An introduction to the theory of money and credit

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1 Introduction

Imagine you are with a small group of people on a cruise in the south Pacific Ocean. A severe storm appears suddenly, leaving your ship crippled and forcing a landing. You find yourself marooned on a deserted island, much like the cast of the famous television sitcom, *Gilligan's Island*. The next day, after the initial shock has passed, you contemplate the prospects for survival: you need to find food, water, and shelter. While it's possible for each person to strike out on their own, it's more likely that people will want to remain together. A survival instinct tells us that our chances of living are likely improved through group cooperation.

What form of cooperation is necessary? Again, the answer is likely to come instinctively: people should be assigned to the tasks for which they have a comparative advantage. The physically strong should perform tasks that require physical strength, like hunting for food and gathering timber for shelter. The physically nimble should look for high ground to scout for resources and gather intelligence. The mentally nimble should be assigned to answering puzzles, like how to start a fire without matches. A thousand tasks will need to be done and maximizing survival odds depends on them being assigned in the best way possible.

How might people be expected to coordinate their activities in an efficient manner? Will a natural leader emerge to make the necessary assignments? Will people instinctively know what needs to be done and volunteer for assignments? Any way that works is fine: how coordination is achieved matters less than whether it is achieved. There are strong Darwinian forces at work here: an econometrician is not likely to observe societies having failed to solve this coordination problem beyond some basic level.

A factor that matters for successful coordination is the manner in which rewards are distributed. People are generally willing to work hard for a social cause, but only if their contributions are sufficiently rewarded. Given that we observe few instances of people living in isolation, we can infer that the problem

of distributing rewards is sufficiently solved to induce voluntary participation in existing societies. Where this is not the case, societies are not likely to form in the first place. And when this is no longer the case in existing societies, they are likely to collapse, with individuals coalescing into smaller, more manageable, groups.

So how might our hypothetical group of castaways coordinate their efforts and distribute rewards? Will the first order of business be to establish a money supply to help facilitate exchange? Based on my readings of how primitive societies were organized and based on what I see in terms of interaction among people belonging to informal networks of friends, family and colleagues, the answer is quite clearly no.[1] Economic exchange is almost surely to occur through an informal credit system where people simply perform favors for each other. Anthropologists have labeled this type of informal credit system a *gift-giving economy*.

In fact, *Gilligan's Island* provides us with not a bad example of how the economy likely to function. This sitcom was based on the lives of seven castaways on a remote island in the south Pacific. The theme song provides a nice summary of the situation:

Just sit right back and you'll hear a tale,

A tale of a fateful trip

That started from this tropic port

Aboard this tiny ship.

The mate was a mighty sailing man,

The skipper brave and sure.

Five passengers set sail that day

For a three hour tour, a three hour tour.

The weather started getting rough,

The tiny ship was tossed,

If not for the courage of the fearless crew

The Minnow would be lost, the Minnow would be lost.

The ship set ground on the shore of this uncharted desert isle

With Gilligan...The Skipper too,

A millionaire and his wife,

A movie star

[1] Economists are fond of pointing to the stone money of the Yap islands as an example of primitive money. It seems highly doubtful, however, that these objects were used to facilitate every day exchange; see Bryan (2004).

The Professor and Mary Ann,

Here on Gilligan's Isle.

As far as I can tell, this island community operated as a classic gift-giving economy. That is, even though the island had an ample money supply (the millionaire, Thurston Howell III, had for some strange reason brought along a chest full of U.S. dollars), it was only ever used for comic effect.[2] The Skipper and Gilligan provided the island's brawn. If something physical needed doing, they did it. The two young women, Ginger (a movie star) and Mary Ann (a farm girl), helped with the domestic chores. The Professor provided the island's brain power–the source of many technological innovations that made island life easier. The millionaire and his wife were the island's charity cases. They were both lovable characters, but essentially useless in terms of contributing to the island's economic development. Every camping trip I've ever been on, whether with family or friends, has reminded me a bit of Gilligan's island.

Note that what I have in mind here has little to do with barter exchange. Barter refers to a *quid-pro-quo* exchange of one good (or service) for another between two parties. I'll swap you these potatoes for those eggs. Implicit in this proposal is the idea I'll *only* acquire your eggs if I offer you my potatoes. While these types of exchanges may take place at times–notably, in cases where trust is lacking–they are not typical in gift-giving societies.[3] My father and mother, both raised in primitive Italian villages during the second world war, have recounted stories like this to me: if you needed eggs, you asked your neighbor for some eggs, and that was that. If you had some potatoes to give, you may have done so. But you would have received the eggs in either case (clearly, if a neighbor comes asking for eggs, they needed the eggs!).

One interpretation of "neighborly behavior" is that it's a way to build up credit in the community. Nothing resembling monetary transactions are necessary for this process to work. And yet, the credit status built up in this manner ends up serving as a form of purchasing power. If a high status person (someone in good standing with the community) needs help, they can use their good reputation to draw on the services of others. These sacrifices are forthcoming from the community because they are, in turn, the way people build up their own credit balances. Money and markets—the two institutions economists love to talk about—simply aren't necessary to achieve an efficient (and fair) allocation of resources. At least, not in a small isolated community inhabited by relatively sensible people.

But isn't money necessary whenever there's a lack of double coincidence of wants between two people? Suppose that the Professor values Gilligan's

[2] In the Voodoo episode, the millionaire attempts to bribe a witch doctor with money tied up in elastic bands. After puzzling over the nature of this gift, the witch doctor throws the worthless bills away and starts playing with the elastic bands. See 15 minute mark here: http://www.dailymotion.com/video/x47x3fc

[3] My understanding is that barter was more likely to occur for inter-tribal exchanges.

labor, but that Gilligan does not have any use for the Professor's intellectual forays. One line of thinking (traditional among economists) is to reason that the absence of bilateral gains to trade implies that barter is infeasible and that therefore money is necessary. Only the first part of this statement is correct. However, as I've explained earlier, not only is barter not feasible when there's a lack of double coincidence, it's not necessary in a gift-giving society. And neither is money. Gilligan is likely to work for the professor because he knows that *others* value what the professor has to offer. If Gilligan helps the professor, and if I value what the professor has to offer, then Gilligan is in effect helping me.

A gift-giving society can be thought of as employing a social credit system.[4] For such a system to work well, it must be relatively easy for people to observe the net contributions everyone makes to society. If all can see everyone's debit/credit operations, then the community can update everyone's net credit balances accordingly. If an individual brings food to the community, his or her account is implicitly credited. If an individual eats food brought to the community, his or her account is implicitly debited. These debit/credit operations are performed on a virtual ledger distributed on a network of brains (computers) and updated by through communal consensus with respect to publicly observable information. Kocherlakota (1998) labels this ledger of historical debit/credit operations *societal memory*. This public ledger and the way it's maintained and updated shares some similarities with what Nakamoto (2008) labels a *(block) chain*.

One problem with these primitive social credit systems is that they do not scale very well. That is, they seem to work well enough for small communities, but not for large ones. The key conditioning statement in the paragraph above is "if all can see everyone's behavior." This conditioning factor is roughly met in small communities where everyone knows just about everything about everyone. The distributed virtual ledger technology defined by a network of brains communicating verbally to update and maintain information, however, has obvious limits. In larger societies, it's hard to keep track of what everyone's up to. Someone may claim to have fought in a war on behalf of society, but the incentive to fabricate such information is pretty clear. Similarly, when I show up to the Tim Horton's coffee shop in the morning, I could claim that I've devoted many hours to teaching, but how would they know? Maybe I'm just a free-rider looking for a cup a coffee and trying to pay for it with counterfeit information.

One theory of money is that it becomes necessary when individual actions (trading histories) are unobservable–or difficult to monitor–as is the case when a community grows large. The basic idea is that money is a record-keeping device (Ostroy, 1973) or a communication device (Townsend, 1987) or memory device (Kocherlakota, 1998) that substitutes for a "missing" record-keeping technology (i.e., the inability of primitive social credit mechanisms to scale). Evidently,

[4] See: https://en.wikipedia.org/wiki/Social_credit

these are old ideas in economics, going back to Adam Smith (18th century) and William Stanley Jevons (19th century); see King and Plosser (1986).[5]

In the next section, I try to formalize these ideas. Before doing so, I provide my working definition of *money*.

Definition 1 *Money: an object that circulates as a medium of exchange.*

This may not be perfect, but it gets at the basic idea. The object in question may take a physical form, like paper money, or a virtual form, like an electronic book-entry item. The object may or may not have intrinsic value. Commodity monies like salt have intrinsic value because we can make use of salt as a seasoning or preservative. Token objects like Bitcoin have no intrinsic value because they can only have value in a social context.[6] Since an object will only circulate over time if it preserves value, a medium of exchange is automatically a store of value (though not necessarily a good one).[7] An exchange medium is something that facilitates exchange. We value money not because we can eat it, but because it helps us acquire the goods we do want to eat. An exchange medium is *necessary* if it facilitates exchanges that would otherwise not have occurred, or would have occurred in a less efficient manner.

What problem is money solving?

2 A simple model

Time is denoted $t = 1, 2, ..., \infty$, with each time period divided into three subperiods: morning, afternoon, and evening. There are three individuals named Adam, Betty and Charlie. They are specialized in production and consumption. Each produces an indivisible output y at different points of the day. Adam produces dinner, Betty produces breakfast, and Charlie produces lunch. Adam values breakfast, Betty values lunch, and Charlie values dinner. They each also value their own output, but not as much as their preferred output.

Let $c_j(t)$ denote the consumption of good j in period t. Then for a given period t, individual preferences are given by,

$$\begin{aligned} U^A(t) &= c_1(t) + \delta c_3(t) \\ U^B(t) &= c_2(t) + \delta c_1(t) \\ U^C(t) &= c_3(t) + \delta c_2(t) \end{aligned}$$

where $0 < \delta < 1$ is a parameter measuring how much a person values their own production. Notice that each person places zero weight on at least one

[5] Achian (1977) presents an information-based theory of money demand that does not rely on money performing a record-keeping role.

[6] Robinson Crusoe, for example, may value salt but would never value Bitcoin.

[7] Money is sometimes also said to be a unit of account. That is, all prices are expressed in terms of money. I do not stress this function of money in what follows.

good–this captures the idea that few people value literally every type of good or service that's out there.

Let $0 < \beta < 1$ denote a subjective discount factor–a measure of patience, which I assume is the same for all people. Then, as of date 1, preferences are given by,

$$\sum_{t=1}^{\infty} \beta^{t-1} U^i(t)$$

for $i = A, B, C$.

Let $y_j(t)$ denote the output of good j produced at date t. Then at each date t, the pattern of production is given by,

$$\begin{aligned} A &: \{y_1(t), y_2(t), y_3(t)\} = \{0, 0, y\} \\ B &: \{y_1(t), y_2(t), y_3(t)\} = \{y, 0, 0\} \\ C &: \{y_1(t), y_2(t), y_3(t)\} = \{0, y, 0\} \end{aligned}$$

In what follows, assume that these goods (or services) are non-storable. For example, the breakfast Betty prepares in the morning must be eaten in the morning since it would otherwise spoil. If it did not spoil, she could just eat her own breakfast for lunch.[8]

Note that this economy is structured such that there are no bilateral gains to trade. And yet, there are quite clearly multilateral gains to trade, which I now turn to examining.

2.1 From each according to their ability, to each according to their needs

The title of this subsection is from Karl Marx's 1875 *Critique of the Gotha Program*. Marx was born in 1818, so happy 200th birthday to the influential scholar. People frequently associate this phrase with communism–a system where all property is owned communally, where people are expected to work hard and share the fruits of their labor fairly. I interpret the phrase instead as a desired outcome (where "desired" could mean in an evolutionary sense). After all, a capitalist system with an appropriate redistributive mechanism and private property is also designed to leverage comparative advantages and assign people the fruits of their labor.

What does a fair and efficient allocation look like for this community consisting of Adam, Betty and Charlie? The answer seems clear enough. Betty should prepare Adam's breakfast, Charlie should deliver Betty's lunch, and Adam should prepare Charlie's dinner. If everyone behaved in this cooperative

[8] One should of course not feel constrained to interpret *breakfast* and *morning* literally. The idea is that expenditure opportunities are sometimes made available in periods where one does not have the resources to fund them.

manner, everyone would achieve a daily utility payoff equal to $U(t) = y$, for t. The present value of this payoff is given by, $W = y + \beta y + \beta^2 y + \cdots \infty$, or

$$W = \left(\frac{y}{1 - \beta} \right)$$

If people were angels, then this would be the end of the story. We could all just join a commune, wear flowers in our hair, and do the right thing. The economic fitness of the community would be maximized.

2.2 Sustaining cooperation without commitment

I mentioned earlier that this type of cooperative outcome could be achieved in a social credit system. Whenever somebody wants something, they receive it (i.e., they consume y). But people are also expected to fulfill their social obligations. In this economy, paying your debt means producing y when somebody wants it. If people could commit to these obligations–if they were angels–then social credit should work well enough.

But suppose that people aren't perfect angels. Suppose that some people are either unwilling or unable to commit to their promises? By way of example, let us suppose that Adam lacks commitment. What this means is that, given an opportunity to renege on an obligation, he will take the opportunity if he can get away with it.

This is potentially a big problem because if anyone in this community does not do their part, the economy will collapse with each person being left to fare for themselves. This state of economic affairs is called *autarky* by trade theorists. What payoffs would people enjoy in the absence of cooperation? It is worthwhile noting that as in most trade theory, I'm assuming that cooperation (trade) is *voluntary*. In the absence of trade, each person is left consuming their own produce, which yields a utility payoff $U(t) = \delta y$ for all t. Let $V = \delta y + \beta \delta y + \beta^2 \delta y + \cdots \infty$, denote the value of this autarkic state, or

$$V = \left(\frac{\delta y}{1 - \beta} \right)$$

Note that $V = \delta W$, so that $V < W$ (since $\delta < 1$).

What $V < W$ tells us is that if trade breaks down, then Adam will ultimately make himself worse off. Perhaps there are conditions where Adam will "do the right thing" because it's in his self-interest to do so. To ascertain whether this might be the case, we have to put ourselves in Adam's position and perform the following cost-benefit analysis.

Suppose we're in the evening of a particular day where Adam is scheduled to deliver dinner. He can do one of two things: either deliver dinner to Charlie, or not. If Adam does not deliver the dinner, he gets to consume it himself

for an immediate utility payoff δy. The key question to ask whether this act of noncompliance will have any consequences. Surely, it must since if they are not, then Adam will be encouraged to renege on his obligations forever while at the same time enjoying the benefits of cooperation (breakfast from Betty).

Because there is no coercion or violence in this society (wishful thinking, I know), the only way to punish Adam for his bad behavior is to refuse anything more to do with him.[9] In the present context, assume that Betty refuses to deliver breakfast any longer. Then the payoff to reneging for Adam is given by $\delta y + \beta V$ (the sum of the immediate payoff plus future payoff). On the other hand, if Adam does deliver dinner, then he can expect to enjoy the fruits of future cooperation forever after, which is valued at βW. Therefore, we can expect Adam to do the right thing if,

$$\beta W \geq \delta y + \beta V \tag{1}$$

or, after some algebraic manipulation simply boils down to the condition, $0 < \delta < \beta < 1$. Intuitively, what this says is that it will be easier to garner Adam's cooperation the more he cares about the future (higher β) and the less he values his own produce relative to what the market has to offer (lower δ).

Exercise 1. Derive the analogous conditions for Betty and Charlie. Are they different in any important way? Explain.

Exercise 2. Suppose that the punishment for noncompliance is somewhat weaker than perpetual ostracism. Derive the analogous condition for Adam when the punishment is that Betty refuses to deliver breakfast for one period only, but is willing to forgive Adam if he behaves himself thereafter. Does anything important change as a result? Explain.

The idea of a social credit system can be formalized as a repeated game where individual trading histories are publicly observable. At any date t an individual is described by his or her trading history. Included in this history is information relating to the person's contributions to society (i.e., have they played nice in the past, or not). At the beginning of a period, Betty must take one of two actions: (i) deliver breakfast; or (ii) consume breakfast. A *strategy* maps a history into an action. Suppose Betty adopts a strategy with the following property: if Adam has always played in nice in the past, then she will play nice with Adam; otherwise, she consumes her own breakfast. Suppose further that all players adopt an analogous strategy. This type of strategy is called *tit-for-tat*.[10]

If $\beta \geq \delta$, then a social credit system can sustain the cooperative outcome as an equilibrium of a non-cooperative game. Money is not necessary. What if $\beta < \delta$? Then the economy will collapse to autarky. Introducing a monetary object will not help in this case.

[9] In fact, ostracism is a very common form of punishment for social noncompliance and was tantamount to a death sentence in some primitive societies.

[10] See: https:// en.wikipedia.org/ wiki/ Eye_for_an_eye

2.3 Sustaining cooperation without commitment and with hidden actions

Let me now make people even less angelic than before by introducing the possibility of lying about one's history. For lying to be feasible, one's actions must be hidden from at least a subset of people in society. To model this, assume that when Betty delivers breakfast to Adam, that Charlie cannot see the event. Similarly, assume that when Charlie delivers lunch to Betty, Adam cannot see the event. Likewise, when Adam delivers dinner to Charlie, assume that Betty cannot see the event. How does this change in the structure of information affect the economy?

Let's reconsider the cost-benefit analysis Adam faces when weighing the options of delivering dinner to Charlie or eating it himself. We already know that the payoff from doing the right thing is βW. What about the benefit of reneging on his obligation? In this case, Adam eats his own dinner for an immediate payoff δy. The next morning, however, Betty does not know that Adam reneged the night before. Thus, Adam gets to consume breakfast the next day, which yields the flow payoff βy. Unfortunately for Adam (and everyone else involved), Betty is going to hear about what happened from Charlie in the afternoon. Using the tit-for-tat strategy described above, Charlie refuses to make lunch for Betty. Adam, anticipating Charlie's reaction, again refuses to deliver dinner. That is, Adam anticipates that the economy will collapse to autarky in the next period, which yields a future payoff βV. Thus, the following condition is necessary to sustain trade,

$$\beta W \geq \delta y + \beta \left[y + V \right] \tag{2}$$

or, after some algebraic manipulation, $0 < \delta \leq \beta^2 < \beta < 1$.

Notice that condition (2) is stronger than (1) in the sense there are parameters that satisfy the latter that do not satisfy the former, in particular, $\beta^2 < \delta < \beta$. If this latter condition holds, then it is possible to sustain cooperation through social credit if actions are publicly visible, but not if actions are hidden.

The role of money in this case is to render actions visible. Thus, imagine that there exists a durable, non-counterfeitable, and easily recognizable token. Imagine that this token is initially held by Adam. Of what use could this intrinsically worthless object have? In particular, could Adam use it to buy his breakfast? To do so, Betty would have to be willing to accept it. Would she? Well, she might if she expects to be able to spend it later on lunch. This, in turn requires that Charlie accept the token as payment for lunch. Would he? This would require Adam to accept it as payment for dinner. Would he? Is it possible for the token to circulate in this manner?

The answer to these questions is yes, it is possible for this token to circulate indefinitely in this economy.[11] That is, it is possible for this token to have

[11] Technically, there are two equilibria in this economy, one in which the token circulates

market value, even though it has zero intrinsic value. The role of the token is to serve as a record-keeping device. The token embeds a certain kind of information (in effect, a credit history). The fact that Adam presents the token to Betty for breakfast communicates to Betty that Adam *must* have delivered dinner to Charlie the previous night.[12]

Exercise 3. Imagine that Adam can commit to his promises. Explain how he can use this ability to create an asset-backed money supply. Hint: he is in a position to issue an IOU against his evening production. Under what parameter restrictions (conditions on β and δ) is monetary exchange possible in this economy?

Exercise 4. Consider the economy above without commitment and with publicly observable actions. Imagine that there is an exogenous probability $0 < \alpha < 1$ that Adam cannot produce bread in the evening, but that when he is able to produce, he can produce $y/(1-\alpha)$ units. Describe the socially optimal trading pattern and the expected utility for each individual. Now, suppose that α represents the probability that Adam is sick (and cannot produce) on any given evening. Consider the following two cases. In the first case, assume that Adam's sickness is publicly observable and verifiable. In the second case, assume that Adam's sickness is private information (only Adam truly knows whether he is sick or not). In both cases, Adam cannot commit. Thus, in the first case, a sequential rationality constraint must be satisfied. In the second case, an additional constraint called an incentive-compatibility condition must be satisfied (incentives must be structured in a manner that induces Adam to tell the truth about his medical condition). Describe the level of cooperation that is sustainable for each case.

Exercise 5. Consider the economy described in Exercise 4. Assume now that in addition to Adam's private information concerning his health status, that actions are also hidden (bilateral exchanges are not directly observable by the third party). Explain how monetary exchange solves both of these problems.

Exercise 6. The model above assumes that society consists of three people that meet pairwise in sequence. Alternatively, we could imagine that A, B, and C correspond to three types of people, with a large number N (a continuum) of people of each type. In this case we could imagine people meeting in a sequence of competitive spot markets, with a fixed money supply M being traded for goods in each spot market. What would be the equilibrium price-level in this economy? Is this market economy in any way superior to the social credit system described above? Explain.

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and one in which it does not.

[12] This of course assumes that the only way to acquire the token is by working for it. Keep in mind too that I have assumed the token to be non-counterfeitable.

Exercise 7. The monetary theorist Karl Brunner (1971) once remarked "We observe over man's history that social groups without generally accepted media of exchange exhibit poor survival characteristics." What do you think he meant by this and how might one extend the analysis above to accommodate competition among groups for survival? Explain how Darwinian selection is likely to work here.

3 Exchange media in bilateral trade

An exchange medium is something that facilitates trade. The U.S. dollar is an exchange medium. But by this definition, so are many other objects, like U.S. Treasury and mortgage-backed securities. The latter objects are often used as collateral for short-term money loans. There is a sense in which collateral is an exchange medium because credit would be more costly (possibly impossible) to obtain without it.

Have you ever thought of your Iphone as money? While it may be difficult to pay for your books with your Iphone, it would not be difficult to visit your local pawnshop and receive a cash loan, using your Iphone as collateral. The same principle is at work in an important financial market called *repo* (short for *sale and repurchase agreement*). In an overnight repo arrangement, a debtor sells a security for cash and agrees to reverse the transaction the next day. From an economic (though not necessarily a legal) standpoint, this equivalent to borrowing the cash overnight, posting the security as collateral.

To formalize this idea, let's consider a version of the economy studied above, but with only two people: A and B. Preferences are given by,

$$\begin{aligned} U^A &= c_1 + \delta c_2 + c_3 \\ U^B &= \delta c_1 + c_2 \end{aligned}$$

where $0 < \delta < 1$. Both Adam and Betty own an asset that produces an income stream $(y_1, y_2) = (y, y)$. Adam also owns a special asset that produces a service x in period 3 that only Adam values. There are clearly bilateral gains to trade here. The efficient pattern of trade is as follows: Betty should lend her morning income to Adam, with Adam returning the favor in the afternoon. In the evening, Adam consumes the service generated by his special asset.

The question is how Adam is to pay for his breakfast. If he could commit to a promise to deliver lunch in the afternoon, then the credit market would function adequately. What if Adam cannot commit to his promises? If Adam's income-generating asset is transferable, then he could consume its first period dividend and sell the asset (ex-dividend) to Betty in the morning. Betty could then collect on the asset's income in the afternoon. But suppose that Adam's asset is not tradeable? (Suppose, for example, that the asset is Adam's human capital and that the income it generates is his wage).[13] This opens the door for

[13] Indentured servitude is illegal in many jurisdictions, but has played an important role in

Adam's special asset (to which Betty attaches zero intrinsic value) to serve as an exchange medium.

The way trade might now work is as follows. Suppose Adam borrows Betty's morning output, posting his special asset as collateral. The loan agreement specifies that if Adam does not repay his debt in the afternoon, Betty gets to keep his asset. Alternatively, and equivalently, Adam sells his special asset to Betty in the morning, promising to repurchase it later that afternoon. Would Betty ever agree to such a deal? The answer is sure, why not? Even though Betty doesn't value the special asset, she knows that Adam does. She can therefore count on Adam working hard to reacquire the rights to the special asset.

The special asset here circulates as an exchange medium, even though there is no lack of double coincidence of wants problem, or any hidden action problem. The lack of commitment, however, continues to play a central role.

Exercise 8. Imagine that the exchange pattern described above is repeated day after day (as is the case in the overnight repo market). Then imagine that one morning, Betty believes that $x = 0$. What happens to the financial market? Is there any role for a socially desirable government intervention in this case? Does the answer to this latter question depend on whether x is actually zero or whether Betty simply believes it to be so? Explain.

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Answer Key

Exercises from *An Introduction to the Theory of Money and Credit*

Exercise 1. Derive the analogous conditions for Betty and Charlie. Are they different in any important way? Explain.

In the morning, Betty can either deliver breakfast or not. Her payoff from delivering breakfast is $0 + y + \beta W$, or W (since $W = y + \beta W$). Her payoff from not delivering breakfast is $\delta y + 0 + \beta V$, or V (since $V = \delta y + \beta V$). Hence, Betty will play nice if and only if $W \geq V$, or

$$\begin{aligned} \left(\frac{y}{1-\beta}\right) &\geq \left(\frac{\delta y}{1-\beta}\right) \\ 1 &\geq \delta \end{aligned}$$

This condition is satisfied by assumption. The same condition holds for Charlie. Hence, the binding constraint is Adam who will only play nice if $1 > \beta > \delta \geq 0$.

Exercise 2. Suppose that the punishment for noncompliance is somewhat weaker than perpetual ostracism. Derive the analogous condition for Adam when the punishment is that Betty refuses to deliver breakfast for one period only, but is willing to forgive Adam if he behaves himself thereafter. Does anything important change as a result? Explain.

Perpetual ostracism yields the punishment payoff V. Suppose, instead, that the punishment for bad behavior is exclusion (no trade) for one period only. In this case, the punishment for bad behavior (*assuming that the bad behavior only occurs once*) is given by $Q = \delta y + \beta(0 + \beta W)$. Taking a cue from Exercise 1, the relevant person to consider is Adam. Under this new penal code, Adam will play nice if and only if $\beta W \geq Q$. Notice that Q can be written as $Q = \delta y + \beta(y + \beta W) - \beta y$, or $Q = (\delta - \beta)y + \beta W$, since $W = y + \beta W$. Thus, the condition $\beta W \geq Q$ implies,

$$\begin{aligned} \beta W &\geq (\delta - \beta)y + \beta W \\ \beta &\geq \delta \end{aligned}$$

Well, how about that? The condition on parameters appears to be the same (I was not expecting this). If this calculation is correct, then it says that as long as $\beta \geq \delta$, Adam will have an incentive to play nice whether he is threatened with exclusion for one or more periods.

Exercise 3. Imagine that Adam can commit to his promises. Explain how he can use this ability to create an asset-backed money supply. Hint: he is in a position to issue an IOU against his evening production.

The theory does not identify what type of object will circulate as money. An alternative monetary instrument could take the form of a financial instrument issued by Adam that promises the bearer the right to redeem the instrument for dinner. A real-world object with this property is Canadian Tire money (redeemable in merchandise at any Canadian tire store). It is of some interest to note that if Adam can commit to his promises, then the condition for cooperative trade is $1 \geq \delta$. (If Adam can commit, there is no need to threaten him with a punishment for behaving badly).

Exercise 4. Consider the economy above without commitment and with publicly observable actions. Imagine that there is an exogenous probability $0 < \alpha < 1$ that Adam cannot produce bread in the evening, but that when he is able to produce, he can produce $y/(1-\alpha)$ units. Describe the socially optimal trading pattern and the expected utility for each individual. Now, suppose that α represents the probability that Adam is sick (and cannot produce) on any given evening. Consider the following two cases. In the first case, assume that Adam's sickness is publicly observable and verifiable. In the second case, assume that Adam's sickness is private information (only Adam truly knows whether he is sick or not). In both cases, Adam cannot commit. Thus, in the first case, a sequential rationality constraint must be satisfied. In the second case, an additional constraint called an incentive-compatibility condition must be satisfied (incentives must be structured in a manner that induces Adam to tell the truth about his medical condition). Describe the level of cooperation that is sustainable for each case.

The socially optimal trading pattern has (as before) everyone delivering their good to the person who wants it most. The only difference here is that Adam only delivers the good with probability $(1-\alpha)$. But because Adam produces $y/(1-\alpha)$ units of output when he's healthy, the expected level of output from Adam is $(1-\alpha)\left[y/(1-\alpha)\right] + \alpha[0] = y$, the same as Betty and Charlie. So, everyone gets an expected utility payoff equal to y (notice that since Charlie is risk-neutral, he doesn't mind the random delivery of output).

Consider the first case where Adam's health is publicly observable. We need to check the sequential rationality constraint: when it comes time to deliver bread, will Adam deliver it? If he plays nice, he gets βW. If he eats his own dinner, he get $\delta y/(1-\alpha) + \beta V$. Hence, we need:

$$\beta W \geq \delta y/(1-\alpha) + \beta V$$

or, after some manipulation (which you should double check):

$$\beta \geq \left(\frac{1-\alpha\beta}{1-\alpha}\right)\delta > \delta$$

So the condition for sequential rationality is stronger now. This is because the one-shot gain to defecting for Adam is increased in this case by a factor of $1/(1-\alpha) > 1$.

Consider now the second case where Adam's health status is private information. Since the accident event is observable only to Adam, we need to ask the question: what incentive structure is necessary to induce Adam to voluntarily tell the truth about his health? An added constraint is needed. This constraint is sometimes called a *truth-telling constraint*, or an *incentive-compatiblity* constraint. To develop the incentive structure, we need to ask: what is the payoff to telling the truth vs lying for Adam?

One thing is absolutely clear: if any degree of cooperation is to be sustained, then Adam has to be punished for failing to deliver his evening output to Charlie–*even if Adam truly is sick*. To see why this has to be the case, suppose that Adam is never punished. Since Adam is not an angel, he will have an incentive to lie about his health status whenever he isn't sick. In this case, Charlie would never get fed, and trade will break down.

So suppose Betty punishes Adam whenever he fails to deliver output to Charlie. In effect, Betty tells Adam that since he did not deliver dinner for Charlie last night, she is not going to deliver breakfast to him this morning. Betty is willing to forgive Adam the next day, but only if Adam delivers output to Charlie. Under this punishment scheme, the value of cooperating for Adam is now given by $(1-\alpha)W$. Therefore, Adam has an incentive to tell the truth if the following condition holds:

$$\beta(1-\alpha)W \geq \delta y + \beta\left[0 + 0 + \beta(1-\alpha)W\right]$$

Note, I am assuming here that if Adam lies, he only lies for one period. If he was to lie forever, his punishment payoff would be autarky, the value of which remains equal to V [convince yourself this is the case]. After some manipulation, we see the expression above implies:

$$\beta \geq \left(\frac{1}{1-\alpha}\right)\delta \quad \left[> \left(\frac{1-\alpha\beta}{1-\alpha}\right)\delta > \delta\right]$$

The condition above tells us that if the incentive-compatibility condition holds, then the sequential rationality condition will hold as well (that is, the incentives necessary to prevent Adam from lying are stronger than those necessary to prevent him from reneging on his societal debt to Charlie.

Exercise 5. To this point, we've established that if $\beta > \delta > \beta^2$, then monetary exchange can solve the hidden action problem. If $\beta \geq \delta/(1-\alpha)$, then the private information problem is solved by not selling goods to a person with a poor credit history. As it turns out, monetary exchange provides the necessary discipine: Betty will not produce for Adam if Adam shows up for breakfast without any money. Because Betty has no money, she cannot buy lunch from Charlie. Charlie, of course, has the money (he could not spend it the night before because Adam was (or pretended to be) sick. Adam can now decide whether he wants to work for some money or not. If $\beta \geq \delta/(1-\alpha)$, he has an incentive to work for money whenever he is not

sick. However, economic exchange collapses in every period that Adam is truly sick (there is a chain reaction, as described above). In an ideal world, Betty would grant Adam some credit when Adam has no money to pay for goods. But extending credit in this manner has its limits (here zero) if Adam is the type of person to fake his illness for very long periods of time (which is what we are assuming when we say that Adam is no angel).

Exercise 6. The model above assumes that society consists of three people that meet pairwise in sequence. Alternatively, we could imagine that A, B, and C correspond to three types of people, with a large number N (a continuum) of people of each type. In this case we could imagine people meeting in a sequence of competitive spot markets, with a fixed money supply M being traded for goods in each spot market. What would be the equilibrium price-level in this economy? Is this market economy in any way superior to the social credit system described above? Explain.

If all money is used to buy goods, then the equilibrium price-level at every point in time will be given by $p = M/(Ny)$. This market economy achieves the same allocation as the social credit sytem described above. It is superior to social credit only to the extent that keeping track of individual trading histories is costly (which it surely is). With competitive markets where money trades with goods, there is no need to keep track of individual trading histories.

Exercise 7. The monetary theorist Karl Brunner (1971) once remarked "We observe over man's history that social groups without generally accepted media of exchange exhibit poor survival characteristics." What do you think he meant by this and how might one extend the analysis above to accommodate competition among groups for survival? Explain how Darwinian selection is likely to work here.

Large societies tend to be stronger than small societies. Thus large societies can attack and potentially destroy small societies. Or small societies become absorbed into the large society. In a large society, there is a large degree of anonymity, so that monetary exchange dominates social credit for many transactions. Social credit (non-monetary) economies need to be small. This may be what Brunner means by the statement that societies without money tend to atrophy and perhaps even perish.

Exercise 8. Imagine that the exchange pattern described above is repeated day after day (as is the case in the overnight repo market). Then imagine that one morning, Betty believes that $x = 0$. What happens to the financial market? Is there any role for a socially desirable government intervention in this case? Does the answer to this latter question depend on whether x is actually zero or whether Betty simply believes it to be so? Explain.

If Betty believes that the value of Adam's collateral (to Adam) is zero, then Betty will not accept it as security. In this case, the credit market breaks down (the way the shadow banking sector collapsed during the financial crisis of 2008). Suppose that the government magically knows the true value of Adam's collateral (while Betty does not). Then one way the government could fruitfully intervene is by guaranteeing the value of Adam's collateral (when it truly is valuable). How the government (or central bank) is supposed to know this when private agents do not is the million dollar question.