The Economic Journal, **98** (*Conference* 1988), 1–24
Printed in Great Britain

MODELS AS ECONOMIES

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To begin I would like you to consider five economies. As I describe each of them, I would like you to think about whether each is real or imaginary:

1. The first economy is a village economy consisting of about 300 households, each of whom can grow wheat with labour inputs, capital inputs of ploughs and oxen, seed, and of course land. But the land of each household is not consolidated. Rather, it is spread out over the arable fields of the village into long narrow strips, typically 30 acres into 30–60 strips. For the most part, households supply virtually all their labour to their own strips and also eat the produce from their own strips. The major exception is that the strips of the largest holder, also the 'protector' of the village, are farmed by the other households, with labour service obligations specified in meticulous detail and effected with a group of 'monitors.'

2. The second economy is also a village economy, somewhat like the first. Households grow rice in paddies, without the aid of irrigation, and though land is sometimes scattered, the pattern is not nearly so systematic as in the first economy. Thus, if monsoon rains are abundant, households with mostly lowlying lands do poorly relative to households with land on a rise, and conversely in a dry year. But in the second village all households are obliged to transfer a prespecified amount of their crop to the local temple. Then, households with relatively low crops are entitled to request an allotment from temple stocks, and repayment is contingent upon subsequent high yields. Other forms of borrowing and lending are unobserved.

3. The third economy consists of a set of villages, separated from one another on a plain by distance and in some instances by rivers, valleys, and other topographical features. Each village specialises in the production of a distinct good, e.g. baskets, earthenware, textiles from a local fibre, vegetables, tools such as machetes, and so on, producing much of that good and relatively little of the others. But each village does value at least some of the commodities it does not produce. In fact, trade occurs periodically in a series of regional markets. Typically, residents of one village meet, at some intermediate location, the residents of a second village producing a good that the first does not produce but does value. At that regional market residents of the first village bargain with previously acquired local currency for the purchase of the commodity produced in the second village. Similarly, residents of the first village meet at intermediate locations with residents of villages who value the commodity the first produces, and residents of the first village sell their product

* Prepared for the Frank Paish Lecture. Lars Hansen, Robert E. Lucas, Jr. and Tom Sargent have contributed materially to the paper though I alone retain responsibility for any errors and the views expressed here. I am indebted to the National Science Foundation for financial support.

in those regional markets to acquire the above mentioned local currency. Thus, trade is characterised by monetary exchange in spatially separated, regional markets.

4. The fourth economy is similar to the third except that each village is located on an island, and the set of islands forms something of a circle. Typically, residents of each island embark periodically in canoes on trading expeditions, travelling either clockwise or counterclockwise to the island of their nearest neighbour. If travelling clockwise, residents of the first island give up their cargo as gifts to neighbouring islanders in a series of elaborate ceremonies, and receive in turn as gifts distinctive white shell armbands. If travelling counterclockwise residents of the first island receive distinctive red shell necklaces. The armbands and necklaces are reserved entirely for this ceremony, that is, cannot be acquired in other ways. An unrequited gift of cargo is rarely observed.

5. The fifth economy is also similar to the third except that regional variations in climate and weather make the yields over villages uneven, even though there is little specialisation in crop production. Further, when traders meet periodically in spatially separated regional markets, they are observed to give up produced goods in return for promisory paper notes, IOU's setting the time and place of future repayment. These notes are observed to circulate among village residents and to be used in exchange in the various regional markets.

Again, one might ask which of these economies are real economies, with actual contemporary or historical counterparts, and which are imaginary, made up by economic theorists. The rough, first pass answer is that the first, second, and fourth economies are real, and the third and fifth are figments of my imagination. In fact, the first economy with the strip system is drawn from descriptive accounts of the typical medieval English village economy, from the works of Bennett (1974), Homans (1940), McCloskey (1976), Postan (1972) and others. The second economy with the temple insurance scheme is one I discovered last summer, August 1986, in the northeast corner of Thailand, in remote and poor country near the Cambodian and Laotian borders. The third economy is in my 'Models of money with spatially separated agents,' cooked up during a leave of absence in Minnesota in 1979. The fourth economy is drawn from Malinowski's (1953) descriptive accounts of the Kula exchange system in a ring of islands off New Guinea. Finally, the fifth economy was invented by Neil Wallace and me in 1984 in 'Circulating private debt: an example with a coordination problem.'

Three related caveats are in order, however. First, the imaginary economies are not so far from reality. Indeed, I am reminded of the model of money with spatially separated agents in reading Malinowski's (1953) account of the regional markets of Oaxaca, Mexico in 1935 (hence the list of commodities) and in reading historical accounts of the emergence of spatially separated markets and currencies in the Commercial Revolution of Europe, accounts of Braudel (1979), Pirenne (1948), and others. Also, I am reminded of the model of circulating private debt in reading about the bills of exchange which circulated

in England, for example, in the 17th century. More generally, both models are grounded in an absence of double-coincidence of wants and at least casual observations by economists from the time of Adam Smith onward. It is hard for theorists to operate in an empirical void, divorced from observations.

The second caveat is that the actual economies are interpreted by me, an observer who, believe it or not, has in mind general equilibrium models in the tradition of Arrow and Debreu. No doubt this plays a big role in determining the allocations, institutions, and arrangements that attract my attention, in determining the way I report observations. In short, observations are filtered through applied general equilibrium theory, so naturally the actual economies that I describe tend to look like models in the theoretical literature. (As must be obvious, I have deliberately overdone this in the descriptive accounts above, trying to conceal somewhat which of the economies are real and which are imaginary.) Some may take this as a statement of a biased observer, but as Koopmans (1947) argued in the context of business cycle theory, there seems to be no satisfactory alternative. To try to record each and every detail of an observed economy would be an impractical if not impossible exercise. The more compelling procedure is to use existing theory to comment on environments or observed patterns of exchange which are consistent with environments or outcomes of existing theory, or to document anomalies, patterns which are not.

The third caveat, and the point of this paper, really, is that the distinction between actual economies and imaginary economies is not sharp. For example, both the simpler economies studied by anthropologists and the stylised theoretical models of the literature can be used to help us to think about the apparently more complicated US and UK economies. Operationally, this point is subtle and deserves elaboration in what follows.

To give a rather extended summary, then, the paper proceeds as follows. Section I makes clear what is meant by an Arrow–Debreu environment or economy, spelling out the primitives used by Debreu (1959), for example. Section I also spells out the devices used to achieve a (tighter) mapping from environments to outcomes, namely, the Pareto optimality hypothesis, the competitive equilibrium hypothesis, or the core hypothesis.

Section II argues that general equilibrium models are useful as a way to catalogue actual economies. That is, in reading descriptive historical or anthropological material, one may be reminded of general equilibrium models. The environment of the actual economy may be reminiscent of the environment of a stylised theoretical model, with some key elements especially prominent. And observed allocations or exchange arrangements of the same actual economy may be reminiscent of those allocations or arrangements predicted by the same theory. When this happens one might say that one has matched an actual economy with a theoretical model, that is, one has found an analogue to the real economy in the catalogue of theoretical models.

The ability to catalogue actual economies in this way is not unrelated to the fact that the set of theoretical models in the catalogue is relatively rich. That is, general equilibrium models can accommodate not only diversity in

preferences and endowments, but also uncertainty, spatial separation, private information, limited communication, and limited commitment. This is illustrated by the subsections of Section II: the first subsection emphasises theoretical models with uncertainty and their usefulness in studying the agrarian, strip system of medieval English villages; the second and third subsections emphasise theoretical models with spatial separation and their usefulness in thinking about emergence of medieval currency and bills of exchange, respectively; and the fourth subsection emphasises theoretical models with the frictions of private information and limited communication and their usefulness in thinking about the tokens of some of the simpler economies studied by anthropologists.

It is not surprising perhaps that observations in these example matches are drawn from historical or anthropological material. For, one can go beyond the cataloging of actual economies and ask whether our class of theoretical models is on the right track, whether the existing class of theoretical models fits the data reasonably well. To do this it seems natural, in the absence of controlled experiments, to study actual economies which are relatively simple and which have prominent elements that resemble the key elements of stylised theoretical models. The economies described by historians and anthropologists seem to have these features. (It was the search for a relatively simple contemporary economy with key elements that underlay my visit to the Thai villages.)

Still, this fitting exercise is fraught with some peril, at least for the researcher, for it might seem that the theory can only be tested fruitfully on the battleground of actual economies that some would find uninteresting. If that were the case, then surely the theory is uninteresting, if not irrelevant, or so it might be argued. The counter to this argument is that both simpler actual economies and stylised theoretical models can be viewed as on a par with one another. Both can suggest associations and patterns that can help us to think about the reality of apparently more complicated economies. Again, the distinction between real and imaginary economies becomes blurred.

Section III of this paper continues this line of argument and tries to make the case that general equilibrium models are a way to trace out the logic of economywide phenomena. For example, it is sometimes argued that private information and incentive problems must be the keys to understanding the dispersed land patterns of the English strip system, as described by historians. But with a stylised general equilibrium model on hand one can trace out as well the logical implications of private information for other phenomena. These implications can be confronted against what might have been thought to be seemingly unrelated observations, also provided by historians. Again, one is 'fitting' theories to observations. Alternatively, the cross-phenomena implications can guide further data collection, so that theory and empirical work are complementary. And finally, a not unrelated point made by McCloskey (personal correspondence) and others, is that theoretical models must be especially good or 'creative' when used to study economies for which there are great gaps in observations, gaps which may never be filled. In such cases a theoretical model provides the web which ties together seemingly unrelated

observations, though web is never seen. Again, theoretical and actual economies are complements.

Section IV continues further and argues with Lucas (1980) that general equilibrium models can be thought of as laboratories in which a researcher can conduct experiments. That is, one can try to find variations in actual environments and look at variations in actual outcomes. Alternatively, one can try out different environments in theoretical models and look at variations in outcomes there. Both ways can help us to understand reality and can aid in policy making. Section IV gives an example of this in arguing that general equilibrium models can be used to help with the design of optimal banking and intermediation arrangements. This section is also motivated by some historical observations, asking whether observed arrangements could be efficient for an environment invented by an economic theorist.

I. THE METHODS OF APPLIED GENERAL EQUILIBRIUM THEORY

General equilibrium models are usually specified at the level of the primitives of Debreu (1959), for example. That is, one makes up an economy by specifying the set of households $i, i = 1, 2, \ldots, n$; linear commodity space L; consumption set X^j in space L for each household j; preferences represented by utility function u^j on set X^j for each household j; endowment w^j in space L for each household j; firms $k = 1, 2, \ldots, m$; and production set Y^k in space L for each firm k. Here, moreover, household k will be said to have access to production technology Y^k so that references to firms as entities apart from households is suppressed. Then, given an Arrow–Debreu environment, the applied general equilibrium theorist tries to make a prediction about the allocations and institutions which will emerge, that is, to form a mapping from the primitives to outcomes. There are several ways to do so, and none is without controversy.

First, one can suppose that outcomes necessarily will be Pareto optimal for the specified environment. One attraction of this premise is that one can often deliver Pareto optimal allocations as solutions to a class of well-defined programming problems, problems of maximising weighted sums of utilities of the households subject to constraints implied by endowments and technology. That is, one can maximise the objective function

$$\sum_{j=1}^{n} \lambda^j u^j(x^j)$$

subject to the constraints

$$x^j \in X^j, \quad j = 1, 2, \ldots, n \quad \text{feasible consumption,}$$

$$y^j \in Y^j, \quad j = 1, 2, \ldots, n \quad \text{feasible production,}$$

$$\sum_{j=1}^{n} x^j = \sum_{j=1}^{n} w^j + \sum_{j=1}^{n} y^j \quad \text{resource feasibility}$$

with values for the weights λ^j satisfying

$$0 \leqslant \lambda^j \leqslant 1, \quad \sum_{j=1}^{n} \lambda^j = 1.$$

Of course the outcome of such a programming problem, a Pareto optimal allocation, can sometimes be decentralised under a price system. That is, there may exist a price system p^* and allocations $x^j{}^*$ and $y^j{}^*$, $j = 1, 2, \ldots, n$ such that

(*i*) for every household j, $x^j{}^*$ solves

$$\underset{x^j \in X^j}{\text{maximise}}\, u^j(x^j)$$

subject to $p^*x^j \leqslant p^*w^j + p^*y^j{}^*$,

(*ii*) for every 'firm' j, $y^j{}^*$ solves

$$\underset{y^j \in Y^j}{\text{maximise}}\, p^*y^j,$$

(*iii*) $$\sum_{j=1}^{n} x^j{}^* = \sum_{j=1}^{n} w^j + \sum_{j=1}^{n} y^j{}^*, \quad \text{market clearing.}$$

The hypothesis that allocations are those achieved in competitive markets often serves to sharpen the predictions of the model, tightening the mapping from environments to outcomes.

An alternative hypothesis to be coupled with Pareto optimality is the idea that allocations must be in the core. That is, an allocation $x^j{}^*, y^j{}^*$, $j = 1, 2, \ldots, n$, is in the core if it is feasible (satisfies the competitive equilibrium condition (*iii*) above) and if there does not exist any subset of households C with allocation $\bar{x}^i, \bar{y}^i$, $i \in C$, with the property that the allocation $\bar{x}^i, \bar{y}^i$ is feasible for C, that is,

$$\bar{x}^i \in X^i, \quad \bar{y}^i \in Y^i \quad \text{and} \quad \sum_{i \in C} \bar{x}^i = \sum_{i \in C} \bar{y}^i + \sum_{i \in C} w^i,$$

and allocation $\bar{x}^i, \bar{y}^i$ improves upon the *-allocation for C, that is,

$$u^i(\bar{x}^i) \geqslant u^i(x^i{}^*) \quad \text{for all } i \in C \text{ with a strict inequality for at least one } i \in C.$$

Again none of these ways of tightening the mapping from environments to outcomes is without controversy. But suffice it to note here that some premise is needed, since the set of feasible allocations is seldom restrictive.

II. GENERAL EQUILIBRIUM MODELS AS A WAY TO CATALOGUE ACTUAL ECONOMIES, TO INTERPRET REALITY

As I noted previously, in reading descriptive historical or anthropological material, I often find that I am reminded of general equilibrium models. That is, the environment of the actual economy is reminiscent of the environment of a stylised theoretical model, often one with some key elements especially

prominent, and observed allocations or exchange arrangements of the same actual economy are reminiscent of those allocations or exchange arrangements predicted by the theoretical model.[1] When this happens one has placed an observed, actual economy in the catalogue of stylised theoretical models. The ability to catalogue actual economies in this way is not unrelated to the fact that general equilibrium models can accommodate not only diversity in preferences and endowments but also uncertainty, spatial separation, private information, limited communication, and limited commitment. In this section I hope to illustrate this with three examples. The first emphasises uncertainty; the second, spatial separation and limited commitment; and the third, spatial separation, private information and limited communication.

II.1 *Uncertainty and the English Strip System*

The nature and importance of one key element, uncertainty, seem evident in reading about a typical medieval English village, from the work of McCloskey (1976) and others. The surprising facts are the extent of variability of crop yields generally, and the extent of variation in yields across dispersed strips, even in the relatively small area comprising a typical village. Essentially, sources of risk were meterological and biological. Soil and land vary by type and typography, so that clay soil in low spots that does well in a relatively dry year may do very poorly in a wet one. Further, hailstorms which move in long narrow bands and crop disease spread by spores in adjacent areas represent serious risks but are spotty in the damage they inflict. One result, then, is a relatively high coefficient of variation in grain harvests on a typical strip, estimated by McCloskey at something like 0.44. Thus, if land were consolidated, a typical household in a typical village would face a shortfall of harvest of less than half of average output roughly something like every 9.3 years. Apparently this would be below subsistence and would result in starvation in a subset of the population. A second result is a relatively low covariation across strips if these strips are associated with different types of land and/or are spatially separated from one another. McCloskey estimates the coefficient of variation on a diversified portfolio of strips at 0.34, or starvation roughly every 13.4 years. The latter seems to correspond with actual English medieval experience. That is, villagers choose the second, diversification option despite a loss of mean output of 10%, as estimated by McCloskey. The picture of landholdings in the village of Elford, Staffordshire reproduced from Homans (1940), tells the dramatic, diversification story. See Fig. 1.

But let us try to study a typical Medieval village systematically. That is, let us write down a simple general equilibrium model with uncertainty as a key element, following the seminal work of Arrow (1953) and Debreu (1959). That is, indexing proposed commodity allocations by the entire history of publicly observed shocks, that is by realisations of the random variables of the model, standard techniques and theorems on the existence of Pareto optimal

[1] Indeed it might be argued that one can always find a theoretical model which fits the observations, and so the theory is not strained or tested. In fact, there is some truth to this argument, something which will be discussed again in Section V.1 below. Here though the argument can be turned on its head.

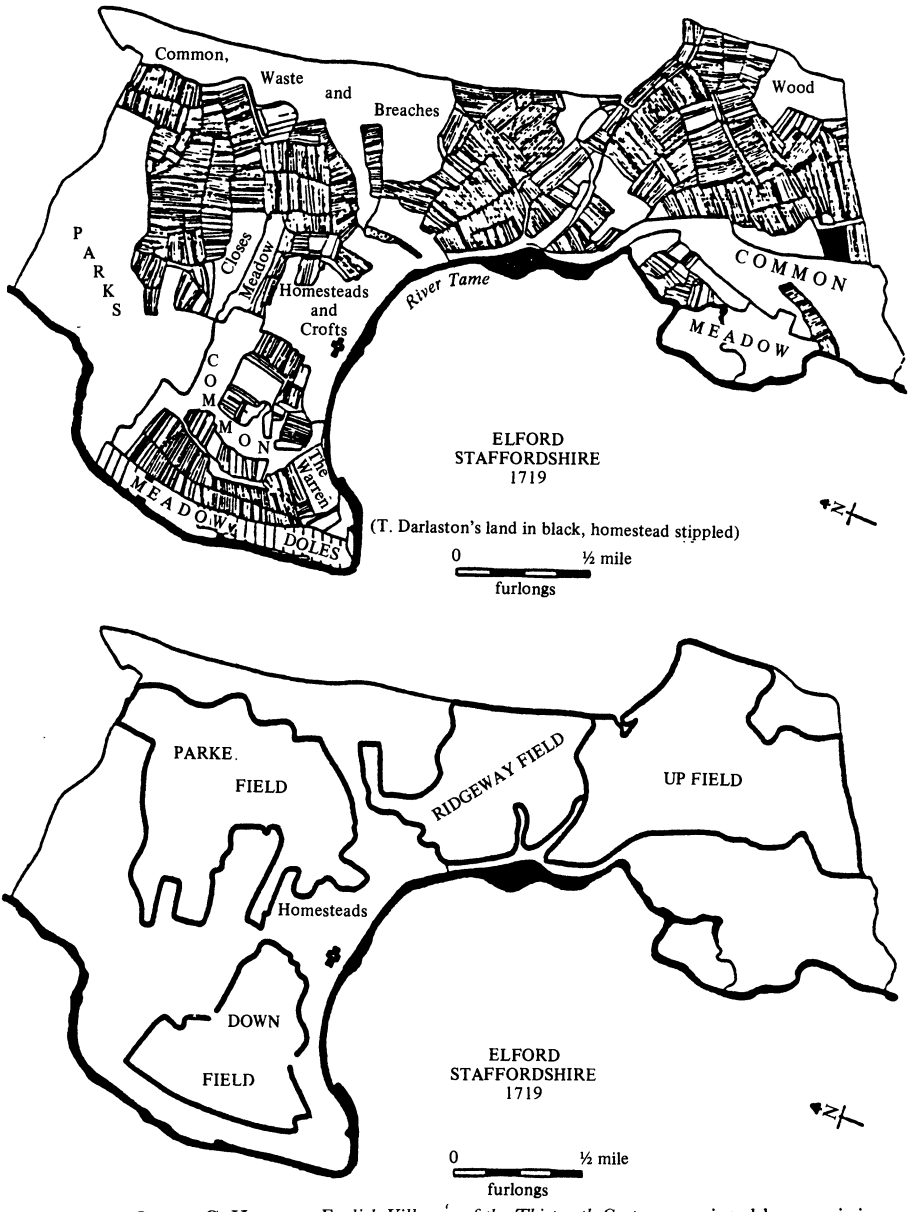

Fig. 1. From George C. Homans, *English Villagers of the Thirteenth Century*, reprinted by permission from Harvard University Press.

allocations apply. For example, treating finite-lived, uniform horizon households as one of the primitives of the model, let $e^j(\epsilon_t)$ denote the endowment of household j at date t of the single consumption good as a function of some vector of publicly observed shock $\boldsymbol{\varepsilon}_t$ at date t and let $c^j(\boldsymbol{\varepsilon}_1, \ldots, \boldsymbol{\varepsilon}_t)$ denote the corresponding consumption, indexed by the entire history of shocks. Also, let U^j denote the preferences of household j over consumption at any date t. Then with time separable, strictly concave utility functions, common discount rates

β, common expectations, and weight λ^j for household j, the programming problem for the determination of Pareto optimal allocations is

Programme 1. Maximise by choice of the $c^j(\varepsilon_1, \ldots, \varepsilon_t)$ the objective function

$$\sum_{j=1}^{n} \lambda^j \left\{ \mathrm{E}_0 \sum_{t=1}^{T} \beta^t U^j[c^j(\varepsilon_1, \ldots, \varepsilon_t)] \right\} \tag{1}$$

subject to history-contingent resource constraints,

$$\sum_{j=1}^{n} c^j(\varepsilon_1, \ldots, \varepsilon_t) \leqslant \sum_{j=1}^{n} e^j(\varepsilon_t), \ \forall(\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_t). \tag{2}$$

This is seen to be a special case of programmes for the determination of Pareto optimal allocations noted earlier. And the theory has content. For as Wilson (1968), Diamond (1967), and others have noted, solutions to programme 1 have strong implications. Specifically, household j's consumption should move monotonically with aggregate consumption.

Guided by the theory, one might ask whether the landholdings of a typical medieval English village could have been such as to support the optimal consumption comovement implication if households ate the produce from their own strips. In fact, this is possible exactly under some conditions, if utility functions display constant relative risk aversion, and if all the uncertainty is associated with land types, for example. Further, the idea may hold good an approximation for a wider class of utility functions, though thoughts about the spatial nature of some shocks and limits on land division imposed by the technology of the plough lead one to some doubts.

Of course the reality of the medieval village does not conform well with all dimensions of the model described above, and some omissions may be serious. There was more than one consumption good in the medieval village (the list of crops includes oats, wheat, barley and rye), and this leads to some interesting issues concerning crop diversification. There may have been nontrivial storage possibilities, and this leads to issues concerning the substitutability of storage for cross household insurance and issues concerning various orders of magnitude, of the productivity of seed and of the depreciation on storage, for example. Crops were not given as endowments but were produced from labour and capital, leading to issues of leisure sharing and the joint distribution of income with oxen and land holdings. And shocks such as illness and disability have yet to be incorporated. It should be pointed out that the theory often *can* accommodate these features. In fact, solutions to modified programmes often leave the consumption comovement implication intact. But these extended models and their implications deserve closer consideration.

Finally, it must be noted that one falls woefully short even in the extended class of models with uncertainty of an explanation of why English villagers seem to have preferred *ex ante* division of land, though the Thai villagers I described earlier seem to prefer the *ex post* redistribution scheme of their temple. A discussion of this issue at this point would take us too far astray, into models

with private information as a key element. But what I want to emphasise is that in reading about the English strip system or in thinking about the Thai temple we are aided by the theory of general equilibrium under uncertainty. We have found a class of theoretical models which can be used as a base to analyse these economies further.

II.2. *Spatially Separated Markets and Medieval Currency*

Various theoretical models begin with the idea that spatial separation is an important friction. Its importance in reality seems evident from a reading of economic history of medieval Europe. Briefly, the decline in economic activity and trade from the 5th to the 10th centuries was progressive, associated with waves of 'barbarian' invaders, Moslem attacks, Viking invasions, and so on. Constantinople remained strong in the east, the centre of what was left of the Empire, and civilisation flourished under the Moslem sphere of influence in the south. But in the northwest, in Britain, France, and Germany, internal turmoil and outside attacks reduced commerce dramatically, to the point that towns more or less disappeared. Centralisation and periods of state control as under Charlemagne proved exceptional and temporary. Essentially, economic life was centred in more or less self-sufficient villages, the genesis of the medieval villages mentioned earlier.

On the up side, as the Moslems lost control of the Mediterranean around the year 1000 and the Vikings turned to trade, exchange flourished again, led by Italian city-states. Itinerant merchants followed overland routes linking spices and the products of Italy to cloth and the products of northern Europe. Large and dramatic international fairs met periodically in intermediate locations, in Champagne, for example, depicted in Fig. 2. More generally, towns developed outside many medieval villages, on the obvious trade routes, as a safe haven for travelling merchants. See Fig. 3. More active and larger towns such as Marseille, Barcelona and the Italian cities developed a life of their own, with links to their respective hinterlands. In fact, by the 12th and 13th centuries, northwest Europe was dotted with market towns and fairs, a pattern which persisted on through the 17th and 18th centuries, as depicted for England in Fig. 4. Finally, with the development of better ships around 1300, overland routes were replaced with large Atlantic coast cities such as Bruges featuring more or less continual trade and permanent (Italian) colonial settlements.

So much for the importance of spatial separation. What about its relationship to money? Most historians seem to agree that little or no use was made of monetary exchange during periods of extreme disorder. Granted, much of the evidence is indirect and concerns mints and the use of specific coins. As Carlo Cipola notes, for example, though coinage was standardised under Charlemagne, establishing the pence–shilling–pound system, only the pence seems to have circulated. Gold coins were not minted, and shortly after Charlemagne, Byzantine and Moslem gold coins had disappeared from circulation. On the other hand, around the year 1000 and the Commercial Revolution, payments in kind became an exception and coins dominated recorded exchange transactions. Mints became more active, and from 1150–1200 onward silver shillings were minted in Genoa, Florence, Venice,

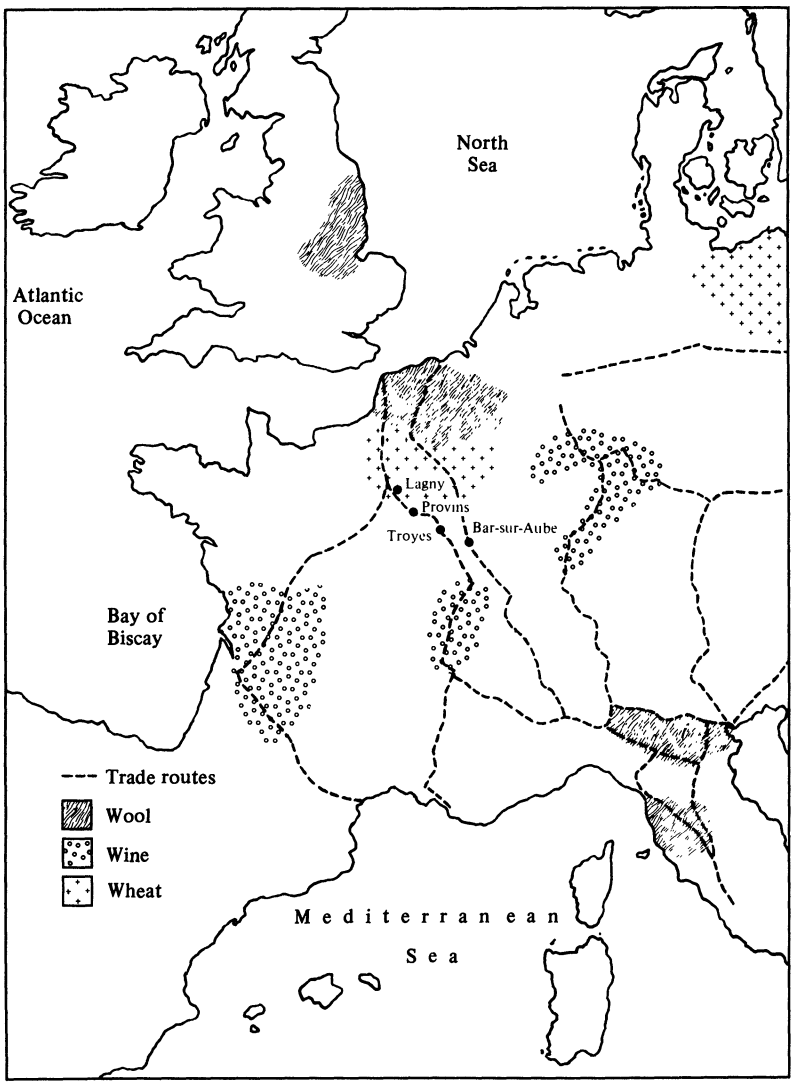

Fig. 2. Created by Anthong Cheung, based in part on map 28 in the *Atlas of World History*, 1981, Paul Hamlyn Publishing and Creative Cartography Limited.

and Tours. Gold coins were minted in the same cities from 1250 onward. Complementary evidence for the proliferation of coins and for monetary exchange is the increased use of coins as units of account for goods and services, this being obvious by the 11th century and evidenced in the contracts collected by Lopez and Raymond (1955) for example. Associated is the better-documented commutation of rents and services in the medieval villages, beginning near great towns by the year 1100.

Observations like these remind me of two related features of general equilibrium models. First, programming problems like programme 1 described earlier do not require currency for their implementation. That is, as has been

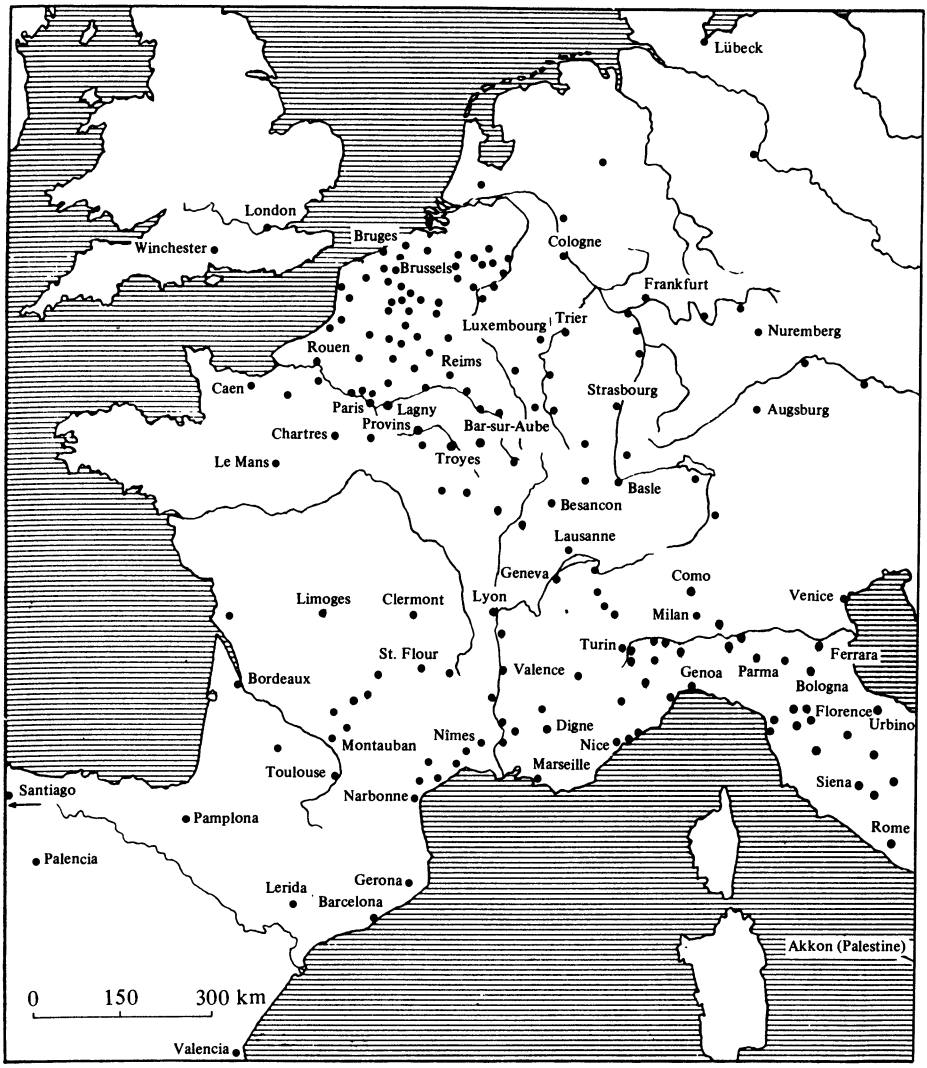

Fig. 3. Towns in contact with the champagne fairs twelfth and thirteenth centuries. This map clearly reveals the economic structure and notably the bi-polarity of thirteenth-century Europe, centred on the Netherlands in the North and Italy in the South. (From H. Ammann, in *Hessisches Jahrbuch für Landesgeschichte*, 8, 1958.) Reproduced from Fernand Braudel, *Perspective of the World: Civilization and Capitalism: 15th–18th Century, Vol. 3*, page 113, Harper & Row Publishers.

emphasised by such diverse authors as Brunner and Meltzer (1971), Cass and Shell (1981), Hahn (1973), and Wallace (1980), one cannot get money into a standard general equilibrium model, at least not without some carefully chosen impediments to trade. Optimal allocations only require enforcement of the social contract; indeed, there need be no 'free' exchange at all. And though optimal allocations can be supported with markets and a price system, only unit of account prices are needed. Is it possible that medieval villages in the 'trough' of the decline were like the stylised models of general equilibrium theory, that money was not in fact needed?

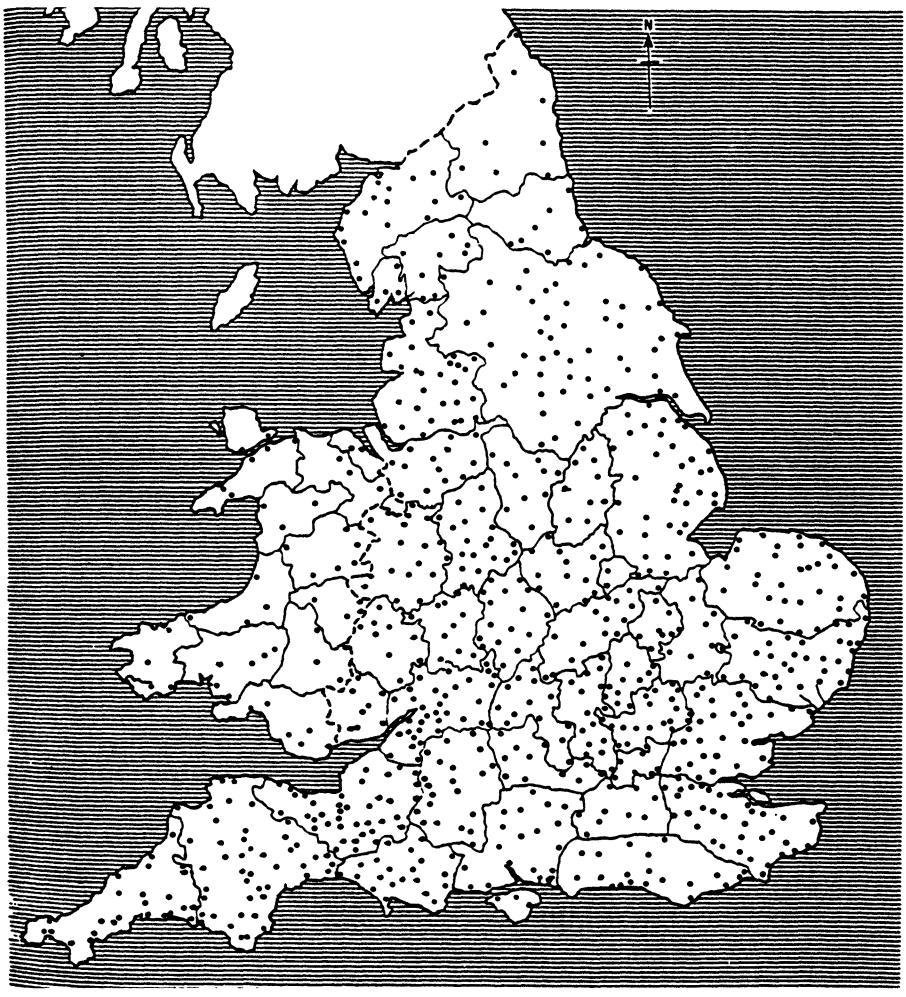

Fig. 4. The 800 market towns of England and Wales, 1500–1640. Each town had at least one market, usually several; and to the markets must be added the fairs. Reproduced from Fernand Braudel, *Perspective of the World: Civilization and Capitalism: 15th–18th Century, Vol. 2*, page 45, Harper & Row Publishers.

Second, the observations remind me of the general equilibrium models of Townsend (1980) and an earlier literature, Harris (1979), Ostroy (1973), and Ostroy-Starr (1974), for example, one of which was described earlier. These models incorporate spatial separation and limited commitment as the key constructs, to explain the use of currency. Specifically, to describe a related but different example, suppose that endowment e_t^j of the single consumption good of each household j varies over time, fluctuating, for simplicity, between high and low realisations. There is no storage. Also, household j cares about consumption c_t^j at date t under utility function U^j and maximises discounted utility. Discount rate β is common over households. And for simplicity there is no uncertainty, so this model is seen to be a special case of the one described earlier! Each household follows an exogenously specified itinerary or path so

that households meet one another in spatially separated markets. But their movement is such that they meet one another only once and share no common trading partners. Specifically, the itineraries of two types of households $j, j = a, b$ are depicted in Fig. 5, with agents type a travelling west and agents type b travelling east. Trade can take place at each 'integer' of the highway at each date, where there is a meeting of a representative household of type a and a representative household of type b.

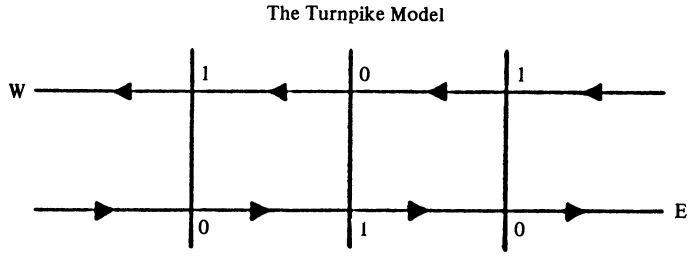

Fig. 5.

The endowment patterns of the a's and the b's is such that there can be mutually beneficial spot market exchange in currency, but not otherwise. In one period a representative household of type a with a high endowment, unity, is paired with a representative agent of type b with a low endowment, zero; the converse occurs in the next period. Thus, agent a sells off goods when he has them, in exchange for currency, and uses the currency to acquire goods later, when he is in short supply. Currency thus serves as a store of value, mediating an absence of double coincidence of wants. Technically, and crucial in terms of model validation, a competitive equilibrium with valued outside currency, otherwise worthless paper, can be shown to exist. One might also conjecture that the same allocation would be supported if programming problems for the determination of optimal allocations were solved period by period when agents meet, yielding core allocations when agents meet, with preferences defined over contemporary consumption and end of period currency holdings. Again, under this interpretation, spatial separation and limited commitment are the key elements needed to explain currency.

Of course the match between the theory of currency with spatially separated markets and the historical observations is suggestive at best. There are many theoretical and empirical questions on the definition of money, on the use of coins, and on the location and time patterns of markets which remain to be explored. But at least one does have a solid general equilibrium starting point for further work, a starting point which is amenable to modifications as observations dictate. In fact, I hope to illustrate this interplay in the next subsection.

II.3. *Spatially Separated Markets and Bills of Exchange*

In reading further about the financial instruments which emerged during the Commercial Revolution one discovers debt contracts are among the earliest

documents, for example collected by Lopez and Raymond (1955). Prominent among these are bills of exchange promising payment at future dates and distinct trading locations. For example, bills were often written in Italian cities for payment some months later at the fairs of Champagne. In fact these large international fairs often served as clearing centres for such IOUs, occasionally serving that purpose alone, as in Lyon, according to Braudel (1979). Finally, bills of exchange began to circulate, in Bruges for example by the year 1600. However, the circulation of bills was spotty, often accompanied by efforts at control or elimination.

The model of currency with spatially separated agents described above can be modified to yield standard debt contracts, bills of exchange, and bills which circulate. In particular, bills emerge if one dispenses with the construct that traders meet at most once, say by breaking the highway at two points and bending the piece around to form a circle. The resulting economy then is essentially equivalent to one in which agents type a and b, and their counterparts a' and b', are paired periodically, as in Table 1 from Townsend and Wallace (1982).

Table 1
Who Meets Whom When

	Location	
Date	1	2
1	(a, b)	(a', b')
2	(a, b')	(a', b)
3	(a, b)	(a', b')
4	(a, b')	(a', b)

Townsend and Wallace (1982) use the economy of the table to deliver the coexistence of valued, standard debt contracts, e.g. between agents a and b at dates 1 and 3; and to deliver valued, circulating, privately-issued IOU's, e.g. issued by a at date 1, passing to b, then to a', then to b' and finally back to a.

Townsend and Wallace also uncover multiple equilibria, unique in consumptions but non-unique in debt combinations. This co-ordination problem suggested to us a need to 'control' or to 'regulate' such security markets, and, in the absence of this, that credit markets would be chaotic. Perhaps one can look more closely at actual observations, to see if this prediction is born out in practice. More generally, unanswered theoretical and empirical questions on currency and debt abound. Can currency and private debt coexist? What are the actual transactions patterns among agents using private debt? Who used it and who did not? In particular, why did it take over 500 years, from the beginning of the Commercial Revolution to 1600, for bills

of exchange to circulate? But again I would like to think that one has a good base model from which to start the analysis.

II.4. *Private Information, Limited Communication, and the Tokens of 'Simpler' Economies*

The rather incredible story of the Kula exchange system discovered by Malinowski (1953) was told earlier. True, it is far from obvious what role the shells of the Kula were playing. Perhaps the entire arrangement was ceremonial, an interesting oddity, as many authors have suggested. On the other hand, if islanders were in possession of white armbands then it seems from the descriptive accounts that this would be evidence that they had at one time or another embarked in canoes and successfully traded with an island to the northeast. Similarly, possession of red necklaces would be evidence of some southeastern expedition. In other words, the Kula shells might be viewed as portable record keeping devices, part of a decentralised, communication–accounting system.

In some respects the Kula was not unique. Raymond Firth (1939) reports similar internal arrangements on the island of Tikopia in 1938. In particular, there seems to have been three spheres of exchange in Tikopia. In the first, various food items were exchanged against small objects and services. In the second, sinnet and bark-cloth items were exchanged against tools and specialists' skills. The third sphere of exchange involved bonito hooks, tumeric cylinders and canoes. Various of these objects passed among participants in ceremonial and 'forced' exchanges. For example, participants in funeral and marriage ceremonies were expected to give to one another specific items in one of the three spheres. Indeed, entire crops could be planted in anticipation of a forthcoming ceremony. Related, according to Firth, the objects and services in the three spheres could not be expressed in terms of one another since normally they were 'never brought to the bar of exchange together.'

Related observations are reported by Baric (1964) and by Armstrong for Rossel island, where two types of shells and up to 36 subcategories of shells were required in various transfers. Again these were not normally exchanged against one another.

What sense can be made of these observations theoretically? Or, to narrow the focus considerably, can general equilibrium models give rise to a role for portable tokens, for some kind of decentralised communication–accounting system? The answer to this question seems to be in the affirmative if spatial separation and private information are brought in as key elements.

Specifically, imagine that agents type a and a' in the economy of Table 1 suffer now from random, privately observed endowments e_t^a and $e_t^{a'}$, respectively, at two dates only, $t = 1, 2$, occurring with probabilities $\text{prob}(e_t^a)$ for example and, for simplicity, that agents b and b' have deterministic, fully displayed, public endowments e_t^b and $e_t^{b'}$, respectively, $t = 1, 2$. Then, applying revelation principle methods developed by Milton Harris and myself (1981) and by Roger Myerson (1979), and ignoring pretransfer displays and

posttransfer non-negativity constraints on consumptions, the programme for the determination of private-information constrained Pareto optimal allocations is

Programme 2. Maximise by choice of transfers $\tau_1(e_1^a)$ and $\tau_2(e_1^a, e_2^a)$ to agent a at dates 1 and 2 and transfers $\tau_1(e_1^{a'})$ and $\tau_2(e_1^{a'}, e_2^{a'})$ to agent a' the objective function

$$\begin{aligned}\lambda^a \sum_{e_1^a} \text{prob}\,(e_1^a)\, U^a[e_1^a+\tau_1(e_1^a)] + \beta \sum_{e_1^a} \text{prob}\,(e_1^a) \sum_{e_2^a} \text{prob}\,(e_2^a \mid e_1^a)\, U^a[e_2^a+\tau_2(e_1^a, e_2^a)] \\ +\lambda^b \sum_{e_1^a} \text{prob}\,(e_1^a)\, U^b[e_1^b-\tau_1(e_1^a)] \\ +\beta \sum_{e_1^{a'}} \text{prob}\,(e_1^{a'}) \sum_{e_2^{a'}} \text{prob}\,(e_2^{a'} \mid e_1^{a'})\, U^b[e_2^b-\tau_2(e_1^a, e_2^{a'})] \\ +\lambda^{a'} \sum_{e_1^{a'}} \text{prob}\,(e_1^{a'})\, U^{a'}[e_1^{a'}+\tau_1(e_1^{a'})] \\ +\beta \sum_{e_1^{a'}} \text{prob}\,(e_1^{a'}) \sum_{e_2^{a'}} \text{prob}\,(e_2^{a'} \mid e_1^{a'})\, U^{a'}[e_2^{a'}+\tau_2(e_1^{a'}, e_2^{a'})] \\ +\lambda^{b'} \sum_{e_1^{a'}} \text{prob}\,(e_1^{a'})\, U^{b'}[e_1^{b'}-\tau_1(e_1^{a'})] \\ +\beta \sum_{e_1^a} \text{prob}\,(e_1^a) \sum_{e_2^a} \text{prob}\,(e_2^a \mid e_1^a)\, U^{b'}[e_2^b-\tau_2(e_1^a, a_2^a)] \end{aligned} \tag{3}$$

subject to the incentive constraint for agent a at date 2, for all $e_1^a, e_2^a, \tilde{e}_2^a$

$$U^a[e_2^a+\tau_2(e_1^a, e_2^a)] \geqslant U^a[e_2^a+\tau_2(e_1^a, \tilde{e}_2^a)], \tag{4}$$

the incentive constraint at date 1 for agent a, for all $e_1^a, \tilde{e}_1^a$,

$$\begin{aligned} U^a[e_1^a+\tau_1(e_1^a)] + \beta \sum_{e_2^a} \text{prob}\,(e_2^a \mid e_1^a)\, U^a[e_2^a+\tau_2(e_1^a, e_2^a)] \\ \geqslant U^a[e_1^a+\tau_1(\tilde{e}_1^a)] + \beta \sum_{e_2^a} \text{prob}\,(e_2^a \mid e_1^a)\, U^a[e_2^a+\tau_2(\tilde{e}_1^a, e_2^a)] \end{aligned} \tag{5}$$

and similar incentive constraints at dates 1 and 2 for agent a'.

Here the objective function (3) is a weighted sum of the expected utilities of the four agents of the model over the two periods of their lifetimes, equation (4) is the incentive constraint at date 2 which ensures that agent a will tell the truth about his endowment realisation at date 2 no matter what endowment was announced in the past, and equation (5) is the corresponding incentive constraint for agent a at date 1. It is an implication of Townsend (1982), for example, that such incentive constraints can be imposed without loss of generality. They capture all of the difficulties of private information in this model, allowing programming methods to remain intact.[2] Finally, it may be stressed that in programme 2, allocations of agent a at date 2 can depend on announcements of agent a at date 1, as if there were full communication possibilities. Under full information such tie-ins are not optimal, but they are

[2] Technically, though, one should search for lotteries on consumptions, rather than for deterministic allocations, as otherwise the programme may not be concave and beneficial trade opportunities may be lost.

generally optimal with private information, serving to lessen the damage from the first period incentive constraints.

Restricted communication among agents of the model can put these optimal intertemporal tie-ins in jeopardy. For example, in a regime with oral communication alone, no tie-ins are possible and some or all of the agents must suffer. But enhanced communication possibilities emerge if agents can carry with them tokens which are otherwise subject to complete societal control. In fact, a judicious use of tokens can allow a complete record of past transactions. That is, past histories and actions of agents are completely identified by the kind and amount of tokens they display. Interestingly enough, multiple tokens may be necessary for this. In a more elaborate model, tokens can also serve to allocate agents to preplanned destinations, and agents at that destination can rest assured that the arrivals have satisfied the intentions of the social plan. In fact, tokens can be used to implement a social plan even without uncertainty, as they may indicate whether or not an otherwise unobserved but preplanned transfer took place. That is, even in the absence of uncertainty, spatial separation can imply private information if reneging is possible, and so communication devices may be needed.

Of course much theoretical work remains to be done. And eventually a closer match with the Kula type observations should be attempted. But at least it can be said that the observations from simpler economies have led us in an interesting theoretical direction.

III. GENERAL EQUILIBRIUM MODELS AS A WAY TO TRACE OUT THE LOGIC OF ECONOMY WIDE PHENOMENA

Again, general equilibrium models allow one to think logically about the implications of some premise, to trace out the implications of the premise not only for the phenomenon of interest but for other phenomena as well. That is, one can keep track of all possible interactions across agents in the economy, showing some phenomena to be logically inconsistent with other phenomena.

One example here will suffice to make this point, an example which brings us back to uncertainty and the English strip system. The premise to be evaluated is that private information gives the rationale for the dispersed lands of the strip system, that is, for *ex ante* division of land rather than *ex post* division of crops.

Indeed, this idea has a long history in the social sciences, though formalised only recently in the context of the literature on principal-agent problems. Essentially, by making individual households bear the consequences of their own actions and decisions, specifically eating their own crops, each household will be more inclined to work harder and to worry more about making good decisions. The key idea which formalises this intuition is that there is uncertainty about crop yields and that labour effort is not inferable *ex post* from observed output. Otherwise, a full information solution could be implemented by tightly specified labour assignments and full enforcement of the social contract. Then the pattern of landholdings would not matter.

An important piece of indirect evidence is consistent with the moral hazard

premise, ironically by its elimination. Specifically, the strips of the lord of the manor were farmed for him by the villagers, and so, if there was some scope for shirking, it should be evident there. In fact, villagers laboured on the lord's strips under highly specified, shock contingent assignments, with duties specified in meticulous detail, and more to the point, there was a group of officials on the strips, as in the meadows and woods, presumably to ensure performance. The hayward, woodward, reeve, and bailiff were officials of the lord who, among other duties, oversaw the ploughing, planting, weeding, harvesting, and transporting of the lord's grain. On a first pass one might suppose that a full information allocation of labour was effected on the lord's land but only at some not inconsequential cost, the cost of monitoring.

But were there other means by which the lord might have obtained grain, and might these have been less costly? In fact, the local church seems to have obtained grain by fixed tithes, roughly 10% of each household's crop. Presumably, the lord might have done the same. In fact, there are references in the historical, descriptive literature to the lord receiving fixed percentage transfers in addition to that produced from his own lands. Thus one is faced with several possibilities about which theory has something to say, at least up to unobserved parameters. That is, one can write down a programming problem for the determination of transfers from agents to the lord, specifying probability distributions of agricultural outputs as functions of labour and capital inputs, specifying the degrees of risk aversion among the households, and specifying the costs of direct monitoring. The solution to this private information programme will then optimally weigh the disincentive effects of sharecropping, as households do not bear the full consequences of their effort, against the direct cost of monitoring on the lord's land. Coexistence of systems is a possibility, unconfirmed at the moment.

If the solution displays at least some sharecropping, then it seems it may also display properties inconsistent with reported observations. Specifically, formal models of sharecropping in the face of private information do not lead one to predict fixed percentage transfers as with the tithes. Further, if there is any common component to the shocks determining each household's crop, or any group of households who experience a common component, then one would predict cross household output comparisons, that is, cross-household tie-ins. In fact, the strip system, with virtually identical pieces of land allocated over various households, would seem to make shirking difficult (arguing for sharecropping rather than direct monitoring). Further, one would predict the intertemporal tie-ins mentioned earlier and insurance-borrowing agreements with the lord. These are the logical if somewhat unanticipated implications of the private information premise.

Actually, general equilibrium theory will be concerned with transfers among villagers themselves, not just with transfers to and from the lord. And if there is incomplete *ex ante* diversification of shocks by land dispersion, or idiosyncratic shocks to labour productivity reflecting illness or disability, then private information theory predicts nontrivial transfers of consumption *ex post* despite the strip system and predicts also nontrivial transfers of labour during the crop year. The nontrivial consumption transfers argue again for intertemporal tie-ins

for a given household, with restricted borrowing-lending possibilities in the village, and also again for cross-household comparisons of output in the determination of cross-household transfers. The Thai temple insurance system mentioned earlier comes to mind as well as many more questions than I had the good sense to ask at the time.The nontrivial labour transfers argue for labour sharing arrangements. Curiously, labour sharing is prevalent in virtually all the Thai villages I visited. That much I was able to verify. But, with neighbours working on one anothers' fields one might also re-evaluate the moral hazard premise. What are the sources of private information and how much is detectable *ex post*? In short, much more work remains to be done, both on a logical and empirical level.

IV. GENERAL EQUILIBRIUM MODELS AS EXPERIMENTAL LABORATORIES, FOR EXAMPLE, FOR THE DESIGN OF OPTIMAL FINANCIAL STRUCTURES

As has been emphasised by Lucas (1980), and noted earlier, general equilibrium models can be thought of as laboratories in which the researcher conducts experiments. That is, the researcher specifies the environment in terms of preferences of the decision makers and the endowments and technology available to them, supposes maximising behaviour on the part of decision makers, and then postulates some outcome from interaction among the decision makers. There follows a prediction, that is, an outcome from the experiment. As Lucas notes, such thought experiments are relatively inexpensive and may yield insights about institutions and outcomes.

Observations on financial structures in medieval Europe provide motivation for me, at least, for some experiments that have yet to be performed adequately. The idea of taking the observations from history is that one naturally suspends disbelief and drops preconceptions about contemporary structures.

1. Exchange at the large international fairs of Champagne was supported by something close to a Walrasian pure credit system, or so it might seem. Each of these fairs was associated with a fixed calendar, the first few days for the introduction goods; the next for transactions in cloth, leathergoods, and drugs and spices, in that order; and the last at the end for settlement. Apparently, potential sellers received credit on the books of local bankers for goods not yet sold, credit transferred to the first sellers relatively early on in the fair sequence. In the end, accounts were to balance, and it seems from various reports that relatively few transactions were closed with the transfer of specie. Numerous historians emphasise that most if not all sellers brought little specie to these fairs.

2. A prominent institution in the cities of Barcelona, Venice, and Bruges early on in the Commercial Revolution was the collection of local banks. Raymond DeRoover (1948) emphasises that transfers on the books of these bankers facilitated payments on a continual, daily basis, outnumbering transactions in coins by a high amount. He concludes that regular customers made extensive use of the bank transfer system, with most local payments made

by assignment on bank accounts. Further, this practice seems to have been facilitated by the fact that each banker had an account with every other banker, so that withdrawal of coins was not necessary to pay a claim outside one's own bank. It is known that accounts across bankers were reconciled and settled from time to time. Finally, one of DeRoover's ledgers shows 11,000 accounts, and he estimates the population of Bruges at the time at not more than 45,000. His conclusion: every merchant, broker, innkeeper, and draper had bank accounts, and probably also realtors, furriers, and goldsmiths. A tentative conclusion might be that, as with the fairs of Champagne, a banking, book-transfer system facilitated routine and more or less systematic payments.

3. Nevertheless, there is little doubt that the banks of Barcelona and Bruges also engaged extensively in intermediary-investment activities, financing relatively long term and occasionally risky commercial undertakings. The account books studied by DeRoover reveal many small overdraft loans, and, more to the point, a few relatively large overdrafts which seem to have absorbed most of the banks' resources. Apparently, the latter were not temporary accounts; rather they were investment loans in which the banker entered into a partnership with the borrower, furnishing him permanently with working capital. The risk of loans in Bruges and elsewhere is explicitly acknowledged by the requirement of collateral or by the assignment of tax revenue in the case of loans to municipal authorities. Often, as in Barcelona, moneychangers were required to post an extraordinary bond before they could accept deposits. Further, municipal authorities occasionally attempted to control the portfolios of banks, as in Venice in 1274, prohibiting bankers from trade in iron, copper, and tin and from holding more than two thirds of their investment in the public debt.

4. Still, banks failed frequently. In Bruges in 1309 the number of moneychangers fell from 19 to 13. And according to one Venetian senator, of the 103 bankers that had existed at one time or another in Venice, 96 came to a bad end. Further, securities were often inadequate to cover losses. One Senior Costello was beheaded in front of his bank in Barcelona in 1360. DeRoover states, moreover, that banks were subject to runs on false rumours, imminence of war, news that a commercial venture had gone awry, or failure of a merchant in debt to the bank. Apparently, these failures and panics caused severe disruptions in the more mundane payments mechanism.

In the face of all this acknowledged risk one might guess that the liabilities of a bank might make a sharp distinction between depositors using the bank as a convenient means of payment and depositors using the bank as an investment–intermediary device. Unfortunately, evidence for any such separation of the means-of-payment role of banks from the investment-mutual fund role is far from overwhelming, with most deposits apparently payable on demand. In fact, the researcher begins to entertain doubts about the feasibility of separation, that is, about the distinction between these two roles. Can a means-of-payment role be separated from an investment–intermediary role? Is separation a matter of degree? What is an optimal bank deposit contract? Further, what kind of competition among banks is optimal? Should banks be

allowed to fail, and to what extent should depositors be protected? Are bank runs an intrinsic part of bank failures? More generally, what is an optimal banking arrangement in which there is uncertainty, that is, when receipts and payments are not entirely predictable?

These questions can be addressed in the experimental laboratories of general equilibrium models. The idea, of course, is first to give banks and/or intermediaries some underlying rationale, as in Douglas Diamond (1984), or Boyd and Prescott (1986), or Townsend (1978) and then to see what else is implied. Actually, even the first part of this research agenda is at a relatively early stage. The model of Diamond and Dybvig (1983), for example, suggests that runs are endemic to banks. But the bank contracts in their model are imposed exogenously and can be circumvented, as they show, by appropriate institutional design. Put another way, Diamond and Dybvig create their own problem. Still, they seem to be close to a problem which would emerge from an environment specified at the level of endowments, preferences, technology and some impediments to trade, that is, from an experimental laboratory.

V. SOME FINAL COMMENTS ON METHOD AND PHILOSOPHY

In this final section I shall comment on some concerns of fundamental importance. Some of them have to do with the interaction between methods and philosophy. I shall try to separate the two.

V.1. *Identification*

At some level general equilibrium theory is vacuous. For example, for pure exchange economies it is known that one can generate any aggregate excess demand function by a suitable specification of endowments and preferences. Related, unobserved shocks to preferences with arbitrary probability distributions can generate arbitrary patterns of cross household consumptions. So, if some version of an enlarged model always fits, to what extent does general equilibrium theory have content?

As indicated initially, general equilibrium models can be regarded as a catalogue for actual economies, and so it is a virtue that there is always something in the catalogue which is close to the actual economy at hand. Still, there may be more than one close economy in the catalogue. That brings me to the view that we should try to catalogue or fit by choosing from relatively simple economies. Further, it seems plausible to me that impediments to trade, such as spatial separation and private information, are important determinants in reality, and so simple theoretical economies with these elements have a special appeal. Finally, impediments to trade can sometimes be checked against reality, whereas unobserved preference shocks cannot.

V.2. *Decentralisation and Competitive Markets*

The competitive markets hypothesis has been viewed primarily as a postulate to help make the mapping from environments to outcomes more precise. It has also been used as a device for simplification and tractability, bringing in

methods about which we know a great deal. In the end though it should be emphasised that market structure should be endogenous to the class of general equilibrium models at hand. That is, the theory should explain why markets sometimes exist and sometimes do not, so that economic organisation falls out in the solution to the mechanism design problem. Put crudely, one can accept the implications of a solution to some social optimum problem without embracing a decentralised, competitive version of the same economy.

V.3. *Optimality and Social Activism*

Pareto optimality has been recommended as the 'standard' technique to deliver the mapping from environments to outcomes, and this is troublesome. Specifically, in attempting to explain reality with the notion that allocations are optimal for some stylised model of reality, one appears close to the philosophy of Candide, that whatever happens we live in (or study) the best of all possible worlds. This philosophy is repugnant to those who believe that the world could be improved if only one were to understand it better. Yet the method of optimality seems to undercut any normative role for social scientists, since, as noted, observed institutions and outcomes are postulated to be optimal. Actually, the criticism at a superficial level is not as severe as it might seem. The 'optimality' models can deliver activist institutions in the sense that recommended actions are functions of perceived states. For example, one can deliver an optimal activist currency rule for the model of tokens as communications devices discussed above. And one can imagine a model in which one group of agents acquires information about the environment and the actions of others and passes that information along to other agents in the model. Still, at a deeper level, one cannot help but get involved in a discussion of free will. If I am an individual in the model, what do I postulate about my behaviour since I only understand that behaviour as I write down the model? As Sargent (1984) noted in a somewhat different policy context, this tension is unlikely to go away. But of course one should be aware of it.

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