DISCOVERING ARTIFICIAL ECONOMICS

How Agents Learn and Economies Evolve

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The Ancient Art of Learning-by-Circulating

"If everything occurred at the same time there would be no development.
If everything existed in the same place there could be no particularity.
Only space makes possible the particular which then unfolds in time."
AUGUST LÖSCH

{A}Pirenne's Hypothesis{/A}

European history has always been a touchy subject. But few historians can match the stormy heights reached by the Belgian, Henri Pirenne. At the heart of this enduring controversy are some of Pirenne's ideas concerning the transition of Europe from classical antiquity to medieval civilization.[1] One fertile thought sparking widespread criticism was his explanation for the revival of medieval towns in Middle Europe during the tenth and eleventh centuries. Another dealt with a broader issue: the general relationship between Roman antiquity and the First Europe.

To see why Pirenne upset the tranquility of the historian's world, we need only examine his first idea. Instead of agreeing with the popular view that the rebirth of urban Europe was triggered by technological change, or by the transfer of political authority from the feudal lords to the communities, Pirenne steered a very different course. He claimed that the impact of Islamic forces in the seventh and eighth centuries destroyed the commercial unity of the Mediterranean, thereby ending the Roman world in economic terms and ushering in a strikingly different civilization in the Carolingian era. Also, he asserted that the unusually fast growth of population and human settlements which

[1] Pirenne's hypothesis is laid out in Pirenne (1925, 1936). Its controversial nature has prompted discussion in many forums. Refreshingly unbiased critiques can be found in Bloch (1962), and North and Thomas (1973). A summary of the suggested defects in the hypothesis can be found in Riising (1952).

followed in the High Middle Ages (1000-1300) was triggered by an expansion of trade over longer distances.

You may be wondering how Pirenne's idea relates to our discussion of adaptive learning and complex economies? The first point to note is that the lynch pin of his idea was the pursuit of profits by trading in scarce goods at novel locations. In other words, his theory of revival was an interactive one. Trade over very long distances was possible only after key transportation routes were opened up again and the safety of travellers could be guaranteed. Only then could merchants circulate freely and expand their trading area. The incentive for such an expansion of trade must have been great, since potential profits were enormous.

A second key factor was that Pirenne saw the revival of urban Europe as a direct response to an *external* stimulus – trade with distant places scattered around the Mediterranean. By way of contrast, the bevy of scholars who opposed him chose to focus almost exclusively upon non-interactive factors internal to European society. Pirenne sensed the importance of circulation and interaction as catalysts of change. His main critics did not.

The third point to note was that Pirenne's explanation was a *qualitative* one. It focused on the phase transition from a weakly-interactive to a strongly-interactive economic system. By arguing that European settlements were transformed by an escalation in trade over longer distances, perhaps unwittingly he stepped into the realm of nonlinear analysis. His thesis was one of positive feedbacks: more merchants meant more circulation, more exchange, and higher profits which, in turn, meant even more merchants. There's a fascinating saga of coevolution to be be unveiled in this chapter. Like today's apostles of complexity and self-organization, Henri Pirenne seems to have sensed the importance of phase transitions associated with the sudden cross-linking of many small, isolated clusters to form a larger, well-connected cluster.

Can we be sure that Europe was in a weakly-interactive state prior to this transition? There's plenty of evidence to suggest that the high risks and costs of transporting goods during the Carolingian period contributed to urban stagnation across western Europe. Norseman controlled the Baltic and the North Sea, making it dangerous

even to live near any waterways. Moslems and Magyars invaded frequently. The dangers of travel by sea or land forced Europeans to refrain from exchanging goods over longer distances. Although it's difficult to confirm the number of European inhabitants at that time, the plagues of the sixth and seventh centuries caused great loss of life. Population levels dropped significantly between the sixth and the ninth centuries (see Table 4.1). Carolingian Europe was thus a very sparsely populated continent.

[Table 4.1 near here]

This doesn't mean that people lived alone or far away from one another. Rather it meant that the villages, or groups of villages, were mostly self-contained; small oases of cultivated land in a largely uncultivated continent. Carolingian Europe was a primitive agrarian society, isolated and underdeveloped. Towns were contained within castle walls and self-sufficient manors, mostly willing to make do with the fruits of their surrounding land and forests. They were populated mainly by farmers and townspeople, the former tilling the land and the latter crafting or distributing simple products from the forests and elsewhere. Given the risks of travel overland, there wouldn't have been much opportunity for different villages to exchange goods over long distances. We may conclude that Carolingian Europe was indeed a weakly-interactive economic system.

Such a feudal state could hardly remain forever. Popular goods like salt, metals and wine were not produced locally and had to be found. If such things could not be obtained by war and plunder, the last resort was to engage in trade over longer distances. Some trade was carried on continuously by the Oriental merchants, who sailed their ships on the Mediterranean (as they had done in Roman times) or travelled by boat up and down the great western and central European rivers - from the Loire to the Rhine and the Elbe. Together with their countless tributaries, these rivers were key transport links rather than barriers. Many "would-be" entrepreneurs of the day must have seen the potential for greater trade over longer distances.

At a time when long-distance commerce was insignificant and money still a rarity, suddenly the circulation of goods and merchants intensified. All forms of trade rose

significantly, but that over longer distances grew most of all. Interestingly, this sudden expansion of trade occurred at the same time as large increases in the urban population. Were these two factors intimately related, as Pirenne would have us believe? We know now that the potential gains from trade attracted more people into the riskier, but potentially-more-rewarding mercantile activity. Was this why many larger towns grew suddenly and explosively? Convincing answers to these questions would certainly help to resolve the debate surrounding Pirenne's hypothesis once and for all.

{A}The Mees Analysis{/A}

A fascinating analytical sketch which shed some light on these questions was devised by the mathematician, Alistair Mees.[2] He analysed the effect of increasing trade opportunities on urban and rural populations. Mees' central idea was that each person knows whether the city or the countryside is more attractive as a place to live and work. Then they tend to move between the two according to their preferences. While being far from the mainstream of economic analysis at the time, his example of employment dynamics illustrates some qualitative features of the world of morphogenesis; our principal area of interest throughout this book. Without delving too deeply into the mathematical intricacies, it's worthwhile exploring some key features of his analysis.

As we mentioned earlier, Medieval Europe's regional populations consisted mostly of farmers and city merchants. Let's call the farmers group f and the city merchants group c. Also there were a few land owners and travelling merchants (the "Orientals"), but they were vastly outnumbered by farmers and city merchants. Furthermore, the self-sufficient nature of most towns and villages in the Carolingian era meant that each region's total population (farmers plus city merchants) remained about constant.

Mees' fundamental idea was that the attractiveness of belonging to either group f or group c could change quite rapidly. Over a period of several years, naturally people

[2] A full description of this analysis can be found in Mees (1975).

would try to move from a less attractive situation to a more attractive one.[3] In an isolated region, the farmers and city merchants depend solely on each other for their needs. Thus the attractiveness of both groups at any time depends only on the size of each group in relation to the demand for their products. Simple economics dictates that when only a few people are producing a *popular* commodity, there'll be excess demand for this commodity. Thus its producers can charge higher prices and earn a higher income. For example, if there are very few city merchants but strong demand for city goods, then it's worthwhile becoming a city merchant.

The dynamics of the situation have been illustrated in Figure 4.1. We'll call the point E_m a stable equilibrium point, corresponding to a mixed region employing both farmers and city merchants. It's stable because, on either side of this point, small changes in each group's working population will not alter markedly the relative attractiveness of either group. You can think of E_m as a fulcrum, where the relative attractiveness of choosing farming ahead of being a city merchant is zero. You're equally happy with either choice.

[Fig. 4.1 near here]

The points E_c and E_f are unstable. For example, a pure farming population puts us at the point E_f. Any small decrease in the farming population sets in motion a self-perpetuating decline in the population of farmers. Because there's demand for both products, complete specialization in farming (point E_f) or city merchandising (point E_c) will always be inferior to a balanced mix of farmers and city merchants (point E_m).

From this simple dynamic analysis, we can see how a stable and self-sufficient economy could be attained; with a balanced mix of farmers and city merchants. Such an isolated state of affairs would have been typical of the autarkic, manor-bound economies dotted across the Carolingian landscape. To retain this delicate state of balance, however,

[3] The notion of attractivenees invoked here is purely one of potential income, thus avoiding more abstract notions like standard of living or perceived opportunities.

the region in question must remain isolated from other regions. If, for any reason, trading opportunities with other towns become easier, the balanced mix of farmers and city merchants could easily disappear.

How might trading opportunities become easier? Safer transportation routes would be one possibility, because they improve the likelihood of successful passage and thus lower transportation costs. If they felt that the risks and costs of travel over longer distances were reasonable, some enterprising city merchants might try to visit a few more distant places where they could sell their goods at higher prices. Such a quest for distant markets would be even more compelling once local demand had been satisfied. If the more adventurous merchants reported profitable trading ventures, then other merchants would surely follow in their footsteps. A positive feedback loop could be set in motion. Suddenly we're confronted with the carrot of an increasing returns economy.

What would happen to our stable, self-sufficient, economy under such conditions? In graphical terms, a rise in the relative attractiveness of being a city merchant vis-à-vis farming can be seen as a change in the shape of the curve between E_c and E_m. It begins to flatten out as the attractions of farming diminish and the appeal of long-distance trading grows. Eventually a stage is reached where the curve between E_c and E_f drops below the axis. This heralds a major qualitative change, leading to an entirely different kind of economy. Our stable equilibrium point E_m disappears and the previously unstable E_c becomes stable. Everyone moves from the country to the city, farming dies out and the region then specializes in city activities.

[Fig. 4.2 near here]

The above analysis is hardly textbook economics. Most of the inspiration for this kind of dynamic analysis comes from outside the social sciences.[4] In a dynamic world, one learns to expect the unexpected. Phenomena like disequilibria, nonlinearity and

[4] Three pioneers of non-equilibrium systems – all of whom have emphasized the importance of self-organizing processes – are Hermann Haken, Gregoire Nicolis and Ilya Prigogine. For glimpses into their early work, see Haken (1977) and Nicolis and Prigogine (1977) .

instability are commonplace. It's something of an exaggeration of course, since farming in and around the key trading centres of Europe never died out completely. Nevertheless, Mees' illustration is fascinating because it shows us that abrupt changes are not just curiosities of the modern world. Sudden, unexpected structural changes to the economy have been going on since the Middle Ages, if not earlier.

The point to grasp is that a change in the relative attractiveness of one economic activity in comparison with another can have unexpected consequences. The economy may self-organize. If conditions had been different - for example, if farming had been particularly profitable in comparison with city activities - then the line between E_c and E_f could have shifted above the axis and a pure farming economy would have emerged. On the other hand, if the city merchants' interest in long-distance trade had been minimal, then the original weakly-interactive (mixed) economy might have remained. Simplicity and predictability might have endured forever.

At the height of the Feudal period, the difficulties and dangers of travel in Europe meant that transport costs were relatively high in comparison with the value of most agricultural goods. Thus Mees reasoned that farmers were less likely to engage in trade than city merchants, and the catastrophic shift depicted in his analysis was more likely to occur. In places where the population of city merchants was small, the mixed-economy equilibrium E_m would have prevailed. By way of contrast, cities much larger than the norm could have appeared rather suddenly as trade costs reduced through a critical range and trade flows grew accordingly.

Mees' explanation for the simultaneity of urban growth and the escalation of trade endorses Pirenne's hypothesis. Slow improvements to the transport system led to greater circulation by merchants, more specialization and more trade. A growing band of interacting merchants created a qualitatively different economic landscape. Suddenly some regions specialized in city goods, others in agricultural commodities. Europe's economy self-organized. A shift away from self-sufficiency towards greater specialization and trade undermined the efficiency of the old feudal and manorial system, setting in motion an explosive positive feedback loop (see Figure 4.3).

[Fig. 4.3 near here]

If each region's population is also assumed to vary with its attractiveness, Mees argued that overall growth can also be explained.[5] Additional arguments based on increasing returns to scale and agglomeration can be drawn upon to show why cities expanded much more rapidly than their rural surroundings. Some of these arguments were discussed in Chapter 1, so we'll bypass them here.

{A}Learning-By-Circulating{/A}

The city merchant seemed to be the key architect of this dramatic change in the economic landscape, so let's take a closer look at his decision problem. Like any entrepreneur, he sought to profit by buying goods in places where supply was abundant and prices relatively low, with the aim of selling them in places where demand was strong and higher prices could be charged. To decide on the viability of such an undertaking for each tradeable product, he would need to know or estimate (1) the purchase price and the selling price in various places, and (2) all the additional costs to transport and protect the product between the two places involved.

The periodic peddling of goods by the "Oriental Traders" was slanted towards the silks of Constantinople and the spices of the Indies. Hardly surprising since only goods of great rarity and profitability could withstand the burden of the high transportation costs and risks of loss that must have beset the early merchants. The Venetians, on the other hand, were quick to realize that trade could be profitable for a variety of goods in various places. Slaves, in particular, could be sold profitably in Constantinople. Then a host of luxury goods could be brought back from the East. Further profits may accrue if various Italian goods could be sold for profit in the East and elsewhere.

[5] Some economic historians have argued that the development and expansion of Europe's market economy in this period was fueled by population growth and its redistribution over space: see, for example, North and Thomas (1973). Putting the emphasis on migration instead of trade merely reinforce Mees' argument, since both are external sources of increased interaction.

Why did the Venetians excel as merchants? Unique topographical conditions, outstanding seafaring skills and plenty of innovative entrepreneurship may have been the answer. For the typical Carolingian town, their protected area of cultivated land surrounding the manor meant everything. But commerce stood for nothing. Venice was a striking exception. Bereft of arable land, its very survival rested purely on commerce. The early fish-eating, marsh-dwelling Veneti gathered and processed salt, then sought other markets where it might be sold for profit. One such market was found in Constantinople.

The search for new markets, where a product is unfamiliar, is not just an act of courage. Nor is it simply revealing a natural talent for sniffing out entrepreneurial profit. A rare, unfamiliar product is valued by purchasers much as gifts of nature or pictures by old masters.[6] Often its price may be determined without regard to the actual cost. Monopolistic profit potentials can be enormous. Despite the innumerable difficulties of the trading venture, the Venetian merchants realized that the rewards could be exceptional.

As the final decade of the tenth century began, Venice prospered under the strong hand of the statesman, warrior and diplomatic genius, Pietro Orseolo II. In less than a year, he negotiated commercial terms with Basil II in Constantinople that guaranteed admittance of Venetian goods at tariffs far lower than those imposed on foreign merchandise in general. By reducing the total transaction costs for Venetian goods sold in Constantinople, the Doge established a major comparative advantage for Venetians trading in the Greek city. Among the bevy of trading centres dotted around the Mediterranean, Venice stood out as a key node, second in status only to Constantinople.

Imagine the thoughts of an enterprising Venetian merchant. Foremost in his mind might have been the idea of trading in a bundle of goods that guaranteed profitability regardless of the trading route traversed. Venetian salt was highly regarded by both Muslim and Christian alike. Constantinople supplied many luxury goods such as silk cloth, gold and silver plate, carved ivory, jewelry, and semi-precious stones. It also

[6] See Schumpeter (1934).

produced more pedestrian commodities such as linen, cotton cloth, and armaments. Sicilian grain could be bought in Palermo and sold for profit in many other ports.

From a host of possibilities, this enterprising merchant decided: (1) to buy salt in Venice for sale in Constantinople, (2) to buy a few luxury goods in Constantinople for sale in Palermo or Venice, and (3) to buy grain in Palermo for sale in Venice. In view of the risks associated with each leg of his journey, how could the merchant ensure that such a voyage would be profitable? He couldn't. But he would have tried to estimate it. How? The longer the journey, the greater the prospect of profit in an era when prices were largely dependent on the rarity of the imported goods. But how could economic determinism prevail when rarity and insecurity increased with distance? Surely the outcome must have been at the mercy of some unwelcome chance events?

[Fig. 4.4 near here]

Imagine for a moment that you, the reader, are this merchant. You've studied a map of the area and realize that the three cities form a simple *network economy*. Each of the cities is a "node" in this network and each leg of your journey serves as a "link" between a pair of nodes. You've also realized that you're searching for a profitable compromise between economic necessities and some elements of chance. Setting off on your maiden voyage to Constantinople, your spirits and profit expectations are high, perhaps even a little unrealistic. You see yourself as an enterprising explorer venturing into unchartered territory. Admittedly your cost calculations and price estimates are crude and approximate, but you sense that your mercantile skills will carry you through. Thanks to good fortune at sea, and the temporary monopoly enjoyed by early entrants in a new market, you manage to earn a healthy profit on your first voyage.

On this maiden voyage, intuition was your guide. But now you have the benefit of a little hindsight. Upon comparing your cost and price expectations with those realized on your first voyage, you realize just how wide of the mark they were. So you decide to record all this economic information in a diary. Your mind is "set" on developing an accounting system which will enhance your ability to estimate costs, prices and

profitability more accurately in the future.[7] A detailed record could even help you to become an expert on each of the economic links: Venice-Constantinople, Constantinople-Palermo and Palermo-Venice.

Your diary records the historical prices, $p_i(t)$, prevailing in each city i on a particular date t, but only for the goods forming part of your chosen bundle of tradeable goods - say salt, silks, spices and grain. It also records the transaction costs, $c_{ij}(t)$, of transporting and protecting them between cities i and j, as well as other data pertaining to the reliability of each leg of your journey. The profitability of each leg, i-j, as well as overall profitability, can now be calculated. All information is based on your own trading experiences in each city. It's your personal diary.

The diary provides enough information to convince you to alter your bundle of goods before your next voyage. Upon checking the profit achieved on each leg of your latest journey, for example, you see that spices produced your most profitable return. So you decide next time to buy more spices in Constantinople. By way of contrast, you note that the profit from selling Sicilian grain in Venice was marginal. Yet grain could be sold at a much higher price in Constantinople. So you decide to call in at Palermo on your way to Constantinople to buy grain. Each of the entries in your diary provides "food for thought" in terms of setting the agenda for your next journey.

But the real value of your diary lies in the fact that it helps you to build a crude mental model of this three-city network economy. Your mental model is relatively simple. It consists of a few basic rules. For example, experience has taught you to apply the following two rules for profitable trade:

> IF p_j (sell) > p_i (buy) + c_{ij} (trade), for a marketable product,
> THEN that product should be traded.

> IF p_j (sell) > p_i (buy) + c_{ij} (trade), summed over all products chosen,
> THEN that bundle of products should be traded.

[7] Pirenne (1936) suggests that a "clerk" formed part of the equipment of every merchant ship sailing abroad, and from this we can infer that shipowners and seafaring merchants of that era had learnt to keep accounts and to despatch letters to their correspondents.

In other words, as you know that you can sell Venetian salt in Constantinople or Palermo at a price, p_j (sell), which covers all the costs incurred - namely the purchase price, p_i (buy), plus all transaction costs, c_{ij} (trade) - then salt should be traded. If you can sell your bundle of different goods at prices which cover the total costs of purchasing and transporting them to their point of sale, then your chosen bundle of goods can be profitable over the whole journey and should be traded.[8] Applying these rules to various combinations of goods enables you to form a picture in your mind of those goods which can be traded most profitably between various nodes of the network.

These aren't the only condition-action rules which form part of your mental model. You've also learnt to rank the goods in terms of their contribution to overall profitability. For example, you invoke the following rule:

> IF unit profits from one product exceed those of another product,
> THEN increase your share of trade in the first product.

and

> IF unit profits on leg i-j of your journey exceed those on leg i-k,
> THEN increase your share of trade on leg i-j.

Furthermore, you've also learnt to chart the safest course in order to reduce the risks of inclement weather or piracy. This leads to a set of rules of a different kind:[9]

> IF my ship sails too close to the Adriatic coastline,

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[8] The above rules could also be used to specify a general trading network equilibrium for any pair of regions and any commodity. A discussion of this kind of equilibrium model can be found in Andersson (1995).

[9] In the literature on induction, the above rules have been called *diachronic* because they specify the manner in which the environment may be expected to change over time. Diachronic rules may be divided into two classes: *predictor* rules, which tell the agent what to expect in the future, and *effector* rules, which cause the agent to act on the environment. In our chosen economic environment, the set of conditions relating to route security are predictor rules whereas those pertaining to profitability are effector rules. For a comprehensive discussion of mental models as rule systems, see Holland, Holyoak, Nisbett and Thagard (1986).

THEN there's a risk of attack by Dalmatian pirates.

or

IF my ship joins in convoy with other ships,
THEN the risks of piracy will be reduced.

and

IF my ship sets sail in winter,
THEN the winds may destroy it completely.

Satisfaction of each of the above rules depends on the sophistification of your know-ware. Earlier voyages have taught you to apply these rules in a certain order. If trading profits are large, you're happy with your decision-making skills. Gradually you build up confidence in your ability to select goods, vessels and routes wisely. You even acquire the knowhow to estimate potential profits on each link.

After a few more voyages, you find that your cost and price estimates are much closer to the mark on each link. Improved risk assessment has also followed from the experience accumulated during each voyage. With the benefit of this additional hindsight, your deductive abilities can now come into play more reliably. But you will always need to display adaptive behaviour on certain occasions. For example, your know-whether skills may cause you to modify your chosen route in response to news of piracy or inclement weather on a particular leg of a journey.

Eventually, your cumulative know-ware allows you to expand your "rule-of-thumb" hypotheses for the profitability of pairwise trades on each link into a crude mental model of the profitability and risk associated with trading across the whole three-city economy. Then you find that certain combinations of goods, city pairs, voyage routes and sailing dates consistently turn out to be the most profitable. Because you've gathered this knowledge during your own voyages, only you and the members of your *hanse* or *gild* have access to it. It's privileged know-ware, the fruits of learning-by-circulating. This inside knowledge allows you to decide more confidently on a preferred strategy for future trading ventures.

The Medieval merchant gained valuable feedback from his experiences during each voyage: the swiftness and riskiness of his chosen route, the wisdom of his chosen bundle of goods, and the profitability of his whole trading strategy. This feedback would have strengthened or weakened his belief in any crude mental model of the three-city economy which he may have developed. Sometimes he would have altered his preferred route if it proved to be too risky or if he happened to hear of a safer or quicker route from other merchants. Naturally he would have altered his bundle of goods if some of them failed to achieve his profit expectations, replacing them with more popular or profitable ones.

There's little doubt that seafaring merchants lacked information about the prevailing economic circumstances. Faced with these uncertainties, undoubtedly they would have been obliged to take a "seat-of-the-pants" approach. For example, they may have simply "papered over" the gaps in their own knowledge. By this we mean that they may have acted like crude economic statisticians, guessing and testing and discarding simple expectational models to fill these gaps. In this way, they could have imagined a more general possibility from their own partial picture of the state of affairs. As logic, this kind of behaviour is inductive.

But the inductive process of learning-by-circulating was never a purely *individual* experience. The diverse perils by which merchants were threatened compelled them to travel in armed convoys. Security could only be had at the price of force, and force was only to be obtained by union. Whatever these unions were called - *frairies, charites, compagnies, gilds* or *hanses*, the reality was the same.[10] Troops of merchants banded together, usually bound by an oath of fidelity. A spirit of close solidarity and unity of purpose prevailed. Often the merchandise was bought and sold in common and the profits divided *pro rata* according to each man's share. The same thing happened in both Italy and the Low Countries, the two regions where commerce was developing most rapidly.

[10] See Pirenne (1936), page 94.

Thus the seeds of coevolutionary learning were sown. A number of specialized *hanses* soon emerged.[11] Merchants' beliefs and hypotheses about trading conditions were constantly formulated, tested and refined amidst the collective experiences of each hanse. As time went on, this learning process led to better-educated merchants, who eventually were able to conduct much of their affairs by correspondence. The need to convoy merchandise grew less urgent and commercial life became more stationary. Merchants could then turn their attention to local issues. In many Italian and German towns, the gilds and hanses had secured a share of urban government by the thirteenth and fourteenth centuries.

According to Pirenne, most merchants possessed a more-or-less advanced degree of instruction.[12] It was this initiative that led to Latin replacing the vulgar tongues used in earlier dealings. In Italy, the practice of writing was so much a part of commercial life that the keeping of books was widespread in the thirteenth century. Soon after it was adopted throughout Europe. Leading scholars wrote works designed to assist the merchants in their endeavours. For example, Leonardo Fibonacci of Pisa composed a treatise on arithmetic for the use of merchants. We'll return to his fascinating sequence of numbers in Chapter 7.

Small wonder that the status of merchants grew remarkably quickly. Out of the ashes of the Carolingian economy, this new class of economic powermongers arose. Entrepreneurial merchants became the economic leaders of the Medieval period. They were upwardly mobile, became aristocrats, and formed powerful patriciates to govern the great trading cities. Even the higher nobility eventually "turned merchant," as the great trading cities grew and prospered to an unprecedented extent. At the start of the eleventh century, who could have possibly foreseen that long-distance merchants would become the doyen of society.

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[11] In the valley of the Seine, it was the Paris Hanse of water merchants. In Flanders, an association of city gilds engaged in trade with England came to be known as the London Hanse. In Italy, the attraction of the Champagne fairs led to the formation of the *Universitas mercatorum Italiae nundinas Campaniae ac regni Franciae frequentantium*. For further details, see Pirenne (1936), pages 95-96.

[12] See Pirenne (1936), page 124.

As Pirenne suggested: "a state of mind was being gradually created which was particularly favourable to the progress of international trade and labour."[13] Founded on learning-by-circulating, long-distance trading proved to be handsomely rewarding, especially for the pioneering *gilds* and *hanses* – the ultimate explorers in our terminology. They carved out a new niche for themselves and their cities. They also "locked-in" competitive advantages by dint of their personal experiences and accrued knowledge. Theirs was an increasing returns economy. But most important of all was the fact that their learning-by-circulating contributed to the emergence of a new urban hierarchy in Europe. Like self-starting nodes in a random graph, the leading mercantile towns of Venice, Genoa and Bruges catapulted up the urban hierarchy (see Table 4.2).

[Table 4.2 near here]

{A}Big Buttons and a Critical Thread{/A}

During the eleventh and twelth centuries, the towns of northern Italy, central Germany, and Flanders became thriving centres of commerce, as population and trade continued to grow. As if part of an autocatalytic network, two "clusters of buttons" began to emerge as the "threads" between them materialized. Surprisingly enough, trade in Northern Europe received a major stimulus from the Vikings. Pirenne suggested that "The Vikings, in fact, were pirates, and piracy is the first stage of commerce."[14] These Norsemen were so well versed in the construction of seaworthy ships and their navigation in distant waters, that when their raids ceased, they simply became merchants.

By dint of its strategic role as a centre for the medieval cloth trade, together with its convenient coastal location, Flanders became the key trading web in Northern Europe. Some merchants threaded their way to Flanders from the interior parts of Europe, along the valleys of the Rhine, the Meuse and the Scheldt. Others threaded a path across from

[13] See Pirenne (1936), page 94.

[14] See Pirenne (1936), page 22.

the British Isles. Still others (mainly German merchants) used Flanders as the entrepot between east and west. Bruges fulfilled a similar role in northern Europe to that of Venice in the south. It was even nicknamed "the Venice of the North"!

Thus emerged two great European clusters of commercial activity - one in the north on the shores of the Baltic and the North seas, the other in the south on the shores of the Mediterranean and Adriatic seas. In between lay a central land mass mostly in the grip of feudalism. But commerce is nothing if not contagious. There's a craving for adventure and the love of profit. The incentive for threading a continuous link between these two vibrant trading areas could hardly have been stronger. Could one giant trading web emerge? Self-organization then lent a hand and wove its now familiar spell.

[Fig. 4.5 near here]

The final thread in this giant web of commerce started in Flanders, ran through Champagne and the Rhineland, down the Rhone valley to Liguria and Lombardy. From there the Pisans, Genoese and Venetians sailed to the eastern Mediterranean. Later the German plains boomed while Baltic and North Sea trade peaked under the direction of the German Hanse. The key threads of Europe's network economy were woven into a vibrant new tapestry.

Nestled centrally within this giant web of commerce, one particular "button" stood out as the meetingplace between north and south. What better place for the Flemish cloth to meet the buyers from Lombardy and Tuscany than at the famous fairs of Champagne. Fairs emphasized the episodic character of trade over longer distances. Each country sought its own.[15] But above all they prospered in France. Two great French centres were universally famous in this respect: the Ile-de-France and Champagne-Brie. But the patterns of circulation threaded by long-distance merchants meant that only the Champagne fairs in the twelfth and thirteenth centuries attracted merchants from the whole of Europe.

The Champagne fairs became the "embryonic clearing-houses" of the European economy. Four towns in the area developed a rotating system of six fairs each year.[16] These fairs were not only a major market for international trade, but also the centre of an embryonic international capital market. A market evolved there for exchanging currencies, with ratios quoted in terms of local and foreign currencies.[17] This was in effect a freely fluctuating exchange rate which mirrored the demand and supply of different European currencies. Trading volume was so considerable that the coin of the district became the model for the standard currency in much of Italy in the second half of the twelfth century. An early prototype of the "bill of exchange" also helped to lower the transaction costs of international trade at the fairs.

We shouldn't underestimate the economic importance of the fairs' institutional innovations. The manorial world of relatively isolated, weakly-interactive, economic units did not have continuous information about relative prices or the underlying supply-demand conditions for their own regions, let alone for foreign dealings. Transactions were simply too infrequent in time and space to support an organized market. During the thirteenth century, this vacuum was filled by the fairs, which embodied huge institutional advances. Along with the improvements in communication, these true marketplaces provided additional stimulus for circulation and trade to become self-reinforcing.

As their trading volume grew, the fairs provided general knowledge of prices for an international market. The transaction cost *per merchant* declined as the information was disseminated among increasing numbers, thereby simplifying the costly search by merchants for market information. Learning-by-circulating was centralized, thus removing much of the uncertainty of earlier days. With the Champagne fairs as a major

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[15] In England it was at Stourbridge; Germany at Aix-la-Chapelle, Frankfurt and Constance; the Low Countries at Bruges, Lille, Messines, Thourout and Ypres; Castile at Seville and Medina del Campo; Italy at Bari, Lucca and Venice.

[16] At the peak of their lifecycle in the middle of the 13th century, each fair lasted from sixteen to fifty days and was succeeded soon thereafter by a new fair in another town within the district of Champagne. The four towns which shared between them the Champagne and Brie fairs in the Middle Ages - namely Troyes, Bar-sur-Aube, Provins and Lagny - were constantly "passing the parcel". The net result was an annual agenda of six fairs which rotated between the four towns from January to October each year.

[17] North and Thomas (1973, page 55) state that "ratios were quoted on the basis of one sou or twelve derniers, equal to some amount of a foreign currency."

hub, other fairs and markets were programmed to avoid clashes and encourage circulation. Thus carriers, merchants and artisans could travel from one fair or market to another, selling their goods and absorbing vital economic information from the markets' transactions. Fernand Braudel refers to this circle of fairs as a sort of "perpetuum mobile".[18] It was also a coevolutionary circuit.

By exercising an incomparable power of attraction, the fairs marked one of the key stages in the advance of Western commerce. They brought classes and nations together, fostered a spirit of enterprise, stimulated cultural exchanges and created a more peaceful Europe. But above all, they provided a meetingplace for circulating merchants to ply their trade and compare notes. More than any other single activity, they did most to bring about an end to the economic isolation which the West had suffered during the Middle Ages. Yet none of the fair sites developed into manufacturing centres, nor did any evolve into cities. Today they're all deader than Troy. Even their names have been forgotten.

{A}Ephemeral Entrepôts{/A}

Why did the fairs prove to be ephemeral? For much the same reason as other entrepôts before them. Something new replaced something old. While the fairs were prospering, goods, coins and credit were all part of the circulation process. Because it was simplest to arrange credit from a central point, single centres came to dominate the European system of payments. In the thirteenth century, it was the larger fairs like those in Champagne. The irony was that by encouraging trade over longer distances, the fairs themselves helped to catalyse a sequence of network changes which ushered in entirely new ways of circulation and means of transaction in Europe.

Four factors conspired to turn positive feedback loops into negative ones. The first was a new thread between north and south, a direct sea connection between Bruges and the towns of the Mediterranean using large Genoese vessels of the late 13th century. The second was the introduction of a regular mail system for Dutch and Italian

merchants. Third came the absorption of the Champagne district into the kingdom of France, thus subjecting the fairs to heavy royal taxation. The final nail in the fairs' coffin was the introduction of more novel payment systems, bringing greater flexibility and frequency than they could offer.

Although each change affected the tapestry of trade and movement, the last was perhaps the most influential in the long run.[19] The Swedish economist, Åke Andersson, points to progressive improvements in the transaction system as the catalyst of a second "Logistical Revolution".[20] The merchants' desire for risk reduction, commercial credit and reliable currencies spawned a growing interest in banking and insurance activities among the merchants, monarchs and speculators alike. As the volume of trade grew, banking, insurance, and commercial law became in urgent need of more explicit instruments. Italian cities led in the formalization of legal forms. Urban markets like Bruges welcomed the opportunity to provide these commercial needs on a grander scale.

First to respond to the need for reliable banking was Amsterdam. By establishing an officially guaranteed central bank, the governors of that city set in motion a spate of central bank openings which were the forerunners of our modern banking system today. But the history of banking is not our principal concern. It suffices to note that this steady improvement in the system of transactions was a key factor in the growth and expansion of long-distance trade. It also contributed to the demise of the fairs.

The emerging industrial centre of Flanders, the ports of Genoa, Venice and Bruges, the fairs in Champagne and Flanders, the Italian colonies in the Levant, and the German Hanseatic towns can be viewed collectively as the principal "buttons" or entrepôts of Medieval Europe's reviving network economy. In each market centre, and along the routes threaded between them, the use of credit became more extensive; towns grew and became more active; and industry for distant markets took on a new lease of

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[18] See Braudel (1982), page 92.

[19] North and Thomas argue that Champagne's destiny as a permanent international marketplace might have been realized, had not royal taxation penalized the fairs at the same crucial period when a new direct sea route between Italy and the Low Countries had just been opened; see North and Thomas (1973), page 56.

life. Progress was not slow and steady. It was abrupt and unexpected. Long spurts of growth alternated with times of stagnation and decline. Yet again, the picture is one of punctuated equilibria.

Surprisingly, none of the places mentioned above rank with the urban powerhouses of today. Yet the coevolutionary web of links threaded catalytically between them still remains. Such ephemerality is difficult to understand. Part of the explanation can be found in earlier chapters, where we saw that entrepreneurial learning is an adaptive process. Self-organizing networks make prediction nigh on impossible. New nodes rise while old ones fall. But another explanation comes from the ingredients which are needed to make a city great in the first place. This intriguing question will be addressed in the next chapter.

[20] Logistical networks are those networks in space and time that are responsible for the movement of goods, people, money and information. For a fascinating analysis of the development of the world economy in terms of four "logistical revolutions," see Andersson (1986).

TABLE 1.1:
Two Economic Worlds - The Simple and the Complex

NECESSITY	CHANCE
Stasis	Morphogenesis
Resource-Based	Knowledge-Based
Unique Outcome	Multiple Outcomes
Equilibrium	Path-Dependent
Mechanistic	Organic
Predictable	Unpredictable
Diminishing Returns	Increasing Returns
Convex	Nonconvex
Easy to Model	Difficult to Model
A SIMPLE WORLD	A COMPLEX WORLD

TABLE 2.1:
Information and Knowledge

Characteristic	Information	Knowledge
Source	External	Internal
Nature	Weakly-interactive	Strongly-interactive
Primary exchange mode	Interface	Face-to-face
Learning rate	Fast	Slow
Usefulness	Temporary	Longlasting
Exchange process	Simple	Complex
Unit of measurement	Quantitative (e.g. bits)	Qualitative (e.g. deep)

TABLE 4.1
Population Growth in Europe

Date	European Population	Margin of Error (%)
200	48	35
500	36	30
800	32	30
1000	39	20
1300	75	20
1500	76	10
1700	102	8

TABLE 4.2:
The Ten Largest Cities in Europe by Population, 1000-1400

1000	1100	1200	1300	1400
Cordova	Constantinople	Constantinople	Paris	Paris
Constantinople	Fez	Palermo	Granada	Bruges
Seville	Seville	Seville	Constantinople	Milan
Palermo	Palermo	Paris	Venice	Venice
Kiev	Cordova	Venice	Genoa	Genoa
Venice	Granada	Cordova	Milan	Granada
Thessalonika	Venice	Granada	Sarai	Prague
Ratisbon	Kiev	Milan	Seville	Constantinople
Amalfi	Salerno	Cologne	Florence	Rouen
Rome	Milan	London	Cologne	Seville

Table 5.1: Changes in Rank of Selected American Cities, 1810-1910

City	Rank in 1810	Rank in 1860	Rank in 1910
New York	1	1	1
Philadelphia	2	2	3
Baltimore	3	3	7
Boston	4	4	5
New Orleans	6	5	14
Cincinatti	42	6	13
St. Louis	-	7	4
Chicago	-	8	2
Buffalo	-	9	10
Louisville	-	10	22
Albany	17	11	44
Washington	12	12	16
San Francisco	-	13	11
Providence	8	14	21
Pittsburgh	28	15	8
Rochester	-	16	23
Detroit	-	17	9
Milwaukee	-	18	12
Cleveland	-	19	6
Charleston	4	20	77

Table 5.2: Similarities Between CAs and Socio-Economic Dynamics

	Cellular Automata	Socio-Economic Dynamics
Basic elements	Cells are the basic units or "atoms" of a CA	Individual agents are the basic units of an economy
Possible states	Cells assume one of a set of alternative states	Agents form mental models which enable them to make choices from alternatives
Interdependence	The state of a cell affects the state of its closest neighbors	The choices made by agents affect the choices made by other agents
Applications and tasks	Modeling the emergence of order, macro outcomes explained by micro rules, and the path dependence of dynamic processes	Important tasks include: understanding the emergence of order, macro to micro relationships, and economic dynamics

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