

What is Money?

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11 Menger's theory of money: some experimental evidence

Peter G.Klein and George Selgin

Introduction

More than a century ago, Karl Menger (1881 [1870], 1892) sought to explain how the social institution of money—a generally-accepted medium of exchange—could develop without deliberate design in an economy of self-interested individuals. Rejecting as unhistorical earlier theories treating money as a product of some explicit agreement or edict, Menger portrayed it as a product of spontaneous evolution. Menger's theory ultimately helped to inspire a large modern literature on the spontaneous emergence of exchange media, including contributions by Jones (1976) and Kiyotaki and Wright (1989, 1993).

Despite its originality and enduring value, Menger's theory leaves many questions unanswered. In particular, Menger had little to say about the dynamic process by which one out of many potential commodity monies becomes a universally-acceptable medium of exchange. Modern theories of the evolution of money likewise suffer from a relative lack of attention to evolutionary dynamics.

Here we use computer simulations to elaborate upon Menger's theory, examining both the dynamics of monetary evolution and the robustness of Mengerian convergence to a single money.

Menger's theory

Menger's account begins in a barter economy. A trader wishing to obtain good A may have difficulty trading endowment good B directly for A because the seller of A does not want B. The trader may then try instead to trade indirectly, swapping B for C in order to swap C for A. Good C may have even less use value to the trader than good B, but is assumed to have a higher degree of marketability (*Absatzfähigkeit*) than B.

Under barter, all goods have very limited marketability: the absence of what Jevons termed a 'double coincidence of wants' makes it difficult for any trader to exchange his or her endowment directly for something having a

higher use value to that trader. Consequently, a significant difference exists between each good's normal buying price and the sale price it will command if it must be disposed of quickly. This is the bid-ask spread. Still, Menger argues, certain goods are more marketable, and hence exhibit lower bid-ask spreads, than others. Such goods 'can be disposed of...at any convenient time' with relatively little loss from their normal purchasing prices (Menger 1892:244). Any trader intending to trade goods of relatively low marketability will therefore benefit by trading those goods 'not only for such as he happens to be in need' but also for a more marketable good that might be utterly useless to the trader except as a medium that can be exchanged more readily for the goods the trader ultimately wishes to acquire.

At first, Menger argues, only a few traders will recognize the advantages of employing especially marketable goods as media of exchange. However, the success of a small number of innovative traders will spur imitation. As traders begin to employ a particular marketable good as an exchange medium, the demand for that good broadens, and its marketability is further enhanced. Eventually, some good that was once only slightly more widely accepted than other goods becomes money, a *universally* accepted medium of exchange.

In game-theoretic terms, the adoption of a particular good as money can be understood as the solution to a pure co-ordination game: in principle, traders could employ any good as money. The more agents who adopt a particular good, the greater that good's marketability, and the more attractive it becomes in the eyes of other agents. Once a good becomes universally accepted, it normally will not be in any trader's interest to abandon that good in favour of any other less marketable indirect exchange medium.

If the monetary co-ordination game just described has many possible Nash equilibrium solutions—one for each exchangeable commodity—how do agents manage to co-ordinate around one particular equilibrium? To answer this question, Menger appeals to what Thomas Schelling (1960:57) later referred to as co-ordination-problem 'focal points'. In Menger's account, certain goods are more marketable than others *before* the monetary selection process begins. The greater marketability of these goods makes them more prominent candidates for adoption as indirect exchange media.¹ Monetary equilibria based on these more prominent goods become focal points of the monetary co-ordination game, while other potential equilibria are ignored. In the simplest case, one good is initially more marketable and hence a more prominent candidate for adoption as money than others, so that traders focus on it to the neglect of all other potential candidates. In this way, the economy selects one particular Nash equilibrium solution to the monetary selection game out of numerous potential alternatives.

Shortcomings of Menger's account

Although Menger's theory provided a plausible and enduring answer to the question 'How can money emerge?', the theory leaves many questions

unanswered. Several of these questions raise doubts concerning the robustness of Menger's main conclusion that barter will inevitably give way to monetary exchange without need for public interference.

First, Menger's explanation of the origins of money lacks an adequate treatment of the *dynamics* of the monetary selection process. Menger's argument, with its reliance upon a monetary co-ordination game with preexisting and directly observable focal points, suggests that agents initially assumed to be engaged in barter would 'jump' immediately from barter to a monetary equilibrium upon discovering that one good is more marketable than the rest. Agents should realize at once that the most marketable good is bound to become money, and so proceed immediately to accept that good in exchange. Instead of evolving gradually, as Menger would have it, money emerges in a flash.

Menger himself does not reach this conclusion, because he assumes that many agents hesitate at first to take advantage of the goods' differing degrees of marketability. But this assumption seems patently *ad hoc*: if the goods' varying degrees of marketability are directly observable, why should anyone refrain from immediately putting this knowledge to use? On the other hand, if agents *do not* directly observe goods' varying degrees of marketability, how can convergence upon a particular medium be guaranteed? Clearly, we need to relax Menger's assumption that marketability is directly observable, both to allow for more interesting evolutionary dynamics and to determine whether Menger's main conclusion holds for an economy with imperfectly informed agents.

Menger's assumption that some goods are initially more marketable than others also begs an important question. Suppose that all goods are at first equally marketable. Would such a starting point preclude convergence upon a particular monetary equilibrium?

Finally, we may ask whether the answers to the above questions depend upon the size of the economy being considered, that is, the number of distinct goods and agents. Does it become more difficult (or perhaps impossible) for an economy to select a monetary equilibrium as the number of distinct goods exchanged in the economy increases?

These questions are only a few raised by Menger's original analysis. In this chapter we provide preliminary answers to several of them with the help of computer simulations of the monetary selection process.

The experimental framework

Imagine an economy in which N agents trade J distinct goods. Each agent is endowed with a single unit of one of the J goods, and wishes to consume one unit of some other good. Agents visit a central marketplace on a daily basis, and each encounters another randomly-chosen agent on each visit. An agent can limit him- or herself to direct exchange, trading

the endowment good only for the good he or she ultimately wishes to consume, or he or she can offer the good in exchange for *either* the desired consumption good *or* some other good considered to be an effective medium of exchange. We assume that an agent restricts him- or herself to accepting in exchange only a single good (perhaps because it is the only good whose quality he or she can expertly judge) apart from the desired consumption good.

In Menger's analysis, some goods are initially more marketable than others, and agents know goods' degrees of marketability. Applying Schelling's focal point theory, Menger's framework leads to trivial learning dynamics in which the most saleable good would immediately become universally accepted were it not for some agents' (unexplained) hesitation to engage in indirect exchange.

Here we assume that, although all agents are prepared to take advantage of indirect exchange, they are not equipped with perfect knowledge of goods' marketability. Instead, they have very limited knowledge, which they acquire by sampling the market. Before any visit to the marketplace, a trader communicates with some randomly-selected agent (not necessarily the one he or she will encounter in the next trip to the marketplace), and notes which good that agent is willing to receive in exchange for the endowment. If the sampled agent has not yet chosen an indirect exchange medium, that agent's desired consumption good is noted. Otherwise, the agent's desired medium of exchange is noted. Traders then visit the marketplace, willing to accept as an exchange medium the good that appears most saleable according to their market sample.

In this incomplete-information framework, different agents may initially choose different exchange media based on their particular market sampling results: the economy no longer jumps at once to a particular monetary equilibrium. But does the economy *eventually* converge upon a particular monetary equilibrium, and, if so, under what circumstances? Does convergence depend on the presence of a starting focal point, where one good is initially acceptable to more agents than the rest? How is the likelihood or speed of convergence affected by changes in the number of agents or in the variety of goods?

Simulation

To answer the above questions, we programmed a computer to simulate trade interactions in the described environment. The program simulates a 'Polya urn' experiment, named after the famous Stanford mathematician George Polya (1887–1985). For a physical analogy to our economy with N agents and J distinct types of goods, imagine an urn filled with beads. Each bead represents a unit of demand (marketability) for a particular type of good, and each type of good is represented by a distinct colour. The

beads are placed in an urn, where the initial number of beads is at least equal to the initial number of agents. Suppose initially there are four agents and four types of goods, yellow, blue, green, and red. If each trader demands one unit of some good with which he or she is not endowed, and no two traders demand the same type of good, the urn will initially contain one bead of each colour only, the market for each type of good consisting of one agent only.

At first, the demand for goods is a consumption demand only. However, each trader will eventually be willing to exchange his or her endowment *either* for the desired consumption good or for an indirect exchange medium. Thus, once each trader has chosen an initial medium of exchange, the total number of beads or 'marketability units' in the urn will be equal to N plus the initial number of beads. After each trader makes an initial selection, the original beads representing consumption demands are removed from the urn, because agents undertaking further market samples inquire what *medium of exchange* a sampled agent is willing to accept, ignoring agents' consumption goods preferences. (We ignore the fact that some agents will not ultimately engage in indirect exchange, because the exchange medium they would select is none other than their preferred consumption good, or because they are initially endowed with what turns out to be the generally-accepted exchange medium.)

The medium of exchange selection process proceeds as follows: an agent planning to visit the marketplace first draws a bead randomly from the urn (samples for information). That colour of good becomes the agent's exchange medium, and the bead is returned *with double replacement*. The extra bead represents the extension of the market for the good by one unit. Eventually every agent chooses an exchange medium, and all the beads which were initially in the urn, representing the consumption demands, are removed. Thereafter the selection process is repeated, with agents taking new market samples, and revising their medium of exchange choices accordingly. As a new exchange medium is selected, and a corresponding bead is added to the urn, a bead representing the previous period's selection is removed. Although the total number of beads in the urn remains equal to the number of traders, the relative marketability of different goods may continue to change. The economy is said to have converged upon a particular monetary steady-state when all the beads in the urn are of one colour.

Our primary goal is to see how changes in initial conditions, the number of agents, the number of goods and the initial prominence of particular goods affect the time needed for convergence to a monetary steady-state. We measure time in 'market days', defined as completed rounds of trading. For example, in a model with twenty agents, the first twenty trades (each agent's initial visit to the market) constitute the first market day, the next twenty trades (each agent's second visit to the market) the second market day, and so on. The simulation continues until the economy has converged on a single medium of exchange.² Because two simulations with the same

initial conditions may produce very different results, we ran a simulation for each set of initial conditions thirty times, then computed the average time to convergence for those thirty simulations.

Results

Our base simulation represents an economy with ten types of goods and ten agents, with each agent wishing to consume one unit of one type of good (so that all goods are equally prominent). In this and all other simulations we perform, agents' exchange medium choices are based on a single market sample only.

Results of simulating this base model are given in the first column of Table 11.1. The economy converged to a monetary steady-state in every run, although the time to convergence varied widely, ranging from 2.3 to 12.4 market days. The average time to convergence over thirty runs was 4.5 market days (or forty-five total trades), with a standard deviation of 2.1 market days. Thus, even in an extremely simple framework with limited information and no focal point, a simulated economy converges on a universally-accepted medium of exchange in a relatively short period.

To learn more about the convergence pattern, let us consider in detail the run with the median time to convergence. Figure 11.1 shows the convergence pattern by plotting the percentages of beads representing each good for each market day until the economy converges. For ease of exposition, we number the goods *ex post* according to their finish in the simulation: the good that is eventually chosen as the medium of exchange is labelled Good 1, the last good to be eliminated is labelled Good 2, the next-to-last to be eliminated is labelled Good 3, and so on.

Figure 11.1 reveals a striking feature of the convergence process: there is no monotonic increase in the percentage of beads representing the good that eventually becomes the medium of exchange. Indeed, the relative shares of the different beads change unpredictably. For example, Good 2 has 90 per cent of the 'money market' after twenty-seven trades (2.7 market days), but begins to lose market share and eventually drops out. This suggests that, in an economy described by this simple sampling and belief-updating process, a good may be the economy's most widely-accepted medium of exchange at one point, yet not be the good that ultimately becomes a universally-accepted medium of exchange.

Changes in the number of agents, number of goods, and scale

Next we study the effects of changing the number of agents, holding the number of distinct goods constant. The results appear in the second, third, fourth, and fifth columns of Table 11.1. We first return to our base model, with ten agents and ten goods, and then progressively double the number

Table 11.1 Simulation results

	(1) <i>Base model</i>	(2) <i>Changes in number of agents</i>	(3)	(4)	(5)	(6) <i>Changes in number of goods</i>	(7)	(8)	(9) <i>Changes in scale</i>	(10)	(11)	(12)
<i>Initial parameters</i>												
Agents	10	10	20	40	80	20	20	20	10	20	40	80
Goods	10	10	10	10	10	5	10	20	10	20	40	80
Simulations	30	30	30	30	30	30	30	30	30	30	30	30
<i>Time to converge (market days)</i>												
Mean	4.5	4.5	10.9	19.2	38.5	8.8	10.8	9.3	4.5	9.3	17.3	34.7
Median	3.9	3.9	9.2	13.2	31.2	7.2	9.2	8.4	3.9	8.4	14.7	32.1
Standard deviation	2.1	2.1	6.7	11.5	15.5	5.8	6.7	4.0	2.1	4.0	7.8	14.5
Minimum	2.3	2.3	3.0	4.9	11.9	1.0	3.0	2.9	2.3	2.9	7.4	13.4
Maximum	12.4	12.4	34.2	49.7	62.5	24.2	34.2	18.5	12.4	18.5	41.5	62.5
<i>Change in mean from first model in set</i>												
	—	—	2.422	4.267	8.556	—	1.227	1.057	—	2.059	3.845	7.711
<i>Change in median from first model in set</i>												
	—	—	2.359	3.385	8.000	—	1.278	1.167	—	2.141	3.769	8.231

Figure 11.1 Convergence path for base model (ten agents, ten goods)

of agents, keeping the number of distinct goods at ten. As seen in Table 11.1, doubling the number of agents roughly doubles the average time to convergence. (Note that increasing the number of agents also increases the number of trades per market day, so the time to convergence measured in total trades more than doubles as we double the number of agents.) Figure 11.2 summarizes the average, minimum, and maximum time to convergence as a function of the number of agents.

To see how the convergence *pattern* changes as we change the number of agents, we again plot convergence paths for the runs of each model having median convergence times. Figures 11.3a through 11.3c show convergence paths for the models with twenty, forty and eighty agents, each with ten goods. It can be seen that all four models have similar convergence characteristics. In each case, a good can have a majority share of the market in the early rounds yet not end up as the chosen medium of exchange.

For the next set of experiments, we hold constant the number of agents and vary the number of distinct goods. Columns (6), (7), and (8) of Table 11.1 give the results of three sets of simulations, the first for twenty agents and five goods, the second for twenty agents and ten goods, and the third for twenty agents and twenty goods. Surprisingly, variation in the number of goods has little effect on the average time to convergence. With five goods, the mean time to convergence is 8.8 market days. With ten goods, the mean time to convergence increases slightly, to 10.8 market days. With twenty goods, the mean time to convergence falls to 9.3 market days. Figure 11.4 summarizes the average, minimum, and maximum time to convergence as a function of the number of goods.

Figures 11.5a through 11.5c plot the convergence paths for the median time-to-convergence run of each model.³ Increasing the number of goods has no systematic effect on the convergence path, because goods with low

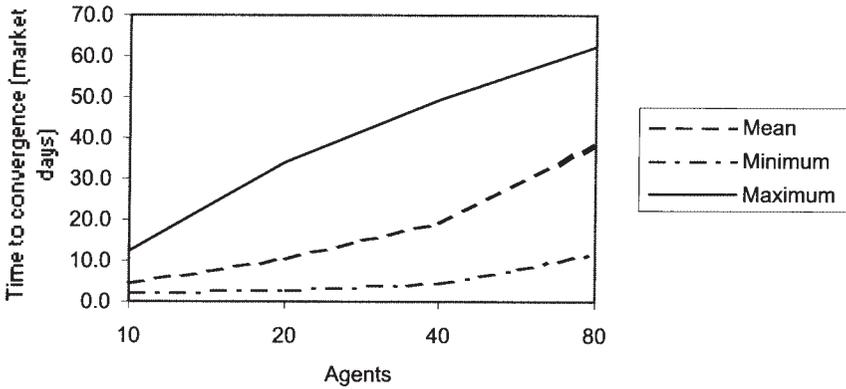


Figure 11.2 Effects of changes in the number of agents

percentages in the early rounds of trading are quickly eliminated from consideration. Thus increasing the initial number of goods has little effect on agents' ability to co-ordinate on a medium of exchange.

Finally, we vary the overall scale of the economy by proportionately increasing the numbers of both agents and distinct goods. Columns (9) to (12) of Table 11.1 reveal the results of four sets of simulations, the first with ten agents and ten goods, the second with twenty agents and twenty goods, the third with forty agents and forty goods, and the fourth with eighty agents and eighty goods. Figure 11.6 summarizes the average, minimum, and maximum time to convergence as a function of scale, and Figures 11.7a through 11.7c plot convergence paths for the median run in

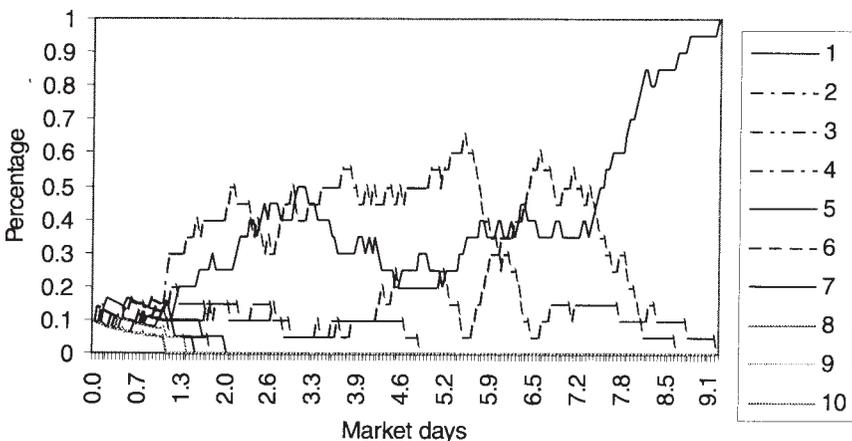


Figure 11.3a Convergence paths with changes in the number of agents (twenty agents, ten goods)

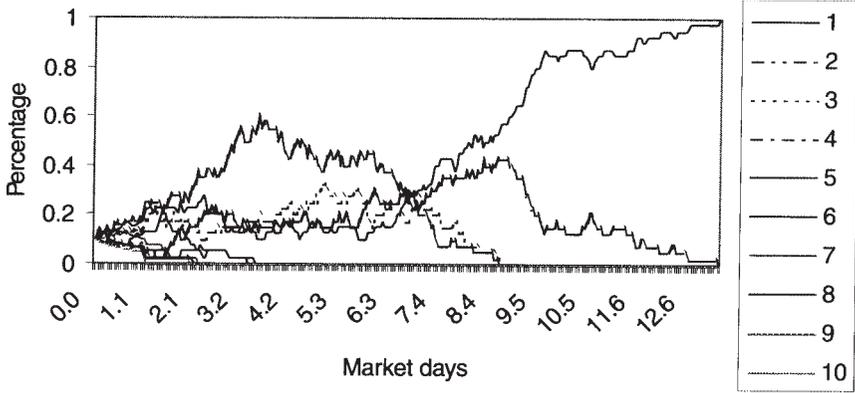


Figure 11.3b Convergence paths with changes in the number of agents (forty agents, ten goods)

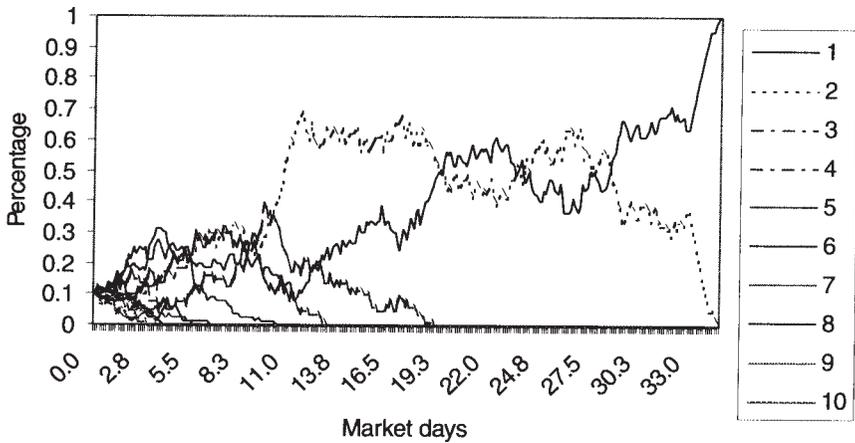


Figure 11.3c Convergence paths with changes in the number of agents (eighty agents, ten goods)

each set. As seen in Table 11.1 and Figures 11.7a through 11.7c, a doubling in the scale of the economy leads to an approximate doubling of the average time to convergence. However, as we learned in the previous experiments, this is primarily due to the effect of increasing the number of agents, not the effect of increasing the number of goods.

Simulating a focal point

In the previous section we showed how, in a very simple model, a universally-accepted medium of exchange can emerge even when all goods

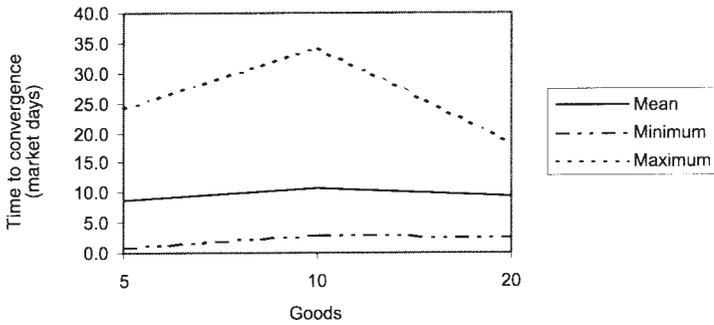


Figure 11.4 Effect of changes in the number of goods

are initially equally marketable. As we noted previously, Menger's account of the origins of money assumes that some goods are initially more marketable, thus constituting focal points on which the economy can converge. To explore the effects of focal points, we ran sets of simulations in which one good was initially more prominent—that is, had more beads in the urn—than the other goods. The results of these simulations are presented in Table 11.2. The first column of Table 11.2 gives results from thirty simulations of our base model with ten agents and ten equally marketable goods, each represented by a single bead in the urn. The average time to convergence is 4.5 market days. Column (2) reports the result of thirty simulations of a model with ten agents and nine goods, one of which is represented by two beads in the urn. As before, we began with the same number of beads as agents; this time, however, one good was

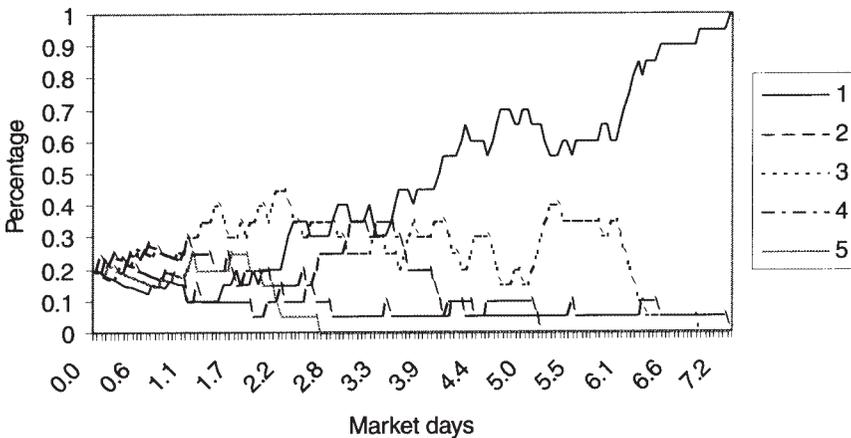


Figure 11.5a Convergence paths with changes in the number of goods (twenty agents, five goods)

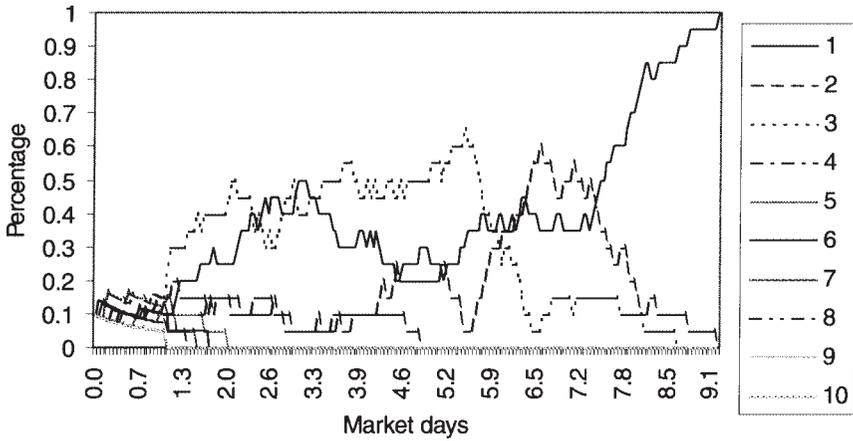


Figure 11.5b Convergence paths with changes in the number of goods (twenty agents, ten goods)

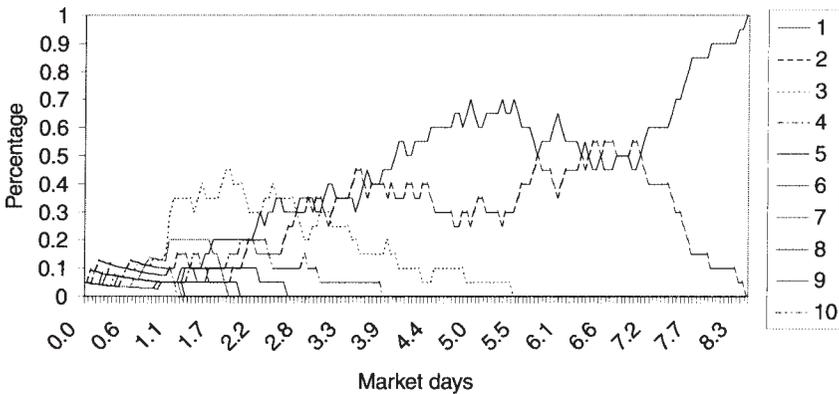


Figure 11.5c Convergence paths with changes in the number of goods (twenty agents, twenty goods)

twice as likely to be selected by the first trader as the remaining eight goods.

Surprisingly, making one good initially more marketable than the others had only a fairly small effect on the average time to convergence. For the simulations reported in column (2) of Table 11.2, in which the focal good is initially twice as saleable as the other goods, the mean time to convergence is 4.6 market days, essentially the same as that of our base simulation. (The standard deviation is larger, 3.4 to 2.1, since one simulation converged in only 1.5 days.) However, the good that is initially twice as marketable was about twice as likely to end up as the generally-accepted medium of exchange. The last row of Table 11.2 shows the percentage of simulations in

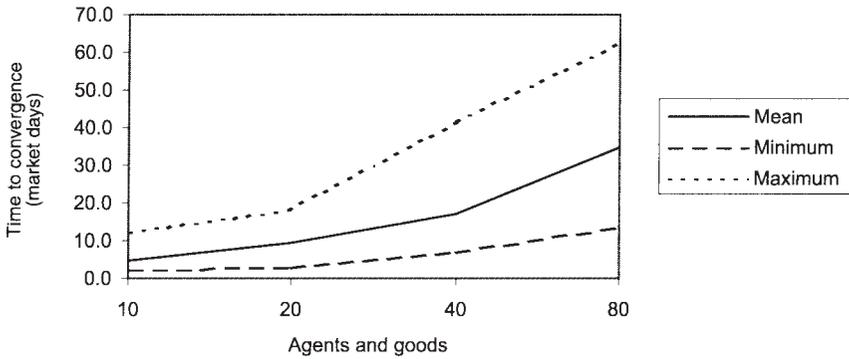


Figure 11.6 Effects of changes in scale

which the good that was initially more marketable became the eventual medium of exchange. In our base simulation with ten equally marketable goods, each good should be chosen, on average, three out of thirty times. For the thirty simulations reported in column (2), the good that is initially more marketable is chosen six times. Thus, although it might be assumed that a small initial advantage would bring a substantial *ex post* advantage, in our model increasing the probability that a particular good would be chosen in the early rounds gave only a roughly proportionate increase in the probability that that good will be chosen as the medium of exchange.

Columns (3), (4) and (5) of Table 11.2 report sets of simulations in which we progressively increased the initial probability that a particular good would be chosen: first we gave one good three times as many initial beads as the other goods, then five times as many, then seven times as many. As seen in column (3), giving one good three times as much initial marketability has about the same effect as giving it twice the initial marketability. The mean time to convergence falls slightly, to 4.2 market

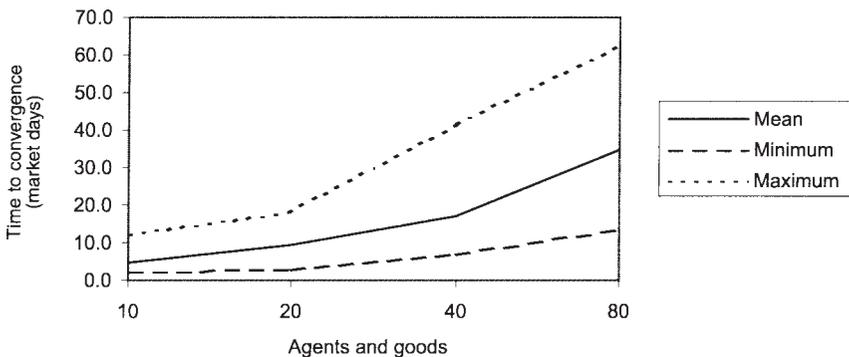


Figure 11.7a Convergence paths with changes in scale (ten agents, ten goods)

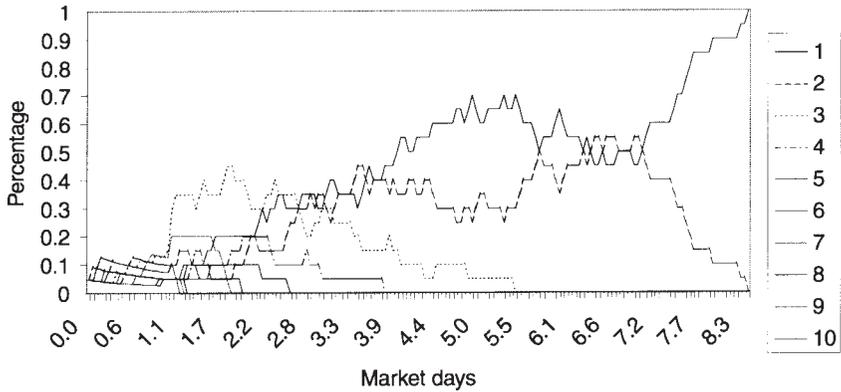


Figure 11 7b Convergence paths with changes in scale (twenty agents, twenty goods)

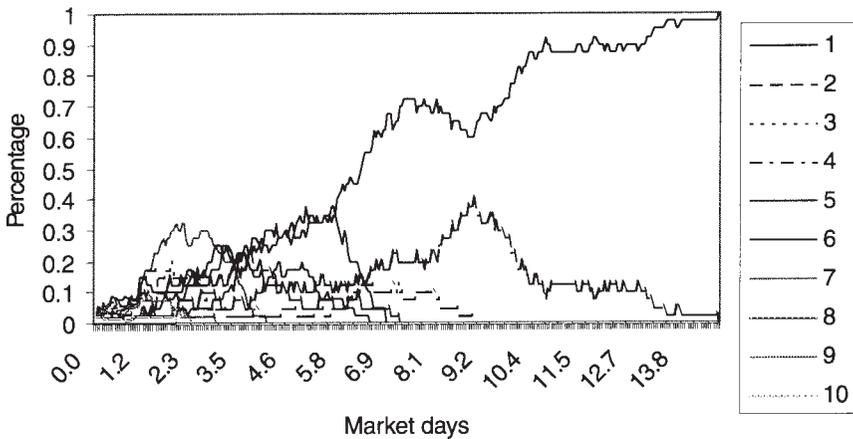


Figure 11.7c Convergence paths with changes in scale (forty agents, forty goods)

days, and the initially more marketable good is chosen as the medium of exchange seven times. Increasing the focal good’s initial advantage to five times the marketability of the other goods causes a slight increase in the mean time to convergence (4.6 market days), but it again leads to a proportionate increase in the effectiveness of the focal point. The initially more marketable good is chosen as the medium of exchange in fourteen of the thirty simulations, roughly five times the probability of any good’s being chosen in the simulations without a focal good.

Figures 11.8 and 11.9 summarize the effects of changes in the strength of the focal point. The horizontal axis measures this strength in terms of the initial share of the focal good. A value of 1 corresponds to the base simulation in which

Table 11.2 Focal point simulation results

	(1) <i>All goods equally marketable</i>	(2) <i>One good twice as marketable</i>	(3) <i>One good three times as marketable</i>	(4) <i>One good five times as marketable</i>	(5) <i>One good seven times as marketable</i>
<i>Initial parameters</i>					
Agents	10	10	10	10	10
Goods	10	9	8	6	4
Initial beads	10	10	10	10	10
Simulations	30	30	30	30	30
<i>Time to converge (market days)</i>					
Mean	4.5	4.6	4.2	4.6	3.4
Median	3.9	4.1	3.9	3.3	3.2
Standard deviation	2.9	3.4	1.7	3.7	1.7
Minimum	2.3	1.5	2.0	1.1	1.1
Maximum	12.4	20.4	10.1	16.4	6.6
<i>Number of simulations in which focal good is chosen as medium of exchange</i>					
	—	6	7	14	19

all goods are equally prominent. A value of 2 represents the simulation in which one good has twice the initial share of the other goods, and so on through 7, representing a simulation in which one good has seven times the initial share of the other goods. In Figure 11.8, the vertical axis measures the average, minimum, and maximum time to convergence. In Figure 11.9, the vertical axis measures the percentage of simulations, based on the sample of thirty, in which the initially more saleable good was chosen as the medium of exchange.

As the strength of the focal point increases, the mean time to convergence tends to fall. When we increased the initial marketability of the focal good to seven times that of the other goods, the mean time to convergence fell to 3.4 market days, with a standard deviation of 3.2. As the column (5) of Table 11.2 indicates, the fastest time to convergence was 1.1 market days, significantly less than the fastest time without a focal good. Moreover, the initially more marketable good was chosen as the medium of exchange in nineteen of the thirty simulations, roughly seven times the probability of any good's being chosen in the simulations with ten equally marketable goods.

Conclusion

In his treatment of the spontaneous origins of money, Karl Menger argued that different goods under barter have different degrees of marketability.

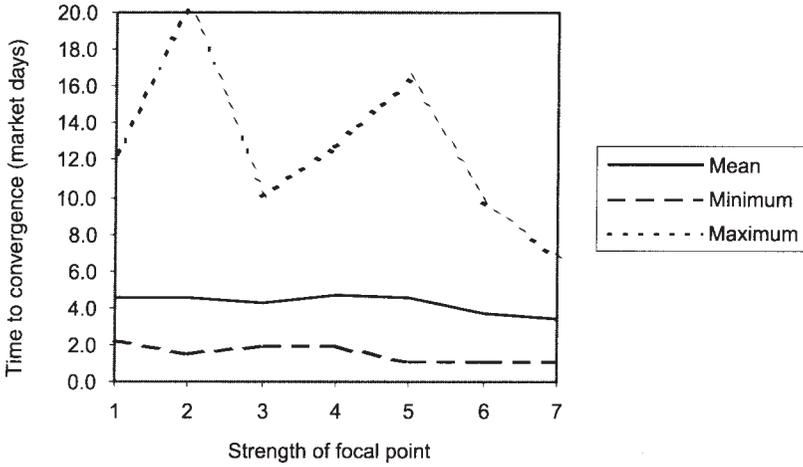


Figure 11.8 Effects of focal point on time to convergence

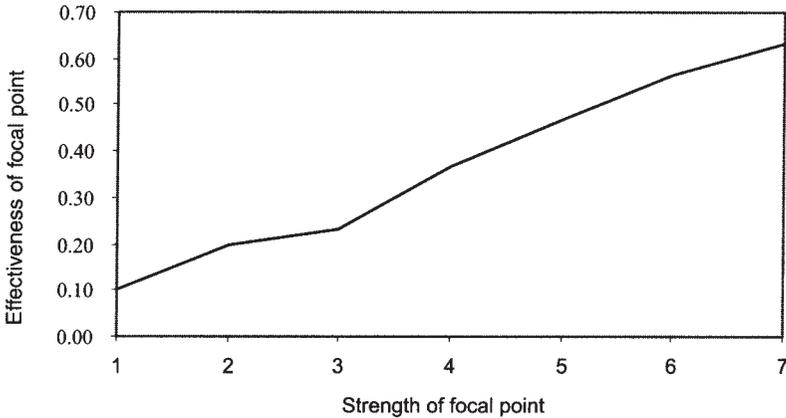


Figure 11.9 Effectiveness of focal point

The most marketable goods become adopted as indirect exchange media by a sub-set of traders, thus further enhancing those goods' relative marketability until all traders are willing to trade for them. Money—a universally-accepted exchange medium—is thus an outcome of human action, but not of human design.

We have shown that money can emerge spontaneously even where traders have only a very dim perception of the marketability of distinct goods, based on very limited random sampling, and even where all goods are equally marketable at the onset of the evolutionary process. The assumption of limited information makes for a much more

interesting evolutionary process than in Menger's own account, where the only factor preventing an economy from jumping all at once to a particular monetary equilibrium is the assumed hesitation of certain traders to become involved in the monetary selection process. In our framework, agents rely on a single market sample to determine which good is most marketable on any market day. Opinions therefore differ at first, but are drawn together as trade continues. The time required for convergence to a monetary steady state is independent of the number of goods in the economy, but is more or less proportional to the number of agents in the economy.

Although no good has to be particularly marketable or prominent at the onset of a monetary selection process for the process to lead to a monetary steady state, as one would expect, a good's initial prominence has a direct bearing on its likelihood of becoming money. A good that is initially twice as prominent as all other goods is about twice as likely to become money. Still, under limited information, a good may be quite prominent at first and yet may not be chosen as money. Finally, and somewhat counter-intuitively, the initial presence of especially prominent goods does not necessarily result in a more rapid convergence to a monetary equilibrium.

In our endeavour to show how money may evolve even under circumstances where agents have very limited knowledge of goods' relative marketability, we have probably exaggerated the extent of agents' ignorance. A more realistic set of simulations might allow agents to rely upon larger market samples to form opinions concerning goods' relative saleability. Also, while we have assumed an extreme version of adaptive expectations in which agents rely on current sample evidence only and ignore findings from past samples, a more realistic model might allow agents to assign a positive but diminishing weight to earlier sample results. These are just two of many possible changes that might contribute to a more realistic depiction of the monetary selection process. We hope to consider the effects of such changes in later work.

Notes

We thank David Robinson and Lawrence H.White for helpful comments.

- 1 A good's initial non-monetary marketability, interpreted narrowly as depending on the number of persons wishing to possess the good for value in use, is only one of several factors that may contribute to its degree of prominence in a monetary co-ordination game. A good's physical properties, its durability, portability, divisibility, etc., may also render it more prominent than other goods.
- 2 To economize on computer resources, we place an upper bound on the total number of trades. The simulation ends either when the economy converges, or when the upper bound has been reached. We used an upper bound of 5000 trades, which was binding in only five of about 400 total simulations.

3 To clarify the pictures, we plot only the ten goods that attain the highest acceptance rates during the process.

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