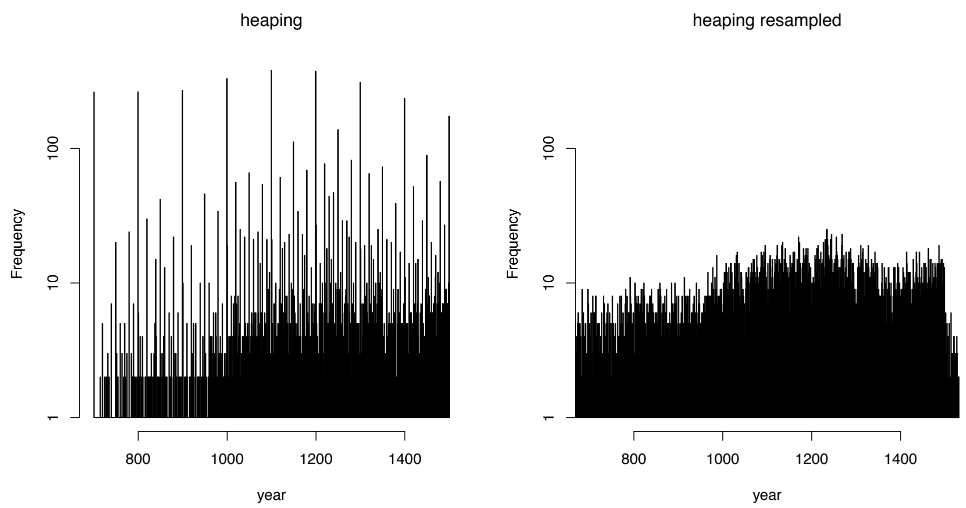

Figure 2. *Distribution of start and end dates of church building phases, showing strong date heaping, (left panel) and an imputed dataset to correct for this (right panel). Frequency is on a logarithmic scale.*

The representativeness of these results has been tested in two ways: first, by adding eight rural areas to the dataset (appendix 2) to test for the bias involved in focusing on cities only, and, second, by comparison with a more detailed reconstruction of the Gothic building boom in the Paris Basin as reconstructed by James (1972, 1989) (appendix 3). Both tests endorse the representativeness of this reconstruction based on large, urban churches.

III RESULTS (A) —Absolute temporal and spatial patterns of urban church construction

Following the method outlined in Section II, figure 3 summarises the development of church building measured in cubic metres in Western Europe between 700 and 1500 CE. The great wave of church building that dominated the High Middle Ages from the 10th to the 13th centuries stands out clearly. An initial brief upsurge in construction activity in the mid-9th century during the Carolingian Renaissance was not sustained and by the 960s church building had subsided to almost its lowest ebb. Renewed growth then began and was maintained with little significant interruption until the opening decades of the 14th century, averaging 0.6 per cent per year between c.960 and c.1260 and generating a near six-fold increase in building activity.

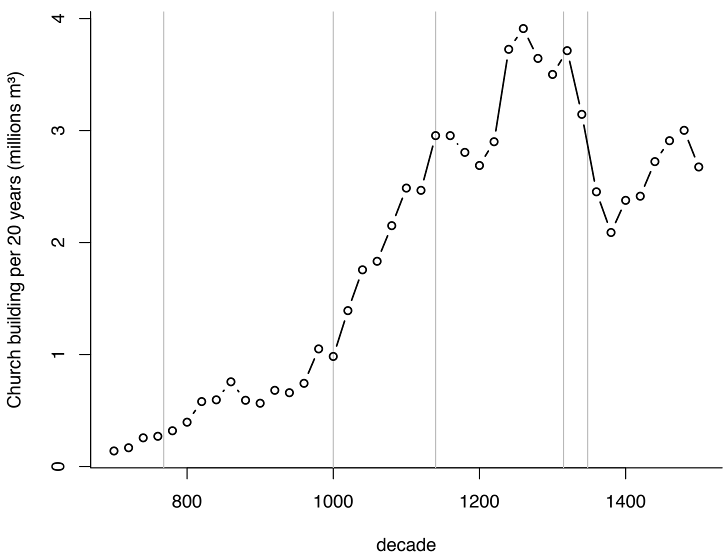

Figure 3. *Aggregate urban church building in Western Europe, in millions of cubic metres per 20-year period. Reference lines at 768 (coronation of Charlemagne), 1000 (start of second millennium), 1140 (start of Gothic architecture) 1315 (beginning of the Great Northern European Famine) and 1348 (advent of the Black Death).*

Starting from a low base, growth was particularly strong during the Ottonian Renaissance (c 960-1000) and strongest of all, 1.1 per cent per year, between c.960 and c.1040. This remarkable growth spurt is well known from the literature. At the time, the monk Glaber, working in Dijon and Cluny, commented that 'on the threshold of the aforesaid thousandth year' Christendom was 'cladding itself everywhere in a white mantle of churches' (Hiscock 2003; Landes 2003; Ó Carragáin 2010). Growth then eased to a steady 0.6 per cent between c.1060 and c.1140, when the papal reform movement and crusading fervour were at their respective peaks, and continued at 0.4 per cent between 1180 and 1260 as diffusion of the Gothic style from the Île-de-France lent church building fresh impetus (Prak 2011: 384), lifting it to a level in 1260 of almost six times that prevailing in the mid-10th century.

From the mid-13th century a saturation point began to be reached, at least as far as the construction and reconstruction of cathedrals and conventual churches was concerned, and over the next 50 years church building, while remaining at a high level, ceased to expand. Indeed, the first signs of contraction began to appear as the effects of, first, commercial stagnation and, then, outright recession started to be felt. Decline then set in and between c.1320 and c.1400 construction activity shrank by -0.6 per cent per year, reducing to a level not seen since the early-12th century. Significantly, as figure 3 demonstrates, this reversal was already clearly evident in advance of the Black Death of 1348-51, as escalating warfare and deteriorating economic conditions began to bite. This echoes the recent finding of Ljungqvist et al. (2018: 81, 86), derived from an analysis of the felling dates of constructional timbers, that within the territories of the former Holy Roman Empire 'preceding the Black Death (1346–1353 CE) by five decades and the Great Famine (1315–1322 CE) by two decades, a significant decline in construction activity at c. 1300 CE is indicative of a societal crisis, associated with population stagnation or decline'. This construction downturn also chimes with the evidence of dramatically contracting European silver production from a high-medieval peak in the 1320s, as reported by McConnel et al. (2019).

Repeated plague outbreaks then led to the suspension or abandonment of a number of large-scale construction projects (Campbell 2016: 310-13) and triggered a further ratcheting down of church-building activity. Not until the shock of the Black Death had been absorbed, did recovery begin. Although spread unequally over the study area, aggregate growth of 0.4 per cent between c.1380 and c.1460 brought output levels back to those of the opening years of the 13th century. Within the lands of the former Holy Roman Empire, rising numbers of felling dates from c.1415 pinpoint a similar recovery (Ljungqvist et al. 2018: 89). But outside a few privileged regions this revival proved relatively short lived and during the economically difficult years of the second half of the 15th century (Hatcher 1996) aggregate church-building activity shrank once again at -0.2 per cent a year.

Spatial analysis of the dataset reveals the changing geographical dimensions of Europe's medieval church-building boom (figure 4 and table 2). Between 700 and 1000 the centre of gravity was in northern Italy (in Lombardy and near Rome). Within Western Europe, western Germany – close to the 'capital' of the Carolingian Empire in Aachen – was the major centre but also northern France, including the epicentre of monastic reform in Burgundy, where the Cluniac Order had been founded in 910. In the next period, the boom years of the 11th and 12th centuries, church building in these two regions intensified and expanded to include the core parts of Flanders (present day Belgium), whereas Northern Italy continued to dominate church building in the south. The region of high building activity stretching from West-Germany to Northern France – between the rivers Rhine and Seine – coincided almost perfectly with the classic region of the feudal society as defined by Marc Bloch (1961). It also extended across the Channel into southern England.

Between 1200 and 1348 the German part of this arc appeared to be weakening, as building activity became more dispersed, and the Low Countries, then riding the crest of an economic wave, came increasingly to the fore. In Italy, Tuscany overtook Lombardy and the north. Finally, during the post-1350 period, building activity became strongly concentrated in the Low Countries, especially in Brabant and the Netherlands. It also held up well in neighbouring parts of northern Germany. By this time, northern France, enmeshed in the Hundred Years War, had lost its former prominence. Southern France fared better but could not match the impressive volumes of church-building activity occurring in the most dynamic northern regions within the research area.

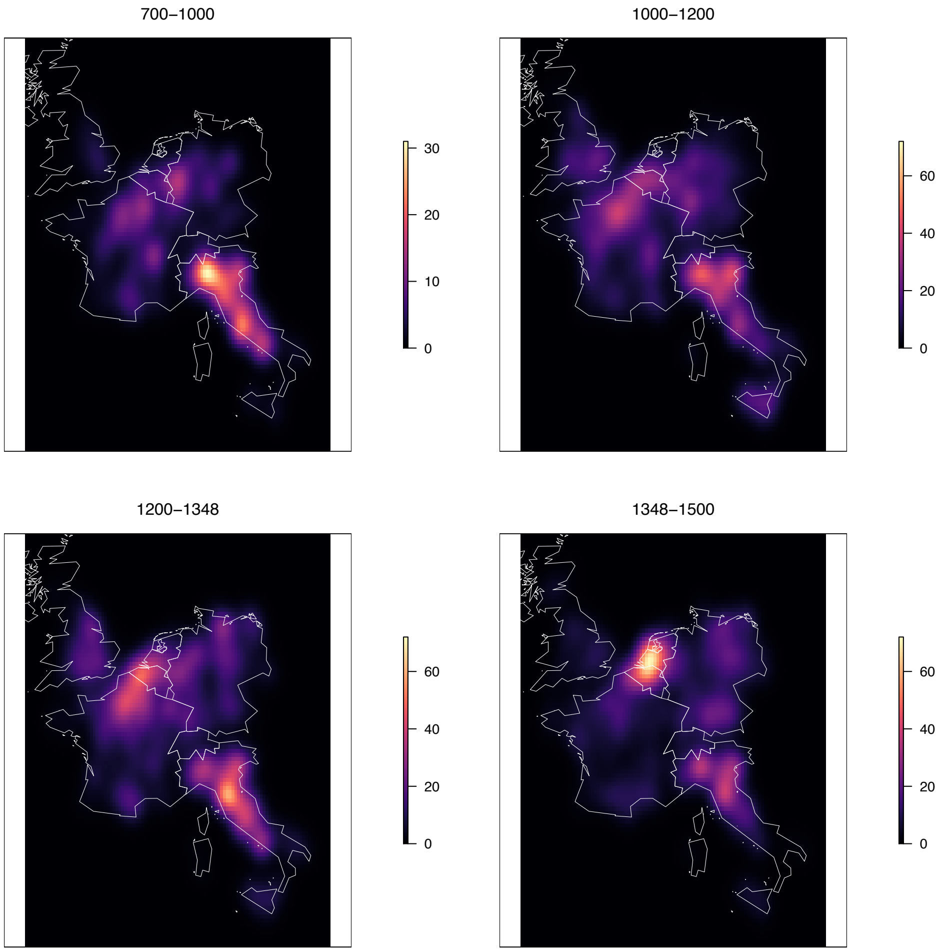

Figure 4. *Heat maps of church building activity in Western Europe (cubic metres per square kilometre), 700–1500*. Maps smoothed using a Gaussian filter (Hijmans 2016). Note: 700–1000 is plotted on a different scale.

Table 2 breaks down church construction by region, splitting the larger countries in two, and also reporting smaller countries that are aggregated elsewhere in the paper. The two- to three-fold increase in the volume of building activity between the 10th and 11th centuries shows up everywhere. Construction then rose to an absolute peak in the 12th or, more usually, the 13th century, with particularly impressive volumes of new church building taking place in central and northern Italy and northern France, where the energising effects of the commercial revolution were particularly strongly felt. In Great Britain the post-conquest boom in activity emerges as more pronounced in the north and west, than southeast, where hitherto there had been little church building on any significant scale. The 14th century brought a slackening of activity almost everywhere, with the conspicuous exception of southern France, where suppression of the Cathars may have elicited a triumphalist surge of construction, and in the commercially buoyant Northern Low Countries and German Rhineland. The latter were the only two regions where church building in the 15th century surpassed the levels reached in the 13th century.

Country or region	Century							
	8th	9th	10th	11th	12th	13th	14th	15th
	Volume of church building (millions m³ per century)							
S Italy	0.2	0.3	0.3	1.1	1.5	1.4	1.2	0.6
N Italy	0.7	1.2	1.4	2.1	3.6	4.4	3.3	2.9
S France	0.1	0.3	0.4	0.8	1.3	1.2	1.5	0.9
N France	0.2	0.6	0.9	2.3	3.2	4.2	2.0	2.2
Switzerland	0.0	0.1	0.0	0.1	0.2	0.3	0.1	0.2
SW Germany	0.1	0.4	0.4	1.3	1.1	1.8	1.6	1.4
NE Germany	0.0	0.1	0.3	0.6	0.8	1.5	1.4	2.1
Belgium & Luxembourg	0.0	0.1	0.1	0.4	0.7	1.0	0.9	1.1
Netherlands	0.0	0.0	0.1	0.2	0.2	0.5	0.8	1.7
SE England	0.0	0.0	0.1	0.5	1.0	1.3	0.7	0.4
Rest Gt Britain	0.0	0.0	0.0	0.1	0.4	0.2	0.2	0.3
W. EUROPE	1.4	3.1	4.1	9.6	13.9	17.7	13.8	13.7
	Indexed church building (100 = mean 1000–1500 CE)							
S Italy	18	25	26	99	126	121	102	52
N Italy	21	36	43	65	111	133	102	88
S France	9	26	32	67	114	104	130	84
N France	6	23	34	84	115	151	72	78
Switzerland	9	48	12	69	106	153	59	112
SW Germany	7	27	29	88	78	126	112	95
NE Germany	4	10	20	46	60	114	112	168
Belgium & Luxembourg	4	9	18	55	81	126	107	130
Netherlands	0	1	13	27	32	74	118	249
SE England	5	4	19	67	124	168	94	48
Rest Gt Britain	1	3	12	49	152	89	98	112
W. EUROPE	10	22	30	70	101	129	100	100

Table 2. *Absolute and relative trends in the volume of European church construction by country or region and century.*

IV RESULTS (B) —Per capita trends in urban church construction

The absolute chronology of church construction plainly echoes wider economic trends and both were powerfully influenced by changing population levels. It therefore makes sense to estimate per capita levels of church construction since such a measure, notwithstanding that available population estimates are subject to wide margins of error, better allows comparison between countries and with the European average. For England after 1086 the series by Broadberry et al. (2015) is used. For all other countries reliance has to be placed on the population estimates published by McEvedy and Jones (1978), log-linearly interpolated and allowing for a break at the Black Death where necessary. McEvedy and Jones probably underestimate the effect of the Black Death and the other demographic shocks of the first half of the 14th century, but, for all their deficiencies, their estimates are the best currently available and are those used in Bosker et al. (2013).

Figure 5 presents the estimates of per capita building activity for present-day countries compared to Western Europe as a whole. Italy's early lead, sustained by high levels of construction in Ravenna and Rome, is immediately apparent. Italy also stands out as the only country in which building activity per capita remained well above the European average throughout the eight centuries surveyed. Italian church building per capita charted a generally upward trend until after 1060, when it suddenly surged, tripling within the space of 60 years (c. 1060-1120) to reach a level in c.1100 that would never be bettered. This remarkable boom nevertheless followed rather than led that which had begun at least 50 years earlier in Germany, France and the southern Low Countries. Thereafter, activity fluctuated around a high level until the first quarter of the 14th century, when it suddenly subsided and then fell further in the immediate aftermath of the Black Death to a per capita level roughly half that prevailing when the 14th century had opened. Although output held up reasonably well until the final years of the 15th century, this was at barely half the level that had prevailed during Italy's commercial golden age in the 12th century and well below that concurrently achieved in the Low Countries. On these estimates the Renaissance was not a period of massive church building: patrons seem to have invested in the embellishment rather than the enlargement of churches.

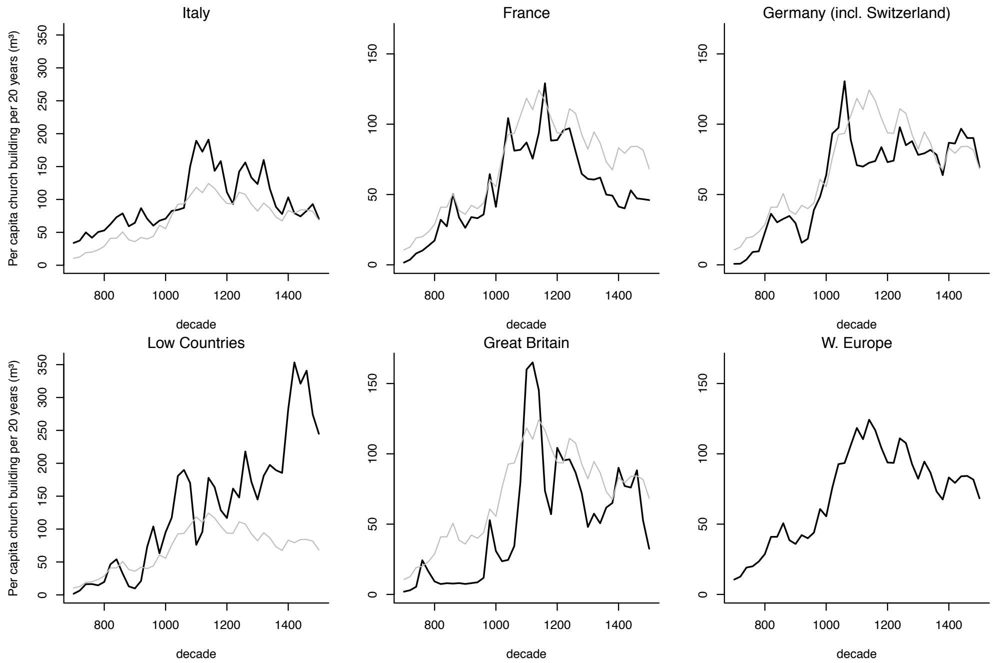

Figure 5. *Per capita church construction in cubic metres per 20-year period in Western Europe by present-day borders (grey reference line = European per capita church construction). Source population figures: McEvedy and Jones (1978); Broadberry et al. (2015). Note: the Low Countries and Italy are plotted on a different scale.*

In all other countries per capita church building began from much lower levels and varied in its relationship to the Western European benchmark level. France and Germany, already during the Carolingian era, appear to have moved in tandem; the post *c.*1000 boom was also clearly present in these two countries. After c.1200, they diverged. In Germany and Switzerland, activity stayed high and per capita levels remained close to the Western European average throughout the 13th and 14th centuries. In France, in contrast, there commenced a long secular decline, congruent from c.1300 with the new GDP per capita series for the 14th and 15th centuries reported by Ridolfi (2016: 192–3). For obvious reasons, the two large countries of France and Germany (with Switzerland) powerfully influenced the Western

European average, which from the 1220s tracked a mid-course between the rather dramatic decline of France and the more stable pattern found in Germany. During the first half of the 15th century Germany fared significantly better than war-torn France.

In Great Britain, where post-Reformation destruction of large conventual churches was probably most extreme, estimated per capita levels of church construction – with two conspicuous exceptions – were consistently below the Western European average. Naturally there was no 9th-century Carolingian Renaissance but Great Britain (or at least southeast England – table 2) did briefly participate in the general European upturn in church building that began in the late 10th century. After an early 11th-century lull, a surge in construction activity then followed the Norman Conquest of 1066 as England's new rulers sought to make their mark. This paralleled the contemporary boom in Italy but was mostly generated by very different factors. The decades around 1100 show some of the highest per capita construction levels of the period, strongly surpassing the Western European average at that point and approaching within 25 per cent the apogee attained at that time in Italy. Thereafter, construction levels subsided and by the second quarter of the 14th century were reduced to half their level at the opening of the 13th century and a third that of c.1100. Not long after the 1340s/50s, however, when GDP per head started to make significant gains (Broadberry et al., 2015), a notable revival in building activity took place that in per capita terms at times matched the prevailing Western European average. Nevertheless, these elevated per capita construction levels did not outlast the mid-15th century. Thereafter, a sharp contraction characterised the decades that ended with the Reformation, which effectively put an end to all outstanding major ecclesiastical building projects in Great Britain.

In the Low Countries from the 10th century, per capita output levels were commonly well above the west European average and more markedly so as the commercial revolution, in which Flanders was an active participant, got under way from the 11th century. After c.1100, when per capita church building elsewhere in Western Europe tended to stagnate or decline, the trend in the Low Countries was strongly if fitfully upwards to an absolute peak in the first half of the 15th century which eclipsed even the impressive levels achieved in commercially buoyant 12th-century Italy. This dynamism is evident in the Southern Low Countries a century earlier than the Northern Low Countries and is consistent with urbanisation trends in both regions. In fact, these high per capita construction levels are in part a function of the focus of the dataset upon large churches erected in towns and cities. Differential levels of urbanisation may therefore partially drive the results, with higher urbanisation rates – notably in Italy and the Low Countries – inflating estimated church-building levels. Nonetheless, the strong increase in the Netherlands after the Black Death persists even after correcting for trends in urbanisation (figure 6), lending some credence to the pre-1500 growth in per capita GDP found by Van Zanden and Van Leeuwen (2012).

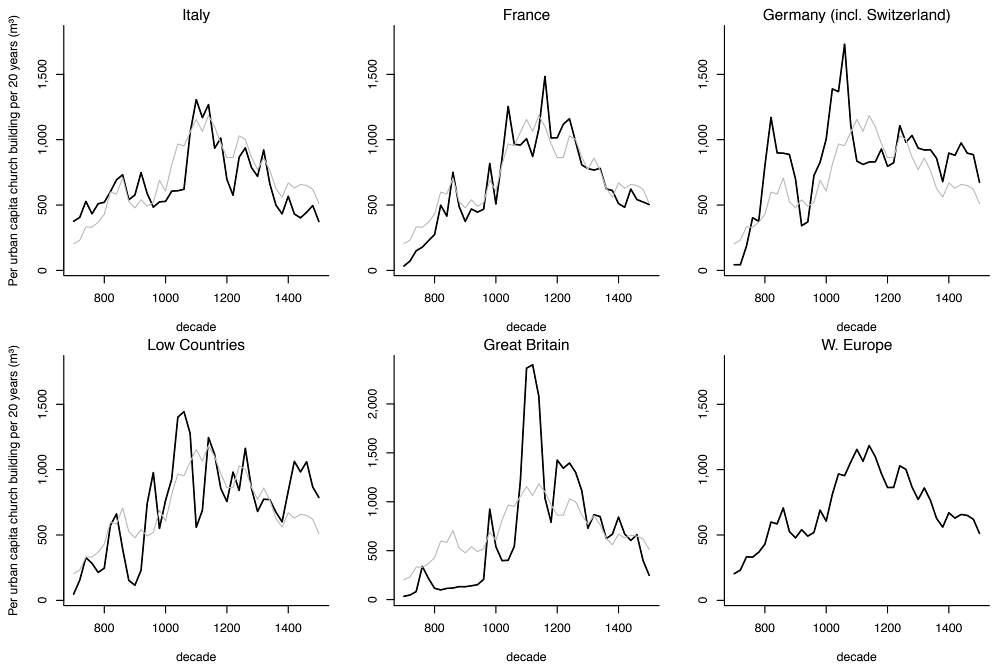

Figure 6. *Church construction in cubic metres per 1,000 urban inhabitants of towns with large churches in Italy, Germany with Switzerland, France, the Low Countries, and Great Britain (grey reference line = European per capita urban church construction). Note: Great Britain is plotted on a different scale.*

To explore the effect of urbanisation levels upon these estimates of per capita church construction, the latter have been re-expressed per 1,000 urban inhabitants, taking urban population estimates from Bosker et al. (2013). What stands out in figure 6 is that the pre-millennial construction peaks were relatively higher on a per urban capita basis, reflecting the combination of low urban population with substantial building projects during the Carolingian period. Italian church building, on the other hand, looks less impressive on this measure owing to the relatively high levels of urbanisation that already prevailed during this period. The opposite applies to relatively weakly urbanised Great Britain. Here, after the post-Conquest building boom, urban per capita construction levels compare favourably with those elsewhere in Western Europe. In contrast, the high urbanisation rates in the Low Countries in the 14th and 15th centuries deflate the otherwise impressively high volume of building activity towards the end of the period. Even so, for most of the 15th century church building per urban inhabitant remained well above the Western European average and especially so in the Netherlands.

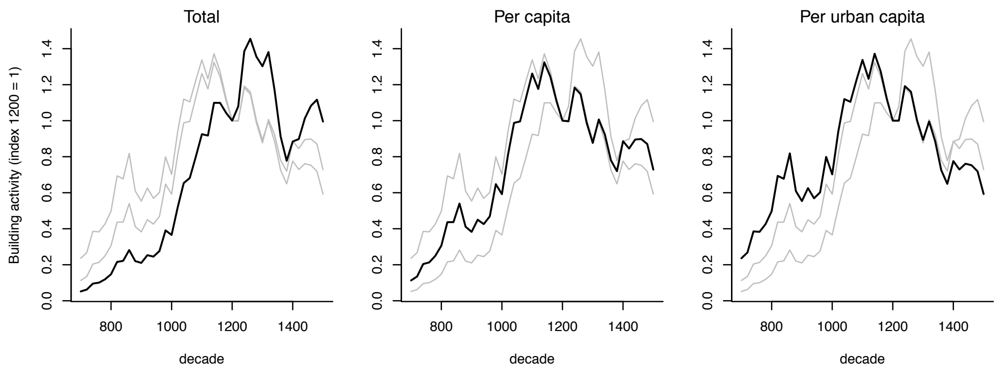

Figure 7. *Indexed (average in 1200 = 1) total, per capita, and per urban capita church building in Western Europe, in cubic metres per 20-years.*

To understand the impact of expressing these series on a total, per capita, or per urban capita basis, all three are presented as indexed series in Figure 7. The effect of filtering out first population growth and then urbanisation emphasises both the post c.1000 take off and the post c.1300 contraction. The broad contours of all three series nevertheless remain the same. The main exception is the Carolingian building boom which becomes far more visible in the per urban capita series because it corrects for the fact that in this period Europe was sparsely populated and its cities small in size. Each method of expressing the data has its own merits. It should not be assumed that the per urban capita series best reflects church building activity or productivity, since many cities extracted resources from the countryside to fund their projects, which means that the population of their hinterlands is also relevant. Both per capita series are also influenced by the reliability of currently available estimates of total population and urban population. Each series therefore provides a cross-check on the others.

V DISCUSSION

What do these trends in church building reveal about the evolution of Western Europe's economy over these eight centuries? Initially the existence of stable state structures was clearly important, as witnessed by the strong link between church building in Germany, France and the Low Countries and the rise and fall of the Carolingian Empire. Something similar can also be detected in the Italian series. Later, the big boom in English construction activity after the Conquest of 1066 and the establishment of a strong territorial state is one of the most remarkable upswings during the entire period. Early on socio-political structures at the local and regional level also seem to have played a large role. Within the Rhine-Seine region the coincidence between the regions of precocious church building and of classic feudalism has already been noted. Here, after the Carolingian Empire disintegrated, new forms of local governance developed in response. The powerful alliance of lay and ecclesiastical lordship promoted the founding of new churches. The proprietary church (*Eichenkirche*) system incentivised lay lords to found churches by giving them access to tithes (Wood 2006). By the 11th century this was a widely occurring system (Fossier 1968: 457; Collavini 2012: 282). Moreover, the reorganisation of production along feudal lines, in which the Church was proactive, made it possible to mobilise the substantial capital and labour resources and assemble the raw materials required by major building projects.

The Church itself– an important state-like actor in its own right – plainly exercised a decisive influence in a variety of ways, especially following the Church reforms that began with foundation of the Cluniac Order in 910 and were greatly extended by Gregory VII (r. 1073–85) (Campbell 2016: 66–76). As Michael Mann (1986: 383) observes, by establishing normative patterns of behaviour between fellow Christians and imposing an over-arching religious infrastructure, these reforms 'enabled more produce to be traded over longer distances than could usually occur between the domains of such a large number of small, often highly predatory, states and rulers'. In turn, the fruits of progress were invested in ever more imposing church buildings (Morris 1979; Johnson 1967a).

At one level, according to Landes (2003: 258), building churches 'emanated from orders, funds, and symbolic programmes generated from high in the [ecclesiastical] hierarchy', as evidenced by the early importance of its most prestigious projects, the building of cathedrals as the seats of bishops. Figure 8 distinguishes between cathedrals (built by bishops), conventual churches (linked to monasteries), parish churches, and other churches and places of worship. For the first five surveyed centuries episcopal projects led the field and created some of the most impressive churches in Europe. Until the cathedral sector went into decline after c. 1300, it accounted for approximately 40 per cent of recorded building activity. Often architecturally ambitious, cathedrals were trend and fashion setters and could benefit from the superior funds bishops and their chapters had at their disposal from rising revenues from their extensive estates, tithe receipts from appropriated benefices, donations from the faithful and offerings from pilgrims venerating the relics of saints (Vroom 1981; 2010).

The construction of conventual churches proceeded in tandem and was rising steadily from the 10th century under the fresh impetus lent by foundation of the Cluniac Order. The monk Glaber, famous for his quote about the 'white mantle of churches', was a Cluniac and a key figure in the reform movement led by that Order. His statement reflects the successes of that movement in the years around 1000. To reform is to build, and to build is to reform, is a way to summarise the link, as the successively enlarged abbey church at Cluny itself illustrates. The final church, Cluny III, erected between 1088 and 1190 was, at that time, the largest church in Christendom. Possibly the spreading influence of the Cluniac-inspired religious reforms helped nurture the gathering momentum of conventual church building apparent during the 11th century. And, over the course of that century, reaction to the perceived excesses of the Cluniacs spawned a rash of new reformed monastic Orders, of which the Cistercians were the most conspicuously successful. Their great churches, almost invariable located in the countryside, are under-represented in the sample because of its focus upon large churches in towns, which were disproportionately Benedictine and Augustinian. The 12th century was certainly the great century of monastic foundation, as the 13th century was of houses of the various mendicant orders, which were much more urban.[9] By 1300, however, foundation of both had largely run its course and ecclesiastical construction initiatives were focusing upon the parish church sector.

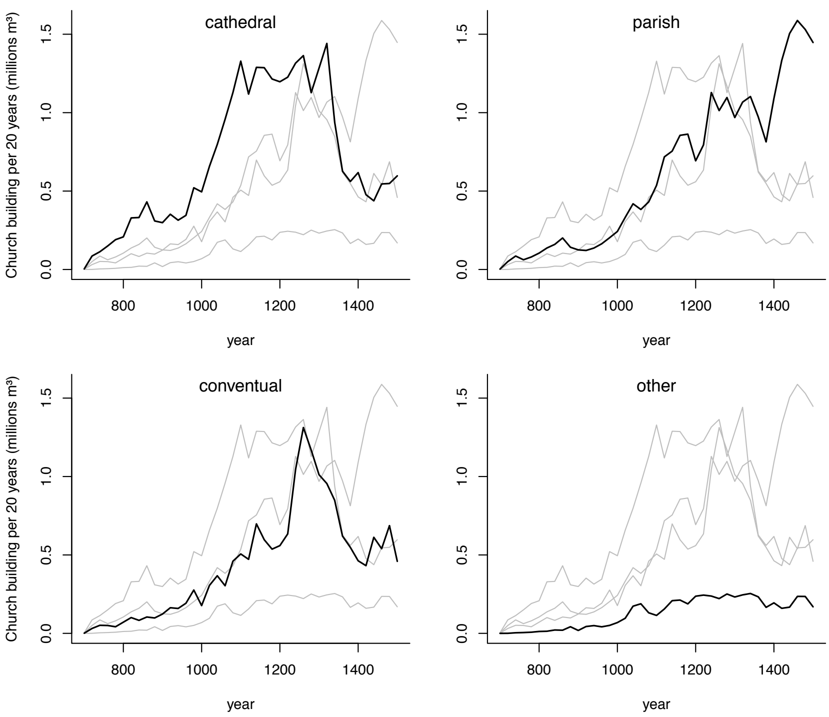

Figure 8. *Cathedral, conventual, parochial and other church-building activity in millions of cubic metres per 20-year period, 700-1500 CE.*

In contrast to the cathedrals and most of the monasteries, the impetus for parish church construction arose primarily 'from forces working their way up from below, from the desires and demands of a religiously aroused populace' (Landes 2003: 258). Erection of these churches accelerated after c.1000, gathered momentum during the 12th and early-13th centuries, eased up during the late-13th and the 14th centuries, before surging during the early-15th century when parish-church building dominated the ecclesiastical

[9] However, the rural sample discussed in appendix 2 revealed no systematic bias other than a stronger fifteenth-century dip in France and Great Britain.

construction sector. Nowhere was this more marked than in the Netherlands, where the number of bishoprics was small and parish churches accounted for the bulk of the construction activity that occurred after 1400. Other church-building projects, including prestigious royal and collegiate chapels, tracked a similar, if less dramatic, trend, and accounted for up to 10 percent of building activity throughout the study period, remaining buoyant in the 15th century when cathedral and conventual projects languished.

In northern Europe the sharp upturn in total and per capita building activity at the start of the new millennium is the most striking chronological discontinuity in the whole series (figures 6 and 7). At one level it represents the north of Europe catching up on Italy; but it is remarkable that it predates both a corresponding boom in Italian church building, which got under way after c.1060, and the papal and monastic reform movements of the final quarter of the 11th century. Whereas the establishment of independent urban communes (Epstein 2000: 6 of 36; Belloc et al. 2016: 1,882-83, 1887-89), revival of international trade (Lopez 1971: 63-70) and the reform of the Church are probably the best explanations for the sudden acceleration in building activity in Italy, their timing does not help to explain the earlier upsurge in construction in northern Europe.

North of the Alps, supply-side factors such as the emergence of new feudal institutions for control and governance may have helped initiate the boom. Agricultural innovation may also have played a role. The development of the heavy plough, occurring in the 9th to 10th centuries and spreading in the period thereafter (Andersen, Jensen, and Skovsgaard 2016), offers an attractive explanation of how more resources (notably the loess and clay soils prevalent in Germany, Flanders, and northern France) may have been brought into play. There is a striking resemblance between the north-western parts of the map shown in figure 4 (700-1000 CE and 1000-1200 CE) above and the distribution of loess soils (Haase et al. 2007). The creation of agricultural surpluses (see also Lauwers 2012: 30), fed into increasing commercialisation and urbanisation, which underpinned the ambition to erect ever larger and more elaborate churches. Many bishops and abbots were active in both founding towns and initiating major new church-building projects.

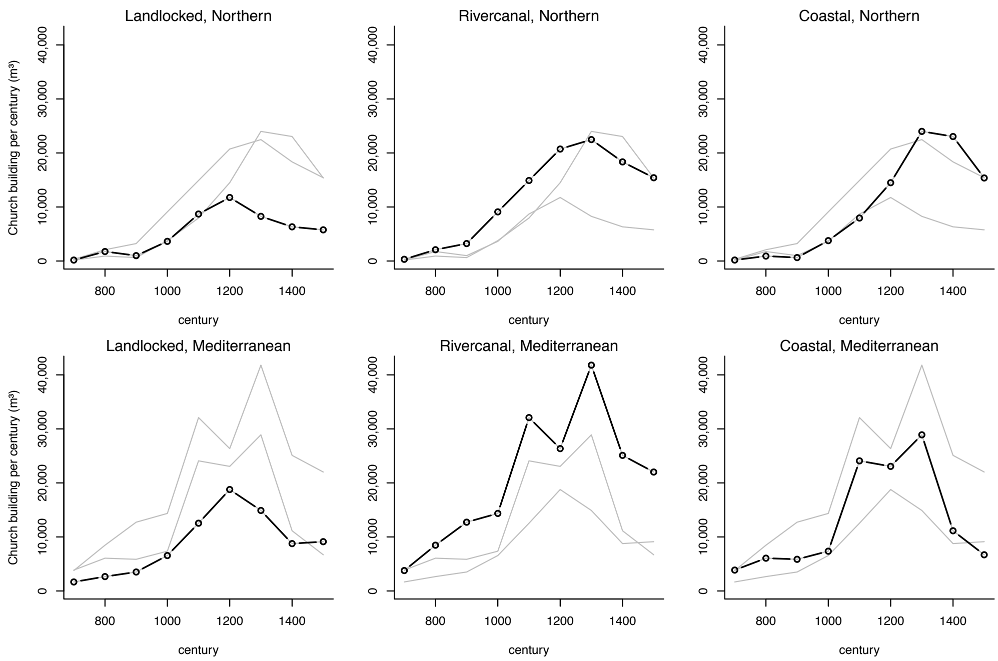

Figure 9. *Average volume of churches in cubic metres per century by type of location and catchment area in Western Europe, 700-1500 CE.*

Further evidence that international trade played a limited role in the initial phases of the building boom of the north-west is based on an analysis of the various 'first nature' locations of cities (Bosker and Buringh 2017: 140). Their accessibility to navigable water and with it their potential for trade, is an important first-nature characteristic. Thus, all urban centres in Europe have been classified as (a) 'land'-towns (landlocked and accessible by land transport only), (b) 'river'-towns (located on navigable non-tidal rivers or inland waterways), or (c) 'sea'-towns (at the sea coast or on the tidal stretches of rivers). This was done for cities in two different catchment areas: watersheds draining into the North Sea and Baltic (including the Atlantic Ocean and the Black Sea) and watersheds ending up in the Mediterranean (figure 9). If agricultural innovation (the heavy plough) and/or institutional innovation in socio-property relations (the spread of feudalism) were the driving factors of the big boom, landlocked towns might be expected to have performed at least as well as towns close to the sea. If trade and commerce were more important, towns on rivers and at the coast should have enjoyed an advantage. In particular, long-distance maritime trade will particularly have benefited coastal ports.

Figure 9 presents the average of each century's built volume of churches by first-nature characteristics for the whole of the study area. It shows that before c. 1000 church building in towns close to the sea enjoyed no particular advantage, presumably because development of international maritime commerce was as yet in its infancy and ecclesiastical settlements and buildings were targets of Viking raids. Thereafter it steadily gained an edge. Between 900 and 1200 church building at all locations was on the increase: it rose by 0.5 per cent a year in towns located on navigable rivers, by 0.6 per cent in landlocked towns, and by 0.6 per cent in maritime towns (0.5 per cent in the Mediterranean and 1.0 on northern seas). Expansion of construction slowed after c. 1200 but the relative advantage enjoyed by maritime and riverine towns over their landlocked counterparts widened to –0.1 per cent and -0.1 per cent versus -0.2 per cent. Being landlocked was becoming a handicap.

After 1300 only maritime cities on the North Sea and Atlantic maintained their rates of building activity whereas riverine and landlocked cities, as well as maritime Mediterranean cities, both experienced contraction, a phenomenon which became more-or-less general from 1400. Once the boom had begun, the consistently superior link between urban church building and river and especially sea trade which is implied by this comparison, and the advantage northern maritime ports came to enjoy over their riverine counterparts, implies that, after an initial start in which landlocked cities were as dynamic as those linked to waterways, commercial opportunities were an increasingly prominent component of Western Europe's great church building boom, with maritime trade accounting for an expanding share of those commercial opportunities.

Architectural developments also played their part. Intrinsic to the post-1000 church-building boom, when European construction levels more than doubled, was the emergence of the mature Romanesque style. The historian of architecture, Hiscock (2003: xiv), summarises this transition as follows:

> 'After the eclectic efflorescence of the first Carolingian architecture, there are few standing remains of importance before the middle years of the 10th century and few which display much architectural consistency until the 980s. By contrast, from the 1020s buildings not

only begin to survive in significant numbers, they are recognisably Romanesque, albeit in various regional guises'.

But the fact that this building boom coincided with the emergence of the Romanesque style does not necessarily mean that the architectural innovations stimulated the growth of church building. Whereas the Gothic style developed in the middle decades of the 12th century was 'revolutionary' in the way in which space was created and light was allowed into the church, the Romanesque style that emerged at about 1000 was in many ways a continuation of stylistic traditions extending back to Roman times. But once the templates of the 'new' style had been set in place, it must have sustained and facilitated – even encouraged – building activity. It was a case of energetic church building begetting architectural innovation which then encouraged further church building and rebuilding. The famous Cluny churches (II and III) were, for example, a source of inspiration all over Europe, as the centralised and hierarchical Cluniac Order was of the Papal Reform Movement of the late-11th century and the various new monastic orders spawned at that time, all of which needed new buildings for worship.

The Gothic style was fundamentally different from its predecessor (although, as always there were borderline cases here as well) and represents a step change in practical engineering knowledge. These developments were, of course, conditional upon the growth of a skilled and experienced workforce (Prak 2011: 386–91). There are many stories of cities and bishops wishing to build a church in the new style, or adapt an existing building plan accordingly. But the new style only came into being when church building was already booming: the 1140/50s were peak years, with new Gothic churches, almost exclusively around Paris, accounting for only a fraction of that peak. Again, the new style sustained and greatly stimulated building activity after the 1140s when it began to spread beyond the Île de France, and clearly intensified building activity in (firstly) northern France, and then in the rest of Western Europe after about 1180. Nevertheless, no clear break shows up in the OSM-dataset that can be linked to this innovation, and it is no surprise that such an effect seems to be totally absent in the Italian case, where the Gothic style was never as popular as in the north.

What is perhaps equally striking is that after the development of these two more or less pan-European architectural styles at about 1000 and 1150, there were no more radical changes in style, at least not in the north. The large churches constructed in Brabant and Holland in the 15th century (at that time the centre of west European church-building activity), for example, are easily recognisable as fitting into the Gothic style. Gothic architecture continued to develop and spawn new styles but these were basically variations on established principles. After the outbursts of creativity in the 11th and 12th century, the Gothic approach became the prevailing style, and continued as such (north of the Alps) until the spread of Renaissance concepts in the 16th century.

South of the Alps, Italian church building was much less affected by these radical changes in style, to which it adapted in its own way, spawning a range of regional styles, such as Pisan Romanesque. In the 15th century a distinct Renaissance style emerged which became influential in the north and the centre of the country, without ever achieving the kind of hegemony that the Gothic style had north of the Alps (the Milanese, exceptionally, built a purely Gothic cathedral). The diversification of Church building styles in Italy is an interesting phenomenon – perhaps because it is so different from the dominance of Romanesque and Gothic architecture in the north – but it is beyond the scope of this paper to analyse it. One of its consequences was probably that, unlike the north, radical new fashions in architecture did not play a large role in stimulating construction activity.

The absence of significant architectural innovation after the 12th century could help to explain why there was no new big wave of building activity in the later Middle Ages. By then a potentially important determinant of building activity may have been the accumulated existing stock of churches, on the principle that past investment in churches reduced the needs for current and future investment in churches. This is a plausible possibility and can be tested by plotting the stock of completed churches per city per century against on-going building activity in the same city and century (figure 10, left panel: only the stock of completed churches is included in these plots). Yet paradoxically, the relationship is not negative but overwhelmingly positive. In other words, on the biblical maxim of 'unto those that have shall be given' (Matthew 25: 29), the towns and cities most likely to build or add to large churches were those with an existing legacy of large churches. Nor is this positive relationship a figment of churches being begun and completed within the same century, for it holds true both when the lag of the existing stock of churches is taken (figure 10, right panel) and when the timeframe of analysis is narrowed to 20 years.

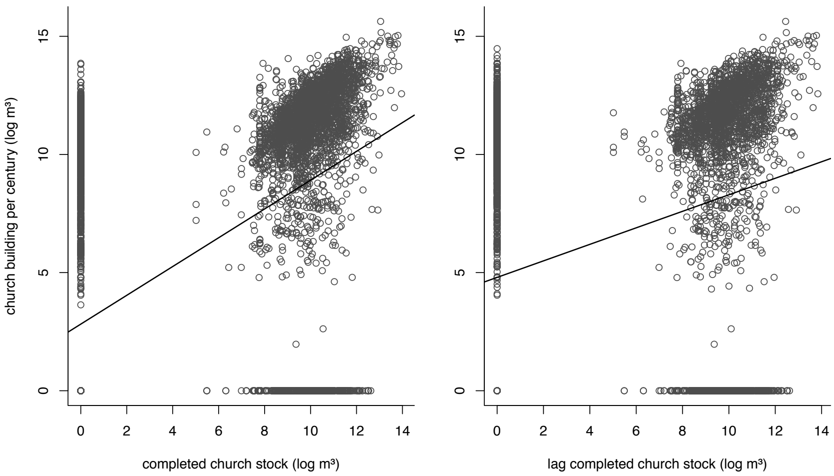

Figure 10. *Church-building activity by century in cubic metres and completed church stock, in current (left panel) and previous century (right panel).*

This may seem counter-intuitive but can be explained by two factors. First, growing towns and cities with an existing stock of churches, would also be the places with the capacity and need to add to and upgrade that stock. Second, having churches was a prerequisite for extending and embellishing them. On average, large churches went through at least four different building phases (table 1) and a substantial share of all recorded building activity entailed partial or total replacement of existing structures in response to advancing architectural fashions and changing devotional practices.

Natural disasters, such as earthquakes, could also elicit extensive rebuilding, especially when the disasters were themselves interpreted as acts of God (Belloc et al. 2016: 1,915-23). Appendix 4 shows that on average, church construction was higher after disasters struck, but that when aggregated at a country-level and for Western Europe as a whole this had only a marginal effect upon the overall patterns shown above. Earthquakes were especially destructive of buildings but were mostly confined to Italy and even there were typically localised in their impacts. Extreme weather and wars were less circumscribed in their effects and therefore across the study area were a more common cause of rebuilding. Nonetheless, they too were rarely frequent and severe enough to generate major temporal and geographical differences. Moreover, the positive link between the existing stock of churches and additions to that stock may point to the fact that once a system of church construction was in place – with stable sources of funding (via the tithe, for example), and institutions that had vested interests in the building process – these continued to develop new projects or extend old ones. They also had the capacity to respond to catastrophes.

These feedback mechanisms help to explain why church building did not cease after either the Great Northern European Famine or the Black Death, when the dramatic decline of the population might have led to a marked decline in the demand for new religious buildings. Of course, often work on big projects was suspended, sometimes never again to be resumed (the cathedral of Siena is one of the most spectacular examples), but on a per capita basis church building never really collapsed. In a scaled-down age individual buildings might prove surplus to requirements but at a time when any questioning of received religious beliefs was condemned as heresy, churches were never redundant. Across the eight centuries under review a changing array of forces shaped creation of the stock of churches and the availability of resources to maintain and enlarge them, and that was as true of the end of the period as it was of the beginning. Initially it was the vanguard economy of Italy that led and northern Europe, and especially the Low Countries that lagged. By the 15th century, in a remarkable manifestation of the 'Little Divergence', the successful commercial and manufacturing cities of the Low Countries were investing most heavily in large-scale church construction.

VI CONCLUSIONS

These are the first results of a project to reconstruct church building in medieval Western Europe over the eight centuries that ended with the Reformation. The construction history of large churches has considerable potential for illuminating wider trends in the medieval economy, with the capacity to shed new light on the debate about the timing and causes of the big boom that transformed European society between c. 920 and c. 1320. While focusing on large urban churches may introduce biases, comparisons with narrower but empirically more precise datasets on church construction indicate that the results are probably quite representative of the evolution of the sector as a whole. Moreover, the trends and patterns revealed are consistent with what is known about the broad chronological and spatial evolution of the European economy at the time.

Key findings from this investigation are as follows. First, from the 8th century until the early 14th century the vanguard economy of Italy led Europe in the levels of church building per capita that it sustained, as it did in levels of urbanisation and GDP per head. Within Italy, leadership shifted from Liguria, Lombardy and the Veneto in the 8th to the 12th centuries to Tuscany in the 13th and early 14th centuries. By the end of the 14th century, however, central and northern Italy had been overtaken by the Low Countries where by the first half of the 15th century levels of church building per capita were treble those prevailing in Italy.

In northern Europe, following the false start of the Carolingian Renaissance in the mid-9th century, a step-change in church building per capita got under way in the second half of the 10th century, as the north began to catch up on Italy. This church-building boom was both a top-down and bottom-up process. Significantly, it antedated a corresponding boom in Italy by a century and was firmly established long before the celebrated church reforms of the late 11th century. Its opening phase appears to have been concentrated in the area between the Rhine and Seine, which is usually linked to classic feudalism, and it did not extend to include the whole of England until after the Norman Conquest of 1066 and subsequent consolidation of Norman power and transformation of land ownership and property relationships.[10] This suggests a connection with this new system of exploitation of agricultural and human resources and associated more efficient extraction of surpluses by institutionally empowered lay and ecclesiastical lords.

[10] For evidence of an upturn of Irish church building (most of it small in scale) after c.1010 see Ó Carragáin (2010), 111.

Once initiated, the big boom prevailed almost everywhere, fitfully gathering momentum throughout the 11th and 12th centuries. These were the centuries when Lopez's commercial revolution took off and, as it got under way, church building in maritime towns displayed progressively greater dynamism than that at other locations. After c. 1200 the disparity between ports and landlocked towns became increasingly pronounced, implying that commercial factors and the cost advantage of shipping bulky goods by water were of growing importance in shaping the distribution of construction activity. At the same time, there was a switch in the balance of building projects as the initiative shifted from cathedral and conventual churches to large parish and non-parochial churches and chapels.

After the initial revolutionary burst of church-building activity in the 11th and 12th centuries, there was a significant loss of momentum in the 13th centuries, especially in France once the initial burst of rebuilding stimulated by diffusion of the new gothic style had subsided. Construction remained at impressive levels almost everywhere but ceased to expand, which implies that Europe's commercialising economy had entered a less dynamic phase. From c.1280 a significant slowdown set in almost everywhere, though in Italy church-building per capita remained at a high level into the opening years of the 14th century. Italy, then, along with most other countries, fell victim to a sharp and deep commercial recession, burgeoning warfare and a serious loss of papal credibility. Even before the Black Death, the second quarter of the 14th century witnessed the first Europe-wide downturn in construction activity, which shrank, almost without exception, both in aggregate and per capita.

Following the massive negative demographic shock inflicted by the Black Death of 1348–51 and its sequel outbreaks, the gravitational centre of church building activity shifted within northern Europe from northern France and Flanders to the Northern Low Countries and adjacent parts of Rhineland Germany, which were benefiting from the realignment of trade routes and proving themselves to be commercially and demographically more resilient to the negative shocks of war, commercial decline and plague. Within this geographically circumscribed but institutionally advantaged region a second church-building boom then ensued in the late 14th and first half of the 15th centuries, which had no counterpart in southern France and in Italy, where church building per capita was steadily subsiding.

These temporal and spatial trends suggest a periodisation of growth, in the sense that initially – during the Carolingian and Ottonian Renaissances – agricultural and institutional drivers played a large role until they were gradually superseded by international trade as the more important motivating factor. Finally, the break between c. 960 and c. 1040 (in Italy and England after 1060) is the single most striking discontinuity in continental church building and highlights the transformative importance of this era for subsequent development of the European economy. Improved security, state formation, changes in religious institutions and renewed religious fervour are potential candidates for explaining what so suddenly set this big wave in motion.

Appendix 1. Floor area back projections and height and volume calculations

This appendix outlines the procedures employed, first, for estimating missing information about the floor areas of predecessor churches and, second, for reckoning their heights and overall volumes in cubic metres. It takes into account the different size relationships that prevailed in Italy and the different nature of the available height information used to estimate the volume of Italian churches.

Floor areas:

As the floor surface area of a church preceding the one in OSM is usually not directly known, the size relationship between predecessor and successor churches is estimated on the basis of a subset of 107 churches for which this relationship is known. The relevant information comes from *Wikipedia*, Oswald et al. (1966, 1968, 1971), Kubach and Verbeek (1976) and Jacobsen et al. (1991). For these well-documented churches (none of them, regrettably, from Great Britain) Table A.1, below, shows the result of regressing predecessor floor area on successor floor area, broken down by present-day country, century, and church type.

	All	All excl. italy	Country split	Century split	Church split
m^2successor	0.48^{***} (0.02)	0.53^{***} (0.02)			
m^2successor × Italy			0.46^{***} (0.03)		
m^2successor × France			0.50^{**} (0.18)		
m^2successor × Switz.			0.53^{**} (0.19)		
m^2successor × Germany			0.54^{***} (0.05)		
m^2successor × Belgium			0.49^{***} (0.09)		
m^2successor × N'lands			0.54 (0.34)		

m²successor × 3^{rd}				0.37^{***}	
				(0.03)	
m²successor × 4^{th}				0.92^{***}	
				(0.09)	
m²successor × 5^{th}				0.76	
				(0.45)	
m²successor × 6^{th}				0.49	
				(0.51)	
m²successor × 7^{th}				0.55^{***}	
				(0.10)	
m²successor × 8^{th}				0.66^{***}	
				(0.06)	
m²successor × 9^{th}				0.48^{***}	
				(0.06)	
m²successor × 10^{th}				0.65^{***}	
				(0.08)	
m²successor × 11^{th}				0.52^{***}	
				(0.07)	
m²successor × 12^{th}				0.59	
				(0.31)	
m²successor × 13^{th}				0.46^{***}	
				(0.06)	
m²successor × 14^{th}				0.30^{*}	
				(0.12)	
m²successor × cathedral					0.45^{***}
					(0.03)
m²successor × conventual					0.58^{***}
					(0.10)
m²successor × parish					0.55^{***}
					(0.05)
m²successor × other					0.56^{**}
					(0.19)
R^2	0.81	0.90	0.81	0.88	0.81
Adj. R^2	0.80	0.89	0.80	0.86	0.81
No. obs.	105	85	105	105	105
RMSE	863.15	401.46	875.44	726.92	855.42

Table A.1. *Floor area of predecessor church regressed on successor floor area, broken down by country, century, and church type.*

Overall, it can be seen that a predecessor church was approximately half the size – 48 per cent, or 53 per cent if Italian churches are omitted – of its successor. Breaking these results down by century reveals some variation in this ratio over time, although for those centuries with sufficient data (7^{th}–

11th centuries, containing 70% of the documented predecessor churches), the result is rarely far from the overall estimate of 0.48. Without more observations per century the results are, however, insufficient robust to justify modifying the back projections by century. Similar reasoning applies to the ratios disaggregated by type of church: the sample sizes are too small and the estimated ratios do not differ significantly from 0.53.

The country breakdown reveals that Italy is something of an outlier compared to the other countries. In the populous and densely built up towns of medieval Italy, where space was at a premium, later churches were regularly built on the same foundations as their predecessors and enlargements of their floor areas were circumscribed. This seems to have been more common than was the case in the smaller, less crowded and typically younger towns north of the Alps. The ratio of predecessor to successor churches in Italy has therefore been estimated as follows: *per cent of surface* = 88.9 – 0.0028 * A [$R^2 = 0.29$]). For all other countries, the ground surface ratio is estimated to have been 0.53 : 1.

To test for possible biases resulting from this two-way distinction, the floor area of each predecessor church results has been re-estimated using a varying slopes/varying intercepts regression model of the form:

log(*A_predecessor*) = *a1[country]* + *a2[century]* + *b1[country]* * log*(A_successor)* + *b2[century]* * log(*A_successor*) + e.

To limit the effect of outliers and small groups and achieve some regularisation of the varying coefficients, a Bayesian multilevel model is used (Gelman and Hill 2007). Differences between this re-estimated series and the simpler approach outlined above and used in the paper are small, which is why the latter is preferred (figure A.1). For France alone do the two methods produce visibly different results but as this corrections is based on a single observation this is hardly a reliable result.

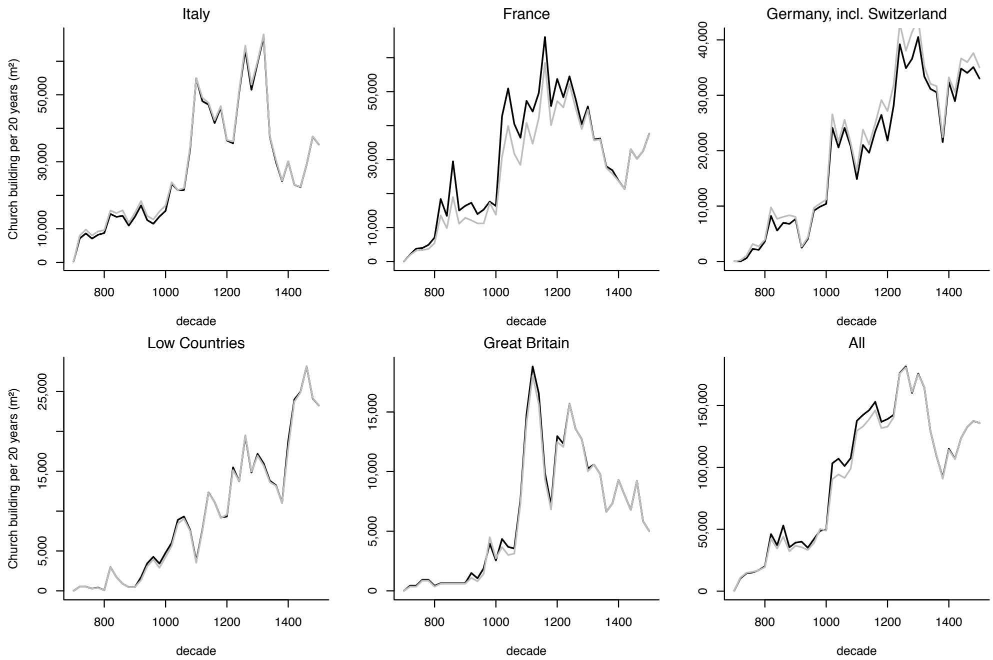

Figure A.1. *Alternative estimates of building activity in millions of square metres per 20 years by country, 700–1500. Grey: original series. Black: series using alternative predecessor church estimates. The correction for date-heaping has not been applied in these series. Different scales are used for each country.*

Heights and volumes:

It is the completed internal volume rather than just the floor area of churches that has been employed as the common unit measure of construction activity, as in figure 3. The approximate volume of each church in cubic metres has therefore been estimated as the surface area of its floor plan multiplied by the height of its nave (cf. Johnson 1967b). For simplicity, no account is taken of the heights of other component elements of the building: aisles, chancels, chapels etc. For 151 non-Italian churches, both the actual height (*H*) of their naves and their overall surface areas (*A*) are known. Figure A.2 shows that these churches have a reasonably consistent relationship of area to height ($R^2 = 0.69$), which translates into $H = 0.45*\sqrt{A}$. For churches outside Italy where no nave height is reported, it is this ratio that has been used to derive *H* from *A*.

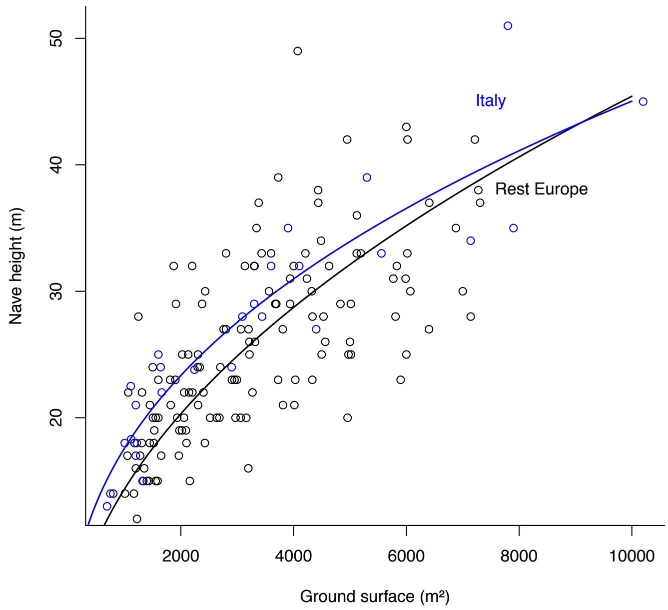

Figure A.2. *Relationship between nave height and ground surface area of 178 churches in the church-building database with fitted regression line (H = 0.45*√A for Europe excluding Italy and H = 0.97A$^{0.4168}$ for Italy).*

For the 27 Italian churches in the database an alternative approach was necessary because the available height information is different and typically relates to the external height of the west façade rather than the internal height of the nave. It is this statistic that is either recorded in the available secondary literature or can be derived from photographs or elevations. For the Italian churches it implies a reasonably consistent relationship of area to height ($R^2 = 0.87$), which translates into $H = 0.97 * A^{0.4168}$, hence it is this ratio that has been used to derive the façade height (*H*) from the known OSM area (*A*). In all churches, however, the external height of the façade was greater than the internal height to the nave vault or roof, especially in churches with a hidden attic above the vaults. On the evidence of five Italian churches with known internal and external height information this ratio was of the order 0.7 : 1. The formula $V = 0.699 * H * A$ has therefore been used to derive estimates of the internal volumes of the Italian churches that are comparable to those estimated for the non-Italian churches in the dataset.

Appendix 2. Urban versus rural church building

Given the exclusive focus upon large urban churches, a test has been made of the effects of extending data collection and analysis to include correspondingly large rural churches. Because it is unfeasible to gather data on all rural churches, the exercise was limited to eight rural areas defined by 100 by 100 kilometre squares around Peterborough and Chester (Great Britain), Amiens, Toulouse and Dijon (France), Maastricht (Netherlands), and Osnabrück and Nürnberg (Germany), each chosen to include a sufficient numbers of monasteries (figure A3).

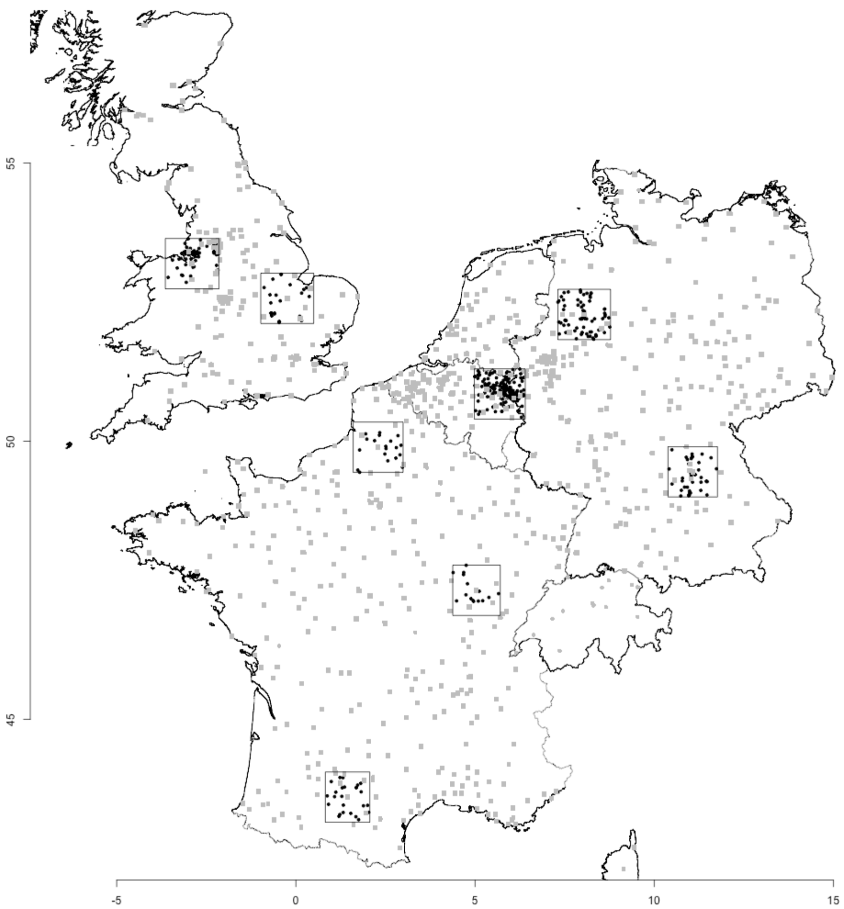

Figure A.3. *Large rural (black) and urban (grey) churches in the study area (excluding Italy). The squares show the rural sampling regions.*

Creating a corresponding rural sample of Italian churches was not viable since the available secondary sources on Italian church construction are less detailed and comprehensive than those for the other countries. Italy is therefore omitted from the aggregate results presented in this appendix. Unfortunate as this is, Italy, like the Low Countries, was highly urbanised hence it is unlikely that correcting for rural church building would make a large difference to the overall results.

These rural samples have been used to create additional time series of construction activity: a rural series and a combined rural-urban series weighted by the surface area of the sample areas. Figure A.4 presents these series for the entire research area minus Italy. Generally, the urban series seems to capture about half of total church building and chronologically is broadly similar to the rural series (correlation: 0.91). The rural series does show more pronounced plateaus in the 11th and 13th centuries, as well as a more pronounced escalation in the 12th and 15th centuries. The differences, however, are not so large as to make more than a modest difference to the overall trends in a combined series factoring in rural church building.

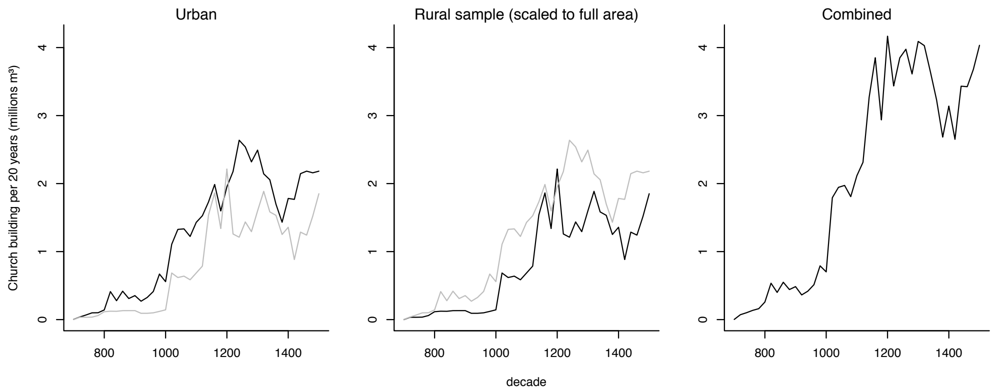

Figure A.4. *Building activity (millions of cubic metres per 20 years) in the urban dataset, a re-weighted rural sample, and a combination of the two series (excluding Italy). The correction for date-heaping has not been applied in these series.*

A similar conclusion holds if the urban bias is examined at a country level (figure A.5). While there are some differences between the rural and urban series at a fine-grained, 20-year level, the overall trends of rural and urban church building, as well as the combined rural and urban series, are similar. In particular, the increase in building activity in the late 12th century seems to have been universal. The overall correlation is 0.8 ranging from 0.6 in

Great Britain and 0.9 in the Low Countries. Smoothing out the series to focus on trends increases the correlation coefficients even further.

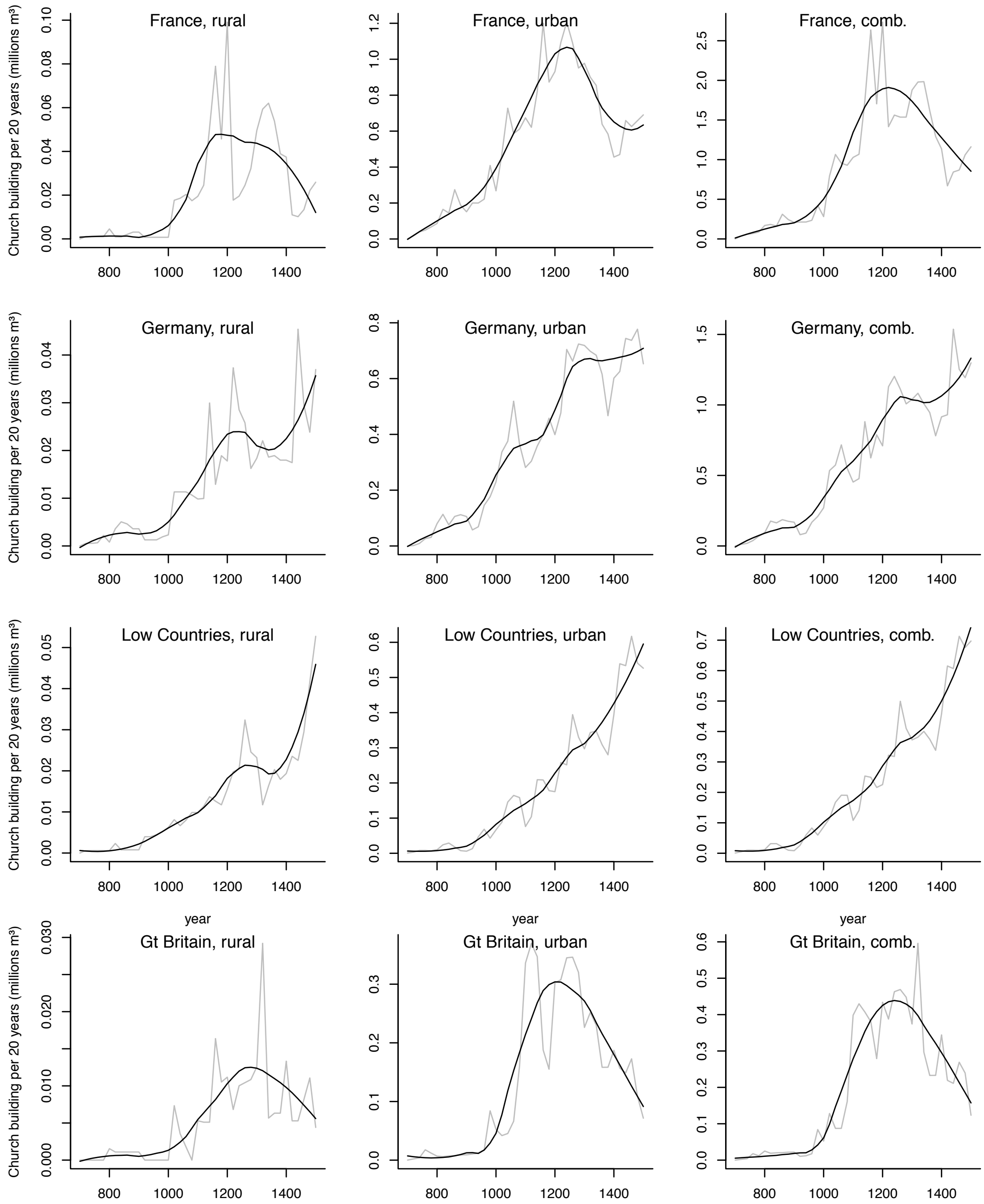

Figure A.5. *Building activity (millions of cubic metres per 20 years) by country in a re-weighted rural sample, the urban dataset, and a combination of the two series (excluding Italy). Original (grey) and smoothed (black) series. The correction for date-heaping has not been applied in these series.*

Appendix 3. Robustness: a case study of church building in the Paris Basin

To test the reliability of the OSM-based dataset, relevant results for the Paris Basin can be compared with those derived for the same region by James (1972, 1989) employing a high-precision archaeological approach.[11] James surveyed all extant Gothic churches built between 1060 and 1250 in the Paris Basin and, further, made estimates of the costs of more than 1,500 churches constructed in that period. His dataset is architecturally comprehensive, covering all surviving churches – rural and urban, large and small – built at that time in the Gothic style in this region. It allows two close comparisons to be made with the corresponding OSM sample of large urban churches within the same region. First, churches in James's dataset have been directly matched against churches in the OSM-based dataset (figure A6). Because many of the churches James surveyed were rural and were not restricted to churches larger than 1,000 square metres, this comparison is based on a limited number of churches. In a second comparison the total expenditure per decade estimated by James (using an arbitrary unit), is matched against total construction activity within the Paris Basin over the same period estimated from the OSM-based database (figure A7).

[11] James' database can be found at <http://creationofgothic.org>.

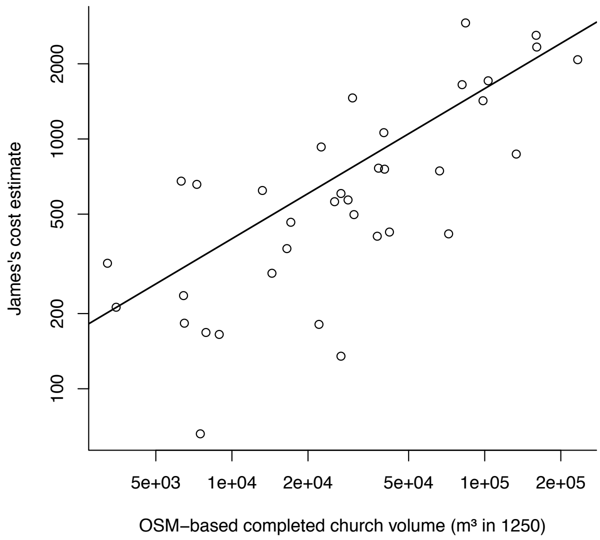

Figure A.6. *Comparison, for a common sample of 36 churches in the Paris Basin between 1060 and 1250, of James's estimates of the costs of construction and their OSM-based estimated completed volumes in cubic metres.*

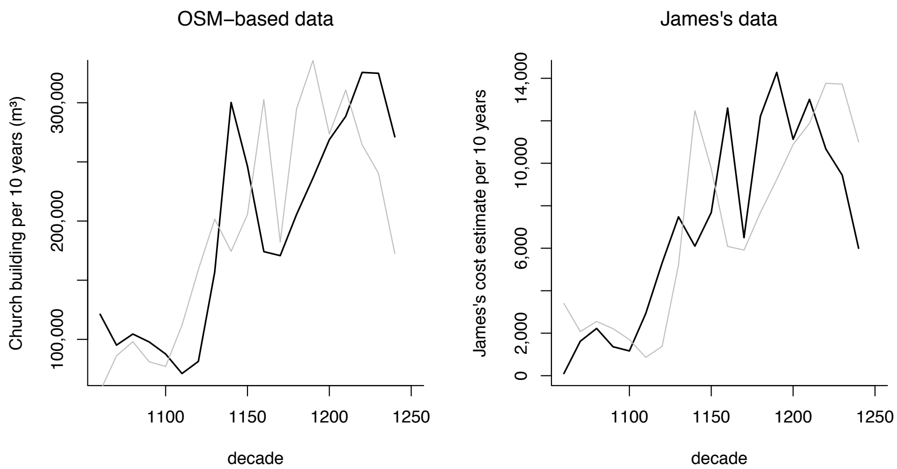

Figure A.7. *Comparison of the estimated volume of church building according to the OSM-based dataset (left panel) with James's estimates of expenditure on church building (right panel) in the Paris Basin, 1060–1250. Scaled comparison series in background (grey). Note that the unit of cost employed by James is one unit = 1/6th of a small first-floor gallery.*

Given their differing natures and methods of estimation, it would be remarkable if the match between the two chronologies was exact. James created his own measure for the expenditure involved in constructing the churches he included in his dataset, whereas construction output is here estimated as the internal built volume measured in cubic metres. Moreover, James ignored the non-Gothic parts of Gothic churches. It is also possible that because the matching was done automatically based on geographic distance, some true matches may have been missed while others may be spurious. Although James's time-consuming approach of surveying each building in detail has undoubtedly yielded the more accurate results, as figure A7 shows, both series (all churches included in James's work and those for the same research area in the OSM-based dataset) nonetheless behave similarly. Indeed, the correlation between the two series is high: 0.7. This is an important result, since it implies that chronologies reconstructed from the OSM-based database of large urban churches are representative of developments in a wider area and endorses the method developed here as a technique for reconstructing church-building chronologies over extensive geographical areas and, ultimately, within Latin Christendom as a whole.

Appendix 4. Disasters and church building

Wars, earthquakes, severe storms, floods and accidental fires could damage church buildings and necessitate extensive rebuilding independently of prevailing economic and religious circumstances.[12] The effects of such disasters varied from place to place and period to period hence this appendix examines the extent to which this is reflected in the aggregate trends reported in this paper. The analysis is based upon documented cases of disaster-related rebuilding reported in the same sources as those used to compile the construction histories of each of the churches in the database. Both natural and man-made disasters are included, classified into the three categories (1) war, (2) earthquake, and (3) other (storms, floods and fires). A

[12] Belloc et al. (2016) show that earthquakes could also increase religiosity, and through that channel, institutional change in Italian communes.

total of 308 churches, amounting to 18 per cent of all the churches in the database, were damaged in one way or another by the 392 natural and man-made disasters that are documented over the course of the eight centuries under review. Their distribution by present-day country and by century is reported in table A.2.

Country	Number of churches damaged by				% of churches damaged by		
	earth-quake	war	other	all	earth-quake	war	other
Italy	38	10	44	92	41.3	10.9	47.8
France	0	66	89	155	0.0	42.6	57.4
Switzerland	3	0	6	9	33.3	0.0	66.7
Germany	1	14	64	79	1.3	17.7	81.0
Belgium	0	2	16	18	0.0	11.1	88.9
Netherlands	0	1	12	13	0.0	7.7	92.3
Gt Britain	2	6	19	27	7.4	22.2	70.4
Century							
8th	1	8	2	11	9.1	72.7	18.2
9th	0	42	6	48	0.0	87.5	12.5
10th	0	10	16	26	0.0	38.5	61.5
11th	0	5	40	45	0.0	11.1	88.9
12th	17	5	51	73	23.3	6.8	69.9
13th	3	7	58	68	4.4	10.3	85.3
14th	16	9	34	59	27.1	15.3	57.6
15th	7	13	42	62	11.3	21.0	67.7
total	44	99	249	392	11.2	25.3	63.5

Table A.2. *Number of churches damaged by wars, earthquakes or other disasters, by country and century, 700–1500 CE.*

Swiss churches alone seem to have been relatively immune to the destructive effects of war. Elsewhere it was the most commonly reported destroyer of churches before 1000, when ecclesiastical sites were deliberately targeted by Viking and Muslim raiders. War's negative effects were, however, dramatically curtailed during the *Pax Christiana* that prevailed from the 11th to the 13th centuries when church building surged throughout Christendom. The escalation of internal European warfare in the

14th and especially the 15th centuries brought renewed destruction, but not on the scale of the 9th century (Table A.2). In contrast, explicit reference to destruction by earthquakes is rare before 1100, dramatic though such collapses must undoubtedly have been. Thereafter earthquakes accounted for a ninth of all reported collapses, rising to around a quarter in the 12th and the 14th centuries. Unsurprisingly, 86% of all such collapses occurred in tectonically active Italy, although even here they were outnumbered by disasters arising from other causes. Damage from the hazards of extreme weather, river and marine flooding and accidental fires could occur almost anywhere and at any time and, collectively, these were the most widely reported accidental causes of rebuilding, especially during the otherwise uneventful 11th to 13th centuries and in Germany and the Low Countries.

Overall, French churches appear to have been the most hazard prone, even after taking into account the higher number of churches there (39 per cent of collapses and 27 per cent of all churches). The prolonged and destructive Hundred Years War with England levied a singularly heavy toll on French churches. Also, French architects, by taking the structural potential of the Gothic style to its limits, may have created buildings that were structurally susceptible to collapse, as in the notorious case of the 1284 failure of the gravity-defying vaults of Beauvais Cathedral. English churches fared better. They were architecturally less ambitious and the country was spared the worst effects of large-scale warfare.

This church-level information on disaster-related reconstruction can be used to estimate the contribution of such largely non-economic and often accidental events to the original church-building activity series. To do this, for each country the amount of additional disaster-related building per church per 20-year period is estimated for the 150 years following a disaster. The extra building activity is estimated using a regression model that includes time and country fixed effects to account for differences in the survival of information about disasters in the historical record of the countries in the dataset. The following model is estimated using OLS: building_activity[i] = b0 + b1[country[i]]*disaster[i] + b2[country[i]] + b3[century[i]] + e[i]. This provides separate estimates of the impact of disasters on building activity for each present-day country in the dataset.[13] Separate models are estimated for each of the three categories of disasters discussed, as well as all disasters together.

	All (1)	All (2)	Earth-quakes (3)	Wars (4)	Other (5)
Switzerland	0.15	-0.30	-0.68*		-0.09
× disaster	(0.34)	(0.34)	(0.30)		(0.50)
Germany	2.98***	2.60***	3.06***	0.98	2.94***
× disaster	(0.30)	(0.30)	(0.59)	(0.51)	(0.35)
France	3.46***	3.33***		1.16***	4.90***
× disaster	(0.32)	(0.32)		(0.26)	(0.52)
Italy	3.82***	3.35***	3.22***	2.34**	3.61***
× disaster	(0.39)	(0.39)	(0.65)	(0.83)	(0.58)
Netherlands	6.77***	6.39***		1.22	6.88***
× disaster	(1.23)	(1.22)		(1.19)	(1.35)
Gt Britain	4.23***	3.67***	14.07***	0.77	3.41***
× disaster	(0.62)	(0.61)	(3.63)	(0.82)	(0.65)
Switzerland	-0.18*	-0.17	-0.20*	-0.21*	-0.18*
	(0.09)	(0.09)	(0.09)	(0.09)	(0.09)
Germany	-0.11*	-0.11	-0.05	-0.05	-0.10
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
France	-0.01	-0.01	0.14*	0.11	0.02
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Italy	0.04	0.04	0.06	0.09	0.08
	(0.06)	(0.06)	(0.06)	(0.06)	(0.06)
Netherlands	0.16	0.16*	0.31***	0.31***	0.17*
	(0.08)	(0.08)	(0.09)	(0.09)	(0.08)
Gt Britain	0.14	0.15	0.21*	0.24**	0.20*
	(0.08)	(0.08)	(0.08)	(0.09)	(0.08)
8th		0.15***	0.16***	0.16***	0.16***
		(0.01)	(0.01)	(0.01)	(0.01)
9th		0.31***	0.36***	0.35***	0.35***
		(0.02)	(0.02)	(0.02)	(0.02)

[13] The logarithm of building activity per 20-year period is not used because there are many cases of zero construction activity for a church. Omitting these cases would underestimate the impact of disasters by excluding zero activity from the comparison.

10th		0.37***	0.48***	0.45***	0.46***
		(0.03)	(0.03)	(0.03)	(0.03)
11th		1.04***	1.13***	1.12***	1.05***
		(0.05)	(0.05)	(0.05)	(0.05)
12th		1.49***	1.61***	1.63***	1.50***
		(0.05)	(0.05)	(0.05)	(0.05)
13th		1.91***	2.05***	2.07***	1.92***
		(0.06)	(0.06)	(0.06)	(0.06)
14th		1.46***	1.60***	1.61***	1.46***
		(0.06)	(0.06)	(0.06)	(0.06)
15th		1.47***	1.60***	1.60***	1.50***
		(0.05)	(0.05)	(0.05)	(0.05)
Intercept	0.99***	0.01	-0.06	-0.07	-0.02
	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)
R^2	0.03	0.05	0.03	0.03	0.05
Adj. R^2	0.02	0.05	0.03	0.03	0.05
Num. obs.	69495	69495	69495	69495	69495
RMSE	4.11	4.06	4.10	4.11	4.07

Table A.3. *Building activity (1000s m³ per 20 year period per church) regressed on disaster-related damage to churches and its aftermath, by country and century. Robust standard errors reported between parenthesis. ***p < 0.001, **p < 0.01, *p < 0.05.*

The results of this model are presented in table A.3. It can be seen that disasters usually had a positive impact on church-building activity during the 150 years that followed them, increasing building activity more than fourfold compared with those unaffected: (4,500 m³ versus c. 1,000 m³ per 20 years). In England the prolonged rebuilding of Lincoln cathedral following the earthquake of 1185 is a good example of this effect. This single outlier explains why the result for the impact of earthquakes in Great Britain is so incongruously high. Only in Switzerland, where the effect is generally negative but insignificant, do disasters emerge as having had a negligible effect upon church building. Note that the inclusion of century fixed effects lowers the estimates.

The coefficients on the country × disaster interaction in models 2 and 3 are used to correct the building activity series for all disasters and earthquakes respectively. These coefficients provide church-level estimates of the country's average additional building following a disaster, adjusted for century fixed effects.[14] By subtracting this amount from disaster-affected churches for the 150 years following a disaster for each country, counterfactual series where no disasters took place can be calculated (figures A.8 and A.9).

[14] For these corrections to be unbiased, the destruction of churches by disasters has to be exogenous. Natural disasters could meet this requirement, though even here there are caveats. A concern is that the size of replacement churches was correlated with their collapsed predecessors (Pearson correlation coefficient of 0.8 for all churches). Since large churches were more likely to collapse, the estimates of the impact of disasters might also be picking up past economic prosperity. Indeed, including the size of the predecessor church lowers the estimates of the effect of disasters. Second, as table A.2 shows, information on disasters is less likely to be available before 1100. Since churches were on average smaller in the earlier period as well, the estimated effect of disasters might be biased upwards because data on the reconstruction of these smaller churches is missing. The year fixed effects are meant to address this and indeed lead to lower estimates (table A.3). Finally, in the case of wars, exogeneity probably does not hold as wealthier regions may have been more attractive to invaders. All these scenarios, however, imply that the estimates in table A.3 are biased upwards. If anything, the corrections below are therefore conservative because the true difference from the original series is probably smaller.

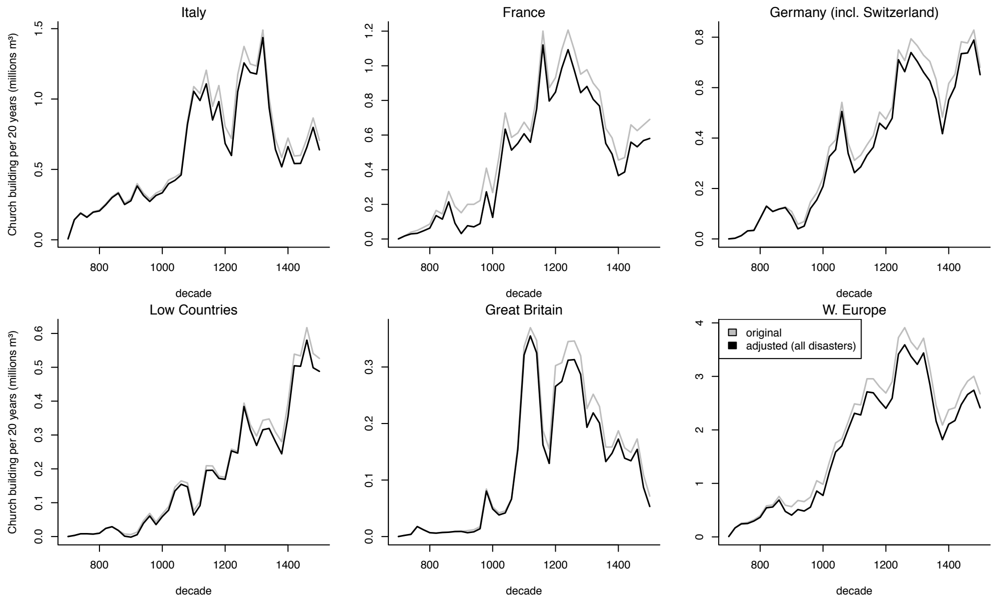

Figure A.8. *Church building in Western Europe, in millions of cubic metres per 20-year period, unadjusted (gray) and adjusted (black) for all disasters.*

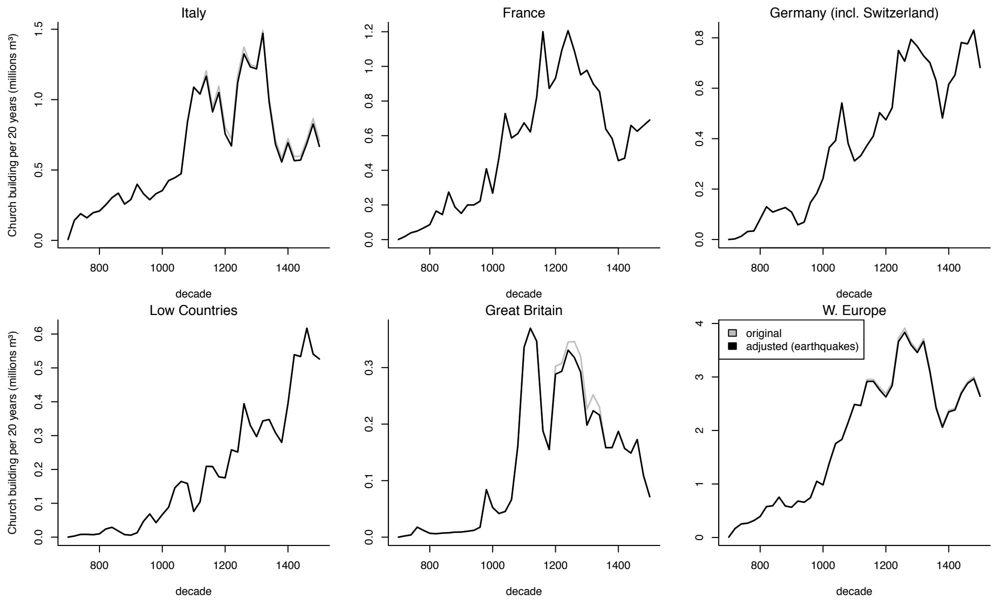

Figure A.9. *Church building in Western Europe, in millions of cubic metres per 20-year period, unadjusted (gray) and adjusted (black) for earthquakes.*

Figure A.8 and figure A.9 show the unadjusted and adjusted church-building series for all disasters and for earthquakes, respectively, both for the individual countries and for Western Europe as a whole. As expected, the disaster-adjusted series are lower. Nevertheless, the differences are small and vary little over time. For all disasters, the corrected series are about 10% lower, and only 1% lower for earthquakes (with a maximum of 2% for tectonically active Italy). The most noticeable deviation from the trend occurs in 9^{th}- and 10^{th}-century France, which is also visible in the overall Western European trends. Wars, especially Viking invasions, were the main category of disaster responsible for this. The subsequent boom in church building that began around the year 1000 may have been stimulated in part by the need and desire to make good the damage that had arisen from these earlier war-related disasters. For the remainder of the Middle Ages further stimulation may have been provided by the impact of natural and man-made disasters upon individual churches, cities and regions. Nevertheless, the estimates outlined in this appendix demonstrate that disasters were not frequent enough, and their occurrence did not vary enough over time and between regions, to impact significantly upon overall trends in church-building activity at the levels of aggregation employed in this paper. Disasters undoubtedly influenced church-building activity but it was other agencies that drove it.

References

La topographie chrétienne des cités de la Gaule dès origines à la fin du VIIe siècle. 1975–Paris [etc.]: CNRS [etc.].

Histoire générale des églises de France, Belgique, Luxembourg, Suisse. 1966. Paris: Laffont.

Allen, Robert C. 2009. *The British Industrial Revolution in Global Perspective*. New Approaches to Economic and Social History. Cambridge [etc.]: Cambridge University Press.

Álvarez-Nogal, Carlos, and Leandro Prados De La Escosura. 2013. "The Rise and Fall of Spain (1270–1850)1." *The Economic History Review* 66 (1): 1–37. doi:10.1111/j.1468-0289.2012.00656.x.

Andersen, Thomas Barnebeck, Peter Sandholt Jensen, and Christian Volmar Skovsgaard. 2016. 'The Heavy Plow and the Agricultural Revolution in Medieval Europe'. *Journal of Development Economics* 118 (January): 133–49.

Baten, Joerg, and Jan Luiten van Zanden. 2008. "Book Production and the Onset of Modern Economic Growth." *Journal of Economic Growth* 13 (3): 217–35. doi:10.1007/s10887-008-9031-9.

Belloc, Marianna, Francesco Drago, and Roberto Galbiati. 2016. "Earthquakes, Religion, and Transition to Self-Government in Italian Cities." *The Quarterly Journal of Economics* 131 (4): 1,875–1,926.

Binding, Günther. 2000. *Was ist Gotik?: eine Analyse der gotischen Kirchen in Frankreich, England und Deutschland 1140-1350*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Bloch, Mark. 1961. *Feudal Society*. Chicago: University of Chicago Press.

Bolt, Jutta, and Jan Luiten van Zanden. 2014. "The Maddison Project: Collaborative Research on Historical National Accounts." *The Economic History Review* 67 (3): 627–51. doi:10.1111/1468-0289.12032.

Bonney, Richard. 1995. *Economic Systems and State Finance: The Origins of the Modern State in Europe 13th to 18th Centuries*. Oxford: Oxford University Press.

Bosker, Maarten, and Eltjo Buringh. 2017. 'City Seeds: Geography and the Origins of the European City System'. *Journal of Urban Economics*, Urbanization in Developing Countries: Past and Present, 98 (March): 139–57.

Bosker, Maarten, Eltjo Buringh, and Jan Luiten van Zanden. 2013. "From Baghdad to London: Unraveling Urban Development in Europe, the Middle East, and North Africa, 800–1800." *Review of Economics and Statistics* 95 (4): 1418–37. doi:10.1162/REST_a_00284.

Boto Varela, Gerardo, and J. E. A. Kroesen, eds. 2016. *Romanesque Cathedrals in Mediterranean Europe: Architecture, Ritual and Urban Context*. Architectura Medii Aevi, vol. VII. Turnhout, Belgium: Brepols.

Britnell, Richard H., ed. 1997. *Pragmatic Literacy, East and West, 1200-1330*. Woodbridge: Boydell Press.

Broadberry, S. N., Bruce M. S. Campbell, Alexander Klein, Mark Overton, and Bas van Leeuwen. 2015. *British Economic Growth, 1270-1870*. New York: Cambridge University Press.

Buchowiecki, Walther. 1967. *Handbuch der Kirchen Roms: der römische Sakralbau in Geschichte und Kunst von der altchristlichen Zeit bis zur Gegenwart*. Wien.

Campbell, Bruce M. S. 2016. *The Great Transition: Climate, Disease and Society in the Late Medieval World*. Ellen McArthur Lectures 2013. Cambridge, United Kingdom; New York, New York: Cambridge University Press.

Clanchy, M. T. 1979. *From Memory to Written Record: England 1066-1307*. London: Arnold.

Collavini, Simone M. 2012. 'La Dîme Dans Le Système de Prélèvement Seigneurial En Italie: Réflexions à Partir Du Cas Toscan'. In *La Dîme, l'Église et La Société Féodale*, edited by Michel Lauwers, 12:281–308. Collection d'études Médiévales de Nice 12. Brepols Publishers. https://doi.org/10.1484/M.CEM-EB.1.101115.

Duby, Georges. 1977. *Le temps des cathédrales: l'art et la société, 980-1420*. Bibliothèque des histoires. Paris: Gallimard.

Enciclopedia italiana di scienze, lettere ed arti. 1929. Roma: Treccani.

Epstein, Stephan R. 2000. "The Rise and Fall of Italian City-States" in M. H. Hansen, ed. 2000. *A Comparative Study of Thirty City-State Cultures: An Investigation Conducted by the Copenhagen Polis Centre*. Copenhagen.

Fossier, Robert. 1968. *La Terre et Les Hommes En Picardie Jusqu'à La Fin Du XIIIe Siècle*. Paris, Louvain: B. Nauwelaerts.

Gatti, Angelo. 1913. *La Basilica Petroniana*. Bologna: Neri.

Gelman, Andrew, and Jennifer Hill. 2007. *Data Analysis Using Regression and Multilevel/Hierarchical Models*. Analytical Methods for Social Research. Cambridge etc.: Cambridge University Press.

Haase, D., J. Fink, G. Haase, R. Ruske, M. Pécsi, H. Richter, M. Altermann, and K.-D. Jäger. 2007. 'Loess in Europe—Its Spatial Distribution Based on a European Loess Map, Scale 1:2,500,000'. *Quaternary Science Reviews* 26 (9–10): 1301–12. https://doi.org/10.1016/j.quascirev.2007.02.003.

Hatcher, John. 1996. "The Great Slump of The Mid-Fifteenth Century", in Britnell, Richard, and Hatcher, John eds. 1996. *Progress and problems in medieval England: essays in honour of Edward Miller*. Cambridge University Press: Cambridge, 237-72.

Heitjan, Daniel F., and Donald B. Rubin. 1990. "Inference from Coarse Data Via Multiple Imputation with Application to Age Heaping." *Journal of the American Statistical Association* 85 (410): 304–14. doi:10.2307/2289765.

Hijmans, Robert J. 2015. *Geosphere: Spherical Trigonometry*. https://CRAN.R-project.org/package=geosphere.

Hijmans, Robert J. 2016. *Raster: Geographic Data Analysis and Modeling*. https://CRAN.R-project.org/package=raster.

Hiscock, Nigel. 2003. "The Ottonian Revival", in Hiscock, Nigel, ed. 2003. *The White Mantle of Churches: Architecture, Liturgy, and Art around* *the Millennium*. International Medieval Research 10. Art History Subseries 2. Turnhout: Brepols, 1-29.

Humphries, Jane, and Jacob Weisdorf. 2015. "The Wages of Women in England, 1260–1850." *Journal of Economic History* 75 (2): 405-47.

Humphries, Jane, and Jacob Weisdorf. Forthcoming 2019. "Unreal Wages? Real Income and Economic Growth in England, 1260-1850." *Economic Journal* 129.

Jacobsen, Werner, Leo Schaefer, and Hans Rudof Sennhauser (eds). 1991. *Vorromanische Kirchenbauten: Katalog der Denkmäler bis zum Ausgang der Ottonen. Nachtragsband*. München: Prestel.

James, John. 1972. "What Price the Cathedrals?" *Transactions of the Ancient Monuments Society* 19: 47–65.

———. 1989. *The Template-Makers of the Paris Basin: Toichological Techniques for Identifying the Pioneers of the Gothic Movement, with an Examination of Art-Historical Methodology*. Leura: West Grinstead.

Johnson, H. Thomas. 1967a. "Cathedral Building and the Medieval Economy." *Explorations in Economic History* 4 (3): 191–210.

Johnson, H. Thomas. 1967b. "Note: Relation of Building Volume and Construction Inputs." *Explorations in Entrepreneurial History* 5 (1): 103–10.

Kubach, Hans Erich, and Albert Verbeek. 1991. *Romanische Baukunst an Rhein und Maas. Katalog der vorromanischen und romanischen Denkmäler*. Deutscher Verlag für Kunstwissenschaft, Berlin.

Landes, Richard (2003) The White Mantle of Churches: Millenium Dyncamics and the Written and Architectural Record, in Nigel Hiscock, ed. (2003) The White Mantle of Churches. Turnhout: Brepols, 249-265.

Lauwers, Michel. 2012. 'Pour Une Histoire de La Dîme et Du Dominium Ecclésial'. In *La Dîme, l'Église et La Société Féodale*, edited by Michel Lauwers, 12:11–64. Collection d'études Médiévales de Nice 12. Brepols Publishers. https://doi.org/10.1484/M.CEM-EB.1.101107.

Ljungqvist, Fredrik C., and W. Tegel, P. J. Krusic, A. Seim, F. M. Gschwind, K. Haneca, F. Herzig, K. U. Heussner, J. Hofmann, D. Houbrechts, R.

Kontic, T. Kyncl, H. H. Leuschner, K. Nicolussi, C. Perrault, K. Pfeifer, M. Schmidhalter, M. Seifert, F. Walder, T. Westphal, U. Büntgen. 2018. "Linking European Building Activity with Plague History." *Journal of Archaeological Science* 98: 81-92.

Little, Roderick J. A, and Donald B. Rubin. 1987. *Statistical Analysis with Missing Data*. New York: Wiley New York.

Lopez, Robert S. 1971. *The Commercial Revolution of the Middle Ages, 950-1350*. The Economic Civilisation of Europe Series 252. Englewood Cliffs: Prentice-Hall.

McConnell, Joseph R., and Nathan J. Chellman, Andrew I. Wilson, Andreas Stohl, Monica M. Arienzo, Sabine Eckhardt, Diedrich Fritzsche, Sepp Kipfstuhl, Thomas Opel, Philip F. Place, Jørgen Peder Steffensen. 2019. "Pervasive Arctic Lead Pollution Suggests Substantial Growth in Medieval Silver Production Modulated by Plague, Climate, and Conflict." *Proceedings of the National Academy of Sciences* 116 (30): 14910-14915.

Mann, Michael. 1986. *The Sources of Social Power*. Vol. I: A history of power from the beginning to A.D. 1760. Cambridge Paperback Library. Cambridge [etc.]: Cambridge University Press.

Martinelli, Patrizia Angiolini. 1964. *Caratteristiche Architettoniche Degli Edifici Paleocristiani Di Ravenna*. Collana Di Quaderni Di Antichità Ravennati, Cristiane e Bizantine 4. Ravenna.

McEvedy, Colin, and Richard Jones. 1978. *Atlas of World Population History*. London: Allen Lane.

Morris, Richard. 1979. *Cathedrals and Abbeys of England and Wales: The Building Church, 600-1540*. Dent.

Munro, John H. (no date), 'The Phelps Brown and Hopkins "basket of consumables" commodity price series and craftsmen's wage series, 1264-1700: revised by John H. Munro', http://www.economics.utoronto.ca/munro5/ResearchData.html; Global Price and Income History Group.

OpenStreetMap contributors. 2016. *OpenStreetMap*. <http://www.openstreetmap.org/>.

Ó Carragáin, Tomás, 2010, *Churches in early medieval Ireland. Architecture, ritual and memory,* New Haven, Yale University Press.

Oswald, Friedrich, Leo Schaefer, Hans Rudolf Sennhauser, and Werner Jacobsen, eds. 1966, 1968, 1971. *Vorromanische Kirchenbauten: Katalog der Denkmäler bis zum Ausgang der Ottonen*. Veröffentlichungen des Zentralinstituts für Kunstgeschichte in München 3. München: Prestel.

Prak, Maarten. 2011. "Mega-Structures of the Middle Ages: The Construction of Religious Buildings in Europe and Asia, c. 1000–1500." *Journal of Global History* 6.3: 381-406.

Ridolfi, Leonardo. 2016. 'The French Economy in the Longue Durée. A Study on Real Wages, Working Days and Economic Performance from Louis IX to the Revolution (1250-1789)'. Ph.D. thesis, Lucca: IMT School for Advanced Studies. http://e-theses.imtlucca.it/211/1/Ridolfi_phdthesis.pdf.

Rijksdienst voor de Monumentenzorg. 1977. *Kunstreisboek voor Nederland*. Amsterdam: Van Kampen.

Rijpma, Auke, Jan Luiten Van Zanden, Eltjo Buringh, and Bruce MS Campbell. 2019. 'Reproduction Files for Church Building and the Economy'. ICPSR - Interuniversity Consortium for Political and Social Research. https://doi.org/10.3886/E115381V1.

Scott, Robert A. 2011. *The Gothic Enterprise: A Guide to Understanding the Medieval Cathedral*. Berkeley: University of California Press.

Simson, Otto Georg von, and Ernst Levy. 1956. *The Gothic Cathedral: The Origins of Gothic Architecture and the Medieval Concept of Order*. London.

Vecchi, Maurizia. 1982. *Torcello: nuove ricerche*. Studia archaeologica 34. Roma: L'Erma di Bretschneider.

Vroom, Wilhelmus Hermanus. 1981. *De financiering van de kathedraalbouw in de middeleeuwen: in het bijzonder van de dom van Utrecht*. Maarssen: Schwarz.

Vroom, Wilhelmus Hermanus. 2010. *Financing Cathedral Building in the Middle Ages: The Generosity of the Faithful*. Edited by Elizabeth H. D. Manton. Amsterdam: Amsterdam University Press.

Wood, Susan. 2006. *The Proprietary Church in the Medieval West*. Oxford etc.: Oxford University Press.

Zanden, Jan Luiten van. 2009. *The Long Road to the Industrial Revolution: The European Economy in a Global Perspective, 1000-1800*. Global Economic History Series, vol. 1. Leiden [etc.]: Brill.

van Zanden, Jan Luiten, and Bas van Leeuwen. 2012. "Persistent but Not Consistent: The Growth of National Income in Holland 1347–1807." *Explorations in Economic History* 49 (2): 119–30. doi:10.1016/j.eeh.2011.11.002.