

Endogenous Growth and Cycles

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There is a famous aphorism that in every cloud there is a silver lining. The alleged silver lining in the cloud of an economic recession is the “shake-out” that results. As firms face declining profits and cash reserves, they typically act to cut out fat, to fire unnecessary workers, and to restructure the firm to make it “leaner and meaner.” There is also a shake-out within each industry. Firms that are less efficient, that have been surviving off previously earned capital, can no longer do so. The Darwinian struggle for the survival of the fittest means that those firms that are less fit cannot make it through a serious downturn; and thus, recessions speed the process of natural selection.

Schumpeter emphasized this aspect of recessions. He wrote, on recessions:

They are but temporary. They are the means to reconstruct each time the economic system on a more efficient plan. But they inflict losses while they last, drive firms into the bankruptcy court, throw people out of employment, before the ground is clear and the way paved for new achievement of the kind which has created modern civilization and made the greatness of this country. (1934, 113)

Indeed, Heilbroner, a student of his, noted that Schumpeter, on balance, seemed to think that depressions were a good thing:

But the students who attended his classes in the late 1930s were regularly shocked to hear this expositor of capitalist growth declare, with obvious

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enjoyment, that depressions, far from being unmitigated social evils, were actually in the nature of "a good cold douche" for the economic system! (Heilbroner 1980, 311)

If there is a silver lining in every cloud, behind every silver lining lies another cloud: not all that is cut out is fat. Typically, firms also reduce their expenditures on R&D and productivity-enhancing expenditures. The reduction in output reduces opportunities to "learn by doing." Thus, the attempt to pare all unnecessary expenditures may have a concomitant effect on long-run productivity growth. In this view, the loss from a recession may be more than just the large, but temporary, costs of idle and wasted resources: the growth path of the economy may be permanently lowered. Figure 1 illustrates the differences between these two views.

Moreover, the firms that are eliminated in the downturn of the recession may not be the "less fit," as measured by their capacity for long-run economic growth, but rather those that are less adapted to surviving economic downturns. There is no general theorem asserting the efficiency of the process of natural selection,¹ and in the presence of imperfect capital markets, firms cannot borrow against their future, long-run potentialities.

The purpose of this paper is to explore the nexus between cycles and growth, a strong theme within the Schumpeterian tradition. The nexus is a complicated one, as we shall see, and central to our story is an understanding of the role that imperfections of the capital market play. While the earlier literature simply posited the existence of an imperfect capital market, recent advances in the theory of asymmetric information have provided theoretical foundations; we now understand why capital markets are frequently characterized by credit rationing;² we understand why, in spite of the marked advantages to equity (in terms of risk diversification and the avoidance of the significant moral hazard problems associated with debt), little use of the equity market is made to raise new capital.³ We have only begun, however, to explore the full ramifications of the implications of these capital market im-

1. In Stiglitz (1992b), I examine the welfare properties of evolutionary processes. I show that there may be multiple equilibria, one of which is better than the others; and that tighter natural selection may actually be welfare decreasing.

2. Raising interest rates charged may actually lower the expected return of the borrower. There are both adverse selection and adverse incentive effects. See, for instance, Stiglitz and Weiss (1981). Introducing collateral will not, in general, resolve these difficulties (Stiglitz and Weiss 1992). While the earlier analysis focused on risk-neutral lenders, the analysis can be extended to risk-averse lenders (see Greenwald and Stiglitz 1990).

3. There are, again, both adverse selection and adverse incentive arguments. See, for instance, Stiglitz (1992) and Greenwald, Stiglitz, and Weiss (1984).

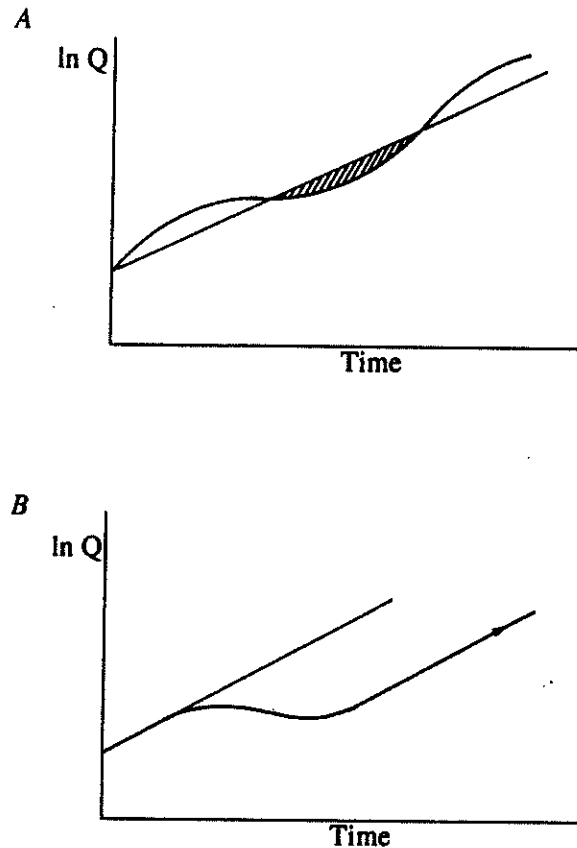


Fig. 1. Alternative views concerning the long-run effects of an economic downturn. (A) The economic downturn leads firms to cut slack and increase economic efficiency, allowing them to return, and temporarily even exceed, the trend line. (B) The economic downturn leads firms to cut back R&D, so that the long-run growth path is permanently lower.

perfections, both for the behavior of the firm (e.g., firms acting in a risk averse manner), and for the behavior of the economy.⁴

Earlier discussions focused mainly on one aspect of the nexus between growth and cycles: the fluctuations in the economy *induced* by technological innovation. Part I focuses on the other side of the relationship: the effect of cycles on induced innovation. Part II presents a simple model illustrating this second aspect of the relationship.

4. See, for instance, Greenwald and Stiglitz (1992a, 1992b), Stiglitz (1992), and Stiglitz and Weiss (1992).

I. Endogenous Growth

As we noted in the introduction, Schumpeter emphasized the long-run efficiency-enhancing aspects of economic downturns. We argue here that by ignoring the deleterious effects on R&D, he underestimated the negative effects of recessions, and that, on balance, macroeconomic policies that stabilize the economy are more likely to be conducive to long-run growth.

This section of the paper is divided into five parts. We first explain why economic downturns have a negative effect on R&D, and on technological progress more broadly; we then explain and evaluate the traditional argument for why they may have some efficiency-enhancing effects. In the third subsection, we attempt to draw up an assessment balancing the competing effects. Next, we present a simple model capturing some of the central effects we have identified. We conclude with a brief discussion of some of the empirical evidence.

A. The Negative Effect on R&D

In the Schumpeterian tradition, innovation is largely endogenous.⁵ It affects, and is affected by, market structure.⁶ In this paper, I want to emphasize, however, another determinant that has, perhaps, not received sufficient attention: financial constraints.⁷ Financial constraints may impinge on the firm's R&D effort in two distinct ways, one as a result of imperfections in the credit market, the other as a result of imperfections in the equity market.

Credit and Equity Rationing

While it has long been recognized that expenditures on research and development are "investments," these investment expenditures differ from other investments in that they are not, in general, collateralizable. Firms can borrow to purchase, say, real estate, because lenders believe that, even should the borrower default, the collateral provided by the real estate protects his interests. By contrast, a firm undertaking R&D expenditures is most likely to default when the research project fails; thus, even if it were possible to precisely define the fruits of an R&D project, and to offer that as collateral, the value of the collateral is likely to be negligible in precisely those circumstances in which the firm defaults.

While, to be sure, "funds are fungible," so that a well-established firm with considerable equity value in its real estate holdings can borrow against

5. While the recent resurgence in these issues by the so-called endogenous growth literature is welcome, the failure of this literature to recognize this long tradition is indeed remarkable.

6. See, e.g., Dasgupta and Stiglitz (1980).

7. Schumpeter, himself, seems to have recognized the importance of financial constraints, in his emphasis on the importance of profits as a source of funds for financing new R&D.

that real estate to finance its research expenditures, many firms (especially newly established firms) find the amount that they can borrow provides an effective constraint on their level of expenditures on R&D.

This means that in the face of economic downturns, firms may be forced to cut back on their R&D expenditures. Their R&D expenditures are constrained by their cash flow plus their available borrowings. Cash flow is simply the difference between the value of their sales and their costs: it is a residual. Slight changes in revenues (as a result of slight decreases in the price or leftward shifts in the demand curve they face) can have large effects on their cash flow. Because of credit rationing, firms cannot offset these reductions in cash flow by increased borrowings. As we noted earlier, in the presence of imperfect information, even competitive capital markets may be characterized by credit rationing; and there is considerable empirical support for the hypothesis that there is credit rationing.⁸ Economic downturns not only have adverse effects on firms' cash flow, which cannot be offset by increased borrowing, but economic downturns are likely to also be accompanied by more extensive credit rationing, exacerbating the firm's problems. The current economic downturn in the United States, which has been accompanied by a severe credit crunch, provides the most recent evidence of this.⁹

The recently developed theory of the risk-averse bank (Greenwald and Stiglitz 1992a, 1992b) provides a theoretical rationale for why we should expect this to happen. They argue that banks are risk averse because imperfections in the equity market (see below) make it impossible for firms to fully divest themselves of risk. Risk-averse banks allocate their portfolio between safe assets—Treasury bills—and risky loans. In an economic downturn, banks are likely to shift their portfolio toward making fewer loans (i.e., there will be more extensive credit rationing). This occurs for two reasons: the large number of defaults reduces banks' net worth; because there is decreasing absolute risk aversion, a decrease in firms' net worth leads to a decrease in risk taking, and, therefore, a decrease in loan activity. (This is the wealth effect.) Secondly, banks' perceptions of the risks associated with loans are likely to

8. For a survey of credit rationing, see Jaffee and Stiglitz (1989). More recent empirical work has shown that cash flow variables affect the level of investment, particularly for small and medium size firms. See Hubbard (1990).

9. To be fair, we should note that there is some dispute about the significance of the credit crunch. Some banks claim that the problem is not the supply of funds by banks, but the demand for funds by firms. (The discussion in the next section will focus on the demand for funds.) But there are at least three pieces of evidence which suggest the importance of credit constraints (besides the perceptions of borrowers that their access to credit is restricted.) First, margins between lending and deposit rates have increased markedly. Secondly, nonprice terms (such as collateral requirements) have increased. Thirdly, studies by the Federal Reserve Board suggest that "standards" for getting loans have been increased.

change adversely; not only are mean returns lower, but perceived variances are likely to be larger.¹⁰ (This is the substitution effect.)

But even if banks did not respond to the economic downturn by increasing credit standards, the decreased value of collateralizable assets would imply that the amounts that firms could borrow would be reduced as the value of the collateral decreased. Thus, economic downturns lead to fewer expenditures on R&D, both because cash flow is adversely affected, and because credit rationing is likely to be more severe.

Equity Rationing and the Portfolio Theory of the Firm

But even if firms were not credit constrained, severe economic downturns would be accompanied by a decrease in R&D expenditures. R&D expenditures are risky, with returns (when they occur) often occurring many years after the initial expenditures. In traditional neoclassical theory, these risks would be of little moment; since, by assumption, there is a complete set of risk markets, firms can fully divest themselves of risks unrelated to the business cycle; and since the principal risk associated with R&D has to do with the success of the research venture—e.g., whether the new chemical is discovered—which is uncorrelated with the business cycle,¹¹ firms ought to act in a risk-neutral manner, with respect to R&D expenditures.

But firms are risk averse precisely because they cannot fully divest themselves of all the risks that they face. Equity markets are imperfect. Indeed, as table 1 shows, firms rely relatively little on equity markets as a source of new funds. There is a simple reason for this: the cost of raising new equity funds is extremely high. Typically, when firms issue new equity, there is a marked decline in the value of existing shares.¹²

The theories of adverse selection and moral hazard (agency), to which we referred earlier, provide an explanation for why we might expect this. Our

10. The reductions in perceived mean returns and increases in perceived variances are not just based on an extrapolation of the higher default rates associated with economic downturns. If firms' net worths are reduced enough, they may undertake riskier actions; and while these firms, which are "going for broke," increase their demand for funds, the "sunder" firms may actually reduce their demand for funds. Even with this reduced demand for funds, of course, these firms may face a higher default probability, both because of their decreased net worth and because of the increased uncertainty associated with the economic downturn. In short, the negative impact of the economic downturn on firms naturally leads to lower expected returns and higher risk associated with loan activity. This has been referred to as the "financial fragility" of loan markets. See Stiglitz (1992a, 1992c) and Gertler and Bernanke (1990).

11. Of course, the economic value of a project is related to the macroeconomic conditions; but since the returns to most R&D ventures are several years in the future, current economic conditions should have little to do with the expected present discounted value of a research project.

12. Perhaps the most widely cited study is that of Asquith and Mullins (1986), who observed that, on average, if a firm raises \$100 million in new equities, old shares decrease in value by more than \$30 million. See also Masulis and Korwar (1986).

**TABLE 1. Net Sources of Finance—1970–89,
Weighted Average, Undepreciated, Revalued**

	France	Germany	Japan	United Kingdom	United States
Internal	66.3	80.6	71.7	98.0	91.3
Bank Finance	51.5	11.0	28.0	19.8	16.6
Bonds	0.7	-0.6	4.0	2.0	17.1
Equity	-0.4	0.9	2.7	-8.0	-8.8
Trade Credit	-0.7	-1.9	-7.8	-1.6	-3.7
Capital Transfers	2.6	8.5		2.1	
Other	-14.9	1.5	1.3	-4.1	-3.8
Statistical Adj.	-5.1	0.0	0.1	-8.2	-8.7
Notes	1970–85	1970–89	1970–87	1970–89	1970–89

Source: Unpublished flow of funds figures from the CEPR International Study of the Financing of Industry. Data courtesy of Tim Jenkinson and Colin Mayer.

concern here, however, is simply that because the cost of raising new equity is so high, firms typically resort to credit (bank and bond) markets to raise any funds beyond those provided by retained earnings for financing investment. They do this in spite of the marked advantages that equity has in spreading risk.

Credit encumbers the firm with a fixed obligation. And, of course, if the firm cannot fulfill this fixed obligation, it goes bankrupt.¹³ Firms—and their managers—seek to avoid bankruptcy, for quite obvious reasons. Not only are there costs to bankruptcy,¹⁴ but bankruptcy provides an adverse signal concerning the quality of management.

The various actions (expenditures) that a firm can undertake jointly affect the probability of bankruptcy. The firm looks at the whole portfolio of its actions. In particular, if there is a decrease in the firm's net worth and cash flow (as a result of an economic downturn), then, if it were to maintain the same level of economic activity (the same level of production, investment, and R&D), it would have to borrow more; and that would increase the proba-

13. In multi-period models, matters are somewhat more complicated, since lenders can choose to reschedule the debt. See Eaton, Gersovitz, and Stiglitz (1986).

14. Of course, the assets of the firm do not disappear upon bankruptcy, but bankruptcies typically entail significant transactions costs. There is often an interruption to normal business (as suppliers and customers become less certain of the value of the continuing relationship), which proves costly to the firm. Modern theories of the firm emphasize the importance of reputation mechanisms; these become less effective when customers think that there is a significant probability that the firm will discontinue operation. (Reputation models emphasize that firms must have profits in order for them not to have an incentive to cheat, e.g., on quality; when the probability of survival is low, the bankrupt firm's profits, and presumably, therefore, prices, must actually increase in order for it to have an adequate incentive not to cheat.)

bility of default. In turn, this implies that the *marginal* cost of each of these actions (that is, taking into account the marginal costs associated with the increased probability of bankruptcy) is increased; and this, in turn, implies that, normally, the firm would reduce the level of these activities. In this perspective, an economic downturn is likely to have the most adverse effect on those activities that are riskiest, and for which the returns are the furthest in the future: R&D activities. While the costs are borne today, when the shadow cost of capital (taking into account the marginal bankruptcy cost) is very high, the benefits accrue in the future, when the marginal value of an increased dollar of earnings (taking into account the reduction in the bankruptcy probability) is likely to be much smaller. To put it another way, the shadow interest rate (taking into account the differences in marginal costs of bankruptcy over time) is very high,¹⁵ and this, by itself, tends to lead to a marked reduction in long-term, risky investments, such as R&D.

There are, to be sure, offsetting effects: costs of adjustment for R&D may be greater than for some other categories of expenditures, and this effect itself may serve to make R&D expenditures less cyclical than certain other categories of expenditures. Indeed, it appears that in the face of small to moderate downturns, firms try to preserve their R&D efforts, but in the face of major economic downturns, where the cash flow constraints really seem to begin to bite, R&D may suffer significantly. In any case, our concern here is not whether R&D is more or less volatile than other categories of investment; only that economic downturns, particularly severe economic downturns, have a deleterious effect on R&D.

The same kind of argument—that economic downturns have a negative effect on technical change—applies when the rate of technological progress is related to either the level of output or investment, as in the standard theories of Learning by Doing (Arrow 1962). Because of the nonexistence of futures markets, there are large risks associated with most production (most production is not made to order, but is, in this sense, “speculative”). Both decreases in net worth and increases in risk perception lead firms (with given capital stock, wages, and expected prices) to reduce their level of output (Greenwald and Stiglitz 1992a). These conclusions hold even in the absence of learning by doing. But the presence of learning by doing strengthens them: for one of the benefits of production is a reduction in future costs; and with higher effective discount rates, the present discounted value of these future decreases in costs is lowered. (For a more extensive discussion of the relationship between growth, learning by doing, and capital market constraints, see Greenwald, Kohn, and Stiglitz 1990.)

15. By contrast, movements in risk-free real rates of interest may vary very little over extended periods of time. For instance, the risk-free 5-year real rate of interest on U.S. government securities varied by less than 1.5 percentage points over the quarter century from 1952 to 1977.

Thus, economic downturns have long-run consequences. With lower expenditures on R&D and lower levels of investment and production, resulting in less learning, the growth path of the economy is shifted down, as we illustrated earlier, in figure 1.

B. Efficiency Enhancing Effects of Economic Downturns

As we noted earlier, however, there are some benefits to the economic downturn, in that firms are forced to become more efficient, to cut out waste. This notion, too, has no place in standard neoclassical theory, in which firms are simply assumed, at all times, to minimize costs. Firms are assumed to be efficient. To be sure, there has been a long tradition of the "managerial theory of the firm" (Berle and Means [1932], March and Simon [1958], Cyert and March [1965], Marris [1964], Baumol [1959]). But these models, which assumed that managers "satisficed"¹⁶ or pursued goals, such as growth maximizing, that were at variance with profit or value maximizing behavior, were dismissed by the mainstream: firms that did not maximize their market value would be taken over, and the new management would make a capital gain simply by changing the actions of the firm to those that did maximize market value. Thus, takeovers provided an effective disciplinary device, which ensured that even if managers might have liked to have pursued other objectives, it was not feasible for them to do so.¹⁷ The new Information Economics paradigm has explained why the takeover mechanism provides, at best, limited discipline. It requires information—which is costly to obtain—to know whether a firm is, in fact, maximizing its market value; and those who expend the resources to obtain the information have a difficult time appropriating the returns.¹⁸ In fact, owners hire managers to manage their firms largely because information is costly: they do not themselves have the requisite information to make all of the decisions. But these information costs, which make delegation necessary, also provide scope for managerial discretion.

Reward structures for managers seldom give managers more than a small

16. See also Leibenstein's theory of X-efficiency (1989).

17. Discipline was also provided by evolutionary mechanisms (firms that did not maximize profits could not survive) and by proxy votes. The more recent literature has explained why these mechanisms, like the takeover mechanism, exert far from perfect discipline.

18. If one firm discovers a firm that is not maximizing its value and makes a bid to buy it, since such bids are public, the bid itself conveys information to other potential buyers; once the firm is "in play," competition among potential buyers bids the price up to its true potential value. See Stiglitz (1975). The empirical evidence (Jensen 1986) suggests that those taking over, in fact, gain little or nothing.

Moreover, there is a public good (free rider) problem: if a shareholder believes that the new management is going to enhance the value of the firm (i.e., increase the value over the price paid—the increased value being, in fact, the reward to the new management), then it does not pay for him to sell his shares. See Grossman and Hart (1980).

fraction of the increased value of the firm that results from their activities. Jensen and Murphy (1990) estimate that top management, as a whole, appropriates less than 0.3 percent of any increases in value. But while “incentive pay” may thus provide small carrots to enhance economic efficiency, bankruptcy provides a big stick. As the threat of bankruptcy looms greater (as the firms’ net worth decreases or risk increases in an economic downturn), management has much stronger incentives to exert efforts to cut costs and avoid waste.

Indeed, one of the principal theories of corporate finance, explaining why firms make limited use of equity, relies precisely on this incentive mechanism. High debt forces management to act efficiently. My colleague, Robert Hall, refers to this as the “backs to the wall theory of corporate finance.”¹⁹

This raises a fundamental criticism of Schumpeter’s contention concerning the desirability of economic downturns: granted the general problems of managerial slack, there may exist alternative ways of providing the necessary incentives for managerial efficiency—for instance, higher debt levels—that have less deleterious systemic effects.²⁰

(There are, of course, other theories which provide an explanation for why one might expect to see economic downturns associated with a reduction in X-inefficiency. For instance, managerial attention is limited; it is a scarce resource. In growth periods, management focuses its attention on exploring new opportunities, introducing new innovations, and developing new markets. Periods of economic slack give management the opportunity to focus their attention on how to do what they do at minimum cost.)

I argue not only that it may be possible to obtain the positive efficiency-enhancing effects of reduced managerial slack without the deleterious effects of economic downturns, but that it is not even clear, on balance, that economic downturns’ efficiency-enhancing effects are as significant as Schumpeter seems to have thought. To be sure, economic downturns do result in some short-run efficiency gains,²¹ though some, perhaps most, of the observed

19. This theory is obviously a special case of the more general theories of corporate finance based on incentive or agency effects (see, e.g., Stiglitz [1974], Jensen and Meckling [1976]), and in particular of Jensen’s theories emphasizing the importance of free cash flow (Jensen 1986).

20. Though, to be sure, such high levels of debt may contribute to the volatility of the economy, as the recent economic downturn in the United States demonstrates, and as suggested by the Greenwald-Stiglitz (1992a) theories of economic fluctuations.

21. The fact that productivity is observed to decrease in a recession should not be viewed as contradicting this result. Productivity decreases partly because there are (at least in the short run) increasing returns; production lines are not being used at the rate for which they are designed. There is, thus, a leftward movement along a downward sloping average cost curve (which increases average cost). Our analysis focuses on the *shifts* in the cost curve—the downward shift in the cost curve resulting from increased efficiency (and the fact that, in the long run, that downward shift may be less than it otherwise would be, because of reduced R&D expenditures and reduced learning by doing).

efforts at shedding off slack are directed mainly at reducing the slack that the economic downturn itself created. But it is sometimes suggested that these short-run efficiency gains have long-lasting benefits—that is, that the cost savings free resources that are needed in the economic recovery. But one must bear in mind that there are costs associated with efficiency-enhancing efforts; these costs must be set against the benefits of those efficiency-enhancing efforts that are concerned with the long-run performance of the firm. Economic downturns increase the probability that the firm will die, and, as the theories of imperfect capital markets described in the previous subsection argued, they increase the “shadow” interest rate (the discount factor by which firms value future benefits). These considerations suggest that economic downturns may actually reduce the efforts firms spend at increasing long-run efficiency. (The model presented in section D illustrates this point.)

Moreover, periods of high growth themselves have their own strong forces which lead to increased efficiency. Prices for labor and other inputs do not adjust instantaneously to clear markets, so that in boom periods, shortages develop. These shortages (effectively imposing very high shadow marginal costs on inputs) provide strong incentives for firms to economize on these inputs and to use them efficiently.²²

Finally, we reiterate the point made in the introduction, that the process of natural selection may not be selecting the firms with the best long-run growth potential, but, rather, only those firms that are best able to withstand economic downturns. In the process of weeding out the least efficient firms, some good firms—particularly more newly established enterprises—are also eliminated. The net effect is far from unambiguous (see Stiglitz 1992c).

More generally, while the managerial and other theories of the firm to which we referred at the beginning of this section provide an explanation for why firms do not always maximize their market value or profits, there are economic forces at work that eventually punish firms that deviate far from this norm for long. Eventually, some entrepreneur will see the managerial slack that exists, and new firms will be created that will devote their attention to minimizing the costs of production, just as they are created to seize the opportunity to make new innovations. The process may work imperfectly, and it may work slowly. Economic downturns may speed up the process. The question is, are the benefits that accrue from the speedup worth the huge economic costs associated with economic downturns?

C. Balancing the Effects

I have tried to argue that Schumpeter’s suggestion that there are beneficial effects from an economic downturn needs to be qualified in several important

22. Several widely cited theories of induced innovation emphasize the importance of these shortages, though to date there has been little formal modeling of this idea. See Habakkuk (1987).

ways: (a) he ignored their negative effects on R&D expenditures and learning; (b) he ignored the deleterious effects of economic downturns on efficiency-enhancing efforts; (c) he ignored the positive effects of economic booms on efficiency enhancement; and (d) there may be alternative, less costly ways of obtaining the same efficiency-enhancement benefits.

In this section, I want to argue, further, that there may be significant discrepancies between social and private costs and benefits, both to the efficiency-enhancing efforts and to the R&D expenditures, but that the discrepancies differ between the two categories.

The social costs of reducing waste in the midst of a recession are greater than the private costs. Firms see their costs reduced. But it is not as if the workers that are fired are immediately redeployed to more productive uses. To a large extent, they are redeployed to a less productive use—they join the unemployment pool.

By contrast, the social benefits of R&D expenditures typically exceed the private benefits: firms seldom capture all of the returns from their inventive activity. Indeed, when many firms engage in R&D activity, say, enhancing the productivity of labor, wages are bid up, and much of the gain is appropriated by workers. Thus, the social costs of cutting back R&D expenditures typically exceed the private costs.

This analysis suggests that, while there are two countervailing effects on productivity of a major economic downturn—an increase in productivity resulting from reduced waste and a decrease in (long-run) productivity resulting from reduced R&D (and reduced learning by doing)—the latter effect is more significant. Cost cutting and reductions in R&D are both carried out beyond the socially efficient level.

D. A Simple Model

The following simple model captures some of the ideas just expressed. We simplify by assuming a two-period model, in which firms are, apart from the costs of bankruptcy, risk-neutral. Firm managers thus maximize

$$\Phi \equiv \alpha\Pi_0 - g(e) - x - cP_0 + (1 - P_0) \delta(\alpha\Pi_1 - cP_1) \quad (1.1)$$

where

α = fraction of profits received by managers²³

Π_i = profits *i*th period

23. We assume that managers obtain a fixed fraction of firms' profits, gross of expenditures on R&D. An alternative formulation nets out R&D expenditures. The results are unaffected.

$g(e)$ = (dollar equivalent of) cost of managerial effort

e = managerial effort

x = expenditures on R&D

c = costs of bankruptcy

P_i = probability of bankruptcy i th period

δ = discount factor

We postulate that profits during the first period are a function of only managerial effort,

$$\begin{aligned}\Pi_0 &= \Pi_0(e); \\ \Pi'_0 &> 0.\end{aligned}\tag{I.2}$$

Expected profits in the second period increase with managerial effort (exerted the first period), and with R&D expenditures:

$$\Pi_1 = \Pi_1(e, x)\tag{I.3}$$

with

$$\partial \Pi_1 / \partial e \geq 0\tag{I.4a}$$

$$\partial \Pi_1 / \partial x > 0.\tag{I.4b}$$

We do not provide here a detailed modeling of bankruptcy (see, for example, Greenwald and Stiglitz [1992a]). We simply postulate that since, in the short run, R&D expenses yield no immediate return, they have an adverse effect in the short run on the firm's financial position, so that increased expenditures on R&D increase the probability of bankruptcy. On the other hand, increased managerial effort (cost cutting) reduces the probability of bankruptcy in the short run. Considering the long run, increased expenditures on R&D have an ambiguous effect on the probability of bankruptcy. While, on average, they

increase profits, since, by their nature, they are highly risky, they may, even in the long run, increase the probability of bankruptcy.²⁴ We thus postulate that

$$P_0 = P_0(e, x), \quad (I.5)$$

with

$$\partial P_0 / \partial e < 0, \quad (I.6a)$$

$$\partial P_0 / \partial x > 0, \quad (I.6b)$$

and

$$P_1 = P_1(e, x), \quad (I.7)$$

with

$$\partial P_1 / \partial e \leq 0, \quad (I.8a)$$

$$\partial P_1 / \partial x > \text{or} < 0. \quad (I.8b)$$

We write the two first order conditions for e and x :

$$\begin{aligned} \alpha \Pi'_0 - g'(e) - [c + \delta(\alpha \Pi_1 - cP_1)] \partial P_0 / \partial e \\ + (1 - P_0) \delta(\alpha \partial \Pi_1 / \partial e - c \partial P_1 / \partial e) = 0 \end{aligned} \quad (I.9)$$

$$\begin{aligned} -1 - [c + \delta(\alpha \Pi_1 - cP_1)] \partial P_0 / \partial x + (1 - P_0) \delta(\alpha \partial \Pi_1 / \partial x \\ - c \partial P_1 / \partial x) = 0. \end{aligned} \quad (I.10)$$

24. P_1 is a conditional probability, given that no bankruptcy occurred in period 0. If there are only two outcomes to the R&D expenditures, success, with a very high profit, and failure, with no return, if an increase in x simply increases the probability of success, and if the only circumstance in which the firm goes bankrupt is when its R&D project turns out to be a failure, and it always goes bankrupt in that state, then an increase in x necessarily will reduce the probability of bankruptcy during the second period. But if these conditions are not satisfied, then it is possible that an increase in x actually increases P_1 . For instance, assume that the firm never goes bankrupt if the R&D project succeeds, but even if it fails, it goes bankrupt if the price of output (and therefore the profit from producing) is low enough. Assume, moreover, that increased R&D expenditures do not affect the probability of success, but only the profits if it is successful. Then the greater x , the greater the probability of default, since the greater x , the smaller the cash reserves that the firm brings into period 1; thus the "threshold" price at which it goes bankrupt is higher.

The first equation can be thought of as giving the optimal value of e , given x :

$$e = e(x); \quad (I.11a)$$

while the second can be thought of as giving the optimal value of x , given e ,

$$x = x(e). \quad (I.11b)$$

The equilibrium (or optimal) values of $\{x, e\}$ are the solution to the pair of first order conditions, and are depicted diagrammatically as the intersection of the two curves, illustrated in figure 2.

The objective of this section is to analyze the effects on $\{e^*, x^*\}$ of an economic downturn. Even if an economic downturn were to leave future *expected* profits unchanged, bankruptcy probabilities would increase, as the firm's net asset position deteriorated. In order to finance the same level of expenditure on R&D, x , the firm would have to borrow more. Thus, even if there were no change in the probability distribution of returns, the probability of bankruptcy would increase. However, economic downturns are also normally associated with increased uncertainty, so that there is a larger probability of returns falling below some crucial threshold level—the level at which the firm goes bankrupt. Accordingly, on both accounts, the probability of bankruptcy increases. If we denote market conditions by M , then we write the probability of bankruptcy as

$$P_i = P_i(e, x, M), \quad (I.12)$$

with

$$\partial P_i / \partial M < 0, \quad (I.13a)$$

where an increase in M denotes an improvement in market conditions.

Similarly, we let $\Pi_0 = \Pi_0(e, M)$, $\Pi_1 = P_1(e, x, M)$, and $g = g(e, M)$. We naturally assume that

$$\partial \Pi_0 / \partial M > 0, \quad (I.13b)$$

$$\partial \Pi_1 / \partial M \geq 0, \quad (I.13c)$$

and

$$\partial g / \partial M \geq 0, \quad (I.13d)$$

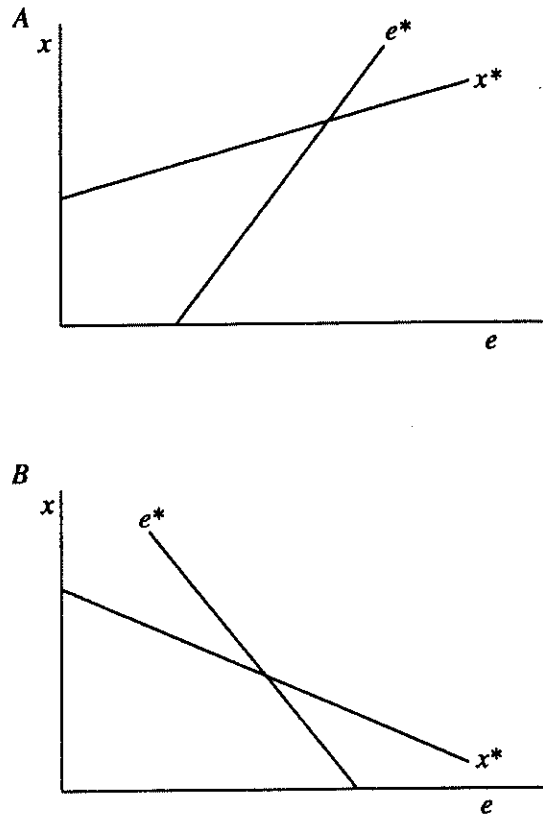


Fig. 2. Equilibrium determination of managerial effort (e) and R&D expenditures. (A) Normal case, where increased level of managerial effort leads to increased optimal level of R&D expenditures, and conversely. (B) Managerial effort and R&D are, in a sense, substitutes so that increased managerial effort leads to reduced equilibrium level of R&D, and conversely.

an economic downturn (a decrease in M) has negative effects on profits, but since managerial resources are less directed at growth, the cost of effort directed at efficiency enhancements is also reduced. (If the economic downturn is thought to be short-lived, then it is natural to assume that $\partial \Pi_1 / \partial M = 0$, i.e., profits for the next period would be unaffected, if e and x were to remain unchanged.)²⁵

What is relevant for the firm's decision regarding finance, of course, is the effect of changes in market conditions on *marginal* returns to effort and R&D expenditures, and that will require some further assumptions, which we will introduce later.

25. For later reference, we note that even if an economic downturn is short-lived, the effects on first period profitability have further repercussions on the second period bankruptcy probability, so that even though $\partial \Pi_1 / \partial M = 0$, $\partial P_1 / \partial M > 0$.

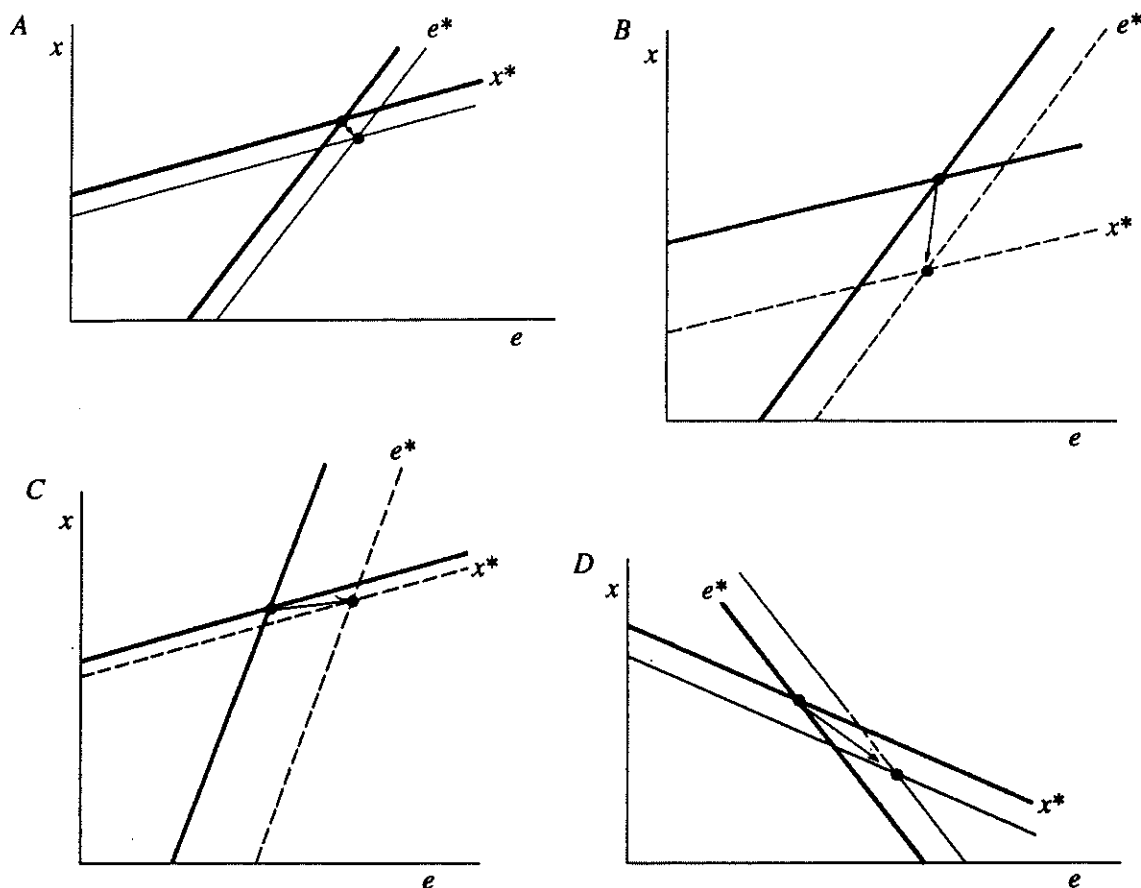


Fig. 3. Effect of economic downturn. (A) Normal case, where effort is increased but R&D reduced. (B) Worst scenario, where R&D is reduced, and the reduced R&D induces less effort; in equilibrium both are lower. (C) Best scenario, where increased effort induces increased R&D; in equilibrium both are increased. (D) In case where R&D and effort are substitutes (both reaction curves are downward sloping), effort is increased and R&D reduced.

Now, our two first order conditions can be written as

$$e = e(x, M) \text{ and } x = x(e, M). \tag{I.14}$$

A change in M shifts both curves, and results in a new equilibrium, as depicted in figure 3. The analysis of the remainder of this section shows that an economic downturn normally leads both to increased effort and to reduced R&D, as suggested by our earlier discussion. At the same time, we show that it is possible that both R&D and effort at cost reductions are adversely af-

fect, in which case the economic downturn has unambiguously adverse effects on the economy.

The analysis proceeds in two steps. First, we need to ascertain the critical properties of the first order conditions; in particular, we show that, normally, the curves $e(x)$ and $x(e)$ are both upward sloping; that is, an increase in effort normally leads firms to undertake more R&D, and an increase in R&D normally leads firms to undertake greater effort at cost reductions. (These are both "partial" equilibrium statements.)

Next, we need to ascertain how an economic downturn shifts each of the two curves. We can then determine how e^* and x^* are affected.

Analyzing the First Order Conditions

We begin by taking a closer look at the two first order conditions I.9 and I.10. We impose the natural restriction that

$$\alpha\Pi_1 - cP_1 > 0, \quad (I.15)$$

for otherwise, it would not pay for managers to have the firm survive. This condition, together with restrictions already imposed, implies that

$$\alpha\partial\Pi_1 / \partial x - c\partial P_1 / \partial x > 0, \quad (I.16)$$

thus, the marginal return (to managers) of additional R&D is positive.

The first term in equation I.9, the first order condition for e , ($\alpha\Pi_0$) is the increase in current profits from greater effort. The third term $\{-[c + \delta(\alpha\Pi_1 - cP_1)] \partial P_0 / \partial e\}$ is the gain from the reduced likelihood of bankruptcy—the reduced bankruptcy costs plus the higher likelihood of enjoying second period profits). The last term $[(1 - P_0)\delta(\alpha\partial\Pi_1 / \partial e - c\partial P_1 / \partial e)]$ is the increased second period profits from greater effort. These gains must be offset against the marginal cost of increased effort, $g'(e)$.

The benefit of increased R&D expenditures is the increased expected future profit $[(1 - P_0) \delta(\alpha\partial\Pi_1 / \partial x - c\partial P_1 / \partial x)]$. There are two costs: the direct costs (the first term), and the cost of the increased likelihood of bankruptcy in the first period resulting from increased expenditures (which, if they pay off, pay off only in the future). The cost of the increased likelihood of bankruptcy, in turn, can be divided into two components, the direct bankruptcy cost, and the loss in future profits that will be precluded by a bankruptcy today.

Whether increases in research expenditure lead to greater effort (and conversely, whether increases in effort lead to greater expenditures) depends on the sign of Φ_{ex} .

$$\begin{aligned}
 \Phi_{ex} = & -[c + \delta(\alpha\Pi_1 - cP_1)] \partial^2 P_0 / \partial e \partial x + \\
 & (1 - P_0) \delta(\alpha \partial^2 \Pi_1 / \partial e \partial x - c \partial^2 P_1 / \partial e \partial x) \\
 & - \delta(\alpha \partial \Pi_1 / \partial x - c \partial P_1 / \partial x) \partial P_0 / \partial e \\
 & - (\partial P_0 / \partial x) \delta(\alpha \partial \Pi_1 / \partial e - c \partial P_1 / \partial e)
 \end{aligned} \tag{I.17}$$

This expression consists of four terms, and to evaluate the sign of Φ_{ex} we must evaluate each. Increased expenditures on R&D increase the bankruptcy probability in the first period, and we would thus normally expect that they would increase the return to exerting greater effort—that is,

$$\partial^2 P_0 / \partial e \partial x < 0. \tag{I.18}$$

We also assume that

$$\partial^2 P_1 / \partial e \partial x \leq 0, \tag{I.19}$$

though the argument in this case is less compelling, since it is possible that increased expenditures on R&D reduce the second-period bankruptcy probability.

Finally, we assume that greater expenditures on R&D will, normally, increase the size of the firm and firm profits, in which case greater efforts at efficiency will pay off in higher returns—that is:

$$\partial^2 \Pi_1 / \partial e \partial x \geq 0. \tag{I.20}$$

Next, we note that increases in effort reduce the bankruptcy probability, thus increasing the likelihood of survival; thus, the expected marginal return to R&D expenditures is increased (the next to final term in eq. I.17). On the other hand, an increase in R&D expenditures increases the probability of bankruptcy in the first period, and so decreases the return to effort to the extent that some of the gains, those in the future, are less likely to be relevant (the final term of eq. I.17). In the normal case, it appears that the effect of this final term is outweighed by the preceding terms, in which case, $\Phi_{ex} > 0$.

In particular, in the special case where the benefits of efficiency enhancing efforts are short-lived, so that²⁶

$$\partial \Pi_1 / \partial e = \partial P_1 / \partial e = 0 \tag{I.21}$$

26. The second condition is not as natural as it might seem at first glance: efficiency enhancing efforts in the first period that increase firm profits in the first period also increase its net worth in the second period, and thus reduce the probability of default in the second period, even if the first-period efforts have no direct effect on the firm's second-period production efficiency.

then, making use of (I.16) and (I.17),

$$\Phi_{ex} > 0,$$

provided only that condition I.21 (and the earlier imposed conditions I.6a) are satisfied.

Accordingly the first order conditions for e and x , $e(x)$, and $x(e)$ are both upward sloping, as depicted in figure 2. As expenditures on R&D increase, the optimal level of effort increases, and conversely.

While we characterize $\Phi_{ex} > 0$ as the normal case, there is, however, the possibility $\Phi_{ex} < 0$. This is the situation often associated with high R&D companies. They seem to go for broke, paying little attention to current costs. Our model provides an interpretation of their behavior: given the high probability of bankruptcy, the returns to the efforts at cost reduction are, on average, only the current returns and the increased survival probability. The future returns from current restructuring giving rise to cost savings simply are not weighed heavily, given the high bankruptcy probability.²⁷ As the firm engages in more research, the probability of bankruptcy may increase, and so the marginal return to effort may decrease.

The Effect of Economic Downturns on the First Order Conditions

We now ask how an economic downturn affects the level of effort, given a particular level of expenditure on R&D, and how it affects the level of R&D, given a particular level of effort. The answer to these questions is provided by looking at the cross partial derivatives Φ_{eM} and Φ_{xM} :

$$\begin{aligned} \Phi_{eM} = & - [c + \delta(\alpha\Pi_0 - cP_1)] \frac{\partial^2 P_0}{\partial e \partial M} + \frac{\partial P_0}{\partial e} \delta c \frac{\partial P_1}{\partial M} - \frac{\partial P_0}{\partial e} \alpha \delta \frac{\partial \Pi_1}{\partial M} \\ & + (1 - P_0) \delta \left(-c \frac{\partial^2 P_1}{\partial e \partial M} \alpha \frac{\partial^2 \Pi_1}{\partial e \partial M} \right) \\ & - \frac{\partial P_0}{\partial M} \delta \left(\alpha \frac{\partial \Pi_1}{\partial e} - c \frac{\partial P_1}{\partial e} \right) + \frac{\alpha \partial^2 \Pi_0}{\partial e \partial M} - \frac{\partial^2 g}{\partial e \partial M} \end{aligned}$$

and

27. We should emphasize, however, that we believe this to be the exceptional case, since, for such firms, the concern about *reducing* their bankruptcy probability should loom large. We have not yet found a simple, interpretable mathematical condition ensuring that the final term will be outweighed by the other three terms.

$$\begin{aligned} \Phi_{xM} = & - [c + \delta(\alpha\Pi_1 - cP_1)] \frac{\partial^2 P_0}{\partial x \partial M} + \delta c \frac{\partial P_1}{\partial M} \frac{\partial P_0}{\partial x} - \frac{\partial P_0}{\partial x} \alpha \delta \frac{\partial \Pi_1}{\partial M} \\ & + (1 - P_0) \delta \left(\alpha \frac{\partial^2 \Pi_1}{\partial x \partial M} - c \frac{\partial^2 P_1}{\partial x \partial M} \right) \\ & - \frac{\partial P_0}{\partial M} \delta \left(\alpha \frac{\partial \Pi_1}{\partial x} - c \frac{\partial P_1}{\partial x} \right) \end{aligned}$$

Under suitable restrictions, when the probability of bankruptcy is higher, the marginal return (the reduction in the bankruptcy probability) to greater effort at cost savings is greater; similarly, the marginal cost (the increase in bankruptcy probability) from greater expenditures on R&D is higher. Thus, we postulate that

$$\partial^2 P_i / \partial M \partial e > 0$$

$$\partial^2 P_i / \partial M \partial x < 0.$$

As a result, we would normally expect that $\Phi_{eM} < 0$, so an economic downturn increases the level of effort at each level of R&D expenditures, and $\Phi_{xM} > 0$, so the level of R&D expenditures at each level of effort decreases, as depicted in figure 3.²⁸

The Effect of Economic Downturns on Equilibrium Effort and R&D

We can now put the results of the previous two sections together to analyze the net effect on the equilibrium value of e and x . The normal case, as we have

28. To obtain this result, we need to impose some further restrictions. In the case of the effect on effort, we make three additional assumptions: (1) We assume that increased M has a zero or negative effect (or, at most, a small positive effect) on the marginal return (to expected profits) of increased effort. (2) We assume that increased M has a positive effect on the marginal cost of increased effort (this is a natural condition, since, as fewer resources become slack, it is more costly to devote managerial energy to cost-cutting restructuring than to production). (3) The increased probability of survival means that there is a higher expected return to cost cutting—a higher probability of future returns from current cost-cutting efforts. We assume, as seems to be normally the case, that this term is dominated by the other terms. This will be the case if effort is directed at short-run cost savings, which have negligible effects on future expected profits or survival.

In the case of the effect on R&D expenditures, only one additional assumption is required: the second term in the expression is negative—an increase in M reduces the next period's bankruptcy probability. This increases the net return to survival—that is, it increases the cost of bankruptcy in this period, and this discourages R&D expenditures. We assume that this term is dominated by the other terms.

noted, is that where the two curves depicting the first order conditions are upward sloping, where an economic downturn shifts the curve giving the optimal value of x at each level of e down, and where an economic downturn increases the equilibrium level of e at each value of x (the e^* curve shifts to the right). Even under all of the assumptions made to obtain these results, there remains some ambiguity concerning the net effect.

Panel A of figure 3 shows the normal case, perhaps the one that Schumpeter had in mind. In this case, R&D is affected relatively little; the major "partial equilibrium" effect is on e . In this situation, the net result is that R&D expenditures decrease and effort at cost cutting increases.

While this is what we view to be the normal case, it is worth noting that other patterns are also possible. Panel B shows a case where the e^* curve shifts very little. This might be the case, for instance, if g' is very large—so that it is very difficult to change e —or if the cross derivatives between M and e are small, so that the economic downturn has relatively little effect on the marginal returns to effort. Then we see that it is possible that both x and e decrease. This is a striking possibility. Even though, if firms were to keep their level of R&D fixed (as Schumpeter may have implicitly assumed), efforts at cost reduction would have increased, because firms find it more difficult or less desirable to invest in R&D, they decrease their R&D expenditures; and with the lower R&D expenditures—with, for instance, their lower expected profits in the next period—it does not pay for firms to exert as much effort at cost reduction in this period.

Panel C of figure 3 shows a third possibility, where the x^* curve shifts little, but the e^* curve shifts a great deal. In this case, it is possible that both effort and R&D expenditures will increase. The increased effort so reduces the bankruptcy probability that the return to R&D has increased, so that even though at a fixed level of e , an economic downturn would have led to less R&D, once the adjustment in e is taken into account, the full equilibrium effect is positive.

Panel D of figure 3 considers the case where the first order conditions are downward sloping. Then e unambiguously increases and x unambiguously decreases in the event of an economic downturn.

Empirical Evidence

Ascertaining the effect of credit constraints (and economic downturns, via this mechanism) on R&D expenditures is not as easy as it might seem. While these expenditures do exhibit considerable cyclical variability, they are, perhaps, not as variable as one might have expected on the basis of simply the credit-constrained theories described above. The reason is that there are large costs of adjustment; the firm-specific human capital involved in a research

team is significant. It is obviously more expensive to replace a skilled researcher than an unskilled laborer.²⁹

There are, furthermore, econometric problems in identifying the role of financial constraints: economic circumstances in which cash flows are adversely affected are highly correlated with the kinds of economic circumstances in which future expectations of returns are adversely affected. A number of studies have attempted to correct for these problems in the context of investment behavior, and they seem to consistently show that cash flow and net worth variables are important in determining firm investment behavior.³⁰

We (Greenwald, Salinger, and Stiglitz [1992]) have conducted two studies focusing on technological change. Both were based on the premise that one should try to identify situations where changes in cash flow (net worth) might be uncorrelated, or negatively correlated, with future expectations.

The first study focused on the automobile industry in the United States, particularly in the aftermath of the oil price shocks. Each of these shocks had strongly adverse effects on sales of American automobiles, particularly since they were not as fuel-efficient as foreign cars. On the other hand, assuming that American firms could acquire the technological know-how to construct fuel-efficient cars, these oil price shocks should have increased the level of expenditures on R&D. For the unexpected change in factor prices meant that, while the industry had gone far along the learning curve for large cars, they were still at the beginning of the learning curve for fuel-efficient cars. A cursory look at the data on R&D expenditures showed that the decrease in cash flow had an immediate and direct effect on those expenditures; those firms that were hit the hardest reduced their expenditures the most. And the same pattern that emerged after the first oil price shock reemerged after the second. In our econometric study, we corrected for the effect of future sales expectations, and even taking this into account, one could strongly see the effect of cash flow changes on R&D expenditures.

The second study focused on the airline industry in the aftermath of deregulation. Deregulation increased competition, lowered prices, and thus, adversely affected cash flows. On the other hand, lower prices that resulted meant increased output (passenger miles). The general theory of technological change says that the return from cost-reducing expenditures is proportional to the scale of output; in other words, the value of reducing the cost of producing a widget by one cent is proportional to the number of widgets produced. Thus, if output is higher, efforts at increasing productivity should be higher. Thus,

29. Recent work (e.g., Dixit [1992]) emphasizing the importance of option value in the presence of fixed costs, and the implications for decisions, for instance, to close down a plant, strengthen this conclusion.

30. See, for instance, Gilchrist (1989), and Hubbard (1990).

while deregulation should (quite apart from the direct effect of increased competition) have increased the rate of increase of productivity in the absence of financial constraints, if the financial constraints were binding, just the opposite effect would have occurred.

Analyzing the effect of deregulation on the rate of change of productivity involved one more complication: there are, at least in the short run, increasing returns, so that an increase in output will, on its own, decrease average costs. Our analysis was concerned with how the cost curve itself shifted, rather than with the combined effect of movements along a cost curve or with shifts in the curve, upon which other studies of deregulation had focused. We showed that, indeed, the cash constraints did seem to be binding; that the rate of productivity increase declined after deregulation; and that those airlines whose cash positions were more adversely affected had the most marked effect on their rate of productivity increase.

Other studies have similarly shown that financial structure and constraints are an important determinant of R&D expenditures. For instance, Hall concludes³¹ that there is strong evidence that changes in the financial structure of firms that tilted the balance sheet toward debt were followed immediately by substantial reductions in both investment and R&D, in a large panel of U.S. manufacturing firms during the 1980s. In the case of R&D investment, these reductions (in the approximately 250 firms that increased their debt by at least one-half the book value of the capital stock during one year) were large enough to account for a reduction in private industrial R&D spending in the United States of 2.5 percent, about one billion 1982 dollars.

These studies are meant to be suggestive of the importance of financial constraints in determining the rate of change of productivity in the economy. There is clearly room for further work examining the magnitude of these effects in other industries and in other countries.

II. Technological Change as a Cause of Economic Fluctuations

We now turn to the other side of the nexus between technological change and economic fluctuations, the side, perhaps, for which Schumpeter is most known. We have seen how fluctuations in the level of economic activity (arising from any source) can give rise to fluctuations in the rate of expenditures on R&D, and accordingly, in the long run, to fluctuations in the rate of technological change. The other side emphasizes that fluctuations in technological progress may give rise to economic fluctuations. In spirit, there is a certain semblance between this view and real business cycle theory, which sees the economy's fluctuations as arising from changes in technology. But

31. Hall (1992), based on work reported in Hall (1990, 1991).

there is a distinction, which is important. While the real business cycle theorists believe that markets are perfect—all markets are perfectly competitive and there are no information problems—the Schumpeterian tradition emphasizes a variety of market imperfections: there is imperfect competition in the product market (if only because of innovation) and there are imperfections in the capital market.

The distinctions are important: the empirical evidence against the real business cycle theory is, in my judgment, overwhelming. For that theory cannot explain economic downturns (economic downturns must be based on regressions in the state of knowledge). Moreover, that theory predicts higher correlations in fluctuations across countries within an industry than across industries within a country, contrary to what is observed.³²

Recent work has provided a better basis for understanding these Schumpeterian fluctuations. In this section, I want to describe and extend that work. The fundamental idea is that, in the presence of imperfect competition and the nonconvexities associated with technological change, whether arising from R&D or learning by doing, there can be multiple equilibria. When the level of future economic activity is (expected to be) low, it does not pay to do much R&D, and the returns from learning by doing are low. (Actual levels of output are important, because they affect cash flow, which, as we noted in the previous part, adversely affects R&D; expectations are, of course, central to any neoclassical interpretation, where investments are determined solely by expectations of future returns.) Thus, technology in the future will not be as “good” as when the level of economic activity is (expected to be) high. But with the lower level of technology, output will, in fact, be lower, and thus, expectations will be confirmed.

The fact that there may be multiple equilibria has been noted elsewhere. (See, e.g., Stiglitz 1988, 1992c, and Shleifer 1986.) We extend these arguments by suggesting why there may be oscillations between the high and low level equilibrium.³³

To focus on the two-sided interaction between technological change and economic fluctuations, we have had to simplify the analysis. We noted in the previous section that economic downturns lead to reduced R&D expenditures, and increased efforts at efficiency enhancement. Elsewhere, it has been noted that economic downturns lead to reduced technological progress because there is less output, and hence, less learning by doing. The previous section also identified several mechanisms by which economic downturns exerted their effects: for example, through their effects on expected future profits, and through their effects on bankruptcy probabilities, both current and future. There are other mechanisms at work as well: financial constraints, including

32. For more extensive critiques, see Mankiw (1989) and Greenwald and Stiglitz (1988).

33. In a manner reminiscent of Kaldor's (1940) discussion of the trade cycle.

credit rationing, may have a direct effect, as economic downturns decrease the supply of working capital, as well as the funds available for R&D. It is beyond the scope of this paper to capture all of these effects within a simple, dynamic model. Accordingly, we develop what appears to be the simplest model capturing the positive feedback interactions upon which we focus here. (Later, we will comment on some of the negative feedback interactions.) In our simplified model, firms have a single decision variable—the level of output.³⁴ Increases in the level of output result in lowered costs, as in standard learning by doing models. In turn, in our simplified model, economic downturns have effects through only one channel, that being the decrease in expected output, which reduces the benefit from learning, and, hence, leads to lower levels of production. Thus, we ignore other channels, such as the financial constraints, which were the center of discussion in the preceding section. Introducing these financial market constraints would only reinforce the results obtained here.

Basic Model

The simplest model illustrating these principles is one in which there are a fixed number of commodities (sectors), denoted by subscript i , with each sector dominated by a single firm. There is learning by doing; each product is produced by labor alone. We simplify by imagining there are two periods. For notational convenience, we drop the subscript i referring to the specific commodities, whenever there is no resulting ambiguity. Output in the first period, Y_{oi} , is proportional to labor input, L_{oi} , and we choose units so we can write

$$Y_{oi} = L_{oi}. \quad (\text{II.1})$$

Output in the second period is proportional to labor input in the second period, with the proportionality constant depending on the level of production in the first period (learning by doing)

$$L_{1i} = C_{1i}(Y_{oi})Y_{1i}, \quad (\text{II.2})$$

with

$$C'_{1i} < 0, C''_{1i} > 0.$$

For simplicity, we assume two classes of individuals, workers who live for only one period, and capitalists who own the firms and receive the profits.

34. Thus, we ignore both the effect on R&D and that on effort at efficiency enhancement. The only assumption that is crucial for our results is that economic downturns lead to less *net* technological progress.

We assume that they all have utility functions that are time-separable, with constant discount rate equal to unity.

$$u = \sum_i \sum_t (Y_{it}^{1-\sigma} / (1 - \sigma)) - v(L_0) - v(L_1), \quad \sigma > 1 \tag{II.3}$$

so that, using symmetry

$$\frac{p_{0i}}{p_{1i}} = \frac{Y_{1i}^{-\sigma}}{Y_{0i}^{-\sigma}} = \left[C_{1i} \frac{L_0}{L_1} \right]^\sigma. \tag{II.4}$$

Given our utility function, demand functions have constant elasticity, denoted by φ .

With our utility function, the labor supply in the i th period is a function of the real wage in that period. Given the symmetric nature of our model, we can write $L_0 = L(p_0)$, $L_1 = L_1(p_1/w_1)$. Capitalists have the same indirect utility function for goods that workers have. The firm maximizes its two-period expected profits,

$$\max_{\{Y_{0i}, Y_{1i}\}} p_{0i}Y_{0i} - L_{0i} + p_{1i}Y_{1i} - Y_{1i}C(L_{0i})w, \tag{II.5}$$

where we recognize that p_{1i} depends on output, and where $L_{0i} = Y_{0i}$.³⁵ Thus, maximizing with respect to Y_{0i} , we obtain

$$p_{1i} = w_1 \left[1 / \left(1 - \frac{1}{\varphi} \right) \right] C_1(L_{0i}) \tag{II.6}$$

and

$$p_{0i} + \frac{\partial p_{0i}}{\partial Y_{0i}} - 1 - wY_{1i}C' = 0 \tag{II.7}$$

or, using (II.6) and (II.2)

$$p_{0i} \left(1 - \frac{1}{\varphi} \right) = 1 + wY_{1i}C' = 1 + p_{1i} \left(1 - \frac{1}{\varphi} \right) L_{1i} \frac{C'_i}{C_i^2}$$

35. Though we formulate the model as a two-period model, it is easy to extend it to a multi-period context. We assume that learning that occurs at period t becomes available to all firms at $t + 2$. Thus, the only private returns with which a firm has to concern itself are those that occur at $t + 1$. In this more explicitly dynamic model, equation (II.8) has to be modified, since the firm will recognize that, next period, in its production decision, it will have to take account of the learning benefits that accrue at $t + 2$. The qualitative properties remain as described here.

Thus, the first period, they set

$$p_{i0} \left(1 - \frac{1}{\varphi}\right) \left(1 - \frac{p_{1i}}{p_{0i}} \frac{L_{1i} C'_{1i}}{C_{1i}^2}\right) = 1. \quad (\text{II.8})$$

(II.6) and (II.8) (together with the labor supply equations) define two equations in two unknowns. This may, perhaps, be seen more clearly if we express everything in terms of outputs in the two periods.

First, define the inverse of the labor supply functions:

$$p_0 = L_0^{-1}(L_0) = h_0(L_0) \quad (\text{II.9})$$

$$\frac{P_1}{W_1} = L_1^{-1}(L_1) = h_1(L_1) \quad (\text{II.10})$$

Next, using (II.4), (II.6), and (II.10), we obtain:

$$h_1(L_1) = \left(\frac{1}{1 - 1/\varphi}\right) C_1(Y_0)$$

or

$$Y_1 = L_1 \left(\frac{1}{1 - 1/\varphi}\right) C'_1(Y_0)/C_1(Y_0), \quad (\text{II.11})$$

giving equilibrium output in the second period as a function of output in the first period.

Then, using (II.8), (II.4), (II.1), and (II.2), we obtain:

$$h_0(Y_0) \left(1 - \frac{1}{\varphi}\right) \left[1 - \left(\frac{Y_0}{Y_1}\right) \frac{Y_1 C'_1(Y_0)}{C_1(Y_0)}\right] = 1, \quad (\text{II.12})$$

giving equilibrium output in the first period as a function of (expected) output in the second.

Multiplicity of Equilibria

We can thus obtain two equations, one relating current output as a function of expectations of future output, the other relating future output as a function of current output. If labor supply has a positive elasticity, both curves have a positive slope, as depicted in figure 4. Heuristically, an increase in expected output next period increases the benefits from learning, and, hence, leads to a

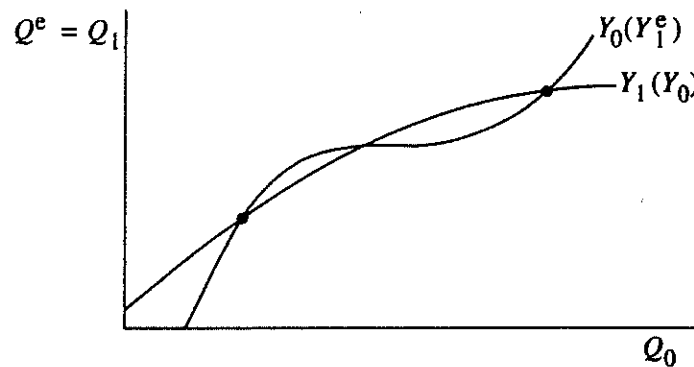


Fig. 4. Multiple equilibrium with learning by doing

higher level of production this period. At the same time, a higher level of production this period leads to more learning, and with the lower costs of production, output next period will be higher. The actual shapes of the curves depend on the shapes of the learning curve and the labor supply curve. Assuming that there is a limit to the amount of learning, the curves may have the shape depicted, exhibiting multiple equilibria.

There is a low-level equilibrium, in which little production occurs because output is expected to be low next period; and given that little production occurs, there is little learning, so that costs in the future are high, and little production does, in fact, occur. There is also a high level equilibrium.

Cyclical Behavior

To generate cyclical behavior, we modify the model in a simple way. We denote the labor requirement per unit output at time t by c_t . We assume that there is an exogenous rate of accumulation of pure knowledge, at the rate γ . Thus the potential best practices technology has a cost of $c_t^* = (1 + \gamma)^{-t}$. Next, we assume the *actual* rate of learning is a function of the gap between current costs and the potential represented by c_t^* , which we define as

$$G_t = c_t/c_t^* = c_t(1 + \gamma)^t:$$

modifying (II.2) in a straightforward way (and dropping the subscripts i), we postulate that

$$c_{t+1} = c_t \psi(Y_t, G_t),$$

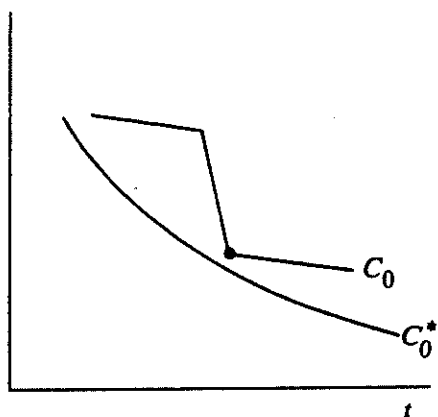


Fig. 5. Growth cycles. The economy alternatively gets closer to and farther from best practice technology.

or

$$\begin{aligned}
 G_{t+1} = c_{t+1}/c_{t+1}^* &= \frac{c_t \hat{\psi}(Y_t, G_t)}{c_{t+1}^*} && \text{(II.13)} \\
 &= G_t(1 + \gamma)\hat{\psi}(Y_t, G_t) \\
 &= \psi(Y_t, G_t).
 \end{aligned}$$

But Y_t itself depends on G_t , as we have just seen. There may in fact be three solutions, which we write as $Y^j(G)$, where $j = u$ denotes the upper solution, $j = l$ the lower, and $j = m$ the middle solution. Figure 5 depicts a trajectory of the economy, showing that it alternatively gets closer to the best practices technology (in booms) and moves away from it (in recessions). We wish to show why this kind of trajectory—involving growth cycles—may be the only possible trajectory.

Assume the economy is initially in the low-level equilibrium. In the low-level equilibrium, production is so low that learning does not take place at the rate γ . The gap between actual and potential practice increases. This means that, at any level of production, the marginal return to production is greater, since there will be more learning. This shifts the curve giving the actual level of output, given expectations of future output, to the right. At the same time, the actual level of learning, at any level of production, is higher, so that at any level of production in the first period, the production in the next period will be high. This shifts the other curve up. There are slight increases in the level of output, as depicted in figure 6. But then, when the gap between actual and

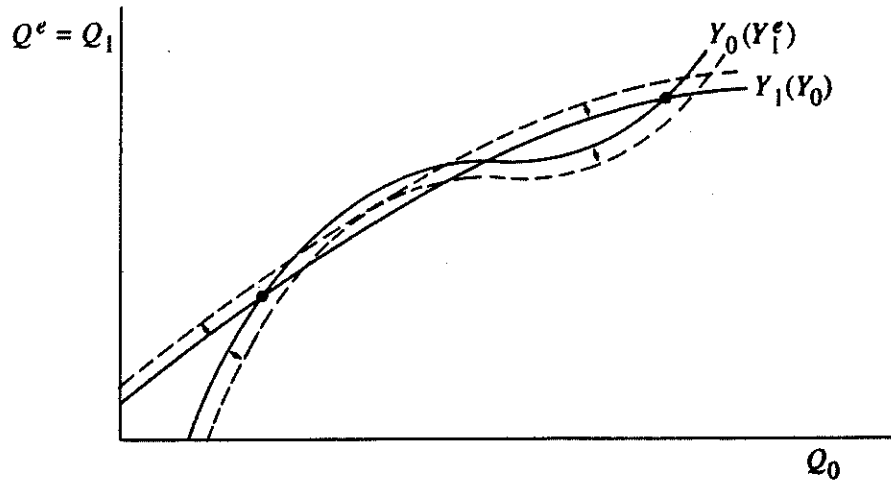


Fig. 6. Effect of changes in the gap between actual and best practices on equilibrium. As the gap increases, the output associated with the lower equilibrium increases and that associated with the middle equilibrium decreases, until eventually, both the lower and middle equilibrium disappear.

potential practice becomes big enough, the low level equilibrium disappears. Only the upper equilibrium survives (fig. 7). At the upper equilibrium, production is so high that the rate of learning exceeds the steady state level γ . The gap is reduced. But this reduces the marginal return to production (since the marginal learning is smaller). This shifts the two curves in a direction exactly opposite to that depicted earlier. Output is reduced slightly.³⁶ Eventually, the upper equilibrium disappears; the only equilibrium is the lower equilibrium. There is a discontinuity in the equilibrium. And the cycle then repeats itself.³⁷

The formal structure of our argument can be seen simply. Equation II.13 gives G_{t+1} as a function of G_t . A steady state equilibrium entails $G_{t+1} = G_t$. Panel A of figure 8 illustrates the case upon which we focus, where the only steady state is unstable (in any natural specification of dynamics). It is the "middle" equilibrium; a slight increase in, for instance, the expected output for the next period will lead to a sufficiently large increase in current output, and a reduction of next period's cost, so that the actual output in the next period will be even greater, more than fulfilling the expectations. In that case, the economy will oscillate as described earlier, and as depicted in figure 8.

36. Observed patterns may depart from that predicted by this simple theory, because we have not incorporated investment and a variety of other lags in adjustment.

37. The similarity between this cycle and that described by Kaldor (1940) should be apparent. A model of endogenous cycles with properties similar to the one here is discussed in Gans (1989).

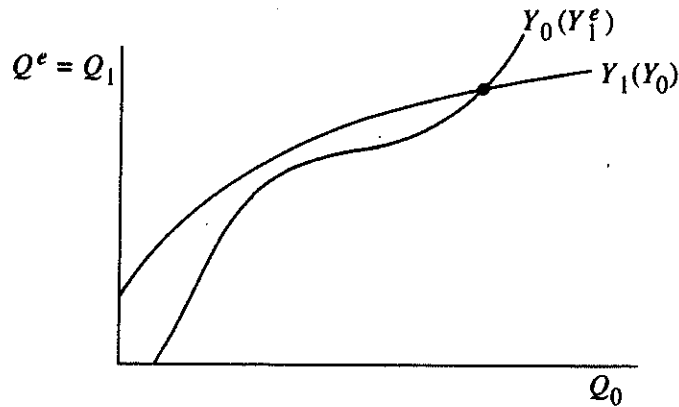


Fig. 7. When the gap between actual and best practices is large, then the only equilibrium is the upper equilibrium.

Corresponding to any size of the gap at time t , we can calculate the equilibrium cost reduction, and hence the size of the gap at $t + 1$. The resulting graph is shown in figure 8b. We postulate that when there are multiple equilibria, the economy will stay in the “nearby” equilibrium. Then, the economy will exhibit the jumps from low-level equilibrium to high-level equilibrium, as shown.

Panel B of figure 8 shows the alternative possibility, where there exists a steady state equilibrium without oscillations.

Interpretations

The essential mathematical structure giving rise to the multiplicity of equilibria which underlie the above analysis is the existence of a positive feedback mechanism.³⁸ There are a variety of mechanisms which can give rise to such positive feedbacks. The discussion above is predicated on *incentives* arising through a learning curve and a positively sloped labor supply curve. Similar incentives arise in R&D: the return to engaging in research depends on the quantity of sales expected in the future. If firms engage in large amounts of research, costs will be low, output will be high, and the high levels of research will be justified.

Other models focus on income effects (Shleifer 1986). Since R&D expenditures are a form of fixed costs, when output is high, profits are high; but then the demand for goods is high, justifying, again, the high expenditures on R&D. These models (when they are used to generate cycles) implicitly assume capital constraints; for otherwise, demand depends on the present dis-

38. See Arthur (1991), David (1987), Sah and Stiglitz (1989), and Stiglitz (1991).

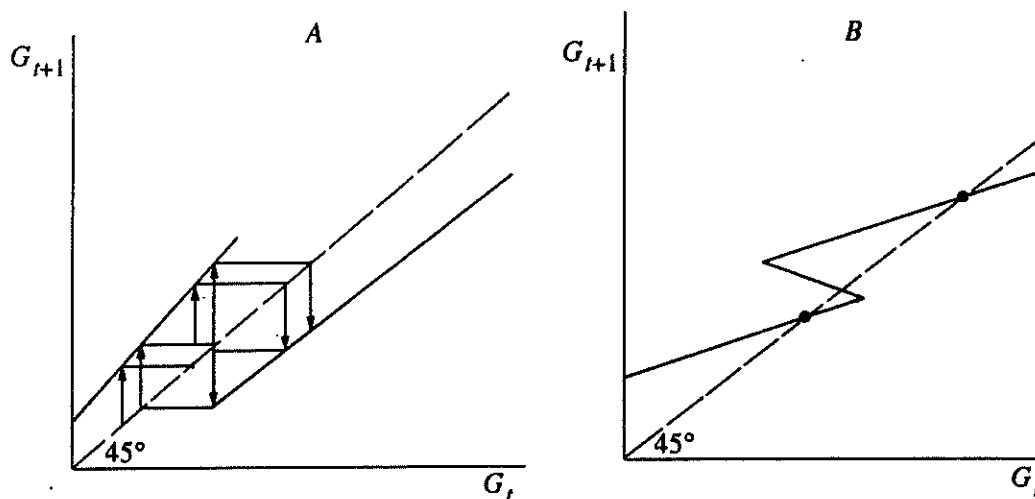


Fig. 8. Dynamics of the economy. (A) The only (stable) equilibrium involves growth cycles. Neither the upper nor the lower equilibrium curves (giving G_{t+1} as a function of G_t) cross the 45° line. (B) There exists multiple steady-state equilibrium.

counted value of future streams of income, and these are far less variable than current income; and indeed, given the observed magnitudes of economic fluctuations, it would be hard to explain economic fluctuations on the basis of variations in (realized) permanent incomes, assuming conventional market real interest rates.

A third channel through which positive feedback can operate is directly through financial market constraints. With capital constraints, low levels of output are associated with low levels of profit, which can finance (in the manner described in part I) low levels of R&D, which lead to high costs and low levels of future output.³⁹

Concluding Remarks

There are three basic lessons to be drawn from this analysis. First, there are real costs to economic fluctuations that extend well beyond the temporary losses in output and the economic waste resulting from unused resources: the future productivity of the economy is adversely affected. These long-run

39. It is important to note that there are also negative feedbacks, and if these negative feedbacks predominate, then there will exist a unique equilibrium. Aghion and Howitt (1992) formulate a model in which there are only negative feedbacks, and so they obtain a unique stationary equilibrium. In their model, an increased rate of technological progress means that the period over which an innovation will be able to earn rents is reduced, and that wages in the future will be higher. On both accounts, they argue that the return to innovation will be reduced.

losses are likely to be far more significant than any temporary gains from induced cost cutting.

Second, while traditional Schumpeterian analyses have focused on the relationships between market structure and innovation, they have paid less attention to the relationship between capital market imperfections (resulting, in many cases, from problems of costly and imperfect information that are particularly important in the context of economies with rapid innovation) and innovation.

Third, the nexus between fluctuations and innovation goes in both directions: not only do fluctuations in economic activity cause fluctuations in innovation; fluctuations in innovation may also give rise to fluctuations in economic activity. The positive feedback relationship between innovation and economic activity may, under a variety of conditions, give rise to multiple equilibria. There is no presumption that the free market, left to itself, will choose the best among these.

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