Alternative Approaches to Analyzing Markets with Asymmetric Information: Reply

By J. STIGLITZ AND A. WEISS*

Shiro Yabushita's comment on "The Theory of Screening" (Stiglitz, 1975) raises some interesting questions which have arisen in a number of different contexts: How should one model markets with imperfect information? What are appropriate behavioral postulates and equilibrium concepts? To restructure the question in terms of game theoretic language: Who are the active players? What are their strategy spaces? Do the players move simultaneously, or does one move before the other?

These questions do not have simple answers: different equilibrium notions are appropriate for different economic contexts. Yabushita's comment illustrates how one can obtain markedly different results using alternative assumptions. Although we believe that for the particular context examined in Stiglitz (1975), the equilibrium concept employed there is better than the alternative implicitly proposed by Yabushita, his formulation merits attention, and there are other contexts in which his would be the appropriate formulation.

In order to illuminate how the Yabushita model differs from the Stiglitz model, it is useful to reformulate their analyses in game theoretic terms. The strategies of individuals entail decisions as to whether or not to screen themselves (go to school), while the strategies of firms are wage offers conditioned on whether or not the individual has screened himself, and the result of that screening. An individual goes to work for the firm which offers him the highest wage. Thus, the payoff to the firm is zero, if it doesn't obtain the worker, and the difference between the worker's productivity and his wage if it obtains the worker. The payoff to the individual is his maximum wage offer minus his screening costs.

There are two alternative ways of viewing the difference between the Yabushita and Stiglitz formulations of the education market. One way is to view Yabushita and Stiglitz as differing in their assumptions about whether firms or individuals move first.

The choice of a schooling program is typically made by individuals *before* a wage offer is received. The Stiglitz model attempts to capture this natural temporal sequence of decision making by formulating a two-period model; in the first period, individuals decide whether or not to screen themselves, while in the second, profit-maximizing firms offer wages to both screened and unscreened individuals (who, in turn, go to work for the firm offering them the highest wage). The wage offer of each firm is assumed to be the profit-maximizing response to the screening decision of workers, given the wage offers of other firms. Hence, if any high ability worker screens himself he will receive a wage equal to his expected productivity θ_1.[1] If no workers screen themselves, the unscreened workers receive a wage equal to their expected productivity of $\bar{\theta}$, and if the type 1 workers screen themselves, the unscreened workers receive a wage of θ_2, their expected productivity. In each case, higher wages would incur losses; and a lower wage could not be an equilibrium, since there would be an opportunity for some other firm to increase its profits by offering a higher wage.[2]

*Princeton University and Bell Laboratories, respectively

[1]This is true whether or not any other workers are screening themselves. Consequently, we are precluding Nash equilibria in which the strategies of all firms are to offer low wages to screened workers and the strategy of all workers is to not screen themselves. Rather, we are assuming that once a screening decision is made, firms always respond optimally at that point. See fn 4 below.

[2]That is, if each firm takes the wage offers and screening decisions as given, unless the maximum wage

In this interpretation of Stiglitz, if no one is screening himself, a high ability type would only increase his income by screening if his productivity, net of screening costs c, exceeds the productivity of a *randomly selected individual* in the population: those are the relevant wages with and without screening starting from a position where no one screens himself. Thus, if $\bar{\theta} > \theta_1 - c$, an equilibrium exists with no screening.

At the same time, a screening equilibrium would also exist if the productivity of the most able, net of screening costs, exceeds the productivity of the *least able*. These provide the relevant wages in a screening equilibrium. Obviously, in this formulation, multiple equilibria may exist. Notice that we are implicitly assuming that there are many workers of each type so that the choice of a single individual has trivial effects on the wage offers of firms. Implicitly we are defining equilibrium as satisfying a backward induction argument, so that workers know that for any choice of an education level (screen), every firm responds in a profit-maximizing way given the strategies of all other firms and workers. This formulation is close to the notion of subgame-perfect equilibrium. (A subgame-perfect equilibrium is a Nash equilibrium which, if written in extensive form, also generates a Nash equilibrium for any game beginning at an information set of the original game containing only one node.)

On the other hand, in the Yabushita analysis, firms make their wage offers prior to individuals choosing whether or not to screen themselves, and the screening decisions of individuals are the optimal reactions to these wage offers of firms. Given this structure, multiple equilibria cannot exist. If the conditions for a pooling equilibrium are satisfied, that is, $\bar{\theta} > \theta_1 - c$, any putative full-screening equilibrium would be broken by a firm offering a wage (conditional on no screening) of $\bar{\theta} - \varepsilon$ where ε is less than $\bar{\theta} - \theta_1 + c$. The reason for nonexistence of multiple equilibria is that if firms are moving first, the wage offer of any firm can determine whether or not individuals screen themselves.[3]

The Yabushita analysis of equilibrium in a market in which firms move first is similar in many respects to a Nash equilibrium in which individuals are not active players in the game. This is the second interpretation for the difference between Stiglitz and Yabushita: Stiglitz is looking at Nash equilibria in which both firms and individuals are active players; Yabushita is looking at Nash equilibria in which only firms are active players. That is, individuals simply work for the firm offering the best contract to them. They do not choose strategies, but simply react to the strategies of the firms. When a firm decides on a strategy, it takes the reaction functions of individuals as given.

This assumption of passive individuals is a plausible one to make if the screening cost c is some preemployment exam administered by the firm as in Guasch and Weiss (1980). Similarly, in the insurance market studied by Rothschild-Stiglitz (1976), it is plausible to think of individuals as passively choosing from a set of insurance policies. However, in the Stiglitz (1975) education model where the screen is implicitly a course of schooling with the property that the more able pass, and the less able fail, it seems implausible to assume that individuals are simply reacting to the strategies of firms. It seems more sensible to view that schooling program as a strategic choice of an individual. Both individuals and firms are active players in this market. Individuals decide whether or not to screen themselves (go to school) and firms make

offer equals the expected productivity, the firm can increase its profits by offering an amount slightly over that offered by other firms.

[3]Some readers may be puzzled why, in such a situation there is a pooling equilibrium: Michael Rothschild and Stiglitz (1976) and Charles Wilson (1980) show that, in general, there cannot exist a pooling equilibrium. The reason is that here we assume that there is a fixed cost, c, associated with identifying oneself as more able and we have not allowed the firm to employ alternative self-selection devices. If, for instance, the firm can require individuals to disclose whether they are more or less able, and can insist that individuals post a bond, which they forfeit if, upon subsequent screening, it turns out that they have lied, then the pooling equilibrium can be broken by a self-selection equilibrium (which itself may be broken by a pooling equilibrium) entailing random testing; under these circumstances, equilibrium may not exist. (See Stiglitz, forthcoming, David Scharfstein, 1982; and J. Luis Guasch and Weiss, 1981.)

wage offers conditional on whether or not the individual has gone to school. With this interpretation, the assumption that the output of a randomly selected individual exceeds the productivity of the most able worker, net of screening costs, which in turn exceeds the output of the least able worker (i.e., $\theta_1 - \theta_2 > c > \theta_1 - \bar{\theta}$) does indeed imply multiple equilibria.[4] The cost c of the screen is a sunk cost. In a full-screening equilibrium, the more able are paid a wage equal to the value of their output and would not be attracted to a firm offering a lower wage. Their lifetime income is $\theta_1 - c$. They may prefer a wage equal to the expected productivity of a randomly selected individual, but that is just to say that no one likes Pareto-dominated equilibria, not that those equilibria do not exist. Weiss (forthcoming) shows that with more realistic assumptions such as a continuum of possible education levels, many types of individuals, imprecise estimates by each worker of his own ability, and imprecise tests, the problems of multiple equilibria do not disappear. Some of the Nash equilibria which arise are clearly implausible, and Weiss introduces more restrictive definitions of equilibrium to eliminate those implausible equilibria.

Section II of Yabushita's comment is motivated by the different implications of signals purchased by the workers and tests administered by the firms. In that section, the difficulty lies in understanding how firms respond to a worker who has screened himself. Because of the assumption of assembly line production, no single worker would gain from screening himself. On the other hand, a coalition of able workers would benefit from screening themselves (and the less able would even find it profitable to subsidize this screening). Yabushita again assumes either that firms do the screening as in Guasch and Weiss (1980), or that individuals passively respond to the wage offers of firms in deciding whether or not to screen themselves. Thus firms do not take the screening decisions of individuals as given when choosing their wage offers; rather, firms make their wage offers before workers screen themselves, and the latter do not act strategically. The lesson to be drawn from these examples is that in adverse selection models it is important to correctly delineate who is actively signaling or screening.

Elsewhere, we have reexamined the nature of the equilibrium which emerges in a variety of market situations. There are some situations, such as the insurance market or labor markets where firms engage in some screening, where the uninformed are active players, while the informed are passive; in those situations the kinds of considerations which Yabushita has raised are central (paralleling the earlier results of Rothschild and Stiglitz). There are other situations, such as the education market examined in Stiglitz (1975), A. Michael Spence (1974), and Weiss (1982), or the capital market, as examined in Stiglitz (1982) and Sudipto Bhattacharya (1980), where the informed are active players, and move prior to the uninformed.

The recent literature on equilibrium with imperfect and costly information has established that the simple price-taking formulations associated with Walrasian general equilibrium analysis may well be inappropriate in such situations.[5] What we have attempted to show in this response to Yabushita's insightful comment is that the choice of an appropriate equilibrium concept entails a careful analysis of the economic structure of the problem at hand. There are no easy or general answers.

[4] If we do not restrict the strategy space of firms to pay types who have screened themselves wages equal to their expected productivities, the only requirement for multiple equilibria is that $\theta_1 - c > \theta_2$: there are always no-screening Nash equilibria. This follows from the definition of Nash equilibrium which allows firms to react nonoptimally to out-of-equilibrium moves. For example, if no workers are screening themselves, firms could offer a zero wage to screened workers. In that case, no screening would be an equilibrium regardless of the value of θ_1.

[5] For instance, while traditional Walrasian analysis defines equilibrium as having zero excess demands, Weiss (1980), Stiglitz and Weiss (1981), Stiglitz (1976) and Wilson (1980) have shown that competitive equilibrium may entail excess supply (of labor) or excess demand (for loans).

REFERENCES

Akerlof, George, "The Market for 'Lemons': Qualitative Uncertainty and the Market Mechanism," *Quarterly Journal of Economics*, August 1970, *84*, 448–500.

Bhattacharya, Sudipto, "Non-Dissipative Signaling Structures and Dividend Policy," *Quarterly Journal of Economics*, August 1980, *95*, 1–24.

Guasch, J. Luis and Weiss, Andrew, "Wages as Sorting Mechanisms in Markets with Asymmetric Information: A Theory of Testing," *Review of Economic Studies*, July 1980, *48*, 653–64.

_____ **and** _____, "A Note on Self-Selection in the Labor Market: Random Testing Revisited," Bell Laboratories Discussion Paper No. 230, 1981.

Rothschild, Michael and Stiglitz, Joseph, "Equilibrium in Competitive Insurance Markets," *Quarterly Journal of Economics*, November 1976, *90*, 629–49.

Scharfstein, David, "On Inducing Honest Behavior: Towards a General Theory of Self-Selection and the Design of Predation Policy," senior thesis, Princeton University, 1982.

Spence, A. Michael, "Competitive and Optimal Responses to Signals: An Analysis of Efficiency and Distribution," *Journal of Economic Theory*, March 1974, *7*, 296–332.

Stiglitz, Joseph, "The Theory of 'Screening,' Education and the Distribution of Income," *American Economic Review*, June 1975, *65*, 283–300.

_____, "Prices and Queues as Screening Devices," IMSSS Technical Report, 1976.

_____, "Information and Capital Markets," in W. S. Sharpe and C. M. Cootner, eds., *Financial Economics: Essays in Honor of Paul Cootner*, Englewood Cliffs: Prentice-Hall, 1982, 118–58.

_____, *Information and Economic Analysis*, Oxford: Oxford University Press, forthcoming.

_____ **and Weiss, Andrew,** "Credit Rationing in Markets with Imperfect Information," *American Economic Review*, June 1981, *71*, 393–409.

Weiss, Andrew, "Job Queues and Layoffs in Markets with Flexible Wages," *Journal of Political Economy*, May 1980, *88*, 526–58.

_____, "A Sorting-*cum*-Learning Model of Education," *Journal of Political Economy*, forthcoming.

Wilson, Charles, "The Nature of Equilibrium in Markets and Adverse Selection," *Bell Journal of Economics*, Spring 1980, *11*, 108–30.

Yabushita, Shiro, "Theory of Screening and the Behavior of the Firm: Comment," *American Economic Review*, March 1983, *73*, 242–45.