Standardized Latin and Medieval Economic Growth

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by

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Abstract

Traditional explanations for Western Europe's demographic growth in the High Middle Ages are unable to explain the rise in per-capita income that accompanied observed population changes. Here, we examine the hypothesis that an innovation in information technology changed the optimal structure of contracts and raised the productivity of human capital. We present historical evidence for this thesis, offer a theoretical explanation based on transaction costs, and test the theory's predictions with data on urban demographic growth. We find that the information-technology hypothesis significantly increases the capacity of the neoclassical growth model to explain European economic expansion between 1000 and 1300.

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On Christmas day of the year 800, Pope Leo III crowned Charlemagne as Western Emperor in Rome. In honor of the event, Alcuin, the abbot of Saint-Martin of Tours, presented his sovereign a magnificent bible with a new, corrected Latin text.[1] For a half century between 800 and 850, the scriptorium at Tours produced two such bibles a year.[2] Each copy in codex (i.e. book) form contained 420-450 leaves of parchment written with a uniform punctuation along with a "hierarchy of scripts".[3] As this new information technology with its standardized characters, grammar, written and spoken language diffused across Western Europe between 900 and 1300, there occurred a remarkable increase in the region's population and wealth. Might there be a link between the standardization of Medieval Latin and the economic achievements of the age of the cathedrals?

Recent research suggests that something is missing in traditional accounts of medieval economic growth. It is well known that the population of medieval Europe rose steadily from the tenth century until the Black Death of the mid-fourteenth century and then recovered to regain its former peak by 1500 (McEvedy and Jones, 1978). This demographic upswing has usually been explained by three concurrent developments: first, the end of the Viking, Magyar and Muslim invasions; second, a rise in long-distance trade flows; and third, the establishment of the feudal system. Each of these factors offers a possible explanation for a rise in economic activity. However, rough estimates by Maddison (2001) along with earlier conjectures by Jones (1987, 3-4), suggest that not only total output but also *per-capita* income rose after the turn of the millennium.[4] Neither the return of peace, nor the rise of long-distance exchange nor the subcontracting of nominal

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[1] Ducket (1951, 261).
[2] Thirteen of these Bibles have survived (McKitterick, 1994, 222).
[3] Bischoff (1990, 208).
[4] Although Maddison's (2001, 244-249) estimates of GDP per capita by continent for 1000 are mere guesses, the notion that the European level was close to the subsistence level seems reasonable. His European figures by country for 1500 are perhaps more reliable. The estimates for Belgium, the Netherlands, Spain and the UK are based on production and asset data. The high Italian figure is conservative, based on stagnant rather than declining income levels from 1500 to 1820. The use of the Belgian growth rate for France is consistent with assessments of French historians. The figures for the other countries obtained by backward extrapolation from 1820 estimates are not unreasonable. Together, these data suggest that Europeans had made substantial progress in per-capita terms over the 500-year interval.

property rights can explain why in this period Europeans were able to produce considerably more output per unit of labor than had previously been possible.

One major difficulty with the traditional approaches to medieval economic growth described above is that they are not based on individual behavior. As Greif (2000) has argued, commercial expansion in medieval Europe required some means by which individuals could commit themselves to fulfil their contractual obligations. Not only individual traders but also rulers had to be constrained from reneging on their promises. In the Latin world, Greif et al. (1994) showed, it was through the formation of formal institutions – merchant-run city governments, inter-city guilds, and supra-governmental organizations such as the German Hansa, -- that an effective way was found to punish defection. In the Muslim world, according to Greif (1994), an informal coalition of Jewish traders enforced sanctions on agents who failed to respect their commitments. However, in the latter case, since there could be no contracts between members of the coalition and non-members, the opportunities for trade were limited. Why, then, did formal institutions that allowed contacts between large numbers of agents arise in Western Europe and not elsewhere? Our goal in this paper is to explore this question.

Before examining contractual relations in detail, however, let us look more closely at the tradition accounts of the demographic acceleration in Western Europe at the turn of the millennium. Perhaps the most frequently offered explanation is that the wave of invasions that had occurred between the eighth and tenth centuries finally died off. As Vikings, Magyars and Muslims ceased their raids on Latin Christendom, the region was able to recover its former prosperity. However, a *willingness* to invade Western Europe from beyond its borders seems to have continued well beyond the turn of the millennium. The Norwegians attacked England in force throughout the eleventh century. In the eleventh and twelfth centuries, the Almoravid and Almohad confederations invaded Spain successively from North Africa. During much of the thirteenth century, the Mongols raided Latin Christendom's eastern frontiers in Poland regularly. What changed between the tenth and the thirteenth centuries was the *success* rate of such attacks. The defenses built by William the Conqueror and his successors in England, the cohesiveness of the Christians in Spain and the tough

resistance of the Polish, Teutonic and Hungarian knights against the Mongols appear to have lowered the expected gains to attackers.

A second explanation for the growth of medieval cities and their hinterlands, offered by Pirenne (1927/1971, 62-75), is that beginning in the tenth century, there occurred an exogenous rise in long-distance trade. However, Verhulst (1989) has shown that the burst of urban expansion in the late ninth and tenth centuries to which Pirenne referred seems not to have been based primarily on long-distance trade. Rather, a new pattern of development emerged in the towns of the Scheldt valley and the North Sea coast. First at Bruges, then at Ghent and Antwerp, commercial and industrial zones sprang up adjacent to fortifications erected by powerful landholders. At Ghent and Antwerp, the site of these new activities was distinct from that of the earlier Carolingian urban settlement.[5] The principal function of these merchant quarters seems to have been trade with the town's clerical and military population rather than long-distance exchange.[6]

A third explanation for accelerated growth at the turn of the millennium was proposed by North (1981, 132), who focused on the emergence of feudalism. By assigning property rights over an extended territory to a single individual, this institution encouraged the cultivation of the spaces between existing settlements. As a result, bandits became less numerous, the transactions costs of exchange fell, and towns could develop. However, during the period of most rapid medieval growth, the twelfth and thirteenth centuries, feudalism began to break down in many regions. Towns such as Venice, Florence, Genoa in northern Italy and Bruges, Ghent and Ypres in the southern Netherlands obtained independence from their feudal overlords. Yet these were precisely the regions where, according to Maddison's (2001) estimates, growth appears to have been most rapid in per-capita terms.

Although these traditional explanations have shortcomings, each nevertheless contains an important kernel of truth. The observed economic expansion in Western Europe would have been impossible if foreign invaders had continually destroyed accumulated wealth, if long-distance trade had

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[5] Verhulst (1989, 26).
[6] *Ibid*., 32.

been sufficiently costly to prohibit regional specialization and if military leaders had failed to respect their subjects' property rights. Might there then be some additional factor that could account not only for the establishment of these necessary conditions for economic growth but also for a change in incentives that allowed productivity to rise? If Greif (2000) is right, the explanation might lie in some change that allowed individuals to commit more effectively to fulfil their contractual obligations. Coalitions of local military leaders could then unite to repel invaders, long-distance trading arrangements could be enforced and property rights could be respected.

In a complex society, a necessary condition for commitment is the use of an information technology that allows multiple copies of contracts to be stored at low cost and compared easily with subsequent actions by the signatories.[7] Several decades ago, Harold Innis (1950) suggested that a communications medium satisfying these conditions may have been responsible for an acceleration in Western Europe's economic growth during the later Middle Ages. "The clear, precise, and simple Carolingian minuscule," he wrote, "replaced a diversity of script and became the basis for more efficient communication."[8] By reducing the cost of storing information over time, he argued, the standardized script led to a productivity-enhancing reorganization of society.

Although this Information Technology (IT) hypothesis might seem plausible at first glance, it suffers from a number of serious shortcomings. First, the evidence submitted by Innis is circumstantial at best. His chronology is correct, but there is a long lag between the reign of Charlemagne and the economic revival of the High Middle Ages, with many causal gaps to be filled in. Second, there has been no attempt to generate refutable predictions by a theoretical examination of the effects of such an innovation on individual behavior. Third, there has been no empirical test of the hypothesis. Indeed, the poor quality of medieval data might seem to preclude such a test.

This paper proposes a more systematic study of the IT explanation of economic growth in medieval Europe. In Section I, we set out relevant historical evidence that has appeared since Innis's

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[7] Holler and Thisse (1996, 180) have observed that little research has been done on the pure coordination problems involved in developing social standards. As Adams (1996, 364) has pointed out, there is no necessary reason that a society's standards be efficient.

death in 1952. We show that there occurred a decentralization of economic activity and the creation of new educational institutions. Both developments clearly followed the standardization of written and spoken Latin. In Section II, we examine the evidence of possible links between the two sets of developments. We note the role of the monasteries in the diffusion of new technologies, the importance of Church-trained scholars in the development of civil law and the role of newly literate groups in promoting written constraints on rulers. Applying Coase's (1937) theory of the firm, we argue that a fall in the cost of storing information will lead to a decentralization of decision-making and a rise in the marginal product of human capital. Finally, in Section III, we test these ideas with data on population growth between 1000 and 1300 for 77 European towns and cities. We find that the information-technology hypothesis adds considerable explanatory power to the neoclassical growth model for this period.

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[8] Innis (1950, 148).

I. Developments to be Explained

Consider the phenomena to be explained. A first set of data concerns changes in per-capita income, the rate of urbanization, and the education system that occurred in Western Europe between 1000 and 1500. A second set of information relates to the development and diffusion of a new information technology in the period that preceded these economic changes.

(a) Economic decentralization and the rise of new educational institutions

How did the economy of Western Europe perform over the last five centuries of the Middle Ages? Maddison's (2001, 264) estimates of per-capita income for present-day European countries in 1500 are measured on the horizontal axis of Figure 1.[9] There is a considerable gap between the poorest country, Portugal, and the richest, Italy; however, all countries had income levels greater than $600 in 1990 international dollars. The latter figure is perhaps 50 per cent higher than the subsistence level (Maddison, 2001, 260). As the vertical axis shows, those countries with the highest income levels -- Italy and Belgium -- were also the most highly urbanized in the latter year.[10] Unfortunately, there are no reliable estimates of per-capita income by individual country for the period *before* 1500. However, it is generally agreed that on the whole income levels at the turn of the millennium were close to the subsistence level. Urbanization rates at that time were also low. We therefore suggest that urban growth rates might be used as a proxy for rates of increase in per-capita income in the years before 1500.

[Insert Figure 1 about here.]

Let us then look more closely at patterns of urbanization during the High Middle Ages, concentrating on the period before the Black Death. The urban population of Latin Christendom tripled

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[9] See Maddison (2001, 244-248) for an explanation of the methodology used to calculate these estimates.

[10] In the linear regression shown in Figure 1, a dummy variable with values of 1 for Portugal and Belgium and 0.5 for Spain and the Netherlands captured the importance of transit trade which would have raised urban population without contributing greatly to value added.

between the end of the first millennium and the end of the thirteenth century.[11] However, this growth did not occur through a uniform expansion of all cities but rather through a demographic decline of the largest urban centers accompanied by extremely rapid growth in many smaller towns (van Werveke, 1971). In northern Europe, for example, the three largest cities in 1000 -- Regensburg, Mainz and Laon -- together lost residents while three smaller centers -- Paris, Ghent and Cologne -- increased their total population fourfold and overtook their rivals. Similarly, south of the Alps, two of the three largest centers -- Sorrento and Rome -- lost population, their places being taken by Genoa and Milan, which also grew extremely rapidly.[12] A striking feature of this reversal of fortune is that of the cities named above, those that were large in 1000 and subsequently declined were either a short distance from the central Rhine valley or too distant to be controlled effectively from that point. As for the expanding cities, with the exception of Cologne, they lay in a 500-mile-wide ring whose inner edge was some 250 miles from the central-German city of Mainz.

Figure 2 shows the initial urban structure of Western Europe in 1000. It will be noted that the principal population centers in northern Europe were in the Carolingian heartland, within 430 km of Mainz in the middle Rhine valley. London and Venice had not been under Carolingian rule. Nor had Naples, Salerno, Sicily or most of Spain.

[Insert Figure 2 about here.]

By 1300, as Figure 3 indicates, there were many more large cities than in 1000. However, virtually all of the centers added in the intervening 300 years are to be found within a ring stretching from roughly 250 to 750 miles from Mainz. Moreover, the centers that have been removed (Laon, Mérida, Cartagena, Almería and Salerno) lie either to the interior or to the exterior of this ring.[13] In

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[11] From the Bairoch et al. (1988) estimates, the urban population of Western Europe was 1,432,000 in 1000 and 4,798,000 in 1300. Note that these figures exclude Palermo and Cordoba, for which the Bairoch estimates of 1000 are probably exaggerated.

[12] No data are available for Milan in 1000, but Genoa's population grew from 15,000 to 100,000 between 1000 and 1300 (Bairoch et al., 1988).

[13] Mérida and Cartagena were not recaptured from the Muslims until the mid-thirteenth century. Almería remained in Muslin hands until 1489.

short, much of the urban growth in the High Middle Ages occurred in this intermediate zone whose cities had previously been sparsely populated.

[Insert Figure 3 about here.]

This decentralization of economic decision-making was accompanied by the rise of new educational institutions. In 909 William the Pious, duke of Aquitaine, founded a Benedictine monastery at Cluny in the vicinity of Mâcon, just inside the eastern borders of the French kingdom. One of the conditions of the charter, unusual for its time, was the protection of the monastery from any secular interference. It was placed under the authority of the Holy See. In 927, Odo, a monk known for his asceticism, inherited the monastery, remaining its abbot until his death in 942. Odo insisted upon the strict observance of the code of Benedict of Aniane, which prohibited the eating of meat, and extended the choir office and the rules of silence. As his own reputation for sanctity spread, he was requested to help reform other monasteries, both in France and in Italy.[14]

From 17 monasteries in 937, the reform movement led by Cluny climbed to about 60 by 1049, and to as many as 2000 by 1109, scattered across France, Italy, Spain, Germany and England (Blumenthal 1988, 14). Wright (1982, 141) has suggested that the Cluniacs were among those responsible for the diffusion of the new standards developed at Tours in the preceding century. Odo was himself educated at Saint-Martin of Tours before moving to Burgundy (Wollasch, 1999, 167). One of the great concerns of the Cluniacs was the spread of literacy in Latin. Within the church, they were strong proponents of reform, insisting that clerics be adequately trained, that they be celibate, and that they obtain their positions on the basis of spiritual qualification rather than wealth or political connections.

At the end of the eleventh century, a new monastic reform movement began when a group of Benedictine monks dissatisfied with the lax observance of their order's rules founded an abbey at Cîteaux in Burgundy. By the mid-twelfth century, the Cistercian order included over 300 affiliated

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[14] Blumenthal (1988, 12-13).

abbeys whose members devoted themselves to manual labor under strict observance of the Rule of St. Benedict.

The monasteries were not the only medieval institutions that formed human capital. As the Church gradually freed itself from secular overseers in the late tenth and eleventh centuries, its archbishops and bishops required literate scribes to administer their dioceses. Accordingly, there emerged schools attached to the urban cathedrals that began to complement the monasteries as centers of intellectual life.[15] One of the principal activities in these cathedral schools was the study of canon law; that is, regulations concerning the behavior of individuals and institutions within the Catholic Church. Late in the eleventh century, legal scholars in Bologna trained in the cathedral schools rediscovered Roman civil law and began teaching it to willing students. Out of the new legal school, there gradually developed two "student universities" dedicated to a wide range of secular learning. A similar process occurred during the twelfth century in Paris, although there, the professors were clerics. Elsewhere, Montpellier and Oxford had established universities by the first decades of the thirteenth century (Verger, 1999, 257-261).

We may conclude that in the period between 1000 and 1300, Western Europe experienced rapid growth in per-capita income, decentralized urbanization and the appearance of a set of new educational institutions.

(b) The standardization of medieval Latin

In search of a possible explanation for these developments, let us now move back in time over the two centuries preceding the millennium in order to concentrate on the information technology used by medieval Europe. By the mid-eighth century, the territories in which later Latin (or Romance) was spoken were on the verge of breaking up into separate linguistic zones.[16] There was a widening gap between the spoken language of the illiterate majority and that of the few able to read and write.[17]

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[15] Reuter (1991, 247-249).
[16] Wright (1997, 267).
[17] Banniard (1995, 699).

Moreover among the latter there were considerable differences in the way Latin was written. There were at least a dozen pre-Caroline scripts. Scriptoria influenced by missionaries from the British Isles used a half uncial; those in southern Italy used a rounded form known as Beneventan; in northern Italy and France, different lower-case forms derived from the late-Roman cursive came to be used for documents and books. A given manuscript might contain cursive, uncial and half-uncial scripts according to the individual preferences of the various scribes who had prepared it.[18] As a result, the retrieval of codified information was becoming increasingly difficult.

Punctuation and spelling posed further problems in written texts. On the continent, before the late eighth century, there was no space left to indicate when a new word began.[19] Ends of sentences were frequently not marked, nor were the ends of paragraphs.[20] Further difficulties in exchanging written documents in the mid-eighth century arose from the growing frequency of irregularities in spelling. As the spoken vernacular in the Romance areas gradually diverged from classical Latin, writers were tempted to modify their spelling to reflect pronunciation changes. Instead of the correct *pago*, *robustus*, and *persona*, one might find *bago* or *paco*, *ropustus*, or *persuna*.[21] Moreover because western Romance speakers began to drop word endings from nouns, declinations began to disappear from colloquial speech.[22]

It is not surprising, then, that by 750 in Western Europe, the use of writing had declined compared to Roman and even Merovingian times; the number of charters and diplomas had sunk to "an alarming level."[23] We have no way of knowing how many documents were actually *written* in Latin in each year of the Middle Ages. However, if it may be assumed that exit hazard rates were approximately equal for all documents in existence at the beginning of a given period, then data from the *Codices latini antiquiores* adjusted for age may be used as a rough measure of the frequency of use.

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[18] Uncials were detached capital letters about an inch in height; half uncials were half the height of uncials; in cursive scripts, the letters were attached and could therefore be written more rapidly (Wright, 1982, 114; Bischoff, 1990, 83-111; Ganz (1995, 797).
[19] Saenger (1990, 448).
[20] Wright (1982, 114).
[21] Keller (1978, 151).
[22] Kontzi (1978, 408).
[23] Brown (1994, 8).

Some 1,750 Latin manuscripts have survived from the first seven centuries of the Christian era in continental Europe, for an average of 25 per decade.[24] However, only five exist for the half century between 700 and 750, for an average of one per decade. We may conclude that the use of writing for communication had declined considerably from classical antiquity. Moreover, by the mid-eighth century, lay education had become increasingly rare: in northern Europe, urban schools had completely disappeared.[25]

Under the information technology of the mid-eighth century, with oral communication supplemented by multiple writing systems, it had become costly to *store* information and retrieve it accurately over time. Essential information had to be kept in the memories of decision-makers. Although use was made of written documents, these were usually not full texts, but simply notes or lists to aid in the recall of oral commands.[26] In effect they served to transfer information from long-term to short-term memory.

During the last decades of the eighth century and the first decades of the ninth century, the primarily oral communication system of Carolingian Europe underwent a profound transformation. The changes, which occurred first in the spoken language and subsequently in the written form, were sufficiently rapid and comprehensive to suggest the presence of what Wright (1991, 106) has described as a 'conscious standardizer.' In 774, Charlemagne conquered the Lombard kingdom of northern Italy and was faced with the challenge of administering the immense territory over which he now reigned. Seven years later, in March 781, while on his way to Rome, he happened to meet the Anglo-Saxon scholar Alcuin in Parma.[27] Aware of the island churchman's reputation as a teacher, the king invited him to accept a position at the *scola palatii*, the school attached to the royal court.[28]

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[24] Ganz (1987, 26-27).
[25] Graff (1987, 40).
[26] Stock (1983, 16).
[27] Duckett (1951, 33).
[28] Before 794, it is doubtful that the palace school was an organized institution (Brown, 1994, 30).

Wright (1982) has compellingly demonstrated that Alcuin carried out Charlemagne's request by introducing a standardized pronunciation and grammar for spoken Latin that was distinct from the vernacular of northern Francia.[29] Using a method similar to that developed for drilling young seminarians at York, Alcuin insisted that each written letter be pronounced. As a result, Latin became much easier to learn for Germanic speakers who were acquiring it as a second language. Unfortunately, the resulting sounds could not be understood easily by native Romance speakers of the Carolingian realms. In effect, a new language was created -- medieval Latin.

A "correct" spoken language could be taught only if it were based on a uniform written code. After his appointment as abbot of Saint-Martin of Tours in 796, Alcuin therefore worked to promote a standardized form of written Latin.[30] Some two decades earlier, the abbey of Corbie in northwestern France had crossed the lower-case letters of the cursive with the separate spacing of half-uncials to produce a clear, economical minuscule script. This script was now polished and refined. Except for a few standard contractions, letters were detached and accordingly could easily be read aloud. At the same time, the compact size of the characters enabled scribes to write rapidly, placing more words on a page of expensive parchment than had been feasible with half uncials.

To help the reader understand the structure of a text, Carolingian scribes also standardized punctuation. Sentences began with a capital letter and ended with a period. For the first time in continental manuscripts, spaces were used to separate groups of words.[31] To indicate the rise in tone at the end of a question, a musical symbol transformed into a question mark was used.[32] In addition, a hierarchy of scripts was established. Chapter headings were in Roman capitals. The first line of a new chapter was written in half uncials. The beginning of a new paragraph was indicated by an enlarged capital that projected into the margin (indentation of paragraph beginnings was introduced only in the seventeenth century). The body of the text was in Caroline minuscule.[33]

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[29] Wright (1982, 103).
[30] Alcuin's contribution to the standardization of Latin is discussed by Wright (1982, 114-115).
[31] Saenger, 1990, 449.
[32] Bischoff (1990, 169-170).
[33] Gaur (1984, 172)

Few of these developments in written communication actually originated in the scriptorium of Tours; however, the integration of all of these best practices into a standardized form of communication can probably best be assigned to Tours during the mandates of Alcuin and his immediate successor.[34]

For the first two centuries after Charlemagne's death, Europe experienced a great decentralization of information storage, with the monasteries playing the major role. Their libraries soon surpassed any libraries of secular authorities in both the quality and quantity of documentation.[35] As the number of storage points rose with the spread of the monastic movement, a great expansion of copying activity occurred. For the ninth century, in the Carolingian Empire alone, there are over 7,000 surviving manuscripts.[36] The number of documents to have survived per decade was thus some 700 times the level of the first five decades of the preceding century.[37]

The innovations in information technology we have just seen clearly preceded the economic changes of the High Middle Ages described earlier. But is there any evidence that the two sets of events may have been related? We turn to this question in the next section.

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[34] McKitterick (1994, 222).

[35] Contreni (1995, 724-725).

[36] McKitterick (1994, 221, 235).

[37] It might be argued that one cannot compare the survival rates of documents between the eighth and ninth centuries because over this period there was a substitution of parchment for papyrus, the former having greater capacity to survive than the latter. There are two difficulties with this argument. First, as Roberts and Skeat (1983, 7) write, 'the myth that papyrus is not a durable material has been authoritatively refuted.' Papyrus has been shown to be strong, flexible and durable. Second, the substitution of papyrus by parchment in Western Europe began long before the eighth century and continued long after (Roberts and Skeat, 1983, 8). In short, the 700-fold increase in survival rates between the eighth and ninth centuries cannot be explained by the replacement of papyrus by parchment.

II. Possible Links between Information Technology and Economic Performance

In the previous section, we noted the appearance and timing of two transformations in European society during the Middle Ages. Between 100 and 1300, there was a shift in the locus of economic growth, from the center toward the periphery of Latin Christendom. This mutation was preceded by the standardization of spoken and written Latin, an innovation that reduced the cost of storing information. In this section, we will look for evidence of possible linkages running from information technology to medieval economic growth and attempt to formulate testable hypotheses.

(a) The evidence of linkages

Since nine Europeans out of ten in the year 1000 lived in the countryside; the key place to look for the impact of a new technology is in agriculture. Here the principal effect of standardized Latin appears to have been in furthering the dissemination of known techniques, with the monastic houses acting as agents of diffusion. The famous innovations of medieval agriculture -- the horse collar, the heavy plow and the three-field system -- were all known at the time of Charlemagne. Yet, as Duby has shown, their use remained limited before the second half of the twelfth century.[38] In the Romance-speaking regions, the great Benedictine monasteries, particularly those associated with the new order of Cluny, took the lead in the application of the new techniques. They systematically used written documents to evaluate application of the new methods of cultivation as they expanded the land that they cultivated.[39]

Since water power was the principal source of energy in medieval industry, much manufacturing activity took place outside the large cities. Mokyr (1990) has described the cluster of technologies that was developed in Europe between 1000 and 1300.[40] By the early twelfth century, the overshot waterwheel had been fitted with cams and cranks that allowed it to be used to drive fulling mills, breweries, wire drawers, sawmills, and cutlery grinders. With their devotion to manual labor, the

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[38] See Duby (1974, 189-194).
[39] Duby (1974, 214).
[40] Mokyr (1990, 35-55).

Cistercians played a major role in the development and diffusion of new industrial techniques during the twelfth and thirteenth centuries. For example, in twelfth-century Yorkshire, the Cistercian abbeys of Riveaulx and Fountains used water to power flour mills, bellows for ironworking, and a fulling mill for beating cloth.[41]

In these examples of the Cluniacs and the Cistercians, we see the different means by which a standardized written vehicular language could affect economic growth. First, it allowed wider and more rapid diffusion of complex information than under oral transmission. The plan for a water mill, for example, could be sent from one monastery to another. Second, the new medium allowed comparison of the results of different technologies over time and distance, permitting the selection of the most efficient procedures. Crop yields from scattered fields could be compared from year to year. Or two plans could be compared and the most effective features of each could be chosen for a new mill. Finally, systematic reference to written rules could sustain the cooperation that was necessary for economic specialization. For example, the annual meetings of the chapter of Cistercian abbots and regular visitation of daughter houses by the founding abbot allowed the order to maintain rigorous adhesion to the Benedictine code.

Standardized written and spoken vehicular language also enabled more efficient contracting in secular activities. In northern Italy, towns such as Genoa, Ferrara and Mantua grew rapidly over the tenth century.[42] A key feature of this urban revival was the replacement of oral agreements by written contracts that could be more detailed and also more easily enforced over time. The appearance of a new official, the *iudex* or literate lay notary, and an accompanying shift from oral to written law made this transformation possible.[43] The use of written documents permitted the systematic prosecution of individual merchants who failed to fulfil their contracts. By the twelfth century in northern France, there were urban *échevins* (magistrates) who signed private legal documents that were preserved in city archives. In Genoa, the generalized use of notarial acts dates from the same period.[44]

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[41] Coppack (1990, 1993).
[42] Delogu (1995, 319).
[43] Stock (1983, 41).

It did not take long for secular leaders to take advantage of the administrative capacity of literate officials. In the late tenth century, new states began to form of approximately the size of an archdiocese of the Church. (This area was perhaps the maximum that could be supervised regularly by a single person traveling on horseback.) For example, by 1050, the autonomous duchy of Normandy under Duke William II, later William I of England, was almost coterminous with the archdiocese of Rouen. William engaged Lanfranc, an Italian abbot trained as a lawyer, to advise him in Normandy and subsequently appointed him as Archbishop of Canterbury to administer his English domain during his absence. Although Flanders was somewhat smaller, its territory fell within two different metropolitan provinces. By the twelfth century, the counts of Flanders too had established their independence from the French crown. They set up their own fiscal administration and a legal system based on Roman law.

Once a considerable percentage of the aristocracy and the upper middle class could read and write Latin, it became feasible to set written constraints on the powers of the rulers themselves.[45] The Concordat of Worms of 1122 between the Pope and the German Emperor, the Treaty of Constance of 1183 between the Emperor and the Lombard League and the Magna Carta of 1215 between the English king and his barons are examples of such constraints.[46] Literacy also allowed the organization of collective sanctions against rulers who reneged on their commitments, as detailed by Greif et al. (1994).

In short, there is evidence of links between standardized Latin on the one hand and sources of productivity increase on the other. In the diffusion of the most efficient agricultural techniques, in the development of new production technologies, and in the increased use of written contracts between

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[44] Reyerson (1999, 63).

[45] The long struggle between the Latin and Muslim worlds is usually viewed as a war between religions. But the same events may also be seen as a confrontation of alternative structures of contracting. The Muslim armies were bound by word of mouth to obey their commanders. However, the Latin Christians, first in southern Italy and then in the Near East, were linked by liegeancy, a new form of structured decentralized contracts (Ganshof, 1952, 93).

[46] The Investiture Controversy between the papacy and the Holy Roman Empire over the right formally to present new bishops is often portrayed as a struggle for power between the papacy and secular rulers. However, alternatively, it may be understood as a conflict between two forms of social organization, one centralized, based on oral contract, and the other decentralized, bsed on written contract. By the Concordat of Worms of 1122, the German emperor agreed to written constraints on his power.

religious, private and public agents, the new communications medium seems to have played an important role. By the first centuries of the new millennium, an abbot, a count or even a wealthy merchant had access to far more information than the Carolingian emperor himself had had before the standardization of Latin.

(b) Contracting costs and social organization

We see, then, that improved information technology may have contributed to economic growth during the High Middle Ages. But how might we assess the importance of such effects compared with those of other possible sources of economic growth? As mentioned in the introduction, the economic expansion of this period is usually attributed to a decline in outside invasions, to a revival of long-distance trade and to the clear assignment of property rights. Are there any refutable hypotheses derived from the information-technology approach that might be tested against these other explanations?

In his analysis of the appropriate organization for production for a particular industry, Coase (1937, 390-391) explained the choice of the firm rather than an equivalent set of market relationships between autonomous agents. The primary considerations, he argued, are the costs of information and of negotiating contracts. When such costs are high, Coase suggested, it is efficient to have a single contract whereby one factor of production agrees to obey the directions of an entrepreneur. Under such circumstances, there should therefore be a preference for firms over markets in allocating resources.

In the same way, we may see that in a society as a whole, if information is costly and contracting expensive, it will be optimal for peasants and artisans to offer their labor services to a lord in exchange for access to sufficient resources to ensure their own survival. North (1981, 129) argued that the medieval manorial system resulted from transaction constraints. We would add that these transaction costs in turn depended on information technology. A vertically organized hierarchy was the optimal response to high costs of storing and retrieving information. In a spatial setting, such a hierarchical structure will imply a centralization of decision making. The efforts of distributed

agents will be coordinated through commands issued by a central authority. A corollary is that when information storage is costly, there will be a low demand for the human capital required to process information. The central decision-maker will of course require well-trained advisors, but there will be no need for highly trained information specialists to be permanently dispersed in local production centers.

If Coase's argument is correct, the introduction of an innovation that reduces the cost of storing information may be expected to lead to a restructuring of production relationships. Information that was previously stored centrally will now be reproduced for storage in multiple dispersed sites. To the extent that the new medium is standardized over a wide area, existing information will be diffused more widely than was previously possible. With information storage less costly, it will become less expensive to make comparisons with previous results or with results from some other district in order to choose the optimal procedure. Agents will tend to use the new storage technology to draw up complex contracts that can be applied reliably over time or over considerable distances. The following proposition captures this idea.

Proposition 1. A fall in the cost of storing and retrieving information will lead to a decentralization of decision-making, with contractual exchange replacing command.

As a result peripheral regions should be expected to grow more rapidly than the central core.

A centralized information processing system requires only a small number of trained agents located near the central command point. Should there be a change to a decentralized information technology, additional training will generally be necessary to prepare the larger number of agents that are required to perform the same functions at each local decision point. We therefore have the following proposition.

Proposition 2. When the cost of storing information falls, the marginal product of human capital will rise.

Transactions-cost theory therefore predicts that a fall in the cost of information storage will increase the incentives to accumulate human capital.

These two propositions appear consistent with the historical evidence presented in the first section of this paper. First, in the centuries that followed the introduction of standardized Latin, there occurred a spatial decentralization of wealth. In the eighth century, urban prosperity was limited to the towns in the central core of theCarolingian territory that benefited from tribute and plunder brought in from the periphery of the realm. In the initial centuries of the new millenium, however, these core territories stagnated, while the surrounding ring of Latin Christendom prospered.

Second, this spatial dispersion of wealth was accompanied by the appearance of a new set of decentralized educational institutions. At the time of Charlemagne, formal education in northern Europe was concentrated in the Carolingian court and in the monastic institutions and cathedrals that depended upon it (Contreni, 1995, 709-714). From the tenth century onward, however, new autonomous networks of monasteries, followed by locally administered cathedral schools and universities brought training in the new information technology into every region of Western Europe (Wollasch, 1999; Verger, 1999).

Might this standardization of a simple phonetic code over a vast area that crossed political borders and linguistic boundaries be one of the keys to explaining the economic success of Western Europe? Not only did the new medium enable people to store information over time and transmit it accurately over long distances, but also since the setup costs of joining the network were low, it encouraged the decentralization of political power. The resulting competition among alternative producing regions had an important consequence. The benefits from standardization could not be captured by a monopolistic provider.[47] Whenever a single state tried to seize control of the papacy, it could be blocked by a coalition of opposing powers.

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[47] Both McNeill (1963) and Jones (1987) have argued that political competition was one of the reasons for Europe's economic success over the last millennium. We would add that a standardized information technology was also necessary. It is interesting to note that from the ninth century, the Arab world was never able simultaneously to attain both political competition and a standardized information system.

III. An Empirical Test

The final step in our analysis is to verify whether a specification that captures the informational innovations of the Carolingian period adds to the explanatory power of the neoclassical growth model. Neoclassical growth theory posits a representative agent who chooses her savings so as to maximize her discounted future utility. In the convergence specification of Barro and Sala-i-Martin (1992), under the assumption of identical institutions in a number of regional economies, the economy of each region converges toward the same steady-state path. In Section I, we suggested that the growth of a city's population could be used as an approximate measure of the growth of its per-capita income. Making this substitution, we shall extend the standard neoclassical model to allow a test of Propositions 1 and 2 of the preceding section.

(a) The model

Let us assume the following growth equation for the population of city j:

$$d \ln Pop_j = b_0 + b_1 \ln Pop_{0j} + b_2 Port_j + b_3 Free_j + b_4 HumCap_j + u_j, \qquad (1)$$

where $d \ln Pop$ is the relative growth in the city's population over the time interval and $\ln Pop_0$ is the log of its initial population. *Port* indicates whether or not the city was a port with access to the sea and u is a random disturbance. Applying the method used by De Long and Shleifer (1993), *Free* takes the value 1 if the city had a feudal or mercantile ruler and 0 if the ruler was an absolutist monarch. Finally, *HumCap* takes on the value 1 if the city had a cathedral in 1000 and 0 if it did not.

How might the Information-Technology (IT) explanation for medieval economic growth be tested against the three other hypotheses mentioned in the introduction? The idea that urban growth in the High Middle Ages is a consequence of the end of the external invasions is captured by the effect of city's base-year population *ln Pop₀* on its subsequent growth. If the coefficient b_1 is less than zero, then in the absence of new shocks, cities that had lower-than-equilibrium populations in the year 1000 tended to recover over the following three centuries. The variable *Port* expresses Pirenne's (1927/1971)

hypothesis that an exogenous increase in inter-regional trade flows triggered medieval urban growth. Cities with access to the sea should have grown more rapidly than cities that were landlocked. North's (1981) hypothesis that the rise of feudalism reduced transactions costs by assigning residual property rights to a single or group is captured by the variable *Free*. Other things being equal, cities ruled by a local lord or a coalition of merchants should prosper more than those subject to the taxation of an absolutist monarch.

Consider now the IT hypothesis presented in the preceding section. Proposition 2 stated that the diffusion of a technology that increases the labor-elasticity of output should raise the marginal product of human capital. This idea is expressed in the human-capital variable, *HumCap*. If the estimated coefficient is greater than zero, then the new technology favored those cities with cathedrals. Proposition 1 stated that an information technology with a greater labor-elasticity of output should lead to a collapse of hierarchical organizational structures, the result being a decentralization of decision-making. Medieval society should shift from a centralized to a decentralized organizational structure. Let the variable *Ring* take on the value one if the town lies within a ring stretching from 430 to 1230 kilometers from the city of Mainz in the central Rhine valley and the value zero otherwise.[48] Now allow a city's presence in this ring to alter the coefficients of *Port*, *Free* and *HumCap* by adding three additional terms to equation (1), namely, *Ring.Port*, *Ring.Free* and *Ring.HumCap*:

$$d \ln Pop_j = b_0 + b_1 \ln Pop_{0j} + b_2 Port_j + b_2^* Ring_j.Port_j$$

$$(2)$$

$$+ b_3 Free_j + b_3^* Ring_j.Free_j + b_4 HumCap_j + b_4^* Ring_j.HumCap_j + u_j.$$

Innis's hypothesis of a decentralizing innovation suggests that the signs of the first two new coefficients, b_2^* and b_3^*, will be greater than zero. The possibilities for new trade should be greater within the ring lying between Europe's center and its periphery. In addition, the presence of a non-absolutist regime should benefit a city more if it is located in this intermediate zone.

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[48] This discontinuous specification for the spatial variable is compatible with Reuter's (1990) historical portrait of the Frankish army as a tranferer of wealth between Latin and Germanic Europe.

Together, b_4 and b_4^* provide a possible measure of the specificity of human capital, thereby offering a complementary verification of the hypothesis that a standardization of information technology was the key to medieval economic growth. If β_4^*, the coefficient of *Ring.HumCap*, is positive, then centers producing human capital that lay close to the rapidly growing ring cities had an advantage over those that produced human capital outside the ring. This result would imply a limited mobility of human capital. However, if β_4 is positive and β_4^* is zero, then centers of learning within the ring had no advantage over those outside it. Fast-growing ring cities with no cathedral, such as Bruges, Ghent, Dresden, Lepzig, Ferrara and Mantua, could recruit human capital from anywhere in Europe.

(b) Data and results

Urban population estimates for the years 1000 and 1300 come from the Bairoch et al. (1988) data set.[49] Our sample comprises 74 cities that were Roman Catholic in 1300 and for which population estimates were available for both 1000 and 1300.[50] Table 1 shows the principal characteristics of the 27 ring cities and the 47 non-ring cities.[51]

[Insert Table 1 about here.]

We first tested conventional explanations of medieval economic growth using two variants of equation (1). We began with the simplest specification having only a constant term and the initial

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[49] Since these estimates are rounded off to the nearest 1000 people, we decided to reduce imprecision by including only cities and towns having populations of 2,000 or more.

[50] This procedure unfortunately omits some of the largest cities of the year 1300, since there are no population estimates for the earlier year. Among the most important of such omissions are Milano, Firenze, Siena, Aquila, Bologna, Cremona, Perugia, Ieper, Arras, Bordeaux, Douai, Lille, Pavia and Luebeck, all of which had populations greater than 25,000 in 1300.

[51] An important question is how to value the variables *HumCap* and *Free* for the cities that were Muslim in the year 1000. Because the kingdom of Granada was still Muslim in 1300, we excluded it from our sample. Since the remaining Moorish cities had been reconquered by 1230, we assigned these cities the values of the latter year.

population, and then added the other explanatory variables. These initial results, shown in the first two columns of Table 2, suggest a variety of influences on economic growth. First, since the convergence coefficient is significantly less than zero, it would appear that an important amount of population change in the High Middle Ages was reversion to an equilibrium level perturbed by earlier shocks such as the Muslim invasions and Viking raids. Second, the trade-shock variable, *Port*, had a significant positive effect on growth. The rise in interregional commerce benefited above all those cities with access to the sea. Third, secure property rights, as indicated by the presence of a feudal or mercantile government, had a positive effect on growth. The presence of competition for mobile resources among small, neighboring states seems to have been favorable to economic expansion. However, cities with cathedral schools seem not to have grown more rapidly than towns without such institutions.[52]

[Insert Table 2 about here.]

In column (3), we add the three decentralization variables of equation (2), namely, *Ring.Port*, *Ring.Free* and *Ring.HumCap.* As explained above, these variables measure the interaction between the explanatory variables *Port*, *Free* and *HumCap* and the city's location. The eight ports within the ring grew significantly more rapidly than the 18 ports outside the ring. In addition, the eight 'free' cities within the ring had significantly faster growth than the 25 'free' cities outside the ring.

The inclusion of the decentralization variables has another effect: the impact of the human capital variable, *HumCap*, is now significant. However, since the coefficient of the interaction variable, *Ring.HumCap* is not significant, centers of human capital production within the ring grew no more rapidly than those outside it. This result suggests the presence of considerable mobility for literate people throughout the network. It is compatible with the evidence described in Section I concerning the standardization of communications media at the end of the first millennium. Those who mastered written and spoken medieval Latin would seem to have been mobile throughout Western Europe.

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[52] It might be noted that the correlation coefficients between *Port*, *Free*, and *HumCap* were low – all below 0.10.

Finally, two robustness checks in columns (4) and (5) show that the significant coefficients of column (3) are insensitive to the presence of non-significant variables and to the addition of dummy variables for location in the German core and for the presence Muslim rulers in 1000.

Our statistical results show that the hypotheses suggested by our historical analysis cannot be rejected. During the first three centuries of the new millennium, the standardization of Latin appears to have brought about a decentralization of economic decision-making and a rise in the marginal product of human capital. These economic effects of the innovation launched by the Anglo-Saxon monk Alcuin in the reign of Charlemagne would last until the early sixteenth century. At that point, Europe was shaken by the intersection of two new developments in information technology, namely printing with movable type and the standardization of the vernacular.[53]

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[53] See Blum and Dudley (2001).

Conclusion

Between 1000 and the Black Death of the fourteenth century, an acceleration in economic growth permitted Western Europe to double its population. Traditional explanations attribute this upswing to favorable shocks -- an end to external invasions, an autonomous rise in trade or the establishment of feudal institutions. Implicitly, once the effects of these shocks had worn off, the region returned to its pre-industrial Malthusian equilibrium.[54] However, Jones (1987) and Maddison (2001) have suggested that Western Europe's per-capita income rose considerably between 1000 and 1500. To the extent that these estimates are accurate, one must look elsewhere for the sources of growth in the High Middle Ages.

Innis (1950) suggested that the key to understanding the medieval European economy was a new information technology (IT) -- the Carolingian minuscule. More recently, Wright (1982, 1991) has broadened the definition of this medium to include standardized forms of both written and spoken forms of a vehicular language -- medieval Latin -- that allowed people of different dialects to communicate with one another. Unlike the cumbersome Chinese writing system, which was also standardized, medieval Latin was phonetic and required only two dozen characters. Unlike Arabic writing, which was also phonetic, medieval Latin benefited from an effective standardizer, the Anglo-Saxon cleric Alcuin (732-804).

This paper presented an argument based on transaction costs that captures this IT hypothesis. The transactions-cost model predicts that by reducing the cost of contracting, a standardization of easily decoded information technology will lead first, to a collapse of hierarchical structures and second, to an increase in the marginal productivity of human capital. During the High Middle Ages, urban growth in Western Europe appears to have followed this pattern. Rapid economic growth was concentrated within a ring that stretched from the North Sea through northern and southeastern France into northern Italy. Cities outside the ring grew to the extent that they supplied the ring cities with human capital.

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[54] For a Malthusian model of pre-industrial Europe see, for example, Galor and Weil (2000).

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Table 1. Characteristics of the sample cities

| | Carolingian | | Muslim in | | |
	Core	Ring	1000	Others	Total
No. of cities	16	27	16	15	74
Average population					
1000	17.5	13.5	72.8	14.7	27.4
1300	20.5	34.6	27.8	21.6	27.4
Average change (%)	17	157	-62	47	0
No. of ports	1	8	6	9	24
No. free	4	20	15	5	44
Bishopric or archbishopric*	12	16	12	13	53

* See the cities in bold face below.

Core cities: Aachen, Braunschweig, Erfurt, Halle, **Koeln**, **Mainz**, **Regensburg**, **Speyer**, **Trier**, **Worms**, **Liège**, **Laon**, **Metz**, **Reims, Strasbourg, Troyes**.

Ring cities: Dresden, Leipzig, Brugge, Gent, **Amiens**, **Angers**, Caen, Dijon, **Lyon**, **Marseilles**, **Paris**, **Poitiers**, Provins, **Rennes**, **Rouen**, **Tours**, Colchester, **London**, **Winchester**, **Bergamo**, Ferrara, **Genova**, Mantua, **Padova**, **Pisa**, Venezia, **Verona**.

Muslim cities in 1000: **Badajoz**, Cartagena, **Cordoba**, Ecija, **Huesca**, **Jaen,** Jerez de la frontera, Merida, **Murcia**, **Palma**, **Sevilla**, **Toledo**, **Valencia**, **Zaragoza**, **Palermo**, **Lisboa**.

Other cities: **Barcelona, Burgos, Valladolid, Narbonne, Toulouse,** Bristol**, Lincoln,** Newcastle**, Norwich, York, Dublin, Bari, Napoli, Roma, Salerno.**

Table 2. Explanations of Population Growth in West-European Cities, 1000 – 1300
(Dependent variable is $d \ln POP$)

Hypothesis Variable	(1)	(2)	(3)	(4)	(5)
CONVERGENCE					
ln *POP0*	-0.634**	-0.731**	-0.699**	-0.685**	-0.677**
	7.50	*9.48*	*9.30*	*9.00*	*7.29*
EXOGENOUS TRADE SHOCK					
Port		0.539**	0.341*	0.370*	0.442*
		3.14	*1.68*	*1.83*	*2.16*
PROPERTY RIGHTS					
Free		0.392*	1 0.104		
		2.63	*0.59*		
HUMAN CAPITAL					
HumCap		0.295	0.457*	0.382*	0.369**
		1.40	*1.97*	*2.10*	*2.05*
DECENTRALIZATION					
Ring.Port			0.585*	0.503*	0.453
			2.06	*1.86*	*1.66*
Ring.Free			0.586**	0.531**	0.596**
			2.38	*2.93*	*3.02*
Ring.HumCap			-0.219		
			0.90		
CORE					0.200
					1.04
MUSLIM					-0.038
					0.16
CONSTANT	2.02**	1.66**	1.52**	1.57**	1.64**
	8.40	*7.86*	*7.63*	*7.65*	*8.17*
Adj. R^2	0.386	0.512	0.586	0.590	0.518
No. of obs.	74	74	74	74	74

The *t*-statistics (in italics) were calculated from heteroskadistic-consistent standard errors.
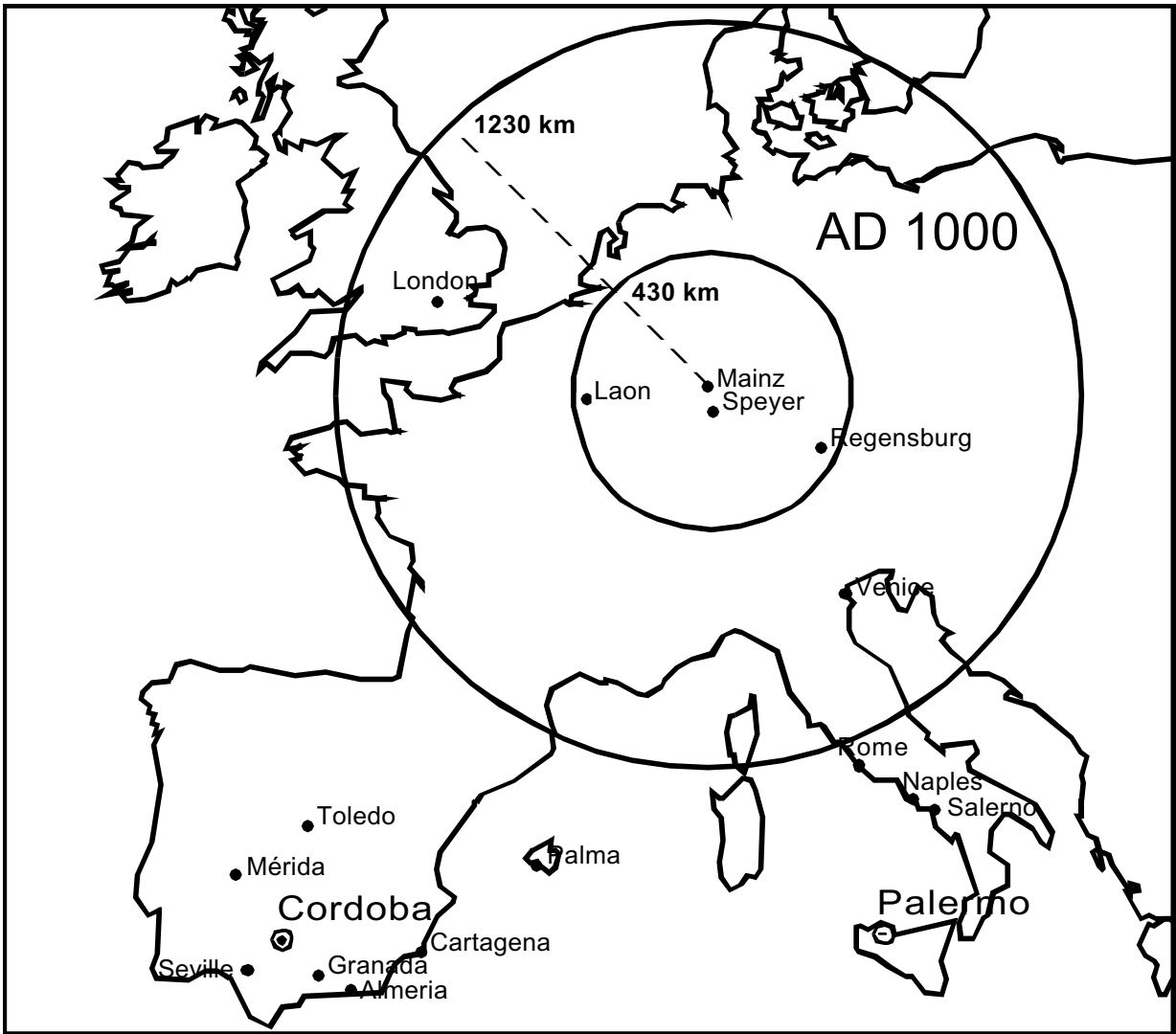 * coefficient significantly different from zero at the 5% level (one-tailed test).
** coefficient significantly different from zero at the 1% level (one-tailed test).
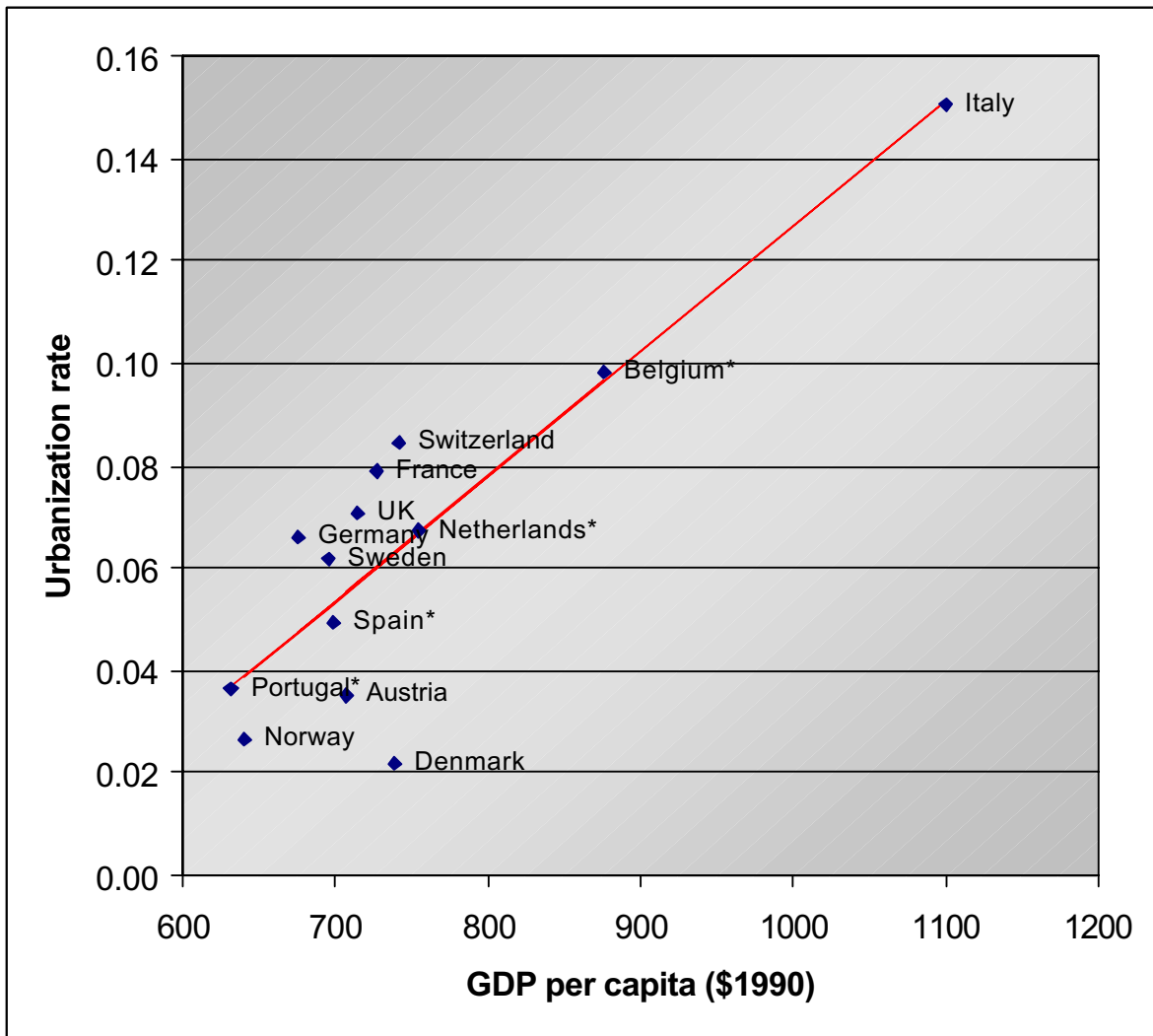
*Adujsted for the importance of transit trade
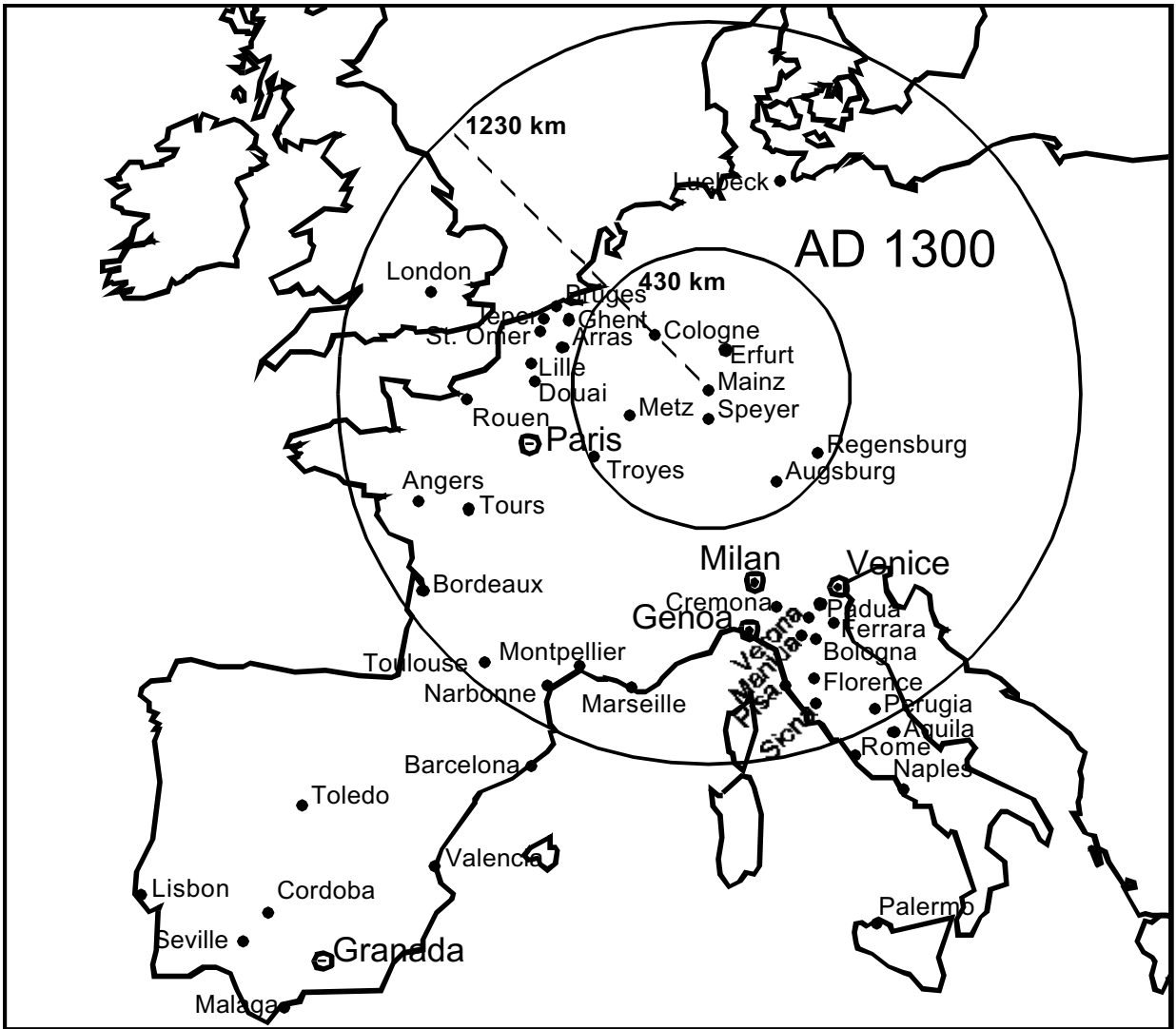Sources: Bairoch (1988), Maddison (2001)

Figure 1. Per-capita income and urbanization rate, 1500

Source: Bairoch et al. (1988)

•   25,000 -99,000   ◎   100,000 and over

Figure 2. Cities of Western Europe with populations of 25,000 or over in AD 1000

Source: Bairoch et al. (1988)

• 25,000 - 99,000   ⬡ 100,000 and over

Figure 3. Cities of Western Europe with populations of 25,000 or over in AD 1300