Nobel Lecture: Multiple Equilibria

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I. Introduction

Bank failures did considerable economic damage during the Great Depression. This empirical result was documented by Ben Bernanke (Bernanke 1983), and the theory by Doug Diamond and myself (Diamond and Dybvig 1983) provides a plausible mechanism for this result. The 2022 Sveriges Riksbank Prize in Economic Science was awarded to the three of us for "research on banks and financial crises," focusing on these two papers and Doug's paper on delegated monitoring (Diamond 1984). My lecture will focus on (having) multiple equilibria, an important feature of the model in my Prize paper with Doug. Multiple equilibria was also a theme in my prior research, and I want to give credit to Gerry Jaynes and Chester Spatt, my coauthors in those prior papers, for their contributions to my thinking. Unlike models with unique equilibria, models with multiple equilibria can have policies driving equilibrium selection, for example, eliminating bad equilibria without disturbing good equilibria.

Our Prize paper has an equilibrium with bank runs and an equilibrium without bank runs. There are prior examples of multiple equilibria sprinkled through the literature in economics. However, I think that at the time we wrote our paper, having multiple equilibria was largely viewed as a defect. In the introductory macroeconomics course, we were told that if you do not have a unique equilibrium, it is not a real economic

This lecture is dedicated to my advisor, the great financial economist Stephen A. Ross, who died too young. I am grateful for helpful comments from Dilip Abreu, Ben Bernanke, Doug Diamond, Roger Farmer, Yishu Fu, Xinyu Hou, Weiting Hu, Gerry Jaynes, Todd Keister, Shu Li, Magne Mogstad, Manju Puri, Karl Shell, and Chester Spatt. Dybvig (2023) is another version of the lecture, intended for a general audience rather than academic economists. I have no conflicts to report. This paper was edited by Magne Mogstad.

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model, because you cannot do prediction. Basically, they wanted to say that we need to have enough equations to determine equilibrium or else something is missing. Like a lot of important-sounding assertions, this assertion does not stand up to close examination. When you are a first-year graduate student, you need something for a foundation, and it would be too confusing to have all the assumptions up for debate when first learning the material. Mostly, we take assertions in first-year classes as absolute truth. Some simplifications are corrected later, but in other cases we carry these ideas through our careers.

The focus of this lecture is on multiple equilibria in the Prize paper and the four other papers, two with Gerry Jaynes and two with Chester Spatt. In the Prize paper, there is a good equilibrium that everyone likes and a bad equilibrium that we interpreted as a bank run in which everyone takes out their money even if they do not need it. The two papers with Gerry Jaynes are labor models with a search flavor. The first paper with Gerry has endogenous wage rigidity and different equilibria with different levels of employment, including the Walrasian equilibrium that has no involuntary unemployment and other equilibria with different amounts of involuntary unemployment. The second paper with Gerry looks for equilibria with multiple wages in the same model, and we find equilibria with a continuum of wages, discrete wages, and a hybrid, with and without involuntary unemployment. The papers with Chester Spatt include a model of adoption externalities and a model of reputation. In the model of adoption externalities, there can be a bad equilibrium in which nobody buys a phone because nobody else has a phone to call, and there can be a good equilibrium in which almost everyone has a phone and almost everyone wants a phone because there are a lot of people to call. In the model of reputation, it is always an equilibrium to have a bad reputation and live down to it, and it can also be an equilibrium to have a good reputation with an endogenous incentive to maintain it, with the best reputation you can credibly maintain increasing with improvement in consumers' information about past quality. This lecture discusses the economics of each of these papers, and provides a concise presentation of the models in each of the prior papers.[1]

Having multiple equilibria changes the flavor of some policy decisions. In many traditional models, the role of policy is to move the equilibrium toward something that is more desirable socially. For example, optimal taxation might trade off the distortions of the tax against the beneficial use of the revenues. In a model with multiple equilibria, the role of policy may be different. For example, in the bank runs model, we might use deposit insurance or a lender of last resort as a way of removing the bad

[1] There are already good concise expositions of the model in the Prize paper; see, e.g., Diamond (2007) or the official scientific background for the Prize (Committee for the Prize in Economic Sciences in Memory of Alfred Nobel 2022).

equilibrium without changing the good equilibrium. Therefore, the purpose of policy is to remove the bad equilibrium (or more generally restrict the set of possible equilibria), not to move or distort the unique equilibrium.

I have been asked what got me interested in multiple equilibria. I am quite sure I did not "get interested" in the sense of looking for examples of multiple equilibria. Rather, my coauthors and I wrote down strategic economic models we found interesting, solved for equilibria, and multiple equilibria were there in the mathematics, waiting for economic interpretation. It probably helped that I was open to the idea of multiple equilibria, or else I might have abandoned the analysis when I could not solve for "the" unique equilibrium. For being open to the idea of multiple equilibria, credit probably goes to some of my mentors and papers by them and others. David Cass and Karl Shell were my teachers in graduate school, and I was familiar with their work on "sunspot equilibria" (Cass and Shell 1983), which we cited in the Prize paper and will be discussed below in the context of the Prize paper. I was also familiar with Hugo Sonnenschein's (Sonnenschein 1972, 1973) result about multiple equilibria in the competitive model, which I will also discuss below. Hugo was my mentor when I was an assistant professor at Princeton, and was instrumental in helping me to find my first job there. Another paper I liked a lot was Hart (1975), which had compelling and clear examples with multiple equilibria, nonexistence, and Pareto-ordered equilibrium in incomplete markets. The paper was focused on optimality, but for me it was a good example of how to do research: write down a sensible model, solve for equilibrium, and give an economic interpretation of what the math says.[2] All of these examples meant that I was sitting in a corner of the profession that did not share the general stigma for multiple equilibria.

II. Bank Runs

Having multiple equilibria is an important feature of the Prize paper Diamond and Dybvig (1983). You can have an equilibrium in which everybody takes their money out whether or not they need it. We call that equilibrium a bank run. It turns out to be bad for everybody. If you think everybody else is trying to take out their money, then you realize the bank is going to run out of money before you get there if you wait. So, you will also try to take out all your money.

[2] Of course, the actual process is more complicated. We adjust the model when we cannot solve it or the solution is unreasonable because of something important that is missing in the model. I should also mention that this is not the only way to do research. I have heard a scholar I respect tell a student that he never writes down a model until he has an idea of what result he is going to get. Personally, I am more willing to go on a fishing expedition and write down a model about an interesting economic situation and see what comes out.

Alternatively, there is an equilibrium in which agents take out their money only if they really need it. It could be that somebody down the street is selling a classic car, which I think is super cool, and I really want my money out now to buy the car, and I am going to take my money out to do this. Or it could be that I have some kind of health expense. Or, I might have a friend who needs money, or it could be that I feel a sudden need to take a trip and get away from things. Whatever the reason that I want the money, it is a private reason so I cannot necessarily demonstrate to the bank that I really prefer to get the money now, but nonetheless it is valuable for me to have the option. That is why bank customers like liquidity in the model.

The feature of demand deposits that allows depositors to get money out at any time makes the demand deposit more valuable than a time deposit that is tied up until the end, because an opportunity or problem may come up that makes the depositor value using the money more than normally. But most bank assets are illiquid; they pay a lot more if you leave them in. Let us say that the bank has made a loan to a developer building a shopping center. A half-completed shopping center cannot be sold, not for very much money. Even if the bank writes a contract with the borrower that gives the bank the option of calling the loan to get money back, the borrower is not going to agree to giving back very much money in this contingency, because the borrower will not have money to return.

Doug and I thought bank assets were illiquid due to information asymmetry. If somebody comes to you to sell bank assets, you know they have spent a lot of time researching loans and they know a lot about what they are worth, and they are going to try to sell the ones that are not so valuable, "lemons" in the terminology of Akerlof (1970). It is exactly this kind of adverse selection that makes most bank assets illiquid. In our model, we made a simpler assumption. We assumed the illiquidity was in the technology, like in the shopping center example. The reason we did that is because the nature of the bank assets' illiquidity is not the most important part of the model, and complexity in the periphery of a model typically makes the model harder to solve and understand without significant additional insights. In general, we worked really hard to make the model as simple as possible.[3] Having a simple model is really beneficial because people have additional degrees of freedom that they can still handle. Scholars have added many other features to the model and they can still solve it. It is a little bit like a crystal or a poem. It is also similar to a gedankenexperiment (thought experiment) in physics like the one in Einstein, Podolsky, and Rosen (1935) with entanglement, as described by the Physics Laureates

[3] Here are some other simplifications we made in the model. We made the liquidation value of the asset in the middle period equal to the initial investment to make riskless storage redundant. We changed the utility for the patient agents to depend on the sum of consumption in the middle and final periods so they would not need riskless storage. We made the banks mutuals so we would not have to model bank owners separately.

this year. I do not think anyone complained that Einstein and his coauthors did not model explicitly how the detectors worked or how the particles are created in the first place.[4] Just as Einstein and his coauthors were looking for the simplest setting in which to discuss entanglement, we want to have the simplest possible setting to explain how valuable liquidity provision by banks makes them subject to runs.

Bank assets are illiquid, which means depositors do not get much back if they are liquidated before maturity. Demand deposits are liquid in response to depositor preferences, and this is a liquidity mismatch. Our model also assumes the bank assets are riskless. That is a feature, not a bug! Some people say they cannot believe Diamond and Dybvig (1983) assumes bank assets are riskless, given that we know actual bank assets are risky! It is a feature because everybody knows that the banks can fail if bank assets are risky. That is obvious. What we are saying is that even if the assets are riskless, and there are enough assets in the bank to pay off all the depositors who should be getting money, then there can still be problems. You can still have bank failures due to strategic runs *even if* bank assets are riskless. Of course, if the assets are risky, it does not take away the possibility that the bank can fail due to strategic runs.

Because of liquidity mismatch, there are multiple equilibria. There is a good equilibrium in which people only withdraw when the money is needed. There is a bad equilibrium (the bank run) in which everyone takes their money out whether they need it or not. There is also another mixed strategy equilibrium in between when people randomize, but it is unstable and its economics are not really much different than the run equilibrium, so we need not discuss it further.

Bernanke (1983) documented that bank failures in the economy did tremendous damage in the Great Depression, consistent with our model. This raises the natural policy question of what government can do to prevent the bank run equilibrium. One way you can prevent people from running on the bank is that you can have deposit insurance so that people are guaranteed to get their money back whether or not there is a run. Even if everyone runs on the bank and the assets are gone, the government-backed deposit insurance fund will pay them off. That is the policy we think is probably most effective. In a setting in which bank assets are risky, you also need monitoring of the banks so they do not take too much risk. That is outside our model.

A second possible policy choice we talked about is a discount window at the central bank, where banks can borrow money if they have trouble meeting withdrawals. This seems less reliable than deposit insurance,

[4] Someone could complain that their example was not rich enough to create results violating Bell's (1964) inequality, but to be fair, that is probably only known with hindsight to be a limitation. Furthermore, because the original gedankenexperiment was very simple, it was easy for other authors (including Bell) to extend it.

since the central bank may suffer from a credibility problem.[5] If people are unsure whether the central bank will always fund the banks that are in trouble, say because the central bank decides the fund shortage is due to fraud and not just excess withdrawals, then lending by the discount window is not going to be an effective way of assuring depositors their claims are safe, and they may still run on the bank.

The third policy we talked about is suspension of convertibility (of deposits into money), which is shutting off withdrawals, a so-called bank holiday. Bank holidays stop the run by preventing anyone from taking money out. But this seems like a bad solution, since it eliminates the benefit of liquidity provision by banks and it may induce a run by depositors wanting to get out before the bank is closed.

It has been said, and with a lot of nuance, that several markets in the 2008 financial crisis look just like our bad equilibrium (see, e.g., Prescott 2010), and other crises have this feature, too. In the 2008 crisis, there were runs on the repo market (the market for repurchase agreements, a big shadow banking market), money market mutual funds, some traditional banks, and bank commercial paper. Those are some of the markets for which the 2008 crisis looked pretty much just like the bad equilibrium in our model.

I want to mention briefly Diamond and Dybvig (1986), a policy piece. It contains insights that are still useful, and I stand by most of it. The description of money market funds is accurate, but a little embarrassing. It says that ignoring some extreme times, you can think of money market funds as being very safe because they normally have both liquid assets and liquid liabilities. However, the extraordinary times are the interesting times, and the assets became illiquid during the financial crisis.

Here is a quotation from the paper that is a pretty good description (from 1986) of the 2008 financial crisis:

> Proposals to move toward 100% reserve banking would prevent banks from fulfilling their primary function of creating liquidity. Since banks are an important part of the infrastructure in the economy, this is at best a risky move and at worst could reduce stability because new firms that move in to fill the vacuum left by banks may inherit the problem of runs.

In modern terminology, this quotation talks about shadow banking. You can think of this as a discussion of the repo market in the 2008 crisis. The

[5] To be fair, an insurance fund can also be subject to a credibility problem. Given current institutions, lack of credibility of the insurer is more likely to be due to soundness of the insurance fund's credit or its government backing, rather than to a decision that the bank is not worthy of the guarantee, although this might change as the scope of responsibilities of institutions like the FDIC expands.

quote mentions 100% reserve banking because that was the theme of the conference where it was presented, but the quote applies more generally to policies that restrict banks from performing their function of providing liquidity. It says that if you restrict banks too much and keep them from doing their jobs, then some other institutions (like the repo market) can arise that will replace banks and their function. But this is risky because bank liquidity may not be surplus liquidity (and it probably is not), and because the loss of liquidity might cause instability because the new firms that move in to fill the vacuum left by banks may have runs. We now have a name—shadow banks—for the firms that move in to replace the functions of banks, and we saw the instability of shadow banks in the 2008 financial crisis. In particular, the run on the repo market was a big part of the contraction of the economy.

Another insight from Diamond and Dybvig (1986) is the reminder that when we say deposit insurance removes the incentive for depositors to run, that means full insurance, not capped insurance. In the classic failure of Continental Illinois Bank, many uninsured deposits ran, creating a big disruption and problems for the regulators, but the regulators insured most of the deposits ex post, incurring the cost of full insurance but getting only part of the benefit. As stated in Diamond and Dybvig (1986), "there is a much stronger case for 100% insurance than for limiting insurance, especially if the alternative is for regulators to retain their discretion to in fact insure most 'uninsured deposits.'" In spite of a few things I would say differently, I still like our policy piece Diamond and Dybvig (1986), and I recommend it to you if you are doing research in this area. I think most of it stands up.

Before turning to the prior papers, I want to discuss another issue in the Prize paper that is related to multiple equilibria. If agents expect the run equilibrium, why would they deposit money in the first place? If you know there is going to be a run, you would be better off not depositing. The answer to the puzzle is given by the "sunspots" model of my professors Dave Cass and Karl Shell (Cass and Shell 1983). Sunspots are supposed to be exogenous shocks, observable by everybody, that are not directly economically relevant. In reality, we know sunspots can disrupt communications, and in extreme cases, could bring down the power grid. But that is not the idea. Sunspots in their model are supposed to be something that is commonly observable and gives us a source of uncertainty on which to coordinate, but does not impact payoffs except through the strategic coordination.[6] The sunspots model says that if there are multiple equilibria and some

[6] Like having riskless assets in the Prize paper, this is an "even if" proposition: sunspots may matter even if they are irrelevant for payoffs except for the equilibrium selection. Of course, commonly observed randomness that affects payoffs a little or a lot can also play a similar role.

randomness that everyone observes, it is also an equilibrium to select one of the equilibria as a function of the commonly observed randomness. It could be that there is a very small fraction of the time when the number and size of sunspots are really big (or really small, or whatever) and cause the bank run equilibrium, in which case it may still pay to put your money in the bank. In other words, introducing sunspots allows a bank run to occur, with some probability, which is consistent with rational beliefs and an optional decision to deposit funds.

This concludes the discussion of multiple equilibria in our Prize paper. If you do not need the money out, you do not run in the good equilibrium, but you do run in the bad equilibrium. I am going to turn now to talking about multiple equilibria in some prior joint papers I wrote with other coauthors.

III. Wage Rigidity and Involuntary Unemployment

Gerry Jaynes and I had two prior papers with multiple equilibria, Dybvig and Jaynes (1979, 1980). Gerry was my professor at Penn and coincidentally he moved to Yale at the same time I moved to Yale with my advisor, Steve Ross. The motivation for these papers grew out of a coffee break when we were discussing what Keynes actually meant by an equilibrium with involuntary unemployment, and what sorts of frictions could be built into a model to generate involuntary unemployment. Both papers have labor models with a search flavor and almost the same assumptions. In the models, firms have to pay not only the wages that they pay to the workers, but they also have to pay training costs to train the replacements for departing workers. Unemployed workers would like to move to firms paying more than the common reservation wage, and employed workers would like to move to firms paying more than their current wage. All workers, employed or unemployed, have submitted applications to all the firms they would like to move to. If there is an opening, the firm picks randomly from the workers who applied. This is what I mean by "search flavor"—workers are searching for higher-paying positions, but the random matching is simpler than in a typical search model in which both sides wait for a match. In a sense, there is search but no search friction, which would be due to structural unemployment while firms wait for a match to fill a position.

The first paper, Dybvig and Jaynes (1979), considers equilibria in which all firms pay the same wage, with the result that there can be involuntary unemployment very similar to what Keynes described. In our models, involuntary unemployment is defined (as is customary) as having people who have no job but are willing to work at less than the prevailing wage. In the paper's equilibrium with involuntary unemployment, there are many firms offering the same wage that is higher than the competitive wage would be, but firms cannot earn higher profits by switching to a lower wage, because some workers would quit to go to firms that pay more, generating higher training costs. This is an equilibrium for any wage in some range above the competitive wage. In this range, the wage savings from offering the workers' reservation wage is less than the increase in training costs. This model anticipated the emphasis on multiple equilibria in macro models by Farmer (2008, 2012, 2013). In our paper, we connect our model to Keynes (1936) using a number of quotations. Interestingly, Keynes said more or less explicitly that he was not talking about a number of explanations traditionally mentioned by Keynesians, such as money illusion, collective bargaining, and rigidity from long-term contracts. Keynes did mention explicitly that he had multiple equilibria in mind:

> the postulates of the classical theory are applicable to a special case only and not to the general case, the situation which it assumes being a limiting point of the possible positions of equilibrium.

That is consistent with our model. The competitive solution is always an equilibrium of our model, and it has either all workers employed or, in a surplus labor economy, fewer than all workers employed with firms paying the workers' reservation wage, but there are also equilibria with a higher common wage and involuntary unemployment.

Here is a more detailed exposition of the model underlying the two papers. The labor market model in the paper is a real model, but includes notation for nominal wages and price level, for insertion into a simple macro model. This discussion will limit attention to the labor market and real variables. The workers and firms are all small, and are price takers. We will use a model with maximization of average payoff, in the spirit of a steady-state model in the limit of a zero interest rate. There is a total mass $N = E + U$ of workers in the labor market, E employed and U unemployed (voluntarily or involuntarily). Workers are identical, and each worker has the same reservation (real) wage ω_R. In this section, we are looking for an equilibrium in which all firms in operation pay the same wage, subject to a Nash equilibrium condition that no firm wants to deviate and offer a different wage. A firm offering a wage ω has an all-in cost (wages + training cost) per worker equal to $\omega + \tau\delta + \tau r(\omega)$, which is the direct wage cost, plus the training cost τ for replacing workers who leave the market at the exogenous rate δ, plus the training cost for replacement of workers who resign at the endogenous rate $r(\omega)$ to go to higher-paying firms. There can be an equilibrium with involuntary unemployment and a wage above the reservation wage because a firm offering a lower wage to hire from the pool of unemployed workers could pay higher training costs (for replacements of workers who go to other firms) that more than offset the wage savings.

To complete the model, assume there is a mass F of firms, each of which has a (real) production function $q(\cdot)$ giving output as a function of the number of workers, with standard assumptions $q(0) = 0$, $q'(l) > 0$, and $q''(l) < 0$, so first-order conditions with respect to labor quantity are necessary and sufficient. A firm offering the same wage ω as the other firms chooses the number l of workers to maximize $q(l) - (\omega + \tau\delta)l$, with first-order condition $q'(l) = \omega + \tau\delta$, or $l = (q')^{-1}(\omega + \tau\delta)$. These conditions say that the marginal product of labor equals the all-in marginal cost of hiring another worker, including the wage and the training cost. Since $q''(l) < 0$, the total demand for labor $L(\omega) \equiv lF = (q')^{-1}(\omega + \tau\delta)F$ is decreasing in the wage ω. If $L(\omega_R) < N$, this is a surplus labor economy, and the Walrasian solution has wage $\omega_W = \omega_R$, employment $E = L(\omega_R)$, and unemployment $U = N - L(\omega_R)$. If $L(\omega_R) \geq N$, then in the Walrasian solution, each firm employs N/F workers and the wage must satisfy the first-order condition $q'(N/F) = \omega + \tau\delta$, from which we know the Walrasian wage is $\omega_W = q'(N/F) - \tau\delta$. We can combine both cases to write the Walrasian wage as $\omega_W = \max(\omega_R, q'(N/F) - \tau\delta)$. In both cases, offering ω_W dominates offering a higher wage, which results in a higher wage bill but the same training costs. On the other hand, offering a lower wage attracts no workers, in the first case because it is below the reservation wage, and in the second case because everyone is already working at the higher wage ω_W. Therefore, as Keynes requires, the Walrasian equilibrium is an equilibrium in our model.

Keynes also says the Walrasian equilibrium is only one of a continuum of equilibria. Suppose all the firms offer the same high wage $\omega_H > \omega_W$. Then, the labor demand is $L(\omega_H) < L(\omega_W) \leq N$, so there is unemployment (all involuntary) $U = N - L(\omega_H)$ and employment $L(\omega_H)$. Is this an equilibrium? It depends on how much larger ω_H is than ω_R. A firm offering ω_H does not want to switch to a higher wage, because this increases the wage bill without reducing training costs. If switching to a lower wage, the firm may as well lower the wage all the way to ω_R (or almost there for strict preference of unemployed workers to join), since moving less than all the way down will have the same training cost and a higher wage bill. Note that the resignation rate at ω_R is $r(\omega_R) = \delta E/U$ because all the unemployed (mass U) and this firm's workers (negligible mass) are applying for openings created by departures from the market at rate δ of the mass E of employed workers. Therefore, reducing the wage does not increase firm value if

$$\omega_R + \tau\delta + \tau\delta E/U \geq \omega_H + \tau\delta, \tag{1}$$

and therefore $\omega_H > \omega_W$ is an equilibrium if $\omega_H - \omega_R \leq \tau\delta L(\omega_H)/[N - L(\omega_H)]$. It is straightforward to show that there exists an interval of wage

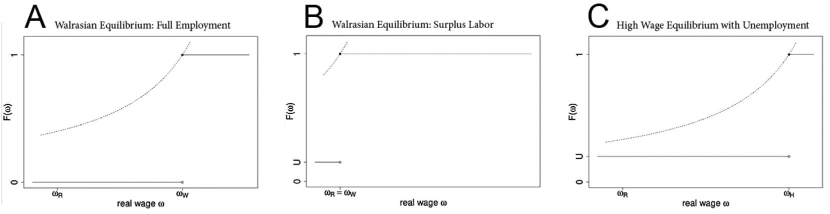

Fig. 1.—In Dybvig and Jaynes (1979), there are Walrasian equilibria as in panels *A* and *B*, and also equilibria with higher wages and involuntary unemployment, as in panel *C*. If a firm tries to hire someone from the pool of unemployed workers at a low wage, the wage bill is smaller than for other firms, but training costs are higher because the firm's workers are quitting at a higher rate to join higher-paying firms, and in equilibria there can be some unemployment. In these panels, $F(\omega)$ is the fraction of workers that are either unemployed or employed at wage ω or lower. Combinations below the dashed line offer lower profits than the common wage offered in equilibrium.

levels $\omega_H > \omega_W$ that are non-Walrasian equilibria in our model,[7] verifying that we satisfy Keynes' requirement that the Walrasian equilibrium is only one of a continuum of possible equilibria.

The nature of the equilibria in the model of wage rigidity (Dybvig and Jaynes 1979) is illustrated in figure 1. The dependent variable $F(\omega)$ is fraction of workers that is either unemployed or working at a wage at or below ω. Here $F(\omega)$ and δ determine the rate at which workers resign from a firm paying ω to join higher-paying firms, and having $F(\omega)$ at or below the dotted line means the all-in labor cost from wages and training costs will be at least as high from switching (details in the next section, especially eq. [3] and the accompanying text). The panels show the cases we have discussed: the Walrasian equilibrium with all workers employed in panel *A*, the surplus-labor Walrasian equilibrium (with $\omega_W = \omega_R$) in panel *B*, and the equilibrium with wage rigidity and a price larger than the Walrasian wage ($\omega_H > \omega_W$) in panel *C*.

IV. Wage Dispersion

The other paper with Gerry, Dybvig and Jaynes (1980), has very similar assumptions. The difference is that we do not restrict attention to equilibria in which firms all pay the same wage. If two firms offer different wages in equilibrium, they must be indifferent between offering the two wages. The firm with the higher wage has a higher wage cost, but also has a lower training cost because fewer of its workers are leaving for other firms. The two exactly offset each other, which is to say that both firms

[7] The right-hand side of (1) is continuous in ω_H for $\omega_H > \omega_W$ and has a positive finite or infinite limit as $\omega_H \downarrow \omega_W$. Therefore, there is an interval of equilibrium wages ω_H just above ω_W.

have the same all-in labor cost. This condition allows us to derive precisely which endogenous wage distributions can arise in the model.

For every equilibrium with wage dispersion, there is a similar equilibrium with a single wage equal to the maximum wage. The two equilibria look almost the same to the employers, since all firms have the same all-in labor costs in both cases and total employment and unemployment are the same. The main difference is that some or all workers are paid less, which covers the additional training cost when workers switch firms. Because of this correspondence, equilibria can have involuntary unemployment or not, with or without wage dispersion.

Given the search flavor of the model, I think of this paper as anticipating Burdett and Mortensen (1998). We share their central assumption that workers search while employed as well as when unemployed, but our random matching does not have "structural unemployment" because firms and workers are never both waiting to be matched. Looking at both papers together makes it clear that wage dispersion comes from the assumption about "searching while employed" more than the general search frictions, since wage dispersion is there in our random matching model that does not make firms search for a match. Our simplified form of search does imply an interesting difference in our results. Our model's solutions include equilibria with mass points in the distribution of wages, while their model does not. The reason is that a firm sitting at a mass point in their model can reduce the structural unemployment and benefit from increasing the wage a little bit above the mass point. That accelerates arrival of agents in their model (since there can now be random matching with the agents who were at the same wage before the increase). In our model, that is not necessarily useful, because the firm chooses immediately one of the workers with a lower wage or unemployed to fill the position, so there is no structural unemployment and no advantage to having more applicants. Solutions of our model can have a discrete set of wages, a continuum of wages, or a hybrid.

The assumptions and structure of the labor market model are mostly the same in the wage dispersion model in this section as they were in the wage rigidity model in the previous section, and mostly we will use the same notation. However, in the model with wage rigidity, we looked for an equilibrium in which all the firms offered a single wage ω_W or ω_H. Now, we consider a model in which there is a distribution of employment across wages. The possible equilibria satisfy a condition that the all-in wage is the same at all wages offered in equilibrium, and the same or higher for other wages. Define the distribution function $F(\omega)$ to be the proportion of the population N of workers that is either unemployed or employed at a wage less than or equal to ω. Accounting for unemployed workers as if they are employed at an arbitrarily low wage will simplify the expression for the quit rates. Unemployment is $U = F((\omega_R)_-)N$ (with the usual notation that $F(x_-)$ is the left limit of F at x), and total employment is $E = N - U = [1 - F((\omega_R)_-)]N$. In the support of F,[8] a firm paying the wage ω is competing with $F(\omega)N$ workers unemployed or employed at the same and lower wages, for positions opening at a rate $\delta(1 - F(\omega))N$ at higher wages.[9] Therefore, the quit rate is $\delta(1 - F(\omega))/F(\omega)$. Let ω_M be the maximum wage in the support of the wage distribution (the maximum can be shown to be finite in equilibrium). Then the all-in wage from paying ω_M must be less than or equal to the all-in wage from paying any other wage ω at which you can attract workers (i.e., for which $F(\omega) > 0$), with equality for wages that are actually offered (that are in the support of F). Therefore, we have that

$$\omega_M + \tau\delta \leq \omega + \tau\delta + \tau\delta\frac{1 - F(\omega)}{F(\omega)}, \tag{2}$$

with equality on the support of F. (Note that this equation has division by zero if $F(\omega) = 0$, but this case is not relevant because the firm cannot hire any workers at such a wage ω, because in that case workers are all already working at a higher wage.) Solving for $F(\omega)$, we have that

$$F(\omega) = \frac{\tau\delta}{\omega_M - \omega + \tau\delta}. \tag{3}$$

This is the expression for $F(\omega)$ on the support of F, and on intervals outside the support where workers can be hired, the value is the same as at the lower end of the interval. When ω is low enough that no workers can be hired (because ω is below the reservation wage or everyone is working for more than ω), then $F(\omega) = U$. This also assures that all of the support of F is at or above ω_R.

The rest of the equilibrium conditions are similar to the conditions in the wage rigidity paper. Since all the firms pay the same all-in cost, they all have the same first-order condition for labor choice as in the single-wage model in the previous section. Let $L(\omega)$ be exactly the same function as in the wage rigidity model. In equilibrium, $L(\omega_M) = E = [1 - F((\omega_R)_-)]N$, and a distribution with the maximum wage ω_M can be consistent with equilibrium if either (1) $\omega_M = \omega_R$ and $L(\omega_M) < N$ (Walrasian solution with surplus labor), (2) $L(\omega_M) = N$ (Walrasian solution with all workers employed and generalizations with wage dispersion), or (3) $\omega_M > \omega_R$ and $L(\omega_M) < N$ with the condition $\omega_M - \omega_R \leq \tau L(\omega_R)/[N - L(\omega_R)]$ (wage rigidity and generalizations with wage dispersion).

[8] We have the convention that the support of $F(\omega)$ does not include the mass of unemployed workers at $\omega = -\infty$.

[9] Note that while some positions at higher wages could be taken by other workers at higher intermediate wages, those departing workers will create openings (or perhaps a sequence of openings), so there will still be a job available for workers currently unemployed or working at a wage less than or equal to ω.

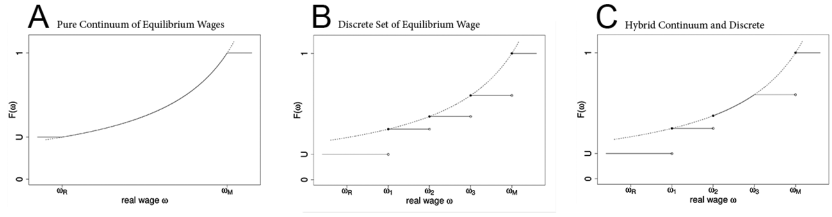

FIG. 2.—Dybvig and Jaynes (1980) has all the equilibria of Dybvig and Jaynes (1979), as illustrated in figure 1, but also includes a variety of equilibria with wage dispersion, as illustrated here. At all the wages in the support of the distribution of wages, the all-in cost (wages plus training costs) is constant, which is equivalent to lying on the dotted line. Panel *A* gives an example with a pure continuum of wages on the interval $[\omega_R, \omega_M]$. Panel *B* shows a discrete distribution of wages taking values ω_1, ω_2, ω_3, and ω_M. Panel *C* shows a hybrid case.

Besides having all the equilibria of Dybvig and Jaynes (1979), figure 2 illustrates that Dybvig and Jaynes (1980) can exhibit a rich variety of solutions with different sorts of wage dispersion with a continuous distribution, discrete distribution, or a hybrid of the two. In all such equilibria, firms are indifferent between being at any point in the distribution of wages. Indifference is characterized by equation (3) and indicated in the plots by the dashed line. The points below the dashed line are where the firm would be worse off. Equilibrium says $F(\omega)$ must be on or below the dashed line for *available* wages. Wages below the reservation wage ω_R are not available, since no worker will work for less than the reservation wage. If all workers are working, wages below the smallest wage in the distribution are also unavailable, since all workers are already employed at higher wages.

Gerry and I never published either of our papers, partly because we moved in very different directions in our careers. A couple of years after this, Gerry was directing a commission studying the status of black Americans, and I moved more into finance. Gerry points out, and I had forgotten, that we did submit the 1980 paper to the *Quarterly Journal of Economics*, but we did not want to make the changes that were requested. Probably, we should have consulted a senior colleague, who would have counseled us to make the changes.

V. Reputation and Product Quality

The next two papers I want to discuss are joint with my buddy Chester Spatt, who was a year ahead of me in graduate school and showed me the ropes. The first paper with Chester, Dybvig and Spatt (1983b), is about consumer information and product quality. In the story, there is a restaurant that is producing food and higher quality is more expensive to produce. The question is how much customers will be willing to pay, which depends on what quality they expect. One equilibrium is for the restaurant to offer the lowest possible quality all the time, and charge customers the (low) price they are willing to pay for that. Expect junk and you get junk, and you are unwilling to pay very much. But there are also equilibria in which higher quality is offered, and how much higher can be offered depends on the consumers' information. This paper was written before the internet and online reviews. At that time, it took a long time for a typical customer to return to a restaurant on a highway or maybe they never return, and as a result they do not have very good information. That is why there was a larger fraction of chain restaurants on the highway than in town. The quality of chain restaurants is assured by a different mechanism, assuring the quality of the chain rather than the quality of the individual restaurant. Multiple equilibria are important in this model because the threat of switching to an inferior equilibrium is the way the incentive for good behavior is maintained.

In the model, there is a restaurant with a continuum of customers, with a mass at time t of g^t, where $g > 0$, allowing growing or declining potential demand over time. Agents are distinguished by their information: an agent with type $k = 1, 2, \ldots$ learns perfect information about past prices and qualities offered by the firm with a time lag k, and the remaining agents know nothing about past prices and qualities. A fraction $n_k \geq 0$ has information lag k, and the remaining fraction $n_\infty \equiv 1 - \Sigma_{k=1}^{\infty} n_k$ never gets information. We assume the customers do not behave strategically; it is as if the customers in different periods are all distinct. I like the interpretation that the information lag comes from purchasing experience, even though this is not in the model, which takes the information structure as exogenous. Each customer has a unit demand $d \in \{0, 1\}$ and a reservation price equal to the expected quality; that is, at time t an agent of type k chooses $d_t \in \{0, 1\}$ to maximize $E[d_t(q_t - p_t) | \{p_\tau\}_{0 \leq \tau \leq t}, \{q_\tau\}_{0 \leq \tau \leq t-k}]$. The conditional expectation is computed using the observations up to time $t - k$ and by following the posited equilibrium from time $t - k + 1$ through t.

At t, the firm chooses price $p_t \geq 0$ and quality $q_t \geq 0$ to maximize expected present value of revenues less costs,

$$\Pi = E\left[\sum_{t=0}^{\infty} d_t [p_t - c(q_t)] \rho^t g^t\right], \tag{4}$$

where $d_t = \Sigma_{k=1}^{\infty} n_k d_{tk} + n_\infty d_{t\infty}$ is total demand per customer at t, $c(q)$ is the unit production cost for quality $q \geq 0$, q_t is the actual quality at time t, and ρ is the one-period discount factor ($\rho \equiv 1/(1 + r)$, where $r > 0$ is the one-period interest rate). We assume $\rho g < 1$ to ensure (with the other assumptions) that the firm's value is finite. The cost function $c : [0, \infty) \to [0, \infty]$ satisfies the usual convexity and Inada conditions: $c(0) = 0$, $c'(0) = 0$, $c'(\infty) = \infty$, and, for $q > 0$, $c'(q) > 0$ and $c''(q) > 0$. We also define average cost $AC(q) \equiv c(q)/q$ and marginal cost $MC(q) \equiv c'(q)$.

There are a lot of equilibria with different quality levels. The equilibrium path can have a constant quality of 0 (junk expected, junk received), a maximum quality $q = AC^{-1}(\Sigma_{k=1}^{\infty} n_k(\rho g)^k)$, or any quality level in between. Each of these qualities can be enforced by a "punishment" equilibrium always offering both price and quality equal to the equilibrium value on the equilibrium path, but with quality equal to zero if any price or quality has been different. Consumers have a demand of 1 so long as they have not seen a deviation, and a demand of zero from then on once they see any deviation. The most profitable equilibrium for the firm is the equilibrium with $q = \min(MC^{-1}(1), AC^{-1}(\Sigma_{k=1}^{\infty} n_k(\rho g)^k))$, where $q = MC^{-1}(1)$ is the first best. In other words, the firm offers the first-best quality if it is credible, or otherwise the maximum credible quality.

A couple of things were unique about this model at the time. One is that we had comparative statics with respect to information. The largest quality the firm can offer, $AC^{-1}(\Sigma_{k=1}^{\infty} n_k(\rho g)^k)$, increases with any first-order stochastically dominating decrease in the distribution of information lags, which says that more information improves the largest quality the firm can credibly offer. Another thing that was unique about the model is that the time between information arrivals can be different from the time between choices.

Our reputation paper was never published because we were silly. The paper was actually conditionally accepted at the *Review of Economic Studies* and the editor, Oliver Hart, wanted us to take out a little section that we thought was really important (because it contained the comparative statics with respect to consumer information) and we said no, that we would go elsewhere. Instead, we should have said, "Can't we leave it in, please? It is important and indeed it is what makes the paper unique." Maybe Oliver would have asked us to take out something else, and that would have been okay. If we had consulted a senior colleague before acting, we would not have made such a silly mistake. Missing out on a top publication was a high cost for the pleasure of being masters of our own fates and making our own decisions.

VI. Adoption Externalities

Chester and I had another paper, Dybvig and Spatt (1983a), that had multiple equilibria. The paper models externalities from adoption of a technology, for example, telephones or a standard unit of measurement. The interest in adoption externalities came because Chester was fascinated by picturephones, then called "picture-tels," that he had seen at the AT&T Pavillion at the 1964 World's Fair in New York. We will call whatever technology people may adopt a "phone." Whether you want a phone or not depends on who else has a phone. If everyone else has a phone, you probably want to pay the money to buy a phone because all your friends will have a phone and you can talk to them. If nobody else has a phone, you do not want a phone because you have to pay for it but you do not get any benefits. This is very similar to the bank run model, in that you like to do what everybody else is doing, although the model is simpler because there are no private shocks. In the interesting case when the technology is useful enough, there is a bad equilibrium (with nobody adopting) like the run equilibrium and a good equilibrium (with a nonempty set of people adopting) like the no-run equilibrium, and possibly more equilibria. We also have the policy prescription of insurance in the form of a guarantee on a minimum number of adopters which, like deposit insurance in the banking model, is costless in equilibrium and eliminates the bad equilibrium. I should note that late in the review process we learned about Rohlfs (1974), which has a model encompassing ours but not the insurance suggestion, and instead suggests a discount for early adopters that is costly in equilibrium.

In our model, each agent $i \in \{1, 2, \dots, I\}$ chooses $x_i \in \{0, 1\}$ to maximize the objective function $\Pi^i(x) = v^i({}_ix)x_i$, where ${}_ix \equiv \{x_1, \dots, x_{i-1}, x_{i+1}, \dots, x_I\}$ is the vector of choices of the other agents. We assume a positive externality (unsolicited advertising and political calls were rare when we wrote the paper), so that v^i is nondecreasing in all its arguments.[10] Given the other agents' choices ${}_ix$, i's set of optimal responses (Nash reaction function) is

$$R^i({}_ix) = \begin{cases} \{1\} & v^i({}_ix) > 0, \\ \{0,1\} & v^i({}_ix) = 0, \\ \{0\} & v^i({}_ix) < 0, \end{cases} \tag{5}$$

and we can define an upper version $\bar{R}^i({}_ix) = \max R^i({}_ix)$ that resolves ties by adopting and a lower version $\underline{R}^i({}_ix) \equiv \min R^i({}_ix)$ that resolves ties by not adopting. (Note that $\bar{R}^i({}_ix)$ and $\underline{R}^i({}_ix)$ are the same if $v^i({}_ix)$ is never 0. When there are ties, we could also have random strategies in some equilibria, but these equilibria do not seem so interesting.) The functions $\bar{R}^i({}_ix)$ and $\underline{R}^i({}_ix)$ are nondecreasing because $v^i({}_ix)$ is nondecreasing. We can find the best equilibrium by starting at $x^0 \equiv (1, \dots, 1)$ and iterating the upper reaction function $x_i^{k+1} \equiv \bar{R}^i({}_ix^k)$. By monotonicity, this is a nonincreasing sequence and converges in finitely many steps (because there are finitely many—2^I—adoption patterns and monotonicity precludes cycling). The limit is clearly a Nash equilibrium, because each agent is playing a best response.

[10] Strictly increasing seems too strong, since there are probably people we would never call anyway.

The worst equilibrium (with the least adoption) can be found similarly by starting at $x^0 \equiv (0, \ldots, 0)$ and iterating the lower reaction function. Probably we want to assume that adoption is costly (no hobbyist who likes adopting because of the joy of building the unit) and has no benefit except the externality. In this case, $v^i(0) < 0$ for all i and nobody adopting $(x = 0)$ is an equilibrium, in which case the iteration starting at $(0, \ldots, 0)$ converges immediately. In general, the set of adopters in any equilibrium is nested between the set in the best equilibrium and the set in the worst equilibrium.

When it is optimal to have people adopting, we propose a strategy of giving agents insurance against having too small a number of adopters, which can implement the first-best if payoffs are symmetric. For example, suppose a symmetric model with a constant purchase price $p > 0$ of adopting and a constant benefit $b > 0$ per other agent who adopts. Then, $v^i({}_ix) = -p + b\Sigma_{j \neq i}x_j$, and the type of equilibrium depends on the common payoff $-p + b(I - 1)$ when everyone adopts. Nobody adopting is always an equilibrium. If $-p + b(I - 1) < 0$, nobody adopting is the only equilibrium, and if $-p + b(I - 1) = 0$, it is not the only equilibrium but no other equilibrium is better. When $-p + b(I - 1) > 0$, everyone adopting is a better equilibrium for everyone, and is in fact the best equilibrium. Guaranteeing each agent i a refund of the purchase price plus 10% if the number of other adopters is not large enough, $\Sigma_{j \neq i}x_j \leq p/b$, gives an agent i a total payoff from adopting that is always positive. In this case, the only equilibrium is for everyone to adopt, since adoption is optimal for i independently of what agent i believes about other people's adoption decisions. This is similar to deposit insurance, which removes the concern about other people running because the insurance makes you better off not running in any case. Like deposit insurance in a bank without risky assets, this insurance is costless in equilibrium because enough people adopt to make the refund inoperative.[11]

The insurance against too few people adopting is similar to a proposal by Rohlfs to subsidize early adopters. The main difference is that our subsidy is contingent on too few people adopting. Because Rohlf's subsidy is not contingent on the total number of adopters, it is not costless in equilibrium.

VII. Conclusion

I have discussed multiple equilibria in the Prize paper with Doug Diamond, and in prior papers with Gerry Jaynes and Chester Spatt. I am grateful for my coauthors, and what I learned working with Chester and

[11] This ability to get to the first best costlessly is a strong result, and is not possible in general if preferences are not symmetric or we do not know the agent's preferences with certainty.

Gerry undoubtedly helped me to work on the Prize paper with Doug. In these models, having multiple equilibria is part of the economic content of the paper, not a defect in the model. Hopefully, the Prize paper has helped people to take multiple equilibria in economic models more seriously.

Ironically, the only one of the prior papers to be published, the adoption externality paper with Chester, was the one I know to have been closest to the prior literature (mostly encompassed by Rohlfs [1974]). I think the other papers, the paper on reputation effects with Chester and the papers on wage rigidity and wage dispersion with Gerry, can still have an impact, but their impact could have been larger if they had been published near the time when they were written. The wage rigidity paper has a flavor similar to work by Farmer on using multiple equilibria in modeling in macroeconomics, and may complement that literature. Similarly, the wage dispersion paper has the same assumption about workers searching while employed as Burdett and Mortensen's search model, and also gets wage dispersion. Our model is simpler (because firms do not have to wait for a match), which might be useful for incorporation in a bigger model. Also, equilibrium in our model can exhibit both discrete and continuous wage distributions.

I should mention that multiple equilibria are still shunned to some extent, and there are still plenty of papers that make strong and sometimes elaborate assumptions to get rid of multiple equilibria. We should remember that the comparative statics in these models come from the strong assumptions, not from economics. The literature on global games is one example of this. Weinstein and Yildiz (2007) argue convincingly that this sort of refinement is not robust. Within banking, Neil Wallace, a big and early contributor to the literature following the Prize paper,[12] asked me recently during the break of a conference a question about a paper just presented, something along the lines of "The probability of a bank run is a parameter of the model. What do you think about that?" I responded, "I don't like it, but I know why they did it." If they made the sunspot realization a continuous variable instead of a Bernoulli variable (whose probability of one outcome is the parameter), there would not be a unique equilibrium.[13] Assuming a Bernoulli variable with given probabilities may give us a single equilibrium and allow us to compute comparative statics, but how much confidence do we have about the robustness of such results?

I want to mention an idea for further work. Manju Puri and coauthors (Iyer and Puri [2012], Iyer, Puri, and Ryan [2016], and Martin, Puri, and Ufier [forthcoming]) have studied actual bank runs. Based on casual observation, the simple equilibria in our model or the dynamic models I

[12] See, e.g., Wallace (1988, 1990, 1996).

[13] If $x \sim U(0,1)$, then a variable that is 1 when $x \leq \pi$ and 0 when $x > \pi$ is a Bernoulli variable that is 1 with probability π and 0 with probability $1 - \pi$. Therefore, having unit uniform noise also gives us Bernoulli variables with all probabilities π.

have seen do not look so much like what they find in actual bank runs. I do not think that invalidates our basic messages, since liquidity mismatch, instability, and the usefulness of deposit insurance will remain. However, we would probably learn something from trying to model practice more closely. One idea is to use another equilibrium concept, the concept of rationalizability of David Pearce (Pearce 1984). He was a student when I was teaching at Princeton. Doug Bernheim also has a similar solution concept (Bernheim 1984). One of the things about Nash equilibrium that is a little unsatisfying is that it is unclear how people can know which Nash equilibrium everybody else is thinking about. Rationalizability says that all I can impose is that everybody in the economy has some reasonable idea that is consistent with the reasonable ideas other people could have. That will give you a larger set of equilibria and maybe could help us to explain the empirical results of Manju and her coauthors. It is possibly also necessary to have different types of depositors with different preferences or beliefs to explain her empirical results.

To summarize, having multiple equilibria can be the main economic point in a model, and incorporating multiple equilibria can have important policy implications, for example, in the use of full deposit insurance to remove the incentives for bank runs in Diamond and Dybvig (1983). Before working on this banking paper, I had previous papers with multiple equilibria. Two papers with Gerry Jaynes had multiple labor-market equilibria with wage dispersion and wage rigidity. One paper with Chester Spatt had multiple equilibrium in a model with adoption externalities, and another had multiple equilibria in a model with reputation for product quality given by endogenous rational beliefs. Understanding multiple equilibria is important because it can change the nature of policy from one of distorting a single equilibrium to one of eliminating bad equilibria without making the remaining equilibria worse.

References

Akerlof, George A. 1970. "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism." *Q.J.E.* 84:488–500.

Bell, John S. 1964. "On the Einstein Podolsky Rosen Paradox." *Physics* 1:195–200.

Bernanke, Ben S. 1983. "Nonmonetary Effects of the Financial Crisis in the Propagation of the Great Depression." *A.E.R.* 73:257–276.

Bernheim, B. Douglas. 1984. "Rationalizable Strategic Behavior." *Econometrica* 4:1007–28.

Burdett, Kenneth, and Dale T. Mortensen. 1998. "Wage Differentials, Employer Size, and Unemployment." *Internat. Econ. Rev.* 39:257–73.

Cass, David, and Karl Shell. 1983. "Do Sunspots Matter?" *J.P.E.* 91:193–227.

Committee for the Prize in Economic Sciences in Memory of Alfred Nobel. 2022. "Financial Intermediation and the Economy: Scientific Background on the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel."

https://www.nobelprize.org/uploads/2022/10/advanced-economicsciences prize2022-2.pdf.

Diamond, Douglas W. 1984. "Financial Intermediation and Delegated Monitoring." *Rev. Econ. Studies* 51:393–414.

———. 2007. "Banks and Liquidity Creation: A Simple Exposition of the Diamond-Dybvig Model." *Fed. Reserve Bank Richmond Econ. Q.* 93:189–200.

Diamond, Douglas W., and Philip H. Dybvig. 1983. "Bank Runs, Deposit Insurance, and Liquidity." *J.P.E.* 91:401–19.

———. 1986. "Banking Theory, Deposit Insurance, and Bank Regulation." *J. Bus.* 59:55–68.

Dybvig, Philip H. 2023. "Multiple Equilibria." In *The Nobel Prizes 2022*. Singapore: World Scientific. Also available at https://www.nobelprize.org.

Dybvig, Philip H., and Gerald Jaynes. 1979. "Microfoundations of Wage Rigidity and Unemployment." Working paper, Dept. Econ., Yale Univ.

———. 1980. "Output Supply, Employment, and Intra-Industry Wage Dispersion." Discussion Paper no. 546, Cowles Found., Yale Univ.

Dybvig, Philip H., and Chester S. Spatt. 1983a. "Adoption Externalities as Public Goods." *J. Public Econ.* 20:231–47.

———. 1983b. "Does It Pay to Maintain a Reputation? Consumer Information and Product Quality." Working paper, Dept. Econ., Yale Univ.

Einstein, A., B. Podolsky, and N. Rosen. 1935. "Can Quantum-Mechanical Description of Physical Reality Be Considered Complete?" *Physical Rev.* 47 (10): 777–80.

Farmer, Roger. 2008. "Aggregate Demand and Supply." *Internat. J. Econ. Theory* 4:77–93.

———. 2012. "Confidence, Crashes and Animal Spirits." *Econ. J.* 122:155–72.

———. 2013. "Animal Spirits, Financial Crises and Persistent Unemployment." *Econ. J.* 123:317–40.

Hart, Oliver. 1975. "On the Optimality of Equilibrium when the Market Structure Is Incomplete." *J. Econ. Theory* 11:418–43.

Iyer, Rajkamal, and Manju Puri. 2012. "Understanding Bank Runs: The Importance of Depositor-Bank Relationships and Networks." *A.E.R.* 102:1414–45.

Iyer, Rakjamal, Manju Puri, and Nick Ryan. 2016. "A Tale of Two Runs: Depositor Response to Bank Solvency Risk." *J. Finance* 71:2687–726.

Keynes, John Maynard. 1936. *The General Theory of Employment, Interest, and Money.* London: Macmillan.

Martin, Christopher, Manju Puri, and Alexander Ufier. Forthcoming. "Deposit Inflows and Outflows in Failing Banks: The Role of Deposit Insurance." *J. Finance.*

Pearce, David. 1984. "Rationalizable Strategic Behavior and the Problem of Perfection." *Econometrica* 52:1029–50.

Prescott, Edward Simpson. 2010. "Introduction to the Special Issue on the Diamond-Dybvig Model." *Fed. Reserve Bank Richmond Econ. Q.* 96 (1): 1–9.

Rohlfs, Jeffrey. 1974. "A Theory of Interdependent Demand for a Communications Service." *Bell J. Econ. and Management Sci.* 5 (1): 16–37.

Sonnenschein, Hugo. 1972. "Market Excess Demand Functions." *Econometrica* 40:549–63.

———. 1973. "Do Walras' Identity and Continuity Characterize the Class of Community Excess-Demand Functions?" *J. Econ. Theory* 6 (4): 345–54.

Wallace, Neil. 1988. "Another Attempt to Explain an Illiquid Banking System: The Diamond-Dybvig Model with Sequential Service Taken Seriously." *Fed. Reserve Bank Minneapolis Q. Rev.* 12:3–16.

———. 1990. "A Banking Model in Which Partial Suspension Is Best." *Fed. Reserve Bank Minneapolis Q. Rev.* 14:11–23.

———. 1996. "Narrow Banking Meets the Diamond-Dybvig Model." *Fed. Reserve Bank Minneapolis Q. Rev.* 20:3–13.

Weinstein, Jonathan, and Muhamet Yildiz. 2007. "A Structure Theorem for Rationalizability with Application to Robust Predictions of Refinements." *Econometrica* 75:365–400.