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THE DIVERSIFICATION OF PRODUCTION

BY

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ABSTRACT

This paper entertains the hypothesis that a firm will diversify its production so as to employ its slack managerial resources, and/or to capture R&D spillovers among its products. The paper builds a multiproduct version of Lucas's span of control model. The first version of the model shows that the historical trend towards larger and more diversified firms can in part be explained by the growth in the economy's capital-labor ratio.

The second version of the model shows that more R&D intensive firms should, on efficiency grounds, be more diversified, although the highly tentative estimate contained in this paper suggests that the size of the R&D spillovers that diversification creates may be small.

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1. Introduction.

Most firms today produce more than one product. In this sense, their production is diversified, or horizontally integrated. This paper addresses the following two questions: First, why have firms become more diversified over the past century? And second, why are diversified firms more R&D intensive?

I tackle these two questions under the assumption that a firm diversifies to maximize its efficiency. Economists have often argued that the firm will reap efficiency gains when it diversifies its production because its managerial and R&D inputs can be shared among its various activities:

> "The sphere in which diversification is most likely to produce economies of scale is research and development. Although the information thus far gathered on this question is inconclusive, it is reasonable to say that a firm with a wide range of products has many opportunities for exploiting the results of a program of research. This is because the directions in which research will produce results are to a large extent unpredictable. Consequently, the greater the range of activities, the higher are the chances that a discovery or development in technology will fit into the firms' existing product structure. In this sense, economies are related not so much to size in terms of output or investment as to the range of goods and services produced. If the level of research and development expenditures continues to rise rapidly, we can expect an increase in diversification motivated by these considerations."[1]

The idea that knowhow can be productively transferred from one activity to another has also been pursued by growth theorists, some of whom argue that spillovers of knowledge among distinct production processes are the engine of growth.[2] Nor is R&D the only input that can be shared among the firm's

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[1] The passage is from Gort (1966, p. 35). Penrose (1959) may have been the first to argue that firms diversify to take advantage of slack managerial resources, and possibly slack technological resources such as R&D. Also, see Richard Nelson (1959). Panzar and Willig (1981) prove that the presence of what they call economies of scope is equivalent to the presence of a shared input.

[2] Stokey (1988), Young (1991), and Lucas (forthcoming).

products. There is managerial knowhow, and there are other indivisible factors that can be used to make, promote, and distribute more than one product at a time.

I shall embed these much talked about but still relatively unexplored ideas in two multiproduct versions of Lucas's span of control model.[3] This is a general equilibrium model of firm formation. Since the trend towards diversification is visible in most sectors in spite of the technological differences among them, one suspects that these sectors share a common reason for this trend, a force that operates at the economy-wide level. The first version of the model isolates the role of the shared managerial input in explaining the trend. The second focuses on the positive relation between diversification and R&D. In both models firms are infinitesimal, they set price of output at marginal cost, and diversification is socially optimal. In fact, firms often have market power, and antitrust policy must then trade off efficiency gains to diversification against its anticompetitive effects. The Justice Department's merger guidelines recognize the possibility that most mergers are not anticompetitive, and that they can raise efficiency and benefit the consumer.[4]

The paper has two main conclusions:

1. The secular increase in the capital-labor ratio is a major cause not only of the growth of firm size, but probably also of their increased diversification.
2. There seem to be significant <u>within</u> firm cross-product spillovers in R&D. I estimate that a diversified firm gets between 1.025 and 1.3 times as much from its R&D as a single product firm would. The estimate is rough, and subject to all sorts of qualifications.

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[3] Lucas (1978).

[4] U.S. Department of Justice (1992, p. 30).

The model aims to fit evidence that I shall survey in section 3. Some of that evidence, however, is consistent with other motives that have been held to drive firms to diversify, motives other than efficiency. To put my model in perspective, then, the next section will briefly survey some reasons why firms diversify.

2. Why Diversify Production?

When analyzing the vertical integration of two firms, we usually take the alternative to be a potential buyer-seller relationship between them, in which case bilateral monopoly, if it is not there initially, can develop over time between them as they make specific investments in their relationship.[5] We thus see vertical integration as the firms' attempt to wipe out efficiency losses that bilateral monopoly gives rise to. No such motive exists with horizontal integration, and although some of the motives I discuss below can also be construed as driving vertical integration, horizontal integration is qualitatively different. Here now are some possible motives for it.

A. Gaining Market Power.

A firm with market power in two substitute products can extract more from the consumer than would two single product monopolies acting noncooperatively, and this may hurt welfare. But since most diversified firms have negligible shares of the markets they serve, we must look beyond this motive.[6]

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[5] A point emphasized by Williamson (1979).

[6] Utton (1981, ch. 7), and Willig (1991) discuss possible anticompetitive effects of horizontal mergers. Ralph Nelson (1959) argues that the quest for market control fueled the first big merger wave in the U.S. in 1898-1902. Ravenscraft and Scherer (1987), however, dismiss this motive for all but a few

B. _Avoiding Risk_. Without bankruptcy risk and liquidity constraints, the firm need not diversify to avoid risk -- the shareholder can do it himself.[7] But with incomplete insurance possibilities, this motive may be important, especially for smaller firms whose investment seems to depend more on cash flow.[8] Note that the risk avoidance motive can not explain _vertical_ integration, because the latter in effect makes the firm put more of its (investment) eggs in the same (final market) basket.

C. _Having Access to Funds_. When capital markets are imperfect, an investment opportunity might not go to the most efficient producer, but rather to the producer who has the funds to finance it. Noticing an opportunity in another industry, a firm with enough funds may diversify into it even if multi-good production is costlier than specialization. Since the large firm can raise capital easier and quicker,[9] this hypothesis should apply especially to large firms, and especially to industries where setup costs are high. It gets support from the finding that industries that a diversifying firm enters are commonly populated by large firms,[10] and that the diversifying entrant is typically bigger than the new startup firm.[11]

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of the mergers they studied.

[7] Levy and Sarnat (1970, section 1). A natural way to analyze this motive is to add multi-good production to Kihlstrom and Laffont's (1979) model.

[8] Fazzari, Hubbard and Petersen (1988).

[9] Scherer (1975), pp. 284-9.

[10] Stigler (1962) makes this point, and MacDonald (1985, table 1) gives evidence that supports it, while McCutcheon (1990) gives mixed evidence.

[11] Baldwin and Gorecki (1987).

D. Making Products Compatible. If products are supplied by different firms, a socially suboptimal array of product-types could emerge. A firm could raise its profits and possibly consumers' welfare too, if it produced the optimal product set jointly. It could do so, that is, even if producing the products together entailed no underlying cost advantage. This may be an important motive in areas such as consumer electronics, and computers. It differs from a "network externality" that operates through the volume of sales of a product such as a telephone, that gives rise not to economies of scope, but to economies of scale emanating from the demand side of the market. This motive can also cause a firm to integrate vertically so as to make sure that it will have the right combination of inputs and thereby raise the value of the chain of production.

E. Reaping Efficiency Gains. By making several products, a firm may increase its sales, and may realize economies of scale in promoting, advertising and distributing its products. The diversified firm probably may also need workers to perform a greater variety of tasks and will therefore offer them a richer internal labor market.[12] These are productive advantages of diversification.[13]

F. Pursuing Managerial Goals. A manager may do things that do not maximize his firm's profits or its shareholders' welfare. Even if his firm is not cash constrained, the manager may diversify to reduce his uninsurable employment risk.[14] Also, managerial power and prestige seem to be tied to the firm's sales more closely than to its profits. So, the manager may pursue conglomerate

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[12] Prescott and Visscher (1980) treat a related issue from this perspective.

[13] Baumol, Panzar, and Willig (1982) call them economies of scope.

[14] Amihud and Lev (1981) give evidence in favor of this proposition.

mergers -- a quick way to raise his firm's sales.[15] Also, because financial statements of a diversified company will often aggregate information from several lines of business into one consolidated statement, managers may prefer to diversify to reduce the accuracy with which their activities can be monitored.[16]

3. Evidence.

Among the many motives for diversification listed above, I will single out the pursuit of efficiency gains, and see how far we can push it as an explanantion of the facts on diversification. The major stylized facts that emerge from the many empirical studies are (a) a trend towards diversification, and (b) a greater R&D intensity of diversified firms. To strengthen the motivation for the type of model that I will use, I will now summarize the relevant evidence.

To measure diversification, an industrial classification is first chosen to determine which of the firm's products are distinct. One measure then simply counts the number of products the firm makes, but since this ignores the relative importance of products, the firm's sales are usually used as weights. A popular example is the Herfindahl index: $D = 1 - \sum_{i=1}^{n} p_i^2$ where p_i is the ratio of the firm's sales in the i^{th} industry to its sales in all n industries. This measure does not pick up any vertical integration because if a firm supplies itself with an input, it gets no revenue from the activity per se. The empirical results largely do not depend on the choice of index.[17]

Next, one can either measure the diversification of firms, or of their

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[15] Mueller (1969) develops this view and cites evidence favoring it.

[16] Lichtenberg (1991).

[17] Gollop and Monahan (1991) discuss several indexes.

plants. Most of the work deals with firms.[18] It turns out that industries that have more diversified firms also tend to have more diversified plants.[19] Most samples are cross-sections, or short panels.[20] Let us begin with the time series results.

A. The Trend Towards Bigness and Diversification. Over the past century, business has gotten bigger and more diversified.[21] Gort's work, after 30 years still the definitive work on the subject, shows a clear increase in diversification between 1929 and 1954 when he uses a measure of diversification that emphasizes diversity. But another sensible measure of diversification is the share of sales coming from the firm's primary activities, in Gort's case the 4-digit industry from which the firm derives most of its sales. In his smaller sample of 111 large manufacturing companies, the ratio of primary industry payrolls to total company payrolls declined only slightly, from 69% in 1929, to 64% in 1954.[22] By this measure, then, diversification hardly went up at all. Still, other measures show a marked increase until quite recently. The first big wave of mergers in the U.S. was in 1898-1902, an episode that must have raised both the size and diversification of firms.[23] And in a sample of 471 large

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[18] There are exceptions: Streitweiser (1991) looks at five digit diversification of plants, while Gollop and Monahan (1991) look at both manufacturing firms and plants at the two digit level.

[19] See Gollop and Monahan (1991, tables 1 and 2). For instance, the cross-country correlation coefficient between plant diversification and firm diversification for the year 1963 was .76.

[20] Gort (1962) is the major exception. His panel covers 25 years.

[21] Berle and Means (1968, pp. 354-8), Prais (1976, chart 6.1), Scherer (1980, figure 3.1), Strickland (1984, table 3), and figure 2 below.

[22] Gort (1962, chapter 3).

[23] Ralph Nelson (1959, p. 3, chart 1).

U.S. manufacturing firms, the number of 4-digit FTC manufacturing categories in which the companies operated rose from 2.55 in 1950 to 7.54 in 1975 -- a threefold increase.[24] Firms in other countries also became more diversified. Utton's sample of large U.K. firms shows an increase until the 1970's. So does a sample of large Japanese firms from 1963 to 1975, which also shows some procyclicality, as does Nelson's sample on mergers.[25]

So much of firm growth occurs by merger and acquisition that it is no surprise that size and diversification move together. In a sample of 460 large U.S. corporations covering the 1960-65 period, Berry shows that firms that diversified more (especially at the 4-digit rather than two-digit level) also grew significantly faster. Thus the time series correlation between size and diversification is apparent in Berry's 6-year panel too. Jacquemin and Berry repeat the exercise on the same sample but using a different measure of diversification -- entropy rather than Herfindahl -- and get even stronger results.[26]

Recently, firm size and diversification have both declined. The 1980's saw a fall in diversification through corporate spinoffs and asset sales. Gollop and Monahan's indexes show that after 1977 diversification fell both at the firm and at the plant level.[27] On the decline of firm-size, Preis's English data show no increase after 1963 in the share of the hundred largest firms in manufacturing

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[24] Ravenscraft and Scherer (1987, table 2-3).

[25] Utton (1981, pp. 88-89), Goto (1981, Figure 1) and Nelson (1959, chapter 5).

[26] Berry (1975, p. 67, table 4-5), Jacquemin and Berry (1979, tables 4 and 5).

[27] Gollop and Monahan (1991, tables 1 and 2), Lichtenberg (1990).

value added.[28] And, the U.S. evidence depicted in figure 2 below shows that firm size has declined since 1980 and this coincides with the period when the diversification declined. Quite aside from the reversal in the growth of employment in the <u>average</u> firm, employment of the Fortune 500 firms has declined even more rapidly.[29]

Taken together, the time series evidence shows that firm size and diversification have moved together; this is more than a mere manifestation of a common upward trend, because recently both have declined.

B. <u>Diversifying to Avoid Risk</u>? Risk-avoidance does not seem to motivate diversification in that firms do not tend to choose stable industries when diversifying.[30] Moreover, they tend to diversify into technologically related industries, thereby exposing themselves to common technological shocks and hence more risk.[31] Moreover, if big firms really find it easier to bear risk, it is surprising that they (and presumably more diversified firms as well) are no more likely than small firms to enter durable goods manufacture -- cyclically the most volatile segment of manufacturing.[32] Of course, in choosing a "portfolio" of industries, a firm would consider the industry's covariance with aggregate consumption. Perhaps countercyclical industries were indeed targeted, but this has not been investigated. A better way to think of diversification is as a form of exit and entry: Firms diversify <u>out</u> of low growth and <u>into</u> high growth

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[28] Preis (1976, table E.1). Also, see Scherer (1980, figure 3.1).

[29] The Wall Street Journal (1992) reports that their share of employment fell from 21% in 1969 to 10.9% in 1991.

[30] Gort (1962, p. 4, and pp. 116-7).

[31] Hughes (1988), Hall (1988), Klavans (1989), and Chang (1992).

[32] Gertler and Gilchrist (1992).

industries.[33] Diversified entry and exit simply mean that a firm is not born when it enters an industry, and it does not die when it leaves it.

C. <u>Cross-Sectional Evidence on Diversification and Size</u>. Big firms are more diversified. In 1954, Gort's larger 721-firm sample showed a strong positive association between size of firm and the number of industries in which it maintained establishments.[34] That this should be true in the economy at large is hardly surprising since the conglomerates on the Fortune 500 list account for a big fraction of the nation's output. But it is also true at the industry level. Big pharmaceutical firms are more diversified than small pharmaceutical firms, big chemicals producers are more diversified than small chemicals producers, and big oil producers are more diversified than small oil producers.[35]

In his larger sample, Gort found something that is at odds with other cross-sectional findings that diversification and size go together: The elasticity of primary employment to the firm's total employment is essentially unity.[36] Since the <u>number</u> of non-primary products increases with firm size in the cross section, this means that the relative importance of a given <u>non</u>-primary activity declined with the size of the firm. This cross sectional result parallels Gort's time-series result that the share of primary activities did not change much between 1929 and 1954. In other words the importance of firm's primary activities is roughly constant in the cross-section and in the time-

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[33] Gort (1962, p. 136), Chandler (1977, p. 473).

[34] Gort (1962, chapter 4).

[35] Grabowski (1968, Table 3), and Teece (1980, table 1). More evidence on the correlation between sales and diversification is in Scherer (1965, p. 115).

[36] Gort (1962, p. 71).

series.

D. The Positive Relation Between Diversification and R&D. Gort's early work showed that more diversified firms employ relatively more technical personnel. This need not mean their R&D-sales ratios are higher, but it does suggest that they use a more complex technology.

Two other measures of a firm's inventive activity are its patents and its R&D-sales ratio. Diversified firms patent more than other firms, but the effect is small: In a sample of 443 companies, Scherer finds that the elasticity of patents with respect to his measure of diversification is .1.[37] Firms' R&D-sales ratios are in most industries positively related to how diversified they are. Even after controlling for scale, Grabowski found this positive relation in the chemical and drug industries but not in the oil industry. Working with a narrower measure of diversification, however, Teece did find a strong positive relation in the oil industry, again after controlling for cash flow which should proxy for firm size.[38]

Further evidence that diversification is related to (or perhaps represents) the capture of technological spillovers is that firms tend to move into products whose technologies are related to the technology of their primary product. High R&D firms also tend to enter other high R&D industries.[39]

Much of R&D goes on in laboratories that are removed from production facilities, such as AT&T's Bell Laboratories, which suggest that spillovers of

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[37] Scherer (1983).

[38] Grabowski (1968, table 1) and Teece (1980, appendix).

[39] MacDonald (1985), Hall (1988). And Gort (1969) finds that firms with high technical personnel ratios had a greater tendency to merge.

knowledge among parallel R&D activities are not confined to the plant, but rather occur largely at the firm level. Indeed, R&D-sales ratios relate more strongly to the diversification of firms than they do to the diversification of their plants. Using 18 two digit manufacturing industries, (so that there were 18 observations in all) I found that the correlation between Gollop and Monahan's 1963 firm diversification index and the 1963 R&D-sales ratio was .43. The correlation between their establishment diversification index for the same year and the R&D-sales ratio was .21. The discrepancy between the correlations is present in other years as well. In 1977, for example, the correlations were .23 and .03 respectively. All this suggests that the capture of R&D spillovers should be reflected more in diversification of firms rather than of their plants.[40]

But not all evidence points to the capture of R&D spillovers as a motive for diversifying. First, the strength of the R&D - diversification relation may be overstated because of the underreporting of R&D by smaller, less diversified firms many of whom report no R&D spending at all, yet they apply for patents, and therefore must be making inventions. Second, the positive correlation between R&D and diversification may be partly a spurious outcome caused by capital shortages, not R&D spillovers. That is, it could be that big firms have the capital needed for entry into new product markets, and for doing R&D on a large scale.[41] Third, Hall found that, if anything, mergers and acquisitions reduced the R&D done by the companies in her short panel. The reduction in R&D intensity

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[40] Many studies (too many to survey here) have looked for evidence of economies of scope in specific areas like advertising (Silk and Berndt, 1990), telecommunications (Evans and Heckman 1984, Kiss and Lefebvre 1987, Elixman 1989), banking and financial institutions (Matthews 1981, Kim 1986, Hunter and Timme 1986), and water utilities (Kim 1987). Most of them find it.

[41] Himmelberg and Petersen (1991) find that after controlling for measures of Tobin's q, small firms' R&D spending is still sensitive to their cash flow.

was large -- half a percentage point. Her explanation was that the increases in debt that accompanied the acquisitions made it harder for these firms to fund R&D.[42] (But one could also rationalize her result by arguing that following a merger the firm may want to economize on a shared input like R&D, since after the merger a given amount of R&D can "go further"). Fourth, a study of pharmaceutical firms found that those with higher R&D-sales ratios subsequently diversified less than other firms.[43] Finally, if R&D spillovers exist, they are an efficiency gain. And yet much of the acquisition-led diversification in the 1960's has been unprofitable for the acquiring firms.[44] The de-diversification of the 1980's can then be seen as undoing previous mistakes, and it seems to have raised the productivity of the firms involved.[45]

All in all, however, the evidence shows a positive relation between R&D intensity and diversification. In linking R&D and diversification theoretically below, two assumptions will be key: (a) distinct products often share the same technology -- knowledge useful for producing one product can help with producing others too, and (b) that such spillovers of knowledge occur more freely within firms than among them. Assumption (a) agrees with casual observation. Moreover, evidence shows that a firm's cost curve is lowered by R&D done by its technological neighbors, or by the suppliers of its capital goods, or by firms in other industries more generally.[46] And specific technologies that firms

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[42] Hall (1990, p. 122).

[43] Hill and Hansen (1991, table 2).

[44] Morck, Shleifer and Vishny (1990), table 4.

[45] Documented by Lichtenberg (1990).

[46] For example, Jaffee (1986) and Scherer (1984). Many other empirical results are summarized by Griliches (1992).

develop often originate with firms in other industries.[47] Assumption (b) follows if the firm enjoys a lead time in having the sole use of its own inventions. How long this lead time is probably depends on the ease of patenting, the size of the firm, the industry that it finds itself in, the number of its rivals, and so on.

4. Slack Managerial Resources: A Model of the Trends.

This section tries to find some of the factors that may have given rise to secular changes in diversification. It will look at a closed, static economy with symmetric firms -- equal in size and scope -- and ask how exogenous increases in the capital stock, in population, in Hicks-neutral productivity, in management-biased technology, and in the aggregate level of product variety, affect the level of diversification. The model addresses the time-series evidence only. The next section will model differences in firms, and will address the cross-sectional evidence.

Suppose that consumers like variety, and that the quantities of the various products enter into their utility functions symmetrically.[48] Let v be the total number of products in the economy. This number is exogenous. If these products enter utility functions <u>and</u> production functions in an exchangeable way, there will be an equilibrium in which they all sell at the same price, a price we shall normalize at one.

Each product is made with three factors of production: management x, capital k, and labor ℓ. The quantity of the product, q, is given by

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[47] Mansfield <u>et al</u> (1971, p. 221).

[48] As, say, in the utility functions proposed by Spence (1976) and Dixit and Stiglitz (1977).

$$q = f(x, k, \ell) ,$$

where f is increasing, and strictly concave in k and ℓ.

The manager's input x is critical here. On the one hand, its fixed nature will generate diversification of production but on the other, its scarcity will limit diversification. It may denote the intensity of managerial monitoring activities if there are agency problems,[49] or the amount of information the manager can interpret,[50] or simply the amount of time the manager devotes to overseeing the manufacture of the good in question. Moreover, one may prefer to think of x much more generally as managerial talent or as any scarce specialized input, or as organizational capital, or indeed as any other factor that is in fixed supply, at least in the short run.

An example will show how slack managerial resources can cause the firm to diversify. Suppose that the manager has one unit of time at his disposal, so that $x \leq 1$. The notion of "slack" in the firm's employment of the scarce specialized input can be captured by assuming that the returns to the managerial input diminish sharply beyond some point. Figure 1 plots the case in which for schedule A the marginal product of managerial time is zero for $x \neq 1/2$. That is, it takes exactly half of the manager's time to run a product. As the figure shows, $f(x, k, \ell) = f(1/2, k, \ell)$ for all $x \geq 1/2$. If the firm were to make two products and devote $x = 1/2$ to each product, its revenue would be $2f(1/2, k, \ell) = 2f(1, k, \ell) > f(1, 2k, 2\ell)$, because f is concave in (k, ℓ). Therefore, the firm will get more revenue if it allocates its labor and capital

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[49] As analyzed by Calvo and Wellisz (1978) and, in a dynamic context, by Gifford (1992).

[50] As analyzed by Radner and Van Zandt (1992).

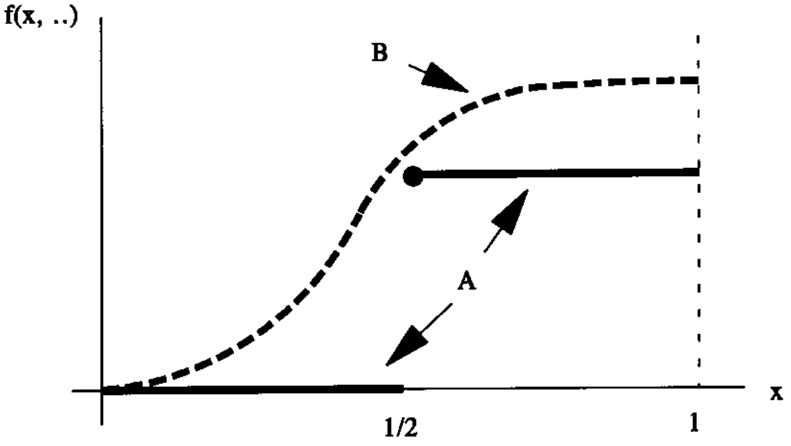

Figure 1: Diversification based on slack managerial input.

equally to making two goods rather than one. And since its costs are the same under the two scenarios, it is better off making two goods. If the discontinuity in schedule A were at the point 1/3 rather than at 1/2, the firm would make three products, not two, and so on. Of course the world is not as dramatic as schedule A depicts it to be. The model below will assume something like schedule B which is less dramatic, but which has the same basic shape so that the firm will have an incentive to diversify, but to a limited extent only.

The production function f is the same for each good that the firm may want to produce, and it may choose to produce several. Let n be the number of products that a firm makes. The firm will produce the same amount of each good, and use the same quantity of inputs on the production of each.

The owner of the firm manages it himself. He can not augment the managerial time input by hiring it from outside.[51] He has one unit of time at his disposal, and he spends it all on production:

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[51] One could let the owner hire managers and add layers of management as discussed by Beckman (1977) but this would not alter our conclusions so long as the process involved some loss of control.

$$x = \frac{1}{n} .$$

Because the production function for each product is the same, and because all products sell at the same price, normalized at one, the firm's revenue is

$$nf\left(\frac{1}{n}, k, \ell\right) .$$

Now let $F(\hat{k}, \hat{\ell})$ be the firm's revenue if it hires a total quantity of inputs $\hat{k}$ and $\hat{\ell}$ and uses them to produce the optimal number of goods. Since its costs do not depend on n once $\hat{k}$ and $\hat{\ell}$ are given, the firm will choose n so as to maximize its revenue, and so

$$F(\hat{k}, \hat{\ell}) = \max_{n} \left\{ nf\left(\frac{1}{n}, \frac{\hat{k}}{n}, \frac{\hat{\ell}}{n}\right) \right\} .$$

Now imagine an economy with L identical agents each of whom has a unit of labor, and an economy-wide capital stock K. This is Lucas's setup, but with identical agents and multiproduct firms.

Let w be the wage and r the rental on capital. (Any of the v final goods can act as numeraire because each will sell at the same price). Each agent can either run his own firm, or work for someone else. In equilibrium, entrepreneurial income must equal the wage:

$$\max_{k,\,\ell} \left\{ F(\hat{k},\ \hat{\ell}) - r\hat{k} - w\hat{\ell} \right\} = w\ . \tag{1}$$

Optimal employment of factors means that their marginal products must equal their prices:

$$F_k = r\ , \qquad \text{and} \qquad F_\ell = w\ .$$

Let m be the number of managers so that the capital stock per manager is K/m, and the number of workers per manager is (L - m)/m. Thus in equilibrium, condition (1) reads

$$F\left(\frac{K}{m},\ \frac{L-m}{m}\right) - \frac{K}{m}F_k\left(\frac{K}{m},\ \frac{L-m}{m}\right) - \left(\frac{L-m}{m}\right)F_\ell\left(\frac{K}{m},\ \frac{L-m}{m}\right) = F_\ell\left(\frac{K}{m},\ \frac{L-m}{m}\right).$$

Rearrangement and cancellation lead to

$$F\left(\frac{K}{m},\ \frac{L}{m} - 1\right) - \frac{K}{m}F_k\left(\frac{K}{m},\ \frac{L}{m} - 1\right) - \frac{L}{m}F_\ell\left(\frac{K}{m},\ \frac{L}{m} - 1\right) = 0\ . \tag{2}$$

This condition yields the equilibrium number of managers m, conditional on the economy-wide endowment of capital and labor. Moreover, equilibrium maximizes the value of aggregate output, in the sense that m solves the problem

$$\max_{m} \left\{ mF\left(\frac{K}{m}, \frac{L - m}{m} \right) \right\}$$

subject to $0 \leq m \leq L$. This is the value of GNP when every good receives the same weight of unity. The output of all products combined is mnq, and since there are v products in the economy, the aggregate output of each product is mnq/v.

We now turn to the time-series behavior of firm size as measured by employment per firm, $(L - m)/m$, and the time series behavior of diversification. First, Hicks-neutral technical change leaves m unchanged and therefore does not affect employment per firm:

Proposition 1 (Hicks-neutral technical change): Let $\lambda f(x, k, \ell)$ be the production function for each product. Then neither m nor n depend on λ, whereas r and w are proportional to λ.

The assertion is true because in eq. (1), F, r and w are all scaled up by the same factor λ, so that the firm's factor demands are unchanged. And since (2) continues to hold, the value of m is unchanged as well. Thus Hicks-neutral change affects relative prices but not equilibrium activity.

This result should be interpreted with care; it holds in a static world and in a closed economy. In a dynamic world, even Hicks-neutral change could affect accumulation of capital. And in an open economy, if other economies did not experience the same shift in production functions, there would be an inflow of resources (K is probably more mobile internationally than L) and that could change factor proportions. While some results that follow do deal with the case of changing factor proportions, the treatment of dynamic and possibly open economies would take us too far from the central theme of this paper.

Second, the past hundred years have seen a rise in the U.S. capital-labor ratio, and in our model this is represented by a secular rise in K/L. While sales per firm have increased over time, so has employment per firm, and the latter does not follow from Hicks-neutral technical change alone. Moreover, proportional increases in capital and labor also will not affect factor employment per firm:

Proposition 2 (Proportional factor accumulation): Let λK and λL be the exogenous factor supplies. Then n, w and r do not depend on λ, and m is proportional to λ.

This assertion holds because an unchanged w and r leave the firm's problem in (1) unchanged, and as a result n is also unchanged. Finally, because m is proportional to λ, K/m and L/m do not depend on λ, and so equation (2) continues to hold.

In the U.S., however, over the past century, the capital stock has increased faster than the supply of labor. The 1909-57 period saw a tremendous growth in employment per firm and in diversification (see section 3A). During this period, the U.S. capital stock grew at 2.4% while hours worked grew by only 1.3%, so that K/L grew.[52] If we think of L not as the economy's stock of raw labor but as the number of efficiency units of labor, then we should adjust for the growth of education per labor force member, which Denison estimates grew by 0.9% over the same period. This means that the stock of

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[52] Denison (1961).

efficiency units of labor grew by 2.2% -- still less than the growth in K.[53] I will now show that employment per firm can rise in response to an increase in the economywide capital-labor ratio. This is a result that Lucas (1978) also proves in a different setting.

Proposition 3 (Increase in K): If the elasticity of substitution between capital and labor is less than one, an increase in the economy's stock of capital, K, will raise employment per firm by lowering m.

To show the validity of this statement, we first differentiate (2) with respect to K to obtain

$$\frac{dm}{dK} = \frac{m(KF_{kk} + LF_{k\ell})}{K^2F_{kk} + 2KLF_{k\ell} + L^2F_{\ell\ell}} < 0 \, . \tag{3}$$

The denominator is positive from the second order conditions that guarantee an interior solution to the problem in equation (1). Lucas was dealing with a production function that was a concave transformation of a linearly homogeneous production function. Linear homogeneity of F would imply that the numerator in (3) is zero, and hence that $dm/dK = 0$,[54] but the concave transform renders the numerator and hence dm/dK negative. The intuition for the result is that when labor and capital are not too substitutable, the increase in the economy's capital stock raises wages more than it raises managerial returns and therefore

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[53] Dennison's (1985) estimates for the later period 1929-1982 also show a rise in K/L, again even after allowing for the growth of labor skills.

[54] If F is linearly homogeneous, F_k is homogeneous of degree zero, and this implies the assertion.

causes an increase in the number of wage-workers, and an increase in firm size.

A corollary of propositions 2 and 3 is that an increase in labor supply, if unaccompanied by a corresponding increase in the capital stock, will lower employment per firm! Moreover, in the U.S. and elsewere, per capita income has increased not only because K/L has gone up, but also because of technical change, which Solow and many others have taken to be Hicks-neutral in nature. So, to test the theory directly, one must relate employment per firm to measures of K/L, and not to income per capita, because the latter includes Hicks-neutral change in technology.

Figure 2 displays the behavior over time of the key variables. In the figure, K is the gross private nonresidential capital stock and L is the labor force excluding government workers. These stand for the endowments if capital and labor. The variable Y stands for GNP and I is gross private domestic investment. To measure the number of firms, m, I use the longest available time series, which is the number of concerns. Since this measure exludes railways and the agricultural, finance, insurance and real estate sectors, the number of <u>concern</u> workers, labelled L^* in the figure, excludes workers in these sectors.[55]

The figure shows that the capital-labor ratio indeed does track firm size fairly closely. The second world war years look quite different, first because many small businesses shut down as their owner-operators joined the armed forces, and second because resources were shifted to the manufacture of ships, aircraft, tanks, weapons, and other items typically made by large firms. For both reasons, employment per firm went up dramatically. After the war ended, it took a couple

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[55] My variable L^*/m is the same as the concern size measure described in table 2 of Lucas (1978). The way in which these sources were updated and the exact calculation of each variable is described in Appendix 1.

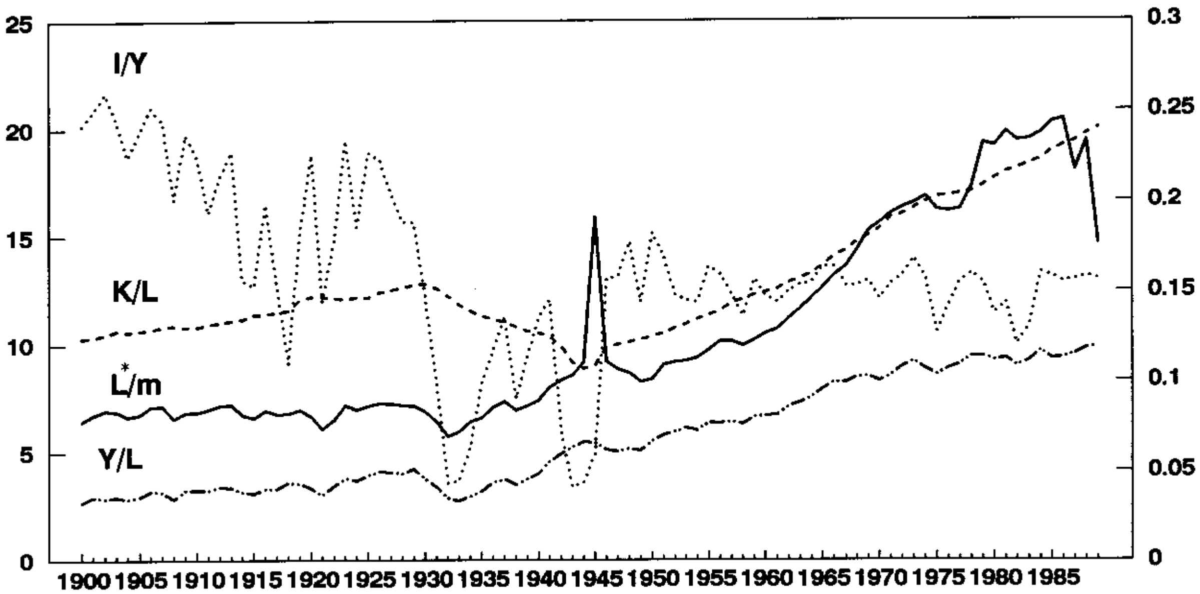

Figure 2: The Time Series Behavior of Firm Size and of Some Aggregates.

Note: The L^*/m scale is on the left axis and the I/Y scale is on the right axis. The variables K/L and Y/L were scaled to fit on the same figure.

Table 1: Dependent Variable: log of Employment per Concern (L^*/m).

	(1)	(2)	(3)	(4)
Constant	11.65 (16.32)	-2.24 (1.79)	4.6 (8.3)	0.63 (0.63)
ln (K/L)	2.11 (13.14)	--	0.82 (7.38)	--
ln K	--	0.68 (4.40)	--	0.57 (5.26)
ln L	--	0.00 (0.01)	--	-0.27 (1.87)
ln (I/Y)	--	--	0.34 (16.28)	0.24 (9.28)
R^2	.689	.889	.930	.948
n	80	80	80	80

Note: t values in parentheses.

of years for things to get back to normal. By proposition 2, the ratio L/m is homogeneous of degree zero in K and L, and so it must depend only on the ratio K/L. And by proposition 3 the ratio L^*/m should be increasing in K/L. I shall now test these propositions by regressing L^*/m first on the log of the ratio K/L and then on the logs of K and L separately, and test the restriction that their coefficients be equal and opposite in sign. The sample range was 1900-89, but because of the extraordinary wartime patterns, the years 1939-48 were omitted. Using the remaining eighty annual observations, ordinary least squares produced the estimates summarized in table 1.

Column (1) of table 1 shows that K/L is positive and significant, as it should be. But column (2) shows that contrary to the theory, L fails to be significantly negative. An F-test rejects the restriction that the coefficients of $\log K$ and $\log L$ are equal and opposite in sign, at the 99% significance level.

The likely reason why $\ln L$ fails to come in with a significant negative coefficient in column (2) is probably the cyclical correlation between the two variables induced by fixed costs of entry and exit into running a firm. Labor productivity, Y/L, and the labor force are both procyclical -- they tend to move together with aggregate output. And, as figure 2 shows, firm size is also procyclical: This is because most of the cyclical adjustment in output occurs through changes in firm size and not through changes in the number of firms, since fixed costs of entry and exit make it unprofitable to switch to and from running a firm in response to transitory, cyclical events. Presumably it is permanent changes in demand that bring about entry and exit in the market for a given product. Temporary changes (if correctly perceived as such) should be accomodated mainly by incumbents.[56] During booms the labor force usually expands (whereas in the model it is fixed at L) and because the fixed costs of starting a firm exceed the fixed costs of getting a job, most of the added labor market participants end up as workers, and not as managers. This cyclical correlation between the labor force and firm size clearly should not be taken as evidence against this static model which is not meant to capture such cyclical patterns. Moreover, the procyclicality of mergers and takeovers is another reason why employment per firm is procyclical, and this too is an effect that this model of long-run behavior is not designed to explain. To deal with the cyclical issue, the next two regressions, described in columns (3) and (4) of table 1, include a cyclical variable -- the logarithm of the investment to GNP ratio. This variable clearly captures the cyclical effect on L/m and the coefficient of $\ln L$ now has the correct sign, although an F test still rejects the "equal but opposite in sign" restriction at the 99% level.

Although the data formally reject the restrictions of the model, it seems broadly consistent with the facts, and so it is natural to ask if the increase in K/L evident in figure 2 could also have caused diversification to go up. To keep things simple, I will analyze this question under the added assumption that better management (in our case a larger x) lowers costs by the same percentage at all levels of output:[57]

Separable Management Input. Assume that the management input enters multiplicatively in the production function of each good:

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[56] Lucas (1978, p. 509) discusses this. Boeri and Cramer (1992) find support for this view in a sample of German firms.

[57] Lucas (1978, p. 511) also assumes this.

$$f(x, k, \ell) = h(x)\phi(k, \ell) .$$

Let ϕ be increasing and strictly concave, and let h be increasing, with $h(0) = 0$, and convex near the origin; if it were concave, the owner would want to expand endlessly on the extensive margin as there would be asymptotically increasing returns to variety in production.[58]

As x increases towards unity, we want h to become convex, otherwise the owner would want to run a single-product firm. Thus we envisage $h(x)$ to be like schedule B in figure 1, in which case the average product of the owner's time looks as drawn in figure 3.

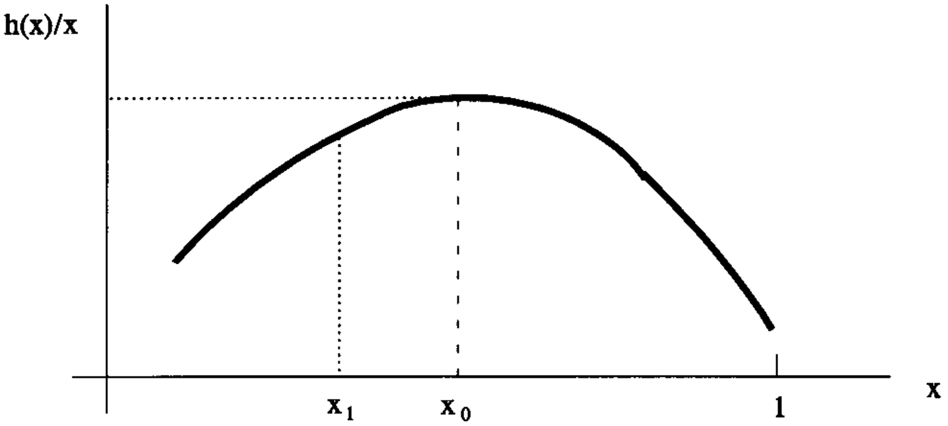

Figure 3: The Average Product of Managerial Time.

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[58] This is because

$$h\left(\frac{1}{2n}\right) > \frac{1}{2}h(0) + \frac{1}{2}h\left(\frac{1}{n}\right) = \frac{1}{2}h\left(\frac{1}{n}\right) ,$$

hence $2h(1/2n) > h(1/n)$, and if the owner was making a profit on each of n products, he could make a bigger one by making $2n$ products using half the scale of inputs of k and ℓ on each one. See the discussion of figure 1.

At first it might look like, the integer problem aside, the manager would want to produce $1/x_0$ goods, thereby maximizing the average product of his time. But this ignores the fact that he is earning positive profits on each brand and therefore has an incentive to produce more brands. Thus, he will choose a point like x_1, where h' is positive. And since x_1 is in the region between 0 and x_0 where h is convex, this means that $h''(x_1)$ is positive. Now let us analyze all this a little more formally.

Let $\pi(n)$ be the entrepreneur's net revenue per product:

$$\pi(n) = \max_{k,\ell} \left\{ h\left(\frac{1}{n}\right) \phi(k, \ell) - rk - w\ell \right\} .$$

Indifference between management and wage work means that

$$n\pi(n) = w . \tag{4}$$

It is convenient to let n take on all real values; an interior optimum for n then satisfies

$$\pi(n) + n\pi'(n) = 0 ,$$

or, in view of (3), that

$$w = - n^2 \pi'(n) . \tag{5}$$

But $\pi'(n) = -h'(1/n)\phi/n^2$. Since π' is negative, this means that h' is indeed positive at the optimum, as claimed in the discussion of figure 3. Optimal choice of labor input implies $w = h\phi_\ell$. Since equilibrium factor employment per product is K/mn and $L/mn - 1/n$, condition (5) becomes

$$\frac{h'(x)}{h(x)} = \frac{\phi_\ell\left(\frac{xK}{m}, \frac{xL}{m} - x\right)}{\phi\left(\frac{xK}{m}, \frac{xL}{m} - x\right)} , \tag{6}$$

where $x = 1/n$.

Figure 4 shows the two sides of equation (6) plotted against x. In the region where h is convex, h'/h increases and thereafter it declines. From the discussion of figure 3 we know that the curves must intersect on the rising portion of the h'/h curve.

Before plotting ϕ_ℓ/ϕ, we specialize things a bit more. Assume with Lucas[59] that $\phi(\ell, k) = \psi[\xi(\ell, k)]$, that ξ is homogeneous of degree one, and that ψ is an increasing concave function with $\psi(0) = 0$. Then

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[59] Lucas (1978, p. 511).

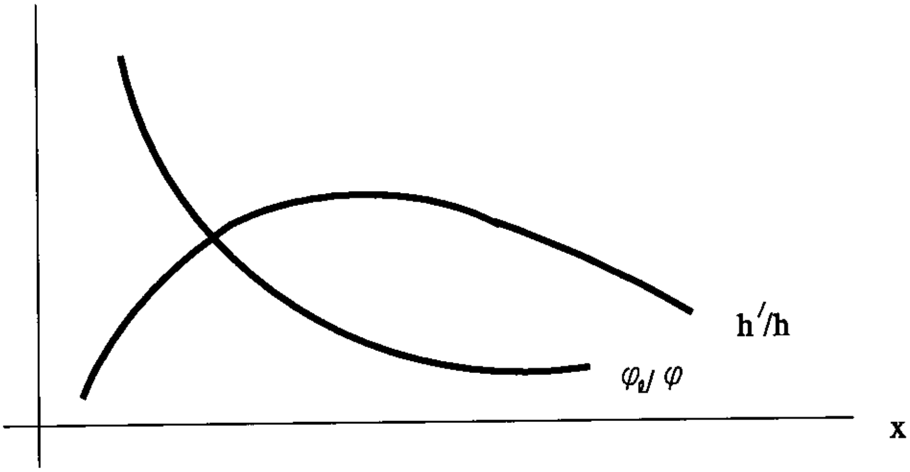

Figure 4: The Determination of x.

$$\frac{\phi_\ell}{\phi} = \left(\frac{\psi'}{\psi}\right)\xi_\ell \; . \qquad (7)$$

Since ξ is linearly homogeneous, ξ_ℓ is homogeneous of degree zero -- it depends only on the capital-labor ratio. The capital-labor ratio is K/(L - m) and it does not depend on x. As x rises, xK/m and xL/m - x both increase (because L/m > 1), which means that ξ goes up and therefore $\psi'(\xi)/\psi(\xi)$ goes down. Therefore ϕ_ℓ/ϕ declines with x, and the situation must be as depicted in figure 4.

Now let us show that under some further conditions, diversification increases with an exogenous increase in K. That is, that x declines when K goes up. The increase in K will lead to a resulting decrease in m (see eq. 3), but since h'/h depends neither on K nor on m, it does not shift.

Now there are two possibilities: the capital-labor ratio

$$\frac{k}{\ell} = \frac{K}{L - m}$$

will either rise or fall. First, take the case in which it falls. This happens if the negative response of m to a rise in K (given by 3) is sufficiently strong. In this case ξ_ℓ (being dependent only on the capital-labor ratio), falls since the capital-labor ratio has fallen. And the rise in both xK/m and $(xL - x)/m$ for all x means that ξ is higher for all x. Therefore ϕ_ℓ/ϕ shifts down for all x, and so diversification increases.

The second possibility is that k/ℓ goes up. This is the more likely case when the elasticity of substitution in ξ is close to (but still less than) 1, because then the induced change in m is small. Since $\xi_{\ell\ell} < 0$ and $d\ell/dK \geq 0$,

$$\frac{d}{dK}\left(\frac{\psi_\ell}{\psi}\right) < \left[\left(\frac{\psi'}{\psi}\right)\xi_{\ell k} + \xi_\ell \xi_k \frac{d}{d\xi}\frac{\psi'(\xi)}{\psi(\xi)}\right]\frac{dk}{dK} \quad .$$

The right-hand side of this expression is negative if

$$\frac{d \log(\psi'/\psi)}{d\xi} \leq \frac{-\xi_{\ell k}}{\xi_\ell \xi_k} , \tag{8}$$

That is, if returns to scale (which depend inversely on the curvature of ψ) diminish fast enough. For the CES production function

$$\xi(\ell, k) = (\alpha k^{\rho} + (1 - \alpha)\ell^{\rho})^{\frac{1}{\rho}}$$

(which since $\sigma = 1/(1 - \rho)$ must have $\rho < 0$ for (3) to hold), the right-hand side of eq. (8) reads $-1/\sigma\xi$, so that (8) requires that

$$\frac{d \log(\psi'/\psi)}{d \log\xi} \leq -\frac{1}{\sigma} . \tag{9}$$

Condition (9) is sufficient, not necessary. Since the left-hand side is equal to $-R - \xi\psi'/\psi$ where $R \equiv -\xi\psi''/\psi'$ is the Arrow-Pratt[60] coefficient of relative risk aversion, equation (10) is equivalent to

$$R \geq \frac{1}{\sigma} - \frac{\xi\psi'}{\psi} . \tag{10}$$

Since $\psi' > 0$, condition (9) will be met if ψ has an Arrow-Pratt coefficient of relative risk-aversion exceeding $1/\sigma$, but this too is not a necessary condition. We have thus derived the following proposition:

<u>Proposition 4 (Diversification and the K/L ratio)</u>: If $f(x, k, \ell) = h(x)\psi[\xi(\ell, k)]$ with ψ strictly concave, and with ξ being CES in form, and if ψ has an Arrow-Pratt coefficient of relative risk-aversion exceeding $1/\sigma$, then an increase in K/L increases firms' diversification.

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[60] Pratt (1964).

This proposition says that the number of products made by the firm will increase if the span of control falls off rapidly enough with the scale of each product. This ensures that the increased output per firm is not transformed into just more output of each product rather than into more products.

Taken together, propositions 3 and 4 say that the trend towards bigness of firms and towards their greater diversification of production could have a common cause: the secular growth in the U.S. capital-labor ratio. If the elasticity of substitution is less than one, this induces a relative reduction of managerial resources, and increases both the number of workers _and_ the number of products that each manager oversees.

Management innovations. An innovation that helps a manager do his job better will generally affect employment per firm and the level of diversification. The past century has seen innovations in book-keeping methods, communication, transportation, and computation, all of which must have raised the effectiveness of managers. But the effect of these innovations on the size and scope of firms is ambiguous. To see why, let λ_1 be an index of managerial input-augmenting technology in _scope_, and λ_2 an index of managerial-augmenting technology in _scale_. With our separability assumptions this means that

$$f(x, k, \ell) = h(\lambda_1 x)\psi[\lambda_2 \xi(k, \ell)] .$$

Equations (6) and (7) then imply that

$$\frac{\lambda_1}{\lambda_2}\frac{h'(\lambda_1 x)}{h(\lambda_1 x)} = \xi_\ell(k,\ell)\frac{\psi'(\lambda_2\xi(k,\ell))}{\psi(\lambda_2\xi(k,\ell))} \quad .$$

Depending on exactly how managerial innovation alters λ_1 and λ_2, any outcome is possible. Indeed, even if they change in the same proporition so that λ_1/λ_2 stays the same, more assumptions are needed on h and ψ. This is because managerial innovation raises the output and the marginal product of capital and raw labor as well as that of management, and the effect on firms' scope and size is uncertain. So while there is no doubt that innovations in communication and transportation have raised managers' productivity, one must assume more about what managers do before one can say much about this question.[61]

Growth in product variety. The past century has also seen a proliferation in the number of goods produced in the aggregate, and it seems natural that this trend should be related to the concurrent rise in diversification. In this model, however, the answer is "no". The parameter v stands for the number of products in the economy, and yet it enters none of the equations. Exogenous changes in the economy-wide extent of product variety therefore have no effect on how diversified the average firm is. Since this implication may at first seem odd, but as noted in the discussion preceeding proposition 1, the aggregate output of each product is mnq/v. Since m, n, and q do not depend on v, it follows that the output of each variety is inversely proportional to the number of varieties, and that the value of GNP, mnq, also does not depend on v.

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[61] The model also lacks any costs of using the market: The firm sell its output and hires factors at exogenous prices. Brynjolfsson et al (1991) argue that recent advances in information technology have made market-based coordination cheaper relative to internal coordination and have partially caused the recent decline in firm size and diversification.

A change in v may be thought of as a demand shift away from each good and towards all other goods. The resulting decrease in output of each variety is acheived entirely by a fall in the number of producers of each good, and not at all in the reduction in output per producer. That is, some of the good's suppliers exit, while those that remain do not change their output. In this respect, the model's implications coincide with those of Viner's U-shaped average cost model.

Taxes. Could some of the growth of employment per firm be due to changes in taxes? In other words, has the tax-treatment of wage-workers improved over time relative to that of firm-owners? The answer is no. Before 1917, corporate income was taxed but personal income was not. Since then, income taxes have gone up faster than corporate taxes. As a result, executive compensation has shifted away from salary and towards ownership income, and an increasing number of doctors, lawyers and dentists have reduced their effective taxes by incorporating. By 1960, large manufacturing company executives earned nearly three times as much from dividends, capital gains and stock compensation as they did from salaries.[62] So, firms have become less numerous relative to workers in spite of the fact that their relative tax treatment has been improving.

What, then, are the factors that could have caused the secular increase in firms' diversification and employment? According to the model, neither Hicks-neutral technical change, nor increases in population, nor the secular increase in product variety in the economy at large, nor changes in taxes are responsible.

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[62] Lewellen (1971, pp. 152-4). King (1977, pp. 112-115) analyzes the incorporation decision when there are various forms of taxation.

Rather, it is the increase in the capital-labor ratio that is likely to have been a major cause. Also, changes in the technology of managing may have played a role.

Before moving on, one should note that the mathematics in this section can also be interpreted as describing a single good economy in which n is the number of plants the firm uses to produce its product. If one added geographical space and transportation costs that increased with the distance between a supplier and his customers, one could use the model to analyze the geographical diversification of firms which also has increased in recent times (witness the growth of multinational companies).

As it stands, the model can not explain the cross section phenomena described in section 3 since in the model all firms are equally diversified. To address differences among firms, the next section adds heterogeneity in management skills to the model.

5. R&D Spillovers Among Products: A Model of the Cross-Section Evidence.

The strongest piece of cross-sectional evidence, summarized in section 3E, is the positive relation between R&D intensity on the one hand, and diversification on the other. This relation is stronger than the one between R&D intensity and firm size. The following model is designed to be consistent with both relations. To keep things simple, I shall now omit the capital input as it is inessential to what follows.

The production function for a good is

$$q = f(x, \ell, y, \theta) .$$

Here once again x is the managerial input, ℓ is the input of labor into the production process, and θ is a characteristic that differs over managers. Output also depends on knowledge, y, specific to producing the good in question.

Production of knowledge y uses only labor, called researchers. Researchers work on specific goods. Let z be the number of researchers working on the product in question, and let z' be the number at work on each of the other products that the firm makes. Since a team of researchers may invent things that are useful to other teams of researchers, the knowledge k relevant to making a product depends not only on the number of researchers z working on that product, but also on the number z' working on each other product:

$$y = g(z, z', n; \theta) .$$

To simplify, managerial time is now excluded from g, and instead, the firm owner's endowment of managerial talent, θ, affects production. Note that z' pertains to the size of research teams on products made by the firm, not to the extent of research in other firms. Thus there are no spillovers of knowledge among firms. Such spillovers would not change the model's positive implications. These require only that spillovers of knowledge among products within the firm exceed spillovers of knowledge among products across firms. This would preserve the incentive to diversify. If spillovers across firms were the same as spillovers within firms, no firms would diversify because it would be incurring organizational costs with no compensating benefit in the form of additional spillovers of knowledge. On the other hand, with spillovers of knowledge among firms, the competitive equilbrium would no longer maximize aggregate output.

The output of a firm's R&D effort can be used only by the firm itself.

There is no market for information. If there were, the spillover-capture motive for diversification would disappear. Rather than incur the span of control diseconomies, the firm could simply buy the necessary information. On these grounds, the motive to diversify for R&D reasons should be stronger in industries whose innovations are not readily patented: in such industries, the sale of new knowledge may require a disclosure of information such as to make it unnecessary for the would be purchaser to pay for the new knowledge.

Since g is the same for every product that the firm produces, the manager will choose research teams to be equal in size. As supplies of labor (research or other), people are perfect substitutes, so that researchers and production workers will sell their labor at the same price. Call this price the wage, w, denominated in units of output. The profit of a firm owned and run by a type θ individual is

$$\pi(\theta, w) \equiv \max_{n, \ell, z} \left\{ nf\left(\frac{1}{n}, \ell, g(z,z,n;\theta); \theta\right) - nw(\ell + z) \right\}.$$

The price of each product is normalized at unity. The entrepreneur is a price taker -- a negligible supplier in each product market that he chooses to enter. This assumption is important for the welfare implications of the model, but not for most of its positive implications that I shall focus on here.

To deter the manager from wanting to monopolize any product, assume decreasing returns to scale in the hired inputs ℓ and z. That is, for each (n, θ) pair, we ask that the function $f(1/n, \ell, g(z, z, n; \theta); \theta)$ be concave in (ℓ, z).[63]

Let $\ell(\theta, w)$ and $z(\theta, w)$ denote his optimal employment of workers and researchers <u>per product</u>, and let $n(\theta, w)$ be his choice of diversification -- the number of products that his firm makes.

The extent of product variety in the economy is exogenous. Spence, Dixit, and Stiglitz have analyzed how the number of products in an economy gets determined, and the relationship between the equilibrium number of products and their socially optimal number. Here the number of products is fixed, and anyone that wants to enter any product market can costlessly access the technology described by f and g. The fixity in the number of all products means, however, that the R&D in this model yields <u>process</u> inventions rather than new products. More generally, this model can not capture R&D that aims to differentiate products.

People are all equally productive as workers and they all are equally productive as researchers, but they differ in their managerial skills. Let $H(\theta)$ be the population distribution of the vector θ. That is, $H(\theta)$ is the number of people with managerial talent not exceeding θ. A person can either manage a firm, or work for someone else. Let $A(w)$ be the set of people who prefer management to wage work. This set will depend on the wage w since the attractiveness of wage work relative to management increases with the wage. Then

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[63] Arrow (1962), Radner (1970), and Wilson (1975) emphasize that a piece of information can be used on any scale. A more appropriate way to model the production process may then be $f(x, \ell, y; \theta) = \phi(x, y; \theta)\ell$, so that x, y and θ all affect the productivity of the variable factor. This would be in the spirit of Beckman's (1977) formulation. The problem with doing this is that if the constraint on x and n, is $x = 1/n$, this setup has increasing returns to ℓ and z (once one recognizes that y is increasing in z). This could, however, be reconciled with competition if the constraint were changed to, say, $x = 1/\ell n$ -- a constraint that makes sense if management needs were to rise in proportion to total labor employed, as Beckman assumes. Information-based theories of the Radner and Van Zandt (1991) type may shed light on the appropriate assumptions on f. I shall nevertheless proceed with the model as set out above.

$$A(w) = \{\theta \mid \pi(\theta, w) > w\}$$

is the set of vectors θ that yield their owners a payoff strictly higher as managers than as workers. The number of firms will then equal the number of people whose characteristics are in this set.

If everyone chooses his preferred option, the supply of labor will be the number of people with θ's in the set $\sim A(w)$, (the complement of the set $A(w)$). Labor demand will thus equal labor supply if

$$\int_{A(w)} n(\theta, w)\,[\ell(\theta,w) + z(\theta,w)]\,dH(\theta) = \int_{\sim A(w)} dH(\theta)\ .$$

The left-hand side is the demand for labor, and the right-hand side is its supply. The strict concavity of f in ℓ and z implies that labor demand slopes down. Because π is decreasing in w, the set $\sim A(w)$ grows as w increases, and so labor supply slopes up. Therefore, a unique equilibrium wage exists.

Because knowledge is assumed not to spill over from firm to firm, one could also show that this equilibrium, like the one in section 4, yields the maximal output, and hence is Pareto optimal. It is optimal under the constraint that people running firms can not share their knowledge. This constraint is a natural one to impose given that the noncooperative situation does not offer entrepreneurs the chance to share information.

For more diversified firms to be bigger, it is enough that n, x and w

all move in the same direction in response to changes in θ. But this will not also guarantee that diversified firms are more R&D-intensive. One could derive general conditions on f, g and H sufficient for the second proposition to hold, but these conditions are complex, and they mean little unless θ itself stands for something specific. Therefore I now specialize things a bit. First, consider again the case where the management input x enters separably:

$$f(x, \ell, y, \theta) = h(x)\ell^{\beta}y^{\gamma} ,$$

an often used formulation.[64] The parameters of h, along with β and γ, should be thought of as components of the vector θ, and so should λ and the parameters of G defined below. So, managers can differ in several dimensions. The function $h(x)$ has the same interpretation here as it did in section 4. Second, let

$$y = g(z, z', n, \theta) = \lambda z + G(n)z' .$$

The parameter λ measures the response of product-specific knowledge to the employment of researchers working on the product itself; $G(n)$ measures its response to employing researchers on each other product that the firm makes, and of course there are $(n - 1)$ other products. This assumption on g resembles what Spence assumes about spillovers across firms all of whom make the same product.[65] At any rate, if $G(n) = 0$, there are no spillovers, and there is no incentive to diversify. Our hypothesis is that diversification enables the

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[64] See Griliches (1979, p. 95).

[65] Spence (1984) chooses units of z so that λ is unity. Then he focuses on the ratio $G(n)/\lambda$ as an index of knowledge spillover among firms. If $G(n) = \lambda$, the R&D input is fully shareable.

capture of spillovers, so that $G(n)$ is an increasing function of n.

Substituting for k into f and noting that $x = 1/n$ implies that

$$q = \Phi(n)\ell^{\beta}z^{\gamma} ,$$

where $\Phi(n) = h(1/n)[\lambda + G(n)]^{\gamma}$. The manager maximizes the firm's profits:

$$\phi(n)\ell^{\beta}z^{\gamma} - nw(\ell + z) ,$$

where $\phi(n) = n\Phi(n)$. We assume that ϕ is increasing in n, at least for low values of n. The first-order condition for a maximum with respect to n is

$$\phi'(n)\ell^{\beta}z^{\gamma} - w(\ell + z) = 0 .$$

The second order condition for a maximum over n is $\phi'' < 0$. Since $q = n^{-1}\phi(n)\ell^{\beta}z^{\gamma}$, the first order condition reads

$$n \frac{\phi'(n)}{\phi(n)} q - w(\ell + z) = 0 .$$

Now $w(\ell + z)$ is total labor cost, and in view of the Cobb-Douglas form, it equals $(\beta + \gamma)q$, because labor's share in output is $\beta + \gamma$. Thus the first-order condition becomes

$$\epsilon_{\phi n} = \beta + \gamma \tag{11}$$

where $\epsilon_{\phi n} = n\phi'/\phi$ is the elasticity of ϕ with respect to n.

The effect on n of variations in γ is of special interest because γ is the share of R&D in output, a quantity that section 3E says is strongly related to diversification. To get cross sectional variation in firms' R&D intensities, it suffices to assume that γ is a component of the vector θ of person specific managerial attributes. Eq. (11) implies the following:

Proposition 5 (Diversification and R&D intensity): if $\epsilon_{\phi n}$ increases with n, then both high β and high γ firms will be more diversified.

The elasticity $\epsilon_{\phi n}$ will increase with n if the marginal benefits to diversification do not fall off too rapidly. Explicitly,

$$\epsilon_{\phi n} = 1 - \frac{h'(1/n)}{nh(1/n)} + nG'(n)\gamma[\lambda + G(n)]^{\gamma-2} . \tag{12}$$

Now $-h'/nh = -xh'(x)/h(x)$, and this term decreases with x if $h'' > 0$ and $xh'(x) < h$, and the latter inequalities follow from figure 4 and its discussion. Therefore the term $-h'/nh$ increases in n. The last term on the right-hand side of (12) can either increase or decrease in n, and it will decrease rapidly if G' decreases rapidly. On the other hand if G is convex, it can cause the second term to increase as well. It may at first have appeared that Proposition 5 should follow more easily. The reason for the added conditions, however, is that a higher γ also raises the manager's incentive to produce more of each product, that is, to raise scale rather than diversification.

Proposition 5 bears on the evidence described in section 3D. But what about the evidence in section 3C that larger firms are more diversified? The model is consistent with this fact if the dominant source of variation in entreprenuerial ability is variation in how to use knowledge productively -- i.e. variation in the parameter γ. High γ types will run more R&D intensive firms. They will also have larger sales. A corrolary therefore is the following:

<u>Proposition 6 (Diversification and sales)</u>: if γ is the dominant source of variation in θ in the population of entrepreneurs, diversification will be positively related to sales.

If we think of γ as varying not over people but over sectors then this proposition says that R&D intensive sectors should have larger firms in them, which is certainly true since the R&D-sales relation holds whether or not one controls for sector. The conditions of Proposition 6 describe just one way in which bigger firms will be more diversified; there are other, more natural ways. For example, some people may be better coordinators, and this would show up formally as variation over entrepreneurs in the form of the function h. Such variation could show up as variation in the parameter λ_1 introduced at the end of the previous section. To derive a version of Proposition 6 involving λ_1, however, would demand further assumptions. Instead of pursuing this line, I will use what remains of this section to arrive at a rough estimate of the R&D-based

efficiencies associated with diversification.[66]

Estimating the Relation Between Diversification and Spillovers.

Here I will use an empirical result of Scherer's to show how one might begin to calculate efficiency gains due to the shared nature of the R&D input. I shall interpret the exercise as yielding an estimate of the role of diversification in creating spillovers, although I shall later mention other interpretations too. Efficiency gains from greater R&D spillovers depend on the response of $G(n)$ to increases in n. I will interpret an estimate that Scherer got some time ago in the context of the model of this section. Then I will estimate some other interpretations and problems of estimation.

Scherer's finding is best described in his own words:

> "Diversification appears to be unambiguously stimulative to patenting. The estimated coefficients suggest that a unit increase in the numbers equivalent diversification index, which would be a 16 percent increase over the mean level of diversification, is accompanied by a 3 to 9 percent increase in the average patent yield per million dollars of R&D."[67]

Suppose that the number of patents the firm gets, P, is proportional to the firm's knowledge y per product times the number of products n, and let the constant of proportionallity be ρ. Then $P = \rho ny$. Evaluated at $z' = z$, the equation $y = \lambda z + G(n) z'$ implies that

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[66] A further reason to not dwell on the diversification-size relation is that it would hold even in worlds very different from the one modelled here. Suppose, for instance that products were randomly assigned to firms -- that some firms got to produce many products, some only a few. Unless the sales of each product were systematically related to the number of other products that their firm produced, there would be a positive relation between firm size and diversification.

[67] Scherer (1983), p. 123.

$$P = \rho[\lambda + G(n)]Z , \tag{12}$$

where Z $(=nz)$ is the firm's total R&D budget, which Scherer measures in millions of dollars. Thus the average patent yield per million dollars of R&D is $\rho[\lambda + G(n)]$. Now Scherer's measure of diversification is the inverse Herfindahl measure $1/\sum_{j=1}^{n} S_j^2$, where S_j is the share of the firm's sales stemming from the j^{th} product. In the model $S_j = 1/n$ so that this measure equals exactly n. With this in mind, we can reinterpret Scherer's statement as saying that a one percent increase in n is accompanied by a $3/16$ to $9/16$ percent increase in the patent yield. Since the patent yield is $\rho[\lambda + G(n)]$, this implies that

$$\frac{3}{16} \leq \frac{n}{\rho[\lambda + G(n)]} \frac{\partial}{\partial n} [\rho(\lambda + G(n))] \leq \frac{9}{16} ,$$

or that

$$\frac{3}{16} \leq \frac{nG'(n)}{\lambda + G(n)} \leq \frac{9}{16} .$$

Now suppose that R&D done on a another product is μ times as useful as the product's own R&D. Since there are $(n - 1)$ other products, this implies that $G(n) = \mu\lambda(n - 1)$. The size of μ would depend on the closeness of the firm's products in technology space.[68] Our symmetric formulation insists, however,

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[68] Jaffe (1986) measured the technological distance among firms and showed that it mattered in determining the extent of technological spillovers among them. Spence (1984) used the same functional form to study spillovers across firms. He interpreted μ as the fraction of knowledge generated by firm A that leaks to firm B.

that μ be the same for all pairs of products. Since $G' = \lambda\mu$, the parameter λ cancels. Evaluating the ratio at the mean n in Scherer's sample which was 9.65 yields the inequality

$$.025 \leq \mu \leq .12 .$$

This pair of inequalities obtains if for n we use the mean number of products. Now in theory this number should also have equalled the mean value of Scherer's diversification statistic $1/\sum_{j=1}^{n} S_j^2$. In fact, because S_j is generally not equal to $1/n$ for all j, this value had a median of 3. Using this alternative value for n yields the pair of inequalities

$$.07 \leq \mu \leq .30 .$$

The two pairs of inequalities differ because I have used a symmetric product model to fit a situation in which products yield the firm unequal revenues. The second interpretation for n seems the more natural one, but if one weighs the two equally and takes the union of the sets defined by the two pairs of inequalities, one gets

$$.025 \leq \mu \leq .30 .$$

Thus the R&D of a two-product firm is $(1 + \mu)$ times as productive as the R&D of a single product firm, with μ ranging between .025 and .30.

This is a rough estimate and an imprecise one at that. Moreover, it is probably an overestimate for several reasons. First, μ is in fact likely to vary over firms and products, and in those products where it is high, firms will choose a higher value of n, precisely so as to capture the higher spillovers. This means that the equation has a random coefficient, μ, and that the realized μ is possibly related to the value of both regressors, Z and n, and the result will be an upward bias on the estimate of the average μ.

Second, firms do not diversify randomly but rather choose technologically-related products (section 3E), products that are closer in technology space and that presumably have a higher value of μ. So we should think of μ as the spillover between a pair of products chosen at random from the firm's portfolio of products, and not from the population of all products.

Third, there is the possibility of reverse causation from patenting to diversification. Given that appropriability, ease, and effectiveness of patenting varies over sectors,[69] and given that diversification is partially driven by R&D spillovers, it will pay to diversify into those activities where R&D has a payoff in that its output can be protected by patents. Thus, the estimate that I have above attributed to measuring the effect of diversification on productivity of R&D, may in part reflect an effect that appropriability has on diversification.

Last, but foremost, my interpretation is that a given level of R&D input, Z, produces $1 + \mu$ as much knowledge in a two-product firm as it does in a one-product firm. Scherer, however, gives two distinct interpretations for his findings:

"...more diversified enterprises might have higher propensities to

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[69] For evidence on cross-industry variability in patent effectiveness, see Levin et al (1987, table 2).

> patent either because cross-fertilization among diverse industry technologies enhances the fecundity of R&D or because a diversified company is better able to commercialize offbeat inventions and hence is more likely to seek patent protection for them."[70]

His "fecundity" interpretation is the one that I have been using here. But the second says that it is not the total stock of knowledge that goes up with diversification, but rather the desire to patent the knowledge, or the desire to protect the knowledge from being used by others. The second interpretation distinguishes knowledge from commercializeable knowledge. The model would still make sense if we could just redefine y to stand for commercializeable knowledge, but that would deny the reality that a firm can productively use a piece of knowledge that it nevertheless does not wish to patent. If, perhaps because of greater visibility, diversified firms were more likely to be targeted by immitators, this would induce them to patent more. Or, it may simply be that an inventor would not bother to patent an invention if he can use it in just one line of business, but if he can use it in several, he would patent it. To add propensity to patent to the model, one might write $P = \rho(n)ny$, where $\rho(n)$, the constant of proportionality, now increases with n. To distinguish the effect of n on ρ from its effect on G, one needs firms' R&D expenditures broken down by business application. The few studies that use detailed R&D data but not patent data, have found that synergies in R&D are present, and this is independent evidence that G' is positive and increasing in n.[71]

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[70] Scherer (1983), p. 117.

[71] The papers by Cockburn and Henderson (1992), and Helfat (1992) both look at the interaction of different types of R&D done in the firm. Also, most of the evidence summarized in section 3D does not involve patent data.

6. Conclusions.

The paper has made two points. First, the historical increase in the diversification of production and in firm size can both be viewed as the product of the same underlying force: the secular increase in the capital-labor ratio. And second, the positive cross-sectional association between firms' R&D intensity and diversification is probably the result of firms trying to internalize cross-product spillovers of productive knowledge, although my estimate of such spillovers is highly tentative.

Much remains to be done. First, both models treat products symmetrically and this is counterfactual in at least one important respect. Section 3A reported a secular increase in measures of diversification that emphasize the numerical diversity of firms' products. But Gort's data showed little change in the share of the firms' primary activities. These activities have retained their importance relative to firms' secondary activities, and it is really firms' secondary activities that have become more diversified over time. This was true over the period covered by Gort's sample and we now need an empirical update to see if this puzzling regularity has held up. If it has, it will need explaining.

Second, a dynamic analysis is needed. In my static model, the only way to interpret a merger is as a response to some external stimulus. And perhaps the big merger waves that we have seen were indeed a mass response to such events. But mergers, takeovers, and disolutions happen all the time, and surely not all of them are adjustments to to macro events. When two firms decide to merge, this is probably a response to some change in their immediate environment. The change may be unforeseen, or it may be a natural step in the process of the growth and decline of firms. Thus it may prove useful to embed the model of section 6 in a cost-reduction model[72] or a model in which the firm's optimal product portfolio is unknown and gets revealed through experience.[73] More importantly, managerial resources are variable in the long run -- albeit at a cost.[74]

Third, the role of management in raising the productivity of other factors should be more explicit than I have made it. The model has an arbitrary asymmetry: the managerial input affects the productivity of <u>large</u> firms differently from how it affects the productivity of <u>diversified</u> firms.

Finally, the link between horizontal integration of firms and the long-run growth of economies should be explored. If the engine of growth is fueled by spillovers of productive knowledge from one activity to the next, <u>and</u> if integrating activities under a firm's roof speeds up this transfer of knowledge, then the ease with which firms can integrate will affect the rate of growth of the economy. This would be true even if the rate of growth of product variety, v, were exogenous. But the argument gains further weight if the speed at which v grows were in turn to depend on how easily firms can exploit the technological similarities among products. All of this suggests that antitrust action may have to trade off allocative efficiency gains today against lower output tomorrow.

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[72] Such as the one in Flaherty (1980).

[73] Resembling, perhaps, the model in Jovanovic (1982).

[74] A possible starting point for modelling this is section 5 of Beckmann (1977), where he discusses the effect on profits from adding an extra layer of management.

References

Amihud, Yakov, and Baruch Lev. 1981. "Risk Reduction as a Managerial Motive for Conglomerate Mergers." *Bell Journal of Economics*. 12 (no. 2): 605-17.

Arrow, Kenneth. 1962. "The Allocation of Resources for Invention." in *The Rate and Direction of Inventive Activity*. Richard Nelson. ed. NBER. Princeton, NJ: Princeton University Press.

Baldwin, John, and Paul Gorecki. 1987. "Plant Creation versus Plant Acquisition." *International Journal of Industrial Organization*. 5: 27-42.

Baumol, William, John Panzar, and Robert Willig. 1982. *Contestable Markets and the Theory of Industry Structure*. New York: Harcourt, Brace, Jovanovich.

Beckmann, Martin. 1977. "Management Production Functions and the Theory of the Firm," *Journal of Economic Theory* 14, no 1: 1-18.

Berle, Adolf, and Gardner Means. 1968. *The Modern Corporation and Private Property*. 2nd edition. New York: MacMillan.

Berry, Charles. 1975. *Corporate Growth and Diversification*, Princeton: Princeton University Press.

Boeri, Tito, and Ulrich Cramer. 1992. "Employment Growth, Incumbents and Entrants," *International Journal of Industrial Organization*. 10: 545-65.

Brynjolfsson, Erik, Thomas Malone, Vijay Gurbaxani and Ajit Kambil. 1991. "Does Information Technology Lead to Smaller Firms?" unpublished paper, Center for Coordination Science, MIT, September.

Calvo, Guillermo, and Stanislaw Wellisz. 1978. "Supervision Loss of Control and the Optimum Size of Firm." *Journal of Political Economy* 86: 943-52.

Chandler, Alfred. 1977. *The Visible Hand: The Managerial Revolution in American Business*. Cambridge, MA: Bellknap Press.

Chang, Sea Jin. 1992. "A Knowledge-Based Perspective on Corporate Growth: Entry, Exit and Economic Performance During 1981-1989." Ph.D. dissertation, The Wharton School, University of Pennsylvannia.

Denison, Edward. 1961. *The Sources of Economic Growth in the United States*. New York: Committee for Economic Development.

________________. 1987. *Trends in American Economic Growth, 1929-1982*. Washington D.C.: The Brookings Institution.

Dixit, Avinash, and Joseph Stiglitz. 1977. "Monopolistic Competition, and Optimum Product Diversity." *American Economic Review* 67: 297-308.

Elixmann, Dieter. 1989. "Econometric Estimation of Economies of Scale and Scope in the German Telecommunications Sector." Wissenschaftliches Institut fur Kommunikationsdienste der Deutschen Bundespost, April.

Evans, David, and James Heckman. 1984. "A Test for Subadditivity of the Cost Function with an Application to the Bell System." *American Economic Review* 74: 615-23.

Fazzari, Steve, Glenn Hubbard, and Bruce Peterson. 1988. "Financing Constraints and Corporate Investment." *Brookings Papers on Economic Activity*: 141-95.

Flaherty, Therese. 1980. "Industry Structure and Cost-Reducing Investment." *Econometrica* 48 no. 5: 1188-1209.

Gertler, Mark, and Simon Gilchrist. 1992. "Monetary Policy, Business Cycles, and the Behavior of Small Manufacturing Firms." unpublished paper, November.

Gifford, Sharon. 1992. "Innovation, Firm Size, and Growth in a Centralized Organization." *Rand Journal of Economics* 23 no. 2: 284-98.

Gollop, Frank, and James Monahan. 1991. "A Generalized Index of Diversification: Trends in U.S. Manufacturing." *Review of Economics and Statistics* 43 no. 2: 318-30.

Gort, Michael. 1962. *Diversification and Integration in American Industry*, NBER, Princeton, NJ: Princeton University Press.

______________. 1966. "Diversification, Mergers, and Profits." in *Corporate Merger*. ed. by William Alberts amd Joel Segall. Chicago, IL: University of Chicago Press.

______________. 1969. "An Economic Disturbance Theory of Mergers, *Quarterly Journal of Economics* 83 no. 4, 624-42.

______________, Henry Grabowski, Robert McGuckin. 1985. "Organization Capital and the Choice Between Specialization and Diversification." *Managerial and Decision Economics* 6 no. 1: 2-10.

Goto, Akira. 1981. "Statistical Evidence on the Diversification of Japanese Large Firms." *Journal of Industrial Economics* 29 no. 3: 271-78.

Grabowski, Henry. 1968. "The Determinants of Industrial R&D: A Study of the Chemical, Drug and Petroleum Industries." *Journal of Political Economy*: 292-306.

Griliches, Zvi. 1979. "Issues in Assessing the Contribution of R&D to Productivity Growth." *Bell Journal of Economics* 10 no. 1: 92-116.

______________. 1992. "The Search for R&D Spillovers," *Scandanavian Journal of Economics* 94, Supplement, 29-47.

Hall, Bronwyn. 1988. "The Effect of Takeover Activity on Corporate Research and Development," in *Corporate Takeovers: Causes and Consequences*. ed. by Alan Auerbach. NBER. Chicago, IL: University of Chicago Press.

______________. 1990. "The Impact of Corporate Restructuring on Industrial R&D." *Brookings Papers on Economic Activity, Microeconomics*: 85-124.

Helfat, Constance. 1992. "Know-how Complementaries and Knowledge Transfer within Firms: The Case of R&D." University of Pennsylvannia, Department of Management, November.

Henderson, Rebecca, and Iain Cockburn. 1993. "Scale, Scope, and Spillovers: Research Strategy and Research Productivity in the Pharmaceutical Industry." unpublished paper, University of British Columbia, January.

Hill, Charles, and Gary Hansen. 1991. "A Longitudial Study of the Cause and Consequence of Changes in Diversification in the U.S. Pharmaceutical Industry 1977-86." *Strategic Management Journal* 12: 187-99.

Himmelberg, Charles, and Bruce Petersen. 1991. "R&D and Internal Finance: A Panel Study of Firms in High-Tech Industries." unpublished paper Stern School, New York University, June.

Hughes, Kristy. 1988. "Concentration and Diversification of R&D in a Conglomerate World." *Oxford Bulletin of Economics and Statistics* 50 no. 3: 243-61.

Hunter, William, and Stephen Timme. 1986. "Technical Change, Organizational Form, and the Structure of Bank Production." *Journal of Money, Credit, and Banking* 18: 152-66.

Jacquemin, Alexis, and Charles Berry. 1979. "Entropy Measure of Diversification and Corporate Growth." *Journal of Industrial Economics* 27 no. 4: 359-69.

Jaffe, Adam. 1986. "Technological Opportunity and Spillovers of R&D: Evidence from Firms' Patents, Profits, and Market Value." *American Economic Review* 76 no. 5: 984-1001.

Jovanovic, Boyan. 1982. "Selection and the Evolution of Industry." *Econometrica*: 649-70.

Kendrick, John W. 1961. *Productivity Trends in the United States.* Princeton, NJ: Princeton University Press.

Kihlstrom, Richard, and Jean-Jacques Laffont. 1979. "A General Equilibrium Theory of Firm Formation Based on Risk Aversion." *Journal of Political Economy* 87 no. 4: 719-48.

Kim, Youn. 1986. "Economies of Scale and Economies of Scope in Multiproduct Financial Institutions: Further Evidence from Credit Unions." *Journal of Money, Credit, and Banking* 18: 220-6.

__________. 1987. "Economies of Scale in Multiproduct Firms: An Empirical Analysis." *Economica* 54: 185-206.

King, Mervyn. 1977. *Public Policy and the Corporation.* London: Chapman and Hall.

Kiss, Ferenc, and Bernard Lefebvre. 1987. "Econometric Models of Telecommunications Firsm: A Survey." *Revue Economique* 2: 307-74.

Klavans, Richard. 1989. "Business Relatedness, and Business Performance." Line of Business Research Paper no. 83, Federal Trade Commission.

Levin, Richard, Alvin Klevorick, Richard Nelson, and Sidney Winter. 1987. "Appropriating the Returns from Industrial Research and Development." *Brookings Papers on Economic Activity (Microeconomics Issue)*: 783-32.

Levy, Haimm, and Marshall Sarnat. 1970. "Diversification, Portfolio Analysis, and the Uneasy Case for Conglomerate Mergers." *Journal of Finance*: 795-802.

Lewellen, Wilbur. 1971. *The Ownership Income of Management.* NBER. New York: Columbia University Press.

Lichtenberg, Frank. 1990. "Industrial De-Diversification and Its Consequences for Productivity." NBER working paper 3231, January.

Lichtenberg, Frank. 1991. "The Managerial Response to Regulation of Financial Reporting for Segments of a Business Enterprise." *Journal of Regulatory Economics* 3: 241-49.

Lucas, Robert E. Jr. 1978. "On the Size Distribution of Business Firms." *Bell Journal of Economics* 9: 508-23.

____________________. forthcoming. "Making a Miracle." *Econometrica*,

MacDonald, James. 1985. "R&D and the Direction of Diversification." *Review of Economics and Statistics* 67 no. 4: 583-90.

McCutcheon, Barbara. 1990. "Investment and Financing Constraints: An Empirical Investigation of Internal Capital Markets in Conglomerates." University of Iowa, working paper 91-01, January.

Mansfield, Edwin, John Rapoport, Jerome Schnee, Samuel Wagner, and Michael Hamburger. 1971. *Research and Innovation in the Modern Corporation*. New York: Norton.

Matthews, John. 1981. "Multiproduct Economies of Scale in the Securities Industry." U.S. Securities and Exchange Commission Capital Market Working Paper no. 7, March.

Montgomery, Cynthia, and Birger Wernerfelt. 1988. "Diversification, Ricardian Rents, and Tobin's q." *Rand Journal of Economics* 19, no. 4: 623-32.

Morck, Randall, Andrei Shleifer and Robert Vishnay. 1990. "Do Managerial Objectives Drive Bad Acquisitions?" *Journal of Finance* 45, no. 1: 31-48.

Mueller, Dennis. 1969. "A Theory of Conglomerate Mergers." *Quarterly Journal of Economics* 83 no. 4, 643-59.

Nelson, Ralph. 1959. *Merger Movements in American Industry, 1895-1956*. NBER, Princeton, NJ: Princeton University Press.

Nelson, Richard. 1959. "The Simple Economics of Basic Scientific Research." *Journal of Political Economy* 67: 297-306.

Panzar, John, and Robert Willig. 1981. "Economies of Scope." *American Economic Review* 71 no. 2: 268-72.

Penrose, Edith. 1959. *The Growth of the Firm*. New York, White Plains: Sharpe.

Prais, S.J. 1976. *The Evolution of Giant Firms in Britain, 1909-70*. New York: Cambridge University Press.

Pratt, John. 1964. "Risk Aversion in the Small and in the Large." *Econometrica* 32: 122-36.

Prescott, Edward, and Michael Visscher. 1980. "Organization Capital." *Journal of Political Economy* 88: 446-61.

Radner, Roy. 1970. "Problems in the Theory of Markets Under Uncertainty." *American Economic Review*: .

__________, and Tim Van Zandt. 1992. "Information Processing in Firms and Returns to Scale." *Annales d'Economie et de Statisique* 25/26: 265-98.

Ravenscraft, David, and Frederick Scherer. 1987. *Mergers, Sell-Offs and Economic Efficiency*. Washington, D.C. The Brookings Institution.

Scherer, Frederick. 1965. "Firm Size, Market Structure, Opportunity, and the Output of Patented Inventions," *American Economic Review* 55: 1097-1125.

__________________. 1975. *The Economics of Multiplant Operation*. Cambridge, MA: Harvard University Press.

__________________. 1980. *Industrial Market Structure and Economic Performance*. 2nd ed., Boston: Houghton Mifflin.

__________________. 1983. "The Propensity to Patent." *International Journal of Industrial Organization* 1: 107-28.

__________________. 1984. "Using Linked Patent and R&D Data to Measure Interindustry Technology Flows." in *R&D, Patents and Productivity*. ed. by Z. Griliches. NBER, Chicago, IL: University of Chicago Press.

Silk, Alvin, and Ernst Berndt. 1990. "Scale and Scope Effects on Advertising Agency Costs." NBER working paper no. 3463, October.

Spence, Michael. 1976. "Product Selection, Fixed Costs and Monopolistic Competition." *Review of Economic Studies* 43: 217-35.

__________________. 1984. "Cost Reduction, Competition, and Industry Performance." *Econometrica* 52: 101-21.

Stigler, George. 1962. "Foreword" in Michael Gort. *Diversification and Integration in American Industry*. NBER, Princeton, NJ: Princeton University Press.

Stokey, Nancy. 1988. "Learning by Doing and the Introduction of New Goods." *Journal of Political Economy* 96 no. 4: 701-17.

Streitweiser, Mary. 1991. "The Extent and Nature of Establishment-Level Diversification in Sixteen U.S. Industries." *Journal of Law and Economics* 34 no. 2, pt. 2: 503-34.

Strickland, Allyn. 1984. *Firm Diversification, Mutual Forebearance Behavior, and Price-Cost Margins*. New York: Garland Publishing.

Teece, David. 1980. "Economies of Scope and the Scope of the Enterprise." *Journal of Economic Behavior and Organization* 1: 223-47.

United States Bureau of Labor Statistics. 1991. *Employment, Hours and Earnings, United States, 1909-90*. Washington D.C.: U.S. Government Printing Office.

United States Bureau of the Census. various years. *Statistical Abstract of the United States*. Washington D.C.: U.S. Government Printing Office.

United States Department of Commerce. 1975. *Long Term Economic Growth 1860-1970*. Washington D.C.: U.S. Government Printing Office.

United States Department of Commerce. 1975. *Historical Statistics of the United States: Colonial Times to 1970*. Washington D.C.: U.S. Government Printing Office.

United States Department of Commerce. 1990. *Survey of Current Business*. Washington D.C.: U.S. Government Printing Office.

United States Department of Justice. 1992. *Horizontal Merger Guidelines*, April.

Utton, M.A. 1981. *Diversification and Competition*, New York: Cambridge Univeristy Press.

Wall Street Journal. 1992. "For New Jobs, Help Small Business," August 10.

Williamson, Oliver. 1979. "Transactions-Cost Economies: The Governance of Contractual Relations." *Journal of Law and Economics*. October.

Willig, Robert. 1991. "Merger Analysis, Industrial Organization Theory, and Merger Guidelines." *Brookings Papers on Economic Activity: Microeconomics*: 281-332.

Wilson, Robert. 1975. "Informational Economies of Scale." *Bell Journal of Economics* 6: 184-95.

Young, Alwyn. 1991. "Learning by Doing and the Dynamic Effects of International Trade." *Quarterly Journal of Economics* 106: 369-406.

Appendix 1: Data sources and definitions of variables used for the plots in figure 2 and the regressions in table 1.

1) GNP in 1958 Prices, denoted by Y in figure 2.

1900-1970: F3, Historical Statistics of the U.S.
1971-1977: Table 710 Statistical Abstract of the U.S. 1978
1978-1984: Table 719 Statistical Abstract of the U.S. 1986
1985-1989: Table 698 Statistical Abstract of the U.S. 1991

2) Labor Force, denoted by L in figure 2, after subtracting government workers.

1900-1947: D1, Historical Statistics of the U.S.
1948-1970: D12, Historical Statistics of the U.S.
1971-1984: Table 658 Statistical Abstract of the U.S. 1986
1985-1989: Table 631 Statistical Abstract of the U.S. 1991

Data for 1948-1989 adjusted as described in Lucas (1978).

3) Number of Concerns, denoted by m in figure 2.

1900-1970: V20 Historical Statistics of the U.S.
1970-1984: Table 884 Statistical Abstract of the U.S. 1986
1985-1989: Table 881 Statistical Abstract of the U.S. 1991

Data for 1985-1989 adjusted to be compatible with data for the previous years.

4) Number of Concern Employees. This variable is denoted by L^* in figure 2. It is calculated as [a - b - c - d], where

a = Total Number of Nonagricultural Employees:

1900-1970: D127 Historical Statistics of the U.S.
1970-1977: Table 654 Statistical Abstract of the U.S. 1978
1978-1984: Table 692 Statistical Abstract of the U.S. 1986
1985-1989: Table 631 Statistical Abstract of the U.S. 1991

b = Total Number of Finance, Insurance and Real Estate Workers:

1900-1970: D137 Historical Statistics of the U.S.
1970-1989: Same as in a)

c = Total Number of Government Workers:

1900-1970: D139 Historical Statistics of the U.S.
1970-1989: Same as in a)

d = Total Number of Railroad Workers:

1900-1946: D179 Historical Statistics of the U.S.
1947-1989: Employment, Hours and Earnings, United States, 1909-1990

Annual data for 1900-1946 interpolated from decade data

5) Capital: Gross Private Nonresidential Capital Stock in 1958 prices, denoted by K in figure 2.

    1900-1924: pp. 320-322, Kendrick (1961).
    1925-1989: Survey of Current Business, October 1990, Adjusted to 1958 prices.

Data for 1900-1924 adjusted to be compatible with data for the later years.

6) Investment: Gross Private Domestic Investment in 1958 Prices, denoted by I in figure 2.

    1900-1928: pp. 186-187, Long Term Economic Growth 1960-1970.
    1929-1982: National Income and Product Accounts of the U.S. 1929-1989.
    1983-1989: Table 698, Statistical Abstract of the U.S. 1989.