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ENDOGENOUS GROWTH AND CYCLES

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ABSTRACT

Schumpeter argued that economic downturns had positive effects, in the incentives that it provided for firms to increase their efficiency. Part 1. provides a simple model confirming Schumpeter's insight. At the same time, the model shows that there are real costs to economic fluctuations which 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, e.g. because of reduced expenditures on R & D. These long run losses are likely to be far more significant than any temporary gains from any induced cost cutting.

While traditional Schumpeterian analyses have focused on the relationships between market structure and innovation, they have paid less attention to the relationship between innovation and capital market imperfections (resulting, in many cases, from problems of costly and imperfect information which are particularly important in the context of innovation). It is these capital market imperfections which give result in the deleterious effect of economic downturns on technological progress.

Part II. of the paper shows that the nexus between fluctuations and innovation goes in both directions: fluctuations in economic activity not only cause fluctuations in innovation, fluctuations in innovation may 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 them. Moreover, it is shown that under certain circumstances, the *only* market equilibrium entails economic fluctuations. It is the structure of the economy, not exogenous disturbances (as in real business cycle theory) which give rise to cyclical behavior.

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 of the survival of the fittest means that those firms which are less fit cannot make it through a serious downturn; and thus recessions speed the process of natural selection.

Schumpeter emphasized this part aspect of recessions. He wrote (1934, p. 113) of 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

¹Invited paper presented at the International Meetings of the Schumpeter Society, Kyoto, August 19, 1992. I have benefitted greatly from the discussion of the paper at the conference, and in particular, from the comments of the discussant, Hiroyuki Itami, and the editor of the Proceedings, Mark Perlman. Financial support from the National Science Foundation, the Sloan Foundation, and the Hoover Institution are gratefully acknowledged. This work is part of a joint research program with Bruce Greenwald and Andrew Weiss. Discussions with Assar Lindbeck on the ideas contained in this paper were particularly helpful. I owe more than the usual debt to my research assistants, Joshua Gans and Thomas Helmann, both for their contributions to the ideas and their expression.

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.

Indeed, Heilbroner, a student of his, noted that Schumpeter, on balance, seemed to think that depressions were a good thing (Heilbroner, 1980, p. 311):

But the students who attended his classes in the late 1930's were regularly shocked to hear this expositor of capitalist growth declare, with obvious enjoyment, that depressions, far from being unmitigated social evils, were actually in the nature of "a good cold douche" for the economic system!

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;² and in the presence of imperfect capital

²In Stiglitz [1992b], I examine the welfare properties of evolutionary processes. I show that there may be multiple equilibria, one of which is

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 theme strongly 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;³ 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.⁴ We have only begun, however, to explore the full ramifications of the implications of these capital market imperfections, both for the behavior of the firm (e.g. firms act in a risk averse manner), and for the behavior of the economy.⁵

"better" than the others; and that "tighter" natural selection may actually be welfare decreasing.

³Raising 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.)

⁴There are again both adverse selection and adverse incentive arguments. See, for instance, Stiglitz [1992] and Greenwald, Stiglitz, and Weiss [1984].

⁵See, for instance, Greenwald and Stiglitz [1992a,b], Stiglitz [1992], and Stiglitz and Weiss [1992].

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 the second aspect of the relationship.

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, macro-economic policies that stabilized the economy are more likely to be conducive to long run growth.

This part of the paper is divided into five parts. We first explain why economic downturns have a negative effect on R & D, and 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 on some of the empirical evidence.

A. The Negative Effect on R & D

In the Schumpeterian tradition, innovation is largely endogenous.⁶ It affects, and is affected by, market structure.⁷ In this paper, I want to emphasize, however, another determinant which has perhaps not received sufficient attention: financial constraints.⁸ 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 were it possible to define precisely the fruits of an R & D project, and to offer that as collateral, the value of the collateral is likely to be negligible precisely in those circumstances in which the firm defaults.

⁶While 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.

⁷See, e.g. Dasgupta and Stiglitz [1980].

⁸Schumpeter 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.

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 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 a slight decrease in the price or a leftward shift 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.⁹ Economic downturns not only have adverse effects on firms' cash flow, which cannot be offset by increased borrowing; but economic downturns are likely to 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

⁹For 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].

of this.¹⁰

The recently developed theory of the risk averse bank (Greenwald and Stiglitz, 1992a and b) 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 divest themselves fully 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 towards 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 firm's net worth leads to a decrease in risk taking--a decrease in loan activity. (This is the "wealth" effect.) Secondly, banks perceptions of the risks associated with loans is likely to change adversely; not only are mean returns lower, but perceived variances are likely to be larger.¹¹ (This is the substitution

¹⁰To 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, non-price terms (such as collateral requirements) have increased. And thirdly, studies by the Federal Reserve Board suggest that "standards" for getting loans have been increased.

¹¹The reductions in perceived mean returns and increases in perceived variances is not just based on an extrapolation of the higher default rates associated with economic downturns. If firms' net worth is reduced enough, they may undertake riskier actions; and while these firms, which are "going for broke" increase their demand for funds, the "sounder" firms may actually reduce their demand for funds. Even with this reduced

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 can borrow would be reduced as the value of the collateral decreases. Thus, economic downturns lead to less 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 principle 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,¹² firms ought to act in a risk neutral manner with respect to R & D

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].

¹²Of course, the *economic* value of a project is related to the macro-economic conditions; but since the returns to most R & D ventures are several years in the future, *current* economic conditions should have little

expenditures.

But firms are risk averse, precisely because they cannot fully divest themselves of all the risks which 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.¹³

The theories of adverse selection and moral hazard (agency), to which we referred earlier, provide an explanation for why we might expect this. Our 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.¹⁴ Firms-- and their managers--seek to avoid bankruptcy, for quite obvious reasons. Not only are their costs to bankruptcy,¹⁵ but bankruptcy provides an

to do with the expected present discounted value of a research project.

¹³Perhaps 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

¹⁴In multi-period models, matters are somewhat more complicated, since lenders can choose to reschedule the debt. See Eaton, Gersovitz, and Stiglitz [1986].

¹⁵Of course, the assets of the firm do not disappear upon bankruptcy; but bankruptcies typically entail significant transactions costs; often, there is an interruption to normal business (as suppliers and customers become

adverse signal concerning the quality of management.

The various actions (expenditures) which 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 probability 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 which 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

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.)

very high,¹⁶ and this, by itself, tends to lead to a marked reduction in a long term, risky investment, 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 either to the level of output or investment, as in the standard theories of Learning by Doing (Arrow, 1962). Because of the non-existence 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

¹⁶By 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.

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.)

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 "satisfied"¹⁷ or pursued goals, such as growth maximizing, which 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, take-overs provided an effective discipline device, which ensured that even if managers

¹⁷See also Leibenstein's theory of X-efficiency [1989].

might have liked to have pursued other objectives, it was not feasible for them to do so.¹⁸ The new Information Economics paradigm has explained why the take-over 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.¹⁹ 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 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 fraction of the increased value of the firm which results from their activities. Jensen and Murphy [1990] estimate that top management as a whole appropriates less than .3% 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

¹⁸Discipline was also provided by evolutionary mechanisms (firms which did not maximize profits could not survive) and by proxy votes. The more recent literature (see below) has explained why these mechanisms, like the take-over mechanism, exert far from perfect discipline.

¹⁹If one firm discovers a firm which 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 anything.

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]).

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 principle 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."²⁰

This raises a fundamental criticism to 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--which have less deleterious systemic effects.²¹

(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, developing new markets. Periods of economic slack give management the "opportunity" to focus their attention on how to do what they do at

²⁰This 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 to Jensen's theories emphasizing the importance of free cash flow (Jensen, 1986).

²¹Though, 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.

minimum cost.)

I want to 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,²² though some, perhaps most, of the observed efforts at shedding off slack are mainly directly 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, i.e. that the cost savings free resources which 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 which 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

²²The 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).

actually reduce the efforts firm 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.²³

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 which eventually punish firms that deviate far from this norm for long. Eventually, some entrepreneur will see the managerial slack that exists; new firms will be created that will devote their attention to minimizing the costs of production, just as that 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

²³Several widely cited theories of induced innovation emphasize the importance of these shortages, though to date there has been little formal modelling of this idea. See Habakkuk [1987].

the process. The question is, are the benefits which accrue from the speed up 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 ways: (a) he ignored the negative effects on R & D expenditures and learning; (b) he ignored the deleterious effects on efficiency enhancing efforts of economic downturns; (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 benefit of R & D expenditures typically exceed the private benefits: firms seldom capture all 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 exceeds 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.

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

$$\Phi = \alpha\Pi_0 - g(e) - x - cP_0 + (1-P_0) \delta \{ \alpha\Pi_1 - cP_1 \} \quad (I.1)$$

where

α = fraction of profits received by managers²⁴

Π_i = profits ith period

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

e = managerial effort

x = expenditures on R & D

c = costs of bankruptcy

P_i = probability of bankruptcy ith period

δ = discount factor

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

²⁴We assume that managers obtain a fixed fraction of firm's profits, gross of expenditures on R & D. An alternative formulation nets out R & D expenditures. The results are unaffected.

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

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 modelling 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, it has 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. On the other hand, in 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.²⁵ We thus postulate that

²⁵ 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 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

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

with

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

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

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 :

$$\alpha \Pi_o' - g'(e) - [c + \delta\{\alpha \Pi_1 - cP_1\}] \partial P_o / \partial e + (1-P_o) \delta\{\alpha \partial \Pi_1 / \partial e - c \partial P_1 / \partial e\} = 0 \quad (I.9)$$

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

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.

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 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 deteriorates. In order to finance the same level of expenditure on R & D, x , it must 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 $\Pi_0 = \Pi_0(e, M)$, $\Pi_1 = \Pi_1(e, x, M)$, 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

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

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 next period would be unaffected, if e and x were to

remain unchanged.²⁶)

What is relevant for the firm's decision, 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.

Now, our two first order conditions can be written as

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

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 reduced R & D, as suggested by our earlier discussion. At the same time, we show that it is possible that both R & D, as well as effort at cost reductions, are adversely affected, 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.

²⁶For later reference, we noted 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 $\partial \Pi_1 / \partial M = 0$, $\partial P_1 / \partial M > 0$.

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 (managers) to have the firm survive. This condition, together with restrictions already imposed, implies that

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

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 expenditure is the increased expected profit in the future $[(1-P_0) \delta\{\alpha \partial\Pi_1 / \partial x - c \partial P_1 / \partial x\}]$. There are two costs: the direct costs (the first term), and the cost of the increased likelihood of bankruptcy 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} .

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

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 the first period, and we would thus normally expect that they would increase the return to exerting greater effort, i.e.

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

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 pay off higher returns, i.e.

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

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). On the other hand, an increase in R & D expenditures increases the probability of bankruptcy 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). 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 that²⁷

$$\partial \Pi_1 / \partial e = \partial P_1 / \partial e = 0 \quad (\text{I.21})$$

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.²⁸ As the firm engages in more research, the

²⁷The second condition is not as natural as it might seem at first glance: efficiency enhancing efforts the first period which increase firm profits the first period, also increase its net worth the second period, and thus would reduce the probability of default the second period, even if first period efforts have no direct effect on the firm's second period production efficiency.

²⁸We 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

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 does an economic downturn affect 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

outweighed by the other three terms.

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

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 3.²⁹

²⁹To obtain this result, we need to impose some further restrictions. In the case of the effect on effort, we make three additional assumptions: (i) 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. (ii) 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

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 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 it 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 that situation, the net result is that both 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

to cost-cutting restructuring rather than to production). (iii) The increased probability of survival means that there is a higher expected return to cost cutting--a higher probability of getting returns from current cost cutting efforts in the future. 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 next period's bankruptcy probability. This increases the net return to survival, i.e. it increases the cost of bankruptcy this period, and this discourages R & D expenditures. We assume that this term is dominated by the other terms.

large--so that it is very difficult to change e --or the cross derivatives between "M" and "e" are small, so 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 next period--it does not pay firms to exert as much effort at cost reduction this period.

Panel C shows a third possibility, where the x^* curve shifts little, but the e^* curve shifts a great deal. In that case, it is possible that both effort and R & D expenditures both 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 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 simply of 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.³⁰

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 show consistently that cash flow and net worth variables are important in determining firm investment behavior.³¹

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 affects 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

³⁰Recent work, e.g. by 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.

³¹See, for instance, Gilchrist [1989], Hubbard [1990].

in factor prices meant that, while the industry had gone far down 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 re-emerged after the second. In our econometric study, we corrected for the effect of future sales expectations, and even taking this into account, one could see strongly the effect of cash flow effects 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; the value of reducing the cost of producing a widget by 1 cent is proportional to the number of widgets produced. Thus, if output is higher, efforts at increasing productivity should be higher. Thus, 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 and 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 concludes³² that there is strong evidence that changes in the financial structure of firms which 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 which 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%, 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 scope for further work examining the magnitude of these effects in other industries and in other countries.

³²Hall [1992], based on work reported in Hall [1990, 1991].

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, in 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 there is a distinction, which is important. While the real business cycle theorist 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 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 retrogressions 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.³³

Recent work has provided a better basis for understanding these

³³For more extensive critiques, see Mankiw [1989] and Greenwald and Stiglitz [1988].

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 non-convexities associated with technological change, whether arising from R & D or learning by doing, there can be multiple equilibria. When the level of economic activity is (expected to be) low (in the future), 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.³⁴

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

³⁴In a manner reminiscent of Kaldor's [1940] discussion of the trade cycle.

downturns exerted their effects, e.g. through their effects on future expected profits, through their effects on bankruptcy probabilities, both current and future. There are other mechanisms at work as well: financial constraints, including credit rationing, may have a direct effect, as economic downturns decrease the supply of working capital, as well as 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 the what appears to be the simplest model capturing the positive feedback interactions upon which we focus here. (Later, we comment on some of the negative feedback interactions.) In our simplified model, firms have a single decision variable--the level of output³⁵. 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 only through one channel, through 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 thinking of there being

³⁵Thus, we ignore both the effect on R & D and on effort at efficiency enhancement. The only assumption which is crucial for our results is that economic downturns lead to less net technological progress.

two periods. For notational convenience, we drop the subscripts i referring to the specific commodities, whenever there is no resulting ambiguity. Output the first period, Y_{0i} , is proportional to labor input, L_{0i} , and we choose units so we can write

$$Y_{0i} = L_{0i}. \quad (\text{II.1})$$

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

$$L_{1i} = C_{1i}(Y_{0i})Y_{1i}, \quad (\text{II.2})$$

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

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

so that, using symmetry

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

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

With our utility function, the labor supply the i th period is a function of the real wage 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,

$$\max_{\{Y_{oi}, Y_{li}\}} p_{oi} Y_{oi} - L_{oi} + p_{li} Y_{li} - Y_{li} C(L_{oi})w \quad (II.5)$$

where we recognize that p_{li} depends on output, and where $L_{oi} = Y_{oi}$.³⁶

Thus, maximizing with respect to Y_{oi} , we obtain

$$p_{li} = w_1 \left[1 / \left(1 - \frac{1}{\varphi} \right) \right] C_1(L_{oi}) \quad (II.6)$$

and

$$p_{oi} + \frac{\partial p_{oi}}{\partial Y_{oi}} - 1 - w Y_{li} C' = 0 \quad (II.7)$$

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

$$\begin{aligned} p_{oi} \left[1 - \frac{1}{\varphi} \right] &= 1 + w Y_{li} C' \\ &= 1 + p_{li} \left[1 - \frac{1}{\varphi} \right] L_{li} \frac{C'_i}{C_i^2} \end{aligned}$$

³⁶Though 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 take account of the learning benefits which accrue at $t + 2$. The qualitative properties remain as described here.

Thus, the first period, they set

$$p_{i0} \left(1 - \frac{1}{\varphi} \right) \left(1 - \frac{p_{11} L_{11} c_{11}'}{p_{01} c_{11}^2} \right) = 1 \quad . \quad (\text{II.8})$$

(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,

$$Y_1 = L_1 \left[\frac{1}{1-1/\varphi} \right] C_1'(Y_0) / C_1(Y_0)$$

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

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

$$h_0(Y_0) \left[1 - \frac{1}{\varphi} \right] \left[1 - \left[\frac{Y_0}{Y_1} \right] \frac{Y_1 C_1'(Y_0)}{C_1(Y_0)} \right] = 1,$$

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

Multiplicity of Equilibria

We thus can 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 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 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 equilibrium.

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 assume that there is an exogenous rate of accumulation of pure knowledge. This occurs at the rate γ . Thus, the "potential best practices" technology has a cost of $C^* = (1 + \gamma)^t$. Next, we assume that the rate of learning is a function of the gap between current costs and the potential represented by C^* :

$$\begin{aligned} C_{li} / C_{oi} &= C_{li} (L_{oi}, C_{oi}/C_o^*) = C_{li} (L_{oi}, C_{oi} (1 + \gamma)^t) \\ &= C_{li} (L_{oi}, G), \end{aligned}$$

where G measures the size of the "gap":

$$G = C_{oi}(1 + \gamma)^t.$$

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 the first period, the production 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 potential practice becomes big enough, the low level equilibrium disappears. Only the upper equilibrium survives (Figure 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 exactly an opposite direction to that depicted earlier. Output is reduced slightly.³⁷ 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.³⁸

The formal structure of our argument can be seen simply. Note that the set of equilibria depends on the parameter G . Depending on the size of the parameter, there may be either one, two, or three equilibria. Each equilibria can be characterized by a particular level of learning (i.e. a particular value of C_1/C_0). Figure 8 plots the set of equilibria as a function of G . If there exists a steady state equilibrium, it entails $C_1/C_0 = 1/1 + \gamma$, so that costs fall at the same rate as the rate as that of the best practices technology. Panel A 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 next period will lead to a sufficiently large increase in current output, and a reduction of next period's cost, that the actual output next period will be even greater, more than fulfilling the expectations. In that case, the economy oscillates as described earlier, and as depicted in Figure 8. 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 9. We postulate that when there are

³⁷Observed patterns may depart from that predicted by this simple theory, because we have not incorporated investment and a variety of other lags in adjustment.

³⁸The similarity between this cycle and that described by Kaldor [1940] should be apparent. A model of endogenous cycles with similar properties to the one here is discussed in Gans [1989].

multiple equilibria, the economy stays in the "nearby" equilibrium. Then the economy will exhibit the jumps from low level equilibrium to the 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 underlies the above analysis is the existence of a positive feedback mechanism.³⁹ 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 discounted 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,

³⁹See Arthur [1991], David [1987], Sah and Stiglitz [1989] and Stiglitz [1991].

assumed conventional market real interest rates.

A third channel through which positive feedbacks 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 output in the future.⁴⁰

Concluding Remarks

There are three basic lessons to be drawn from this analysis. First, there are real costs to economic fluctuations which 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 losses are likely to be far more significant than any temporary gains from any 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 which are particularly important in the context of economies with rapid innovation) and innovation.

Thirdly, the nexus between fluctuations and innovation goes in both

⁴⁰It 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.

directions: fluctuations in economic activity not only cause fluctuations in innovation, fluctuations in innovation may 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 them.

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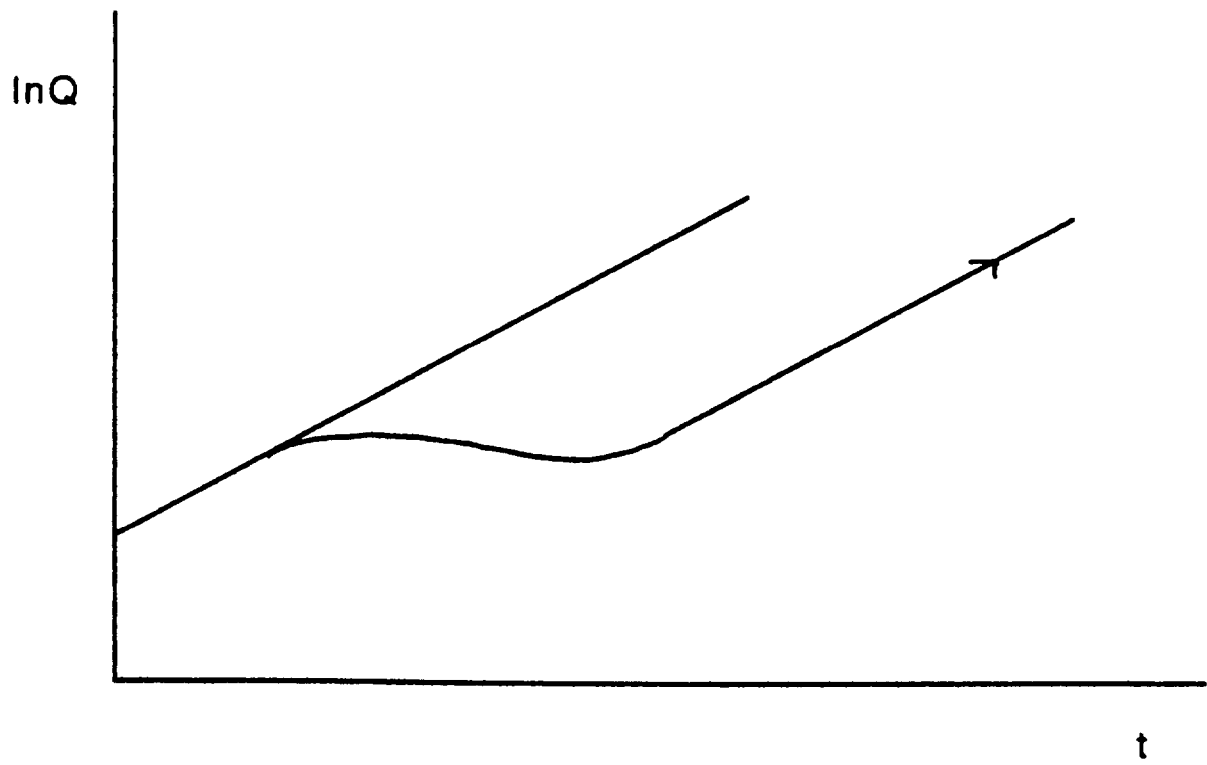
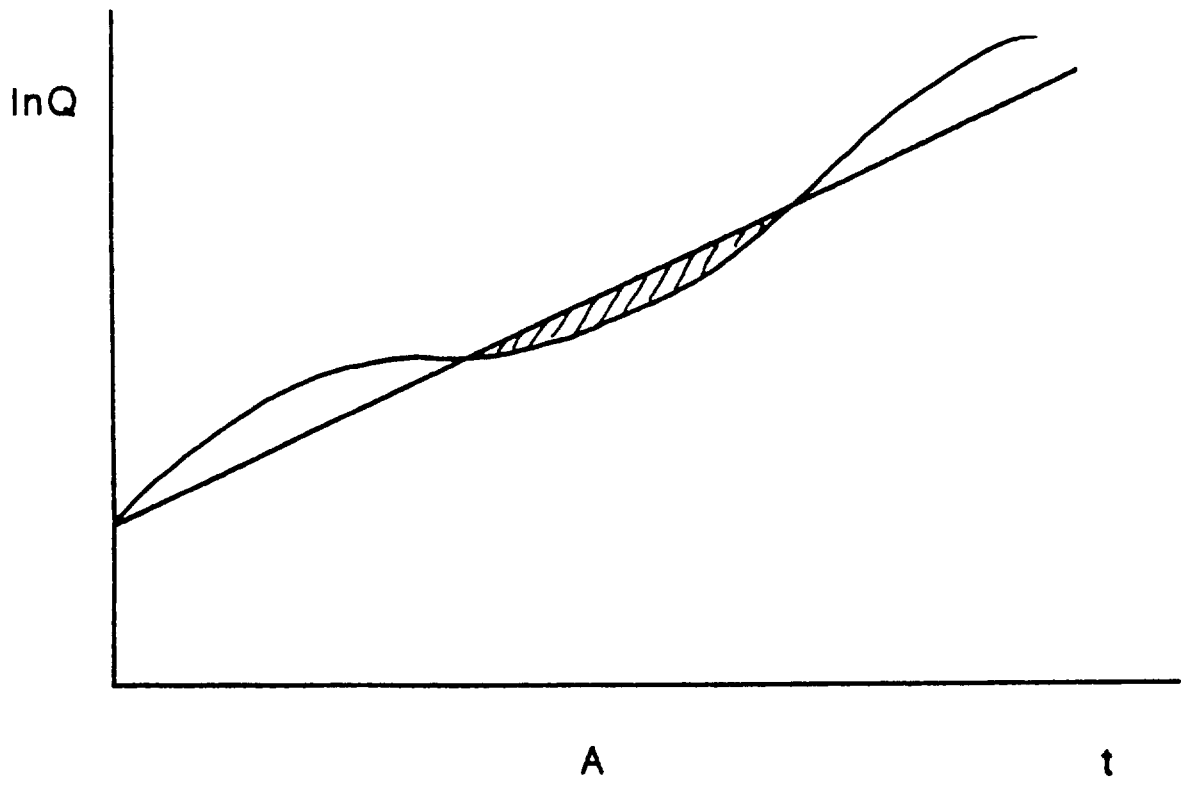


Figure One

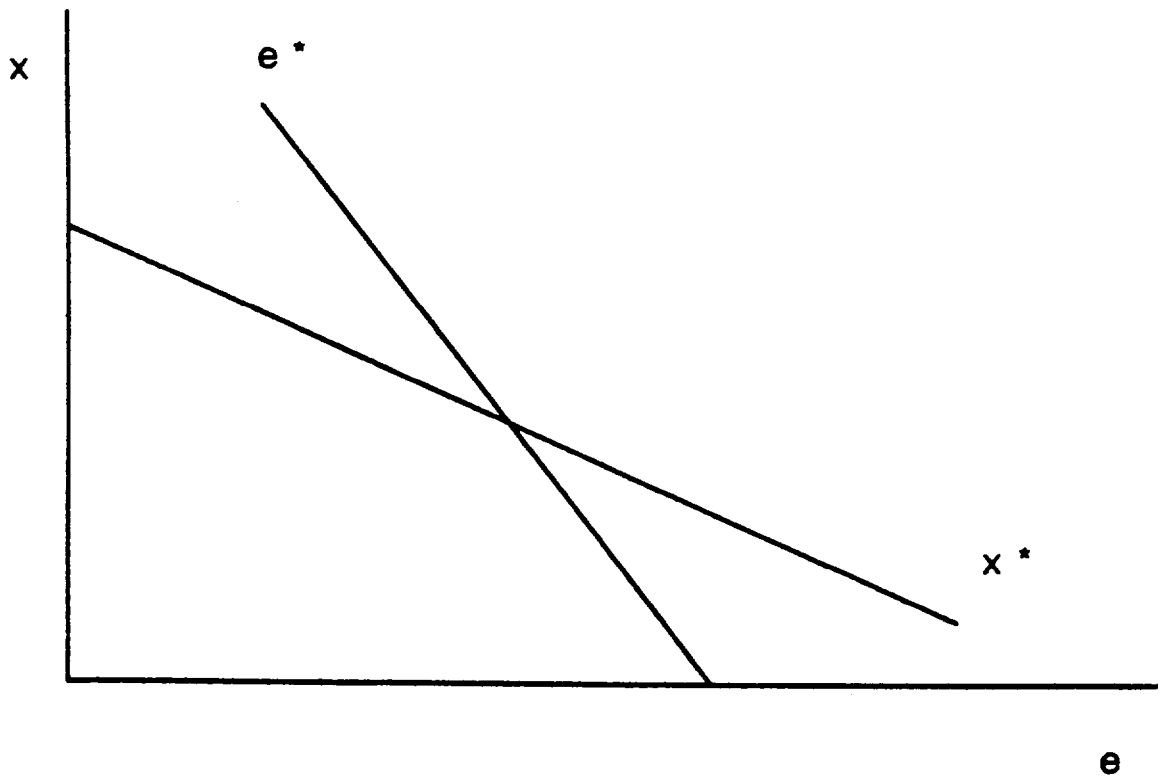
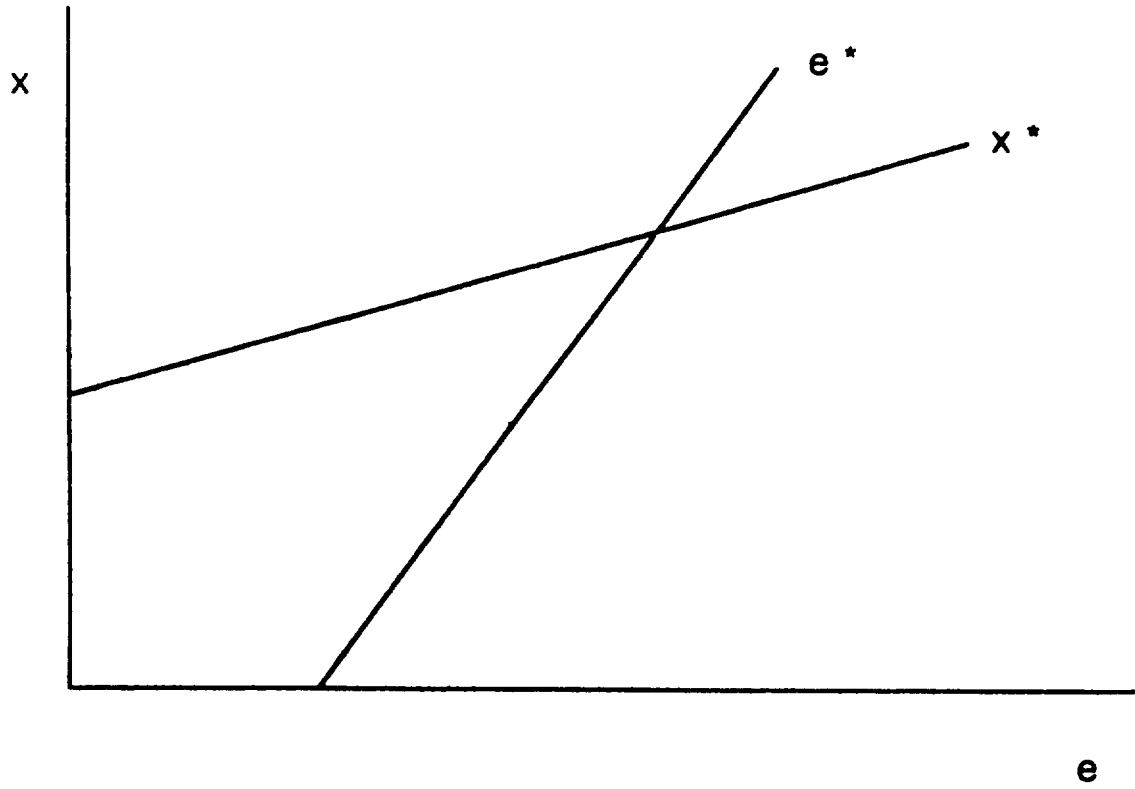


Figure Two

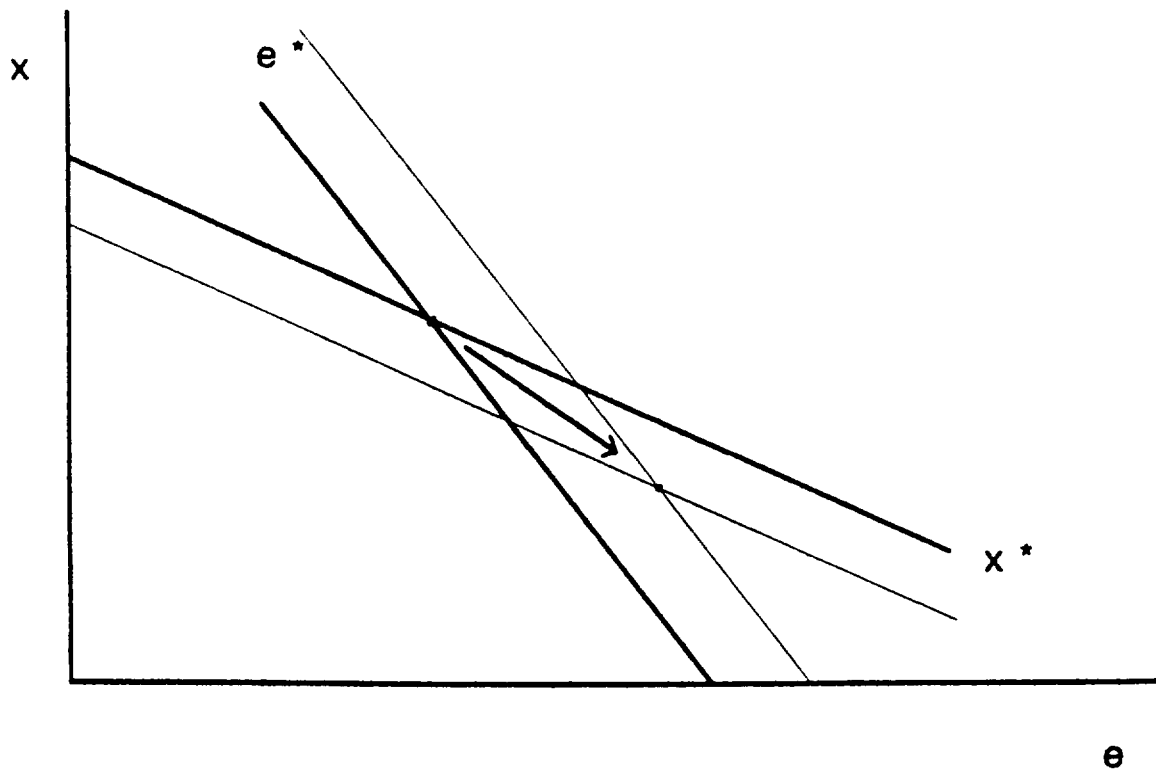
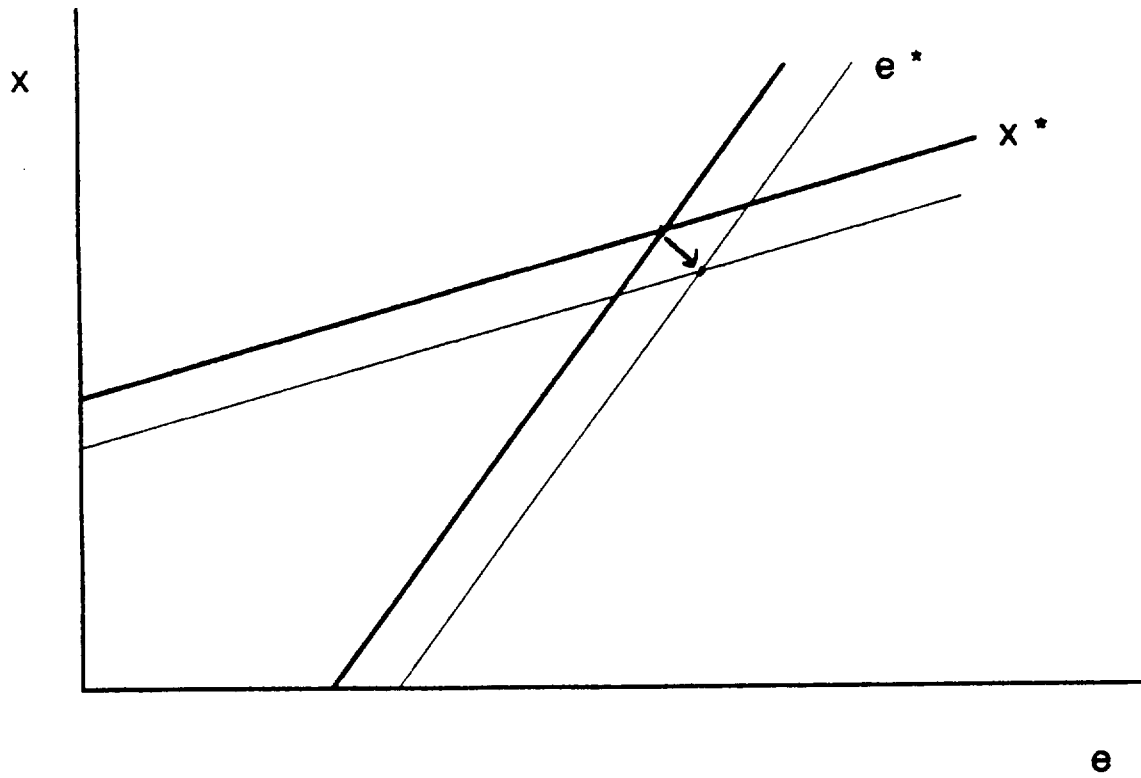


Figure Three

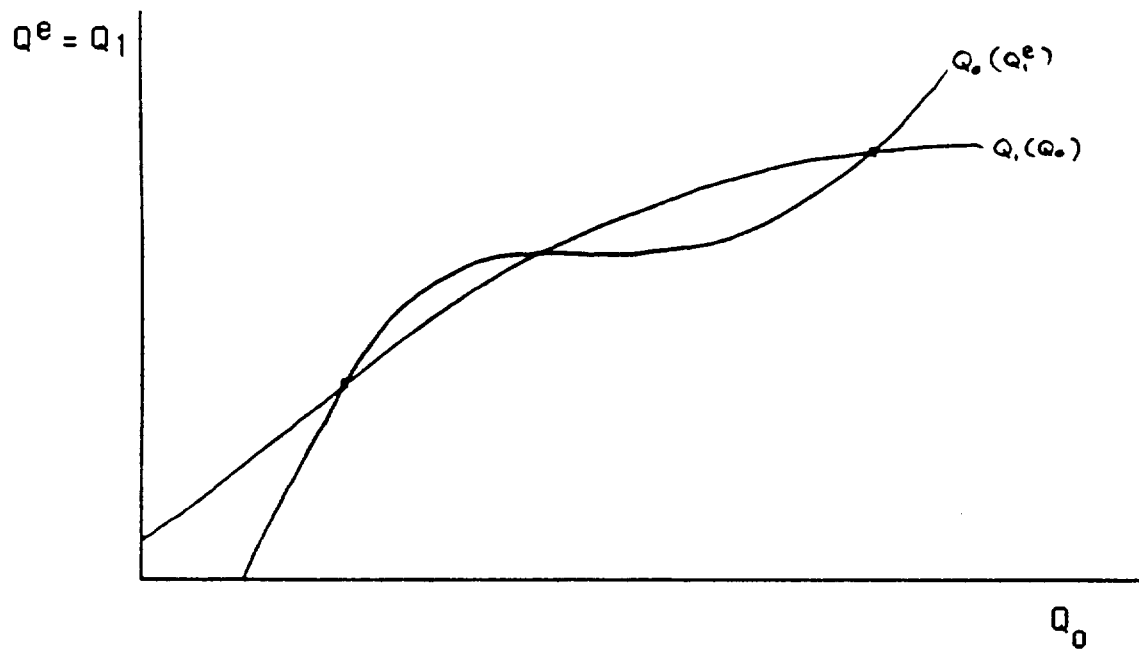


Figure Four

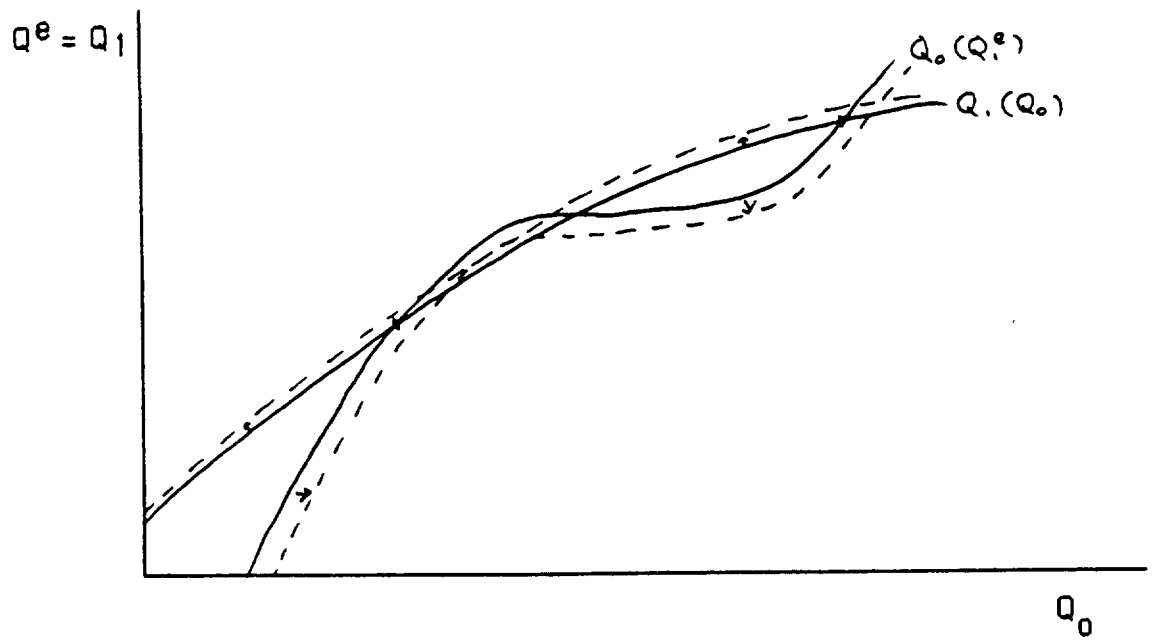


Figure Five

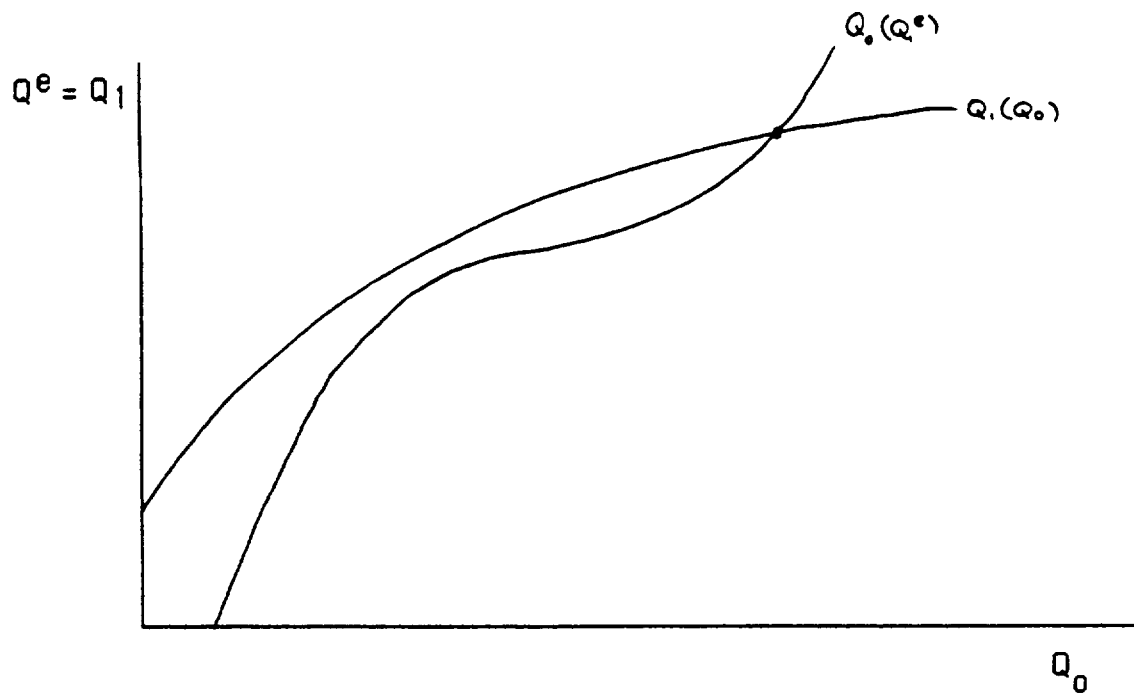


Figure Six