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CORPORATE GROWTH AND PROFITABILITY

Paul A Geroski, Stephen J Machin
and Chris F Walters

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Paul A Geroski, Steve J Machin and Chris F Walters

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Centre for Economic Policy Research
25–28 Old Burlington Street
London W1X 1LB
Tel: (44 171) 878 2900
Email: cepr@cepr.org

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ABSTRACT

Corporate Growth and Profitability*

This paper argues that current-period corporate growth rates reflect changes in current expectations about the long-run profitability of a firm. Using data on a balanced panel of 271 large, quoted UK firms over the period 1976–82, we report the existence of a positive, statistically significant and robust correlation between current-period growth rates and a natural measure of changes in current expectations about long-run profitability, namely changes in the stock market valuation of the firm.

JEL Classification: L1, L2
Keywords: corporate growth, Gibrats law, panel data

Paul A Geroski and Chris F Walters
London Business School
Sussex Place
Regent's Park
London NW1 4SA
UK
Tel: (44 171) 262 5050

Stephen J Machin
Department of Economics
University College London
Gower Street
London WC1E 6BT
UK
Tel: (44 171) 387 7050

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NON-TECHNICAL SUMMARY

A long tradition of research on corporate performance has repeatedly thrown up an empirical result which makes many people uneasy, namely that corporate growth rates are very nearly random. That is, while differences in profitability between firms appear to persist for long periods of time, differences in growth rates between firms are transitory and essentially unpredictable.

It is the implication of this result which has commanded most attention, since it predicts that, in the absence of reversion to the mean (i.e. a tendency for large firms to grow more slowly than smaller firms), markets will become increasingly concentrated over time. The result that corporate growth rates are random is also interesting, however, because it raises questions about the process of corporate growth, and about decision-making within firms.

In this paper we argue that there is a perfectly natural interpretation of this empirical result. In most contexts, firms must think about the future when they make decisions, and this means they must form expectations about future market events. If a firm uses all the information available when forming such expectations, it follows that expectations will change only when some new and surprising event affects the firm. That is, changes in expectations will be both transitory and unpredictable. Most models of the firm predict that current-period output choices are likely to be linearly related to current-period expectations of future profitability, from which it follows that unpredictable changes in expectations will lead to unpredictable changes in size, i.e. that corporate growth rates will be random.

This strictly theoretical argument is supported by an empirical examination of the relationship between the growth of a number of large UK firms and a natural proxy for their expected future profitability, namely their market value. It turns out that there is a clear, robust but relatively small, positive correlation between the two. It also appears to be the case that corporate growth rates are very sensitive to macroeconomic (but not industry-specific) conditions, and that they are relatively unaffected by the production of major innovations or patents (which probably have more effect on profits than on growth).

One of the major puzzles which emerges from this work is the question of whether it really is sensible to argue that managers trade off (relatively stable streams of) profitability for (relatively unpredictable and highly variable rates of) growth, as a large literature on managerial discretion presumes. In fact,

were it the case that managers systematically traded off profits for growth (for some reason), one would expect to see a negative correlation between the two. We find no sign of this in our data.

I. INTRODUCTION

It is now generally accepted that corporate growth rates vary (more or less) randomly across firms and over time. In fact, the data seem to be fairly well described by a Gibrat process which allows for reversion to the mean. Although these conclusions have been replicated in numerous studies, many scholars remain uneasy about accepting them. One source of concern is that of reconciling these empirical results with conventional, deterministic theories of the firm.[1] Another is that many of the models used to empirically explain the data are rather simple, and the conclusion that growth rates are random may be more an artifact of the empirical models than of the data itself.

In this paper, we show that conventional profit maximizing models of output choice generate a relationship between current period growth and changes in current expectations of future profitability (Section II). If expectations are formed rationally, changes in expectations will be impossible to predict using current and past information about the operations of the firm. As a consequence, corporate growth will be unpredictable. We also examine the annual growth rates of 271 UK firms over the period 1976-1982 using a relative rich dynamic model that includes proxies for changes in current expectations of future profits (Section III). Although this empirical model seems to make more progress than many of its predecessors in explaining times series and cross section variations in corporate growth rates, the simple fact is that most of the variation in the data appears to be unsystematic and unpredictable. The conclusion that corporate growth rates are (more or less) random is, it seems, both an understandable and a very robust feature of the data (Section IV).

II. A MODEL OF CORPORATE GROWTH AND PROFITABILITY

Most theories of the firm are strictly deterministic. To make them compatible with the empirical observation that firm size (roughly) follows a random walk, one must impose some stochastic variation on one (or more) of the exogeneous variables suggested by the theory, and then trace its consequences through to the induced movements of endogenous variables like firm size. Innovation and demand shocks are obvious candidates for this kind of treatment, as are expectations variables. However, unlike innovation and demand shocks, changes in expectations are likely to follow a particularly simple stochastic process: when the expectations variables which drive output (and other) choices are rational, changes in these expectations are normally distributed i.i.d. random variables. This, in turn, means that the output choices of profit maximizing firms will (at least in part) follow a random walk over time.

Consider the simplest possible model of a firm that chooses output x_t in every period t subject to demand $p = p(X_t)$, where $X_t \equiv \Sigma x_t$ is industry output, costs are $c(x_t) = cx_t$ and costs of adjustment. Adjustment costs mean that firms will respond to shocks only gradually, and, as a consequence, current period corporate growth rates are likely to have forward and backward looking components. At any time t, the firm will try to anticipate future shocks and begin the process of costly adjustment to them as early as possible. Further and at the same time, the firm will still be responding to the past shocks which are working their way through the system.[2]

The formal model which is appropriate in this context is well known, and need only be briefly described here (see Sargent, 1987, pp. 199-204, for an analysis of this kind of control problem). The problem of a firm facing costs of adjustment is to choose a time path for output to maximize the expected present discounted value of profits,

$$(1) \qquad V_t = \Sigma\rho^{\tau}[(p(X_{t+\tau}) - c)x_{t+\tau} - (\lambda/2)(\Delta x_{t+\tau})^2],$$

where ρ is the discount factor, and adjustment costs are assumed to be proportional to the square of the current period change in firm i's output, $(\Delta x_t)^2$, with a factor of proportionality of $\lambda/2$. The Euler conditions which describe the sequence of values of $x_{t+\tau}$ which maximize V_t are

$$(2) \qquad (\rho\lambda)x_{t+\tau+1} + [p'(X_{t+\tau})\theta X_{t+\tau} - \lambda - \lambda\rho]x_{t+\tau} + \lambda x_{t-\tau-1} + p(X_{t+\tau}) - c = 0,$$

where $\theta = (\partial X_t/\partial x_t/X_t)$, a conjectural variation which summarizes what the firm believes will be the response of its rivals to its action (and which, for simplicity, we will assume to be constant over time).[3] λ is measured in money per unit of output, and we assume that real adjustment costs, $\psi \equiv \lambda/p(X_t)$, are constant over time. This assumption converts equation (4) into a second order linear difference equation in $x_{t+\tau}$. Defining ξ_0 and ξ_1 by the two relations: $\xi_0\xi_1 = 1/\rho$, $\xi_0 + \xi_1 = (\eta\psi + (1+\rho))/\rho$ enables us to solve for

$$(3) \qquad x_t = \xi_0 x_{t-1} + (\xi_0/\psi)\Sigma(1/\xi_1)^{\tau}\{m_{t+\tau}\} \equiv \xi_0 x_{t-1} + \xi Z_t.$$

The first term on the right hand side of (3) is the backward looking component of current decisions about production, and reflects the continuing effects of past shocks which the firm has not fully responded to. The second term on the right hand side of (3) is the forward looking component, and describes how the firm adjusts its current rate of output in anticipation of the cost and demand shocks that it currently expects to occur in the future.[4]

First differencing both sides of (3) reveals the existence of a simple relationship between current period changes in firm size, recent past changes in firm size, and changes in current expectations of future profitability. If current period expectations are rational (that is to say, formed using all information available in t and before), then, by definition, changes in current expectations, ΔZ_t, will be unpredictable using information dated t or earlier. This, of course, means that changes in firm size will depend upon past changes in size and an unpredictable "error" $\mu_t \equiv \xi \Delta Z_t$. If, in addition, adjustment costs are small, the link between current and past changes in firm size will be broken, and current period changes in size will depend only on the unpredictable "error" μ_t. This means that firm size will follow a random walk over time, which is exactly what Gibrat's Law predicts. It follows, then, that what we observe in the data on corporate growth is almost exactly what we would expect to observe in a profit maximizing firm holding rational expectations about its future prospects.

III. AN EMPIRICAL ANALYSIS OF CORPORATE GROWTH

Even if one accepts the proposition that Gibrat's Law is exactly what one expects to see in the data, the fact that one does observe it may still be a consequence of using overly simple empirical models. Most of the empirical work on corporate growth rates over the years has focused on the relation between firm size and growth, and it has hardly explored many other possible determinants of growth (including those whose variation is unpredictable enough to account (in principle) for the unpredictability of corporate growth rates).[5] Further, most of the extant work has not paid much attention to dynamic specification and has not, therefore, explored the extent to which current growth depends on previous growth. Our goal in this section, then, is to explore how robust the unpredictability of corporate growth is with respect to empirical model structure.

(a) the data

The sample that we shall use consists of a balanced panel of 271 large, quoted UK firms observed continuously over the period 1976-1982 (for more detail, see the Appendix). Firm size is measured by the log of sales.[6] In the absence of reliable firm specific price deflators, we concentrate on nominal growth (growth in turnover) rather than real growth (growth in volume).[7] The sample period includes a major recession plus high and variable inflation rates (ranging from 7% to over 20%), and, partly as a consequence, annual rates of growth of turnover averaged 11.4%, with a standard deviation of 16.65. The distribution of growth rates in any year and over all years taken together was almost but never quite normal, mainly because of the presence of several extreme outliers.

Corporate growth rates are interesting to analyze because they are very variable, their variation is hard to predict and they differ statistically from other familiar measures of performance in a number of important ways. In our data, the co-efficient of variation of growth was 1.46, which is much higher than that of firm size (.373) or of the ratio of profits to sales (.861). The maximum sample growth rate was nearly 15 times larger than the mean (for size and the return on sales the maximum was 4.7 and 2.1 times larger than the mean). Further, while simple first order autoregressions in firm size and the return on sales were fairly well determined (with an R^2 well above .95), the fit on autoregressions in growth even up to order 4 was very poor (with an R^2 usually less than .10). Indeed, firm size appeared to follow a random walk with drift, and calculations using a measure suggested by Cochrane (1988), suggested that the random walk component accounted for a very high percentage of the variation in firm size over time.[8] Much the same message emerged from an inspection of simple partial correlations across the sample of firms over time. For example, the partial correlation in growth rates between 1981 and 1982 across all firms in the sample was .3004, and between 1976 and 1982 it was .0432. For (accounting) profit margins, the two correlations were .8397 and .4787.

Finally, an analysis of variance revealed that only 17% of the total variation in growth rates was between firm variation (much the same is true if we drop outliers). For profitability, more than 90% of the total variation was between firms. That is, whatever it is that determines profitability seems to differ across firms but is relatively stable over time. This is, in part, why predicting the future profitability of specific firms using information on their past profitability is not too difficult. By contrast, the determinants of growth rates seem to be highly firm specific and very variable over time. One has neither stable firm specific differences in growth or temporally fixed factors to use in predicting future growth rates, and that is why predicting growth is a much more difficult exercise.

(b) the empirical model

Accounting for all of this variation is a fairly daunting task. Following in the spirit of (3), the basic empirical model that we worked with explains current period growth rates, G_t, by previous growth rates and changes in current expectations of future profitability, ΔZ_t. That is,

$$(4) \qquad G_t = \phi(L)G_{t-1} + \beta\Delta Z_t,$$

where $\phi(L)$ is a polynomial in the lag operator L, and G_t is defined as the first difference of the log of firm size.[9] What makes (4) difficult to work with empirically is the fact that current period changes in expected future profitability are not directly observable. There are two ways to solve this problem: one can use a number of observables, W_t, to account for movements in the unobserved ΔZ_t, or one can try to measure ΔZ_t directly. As we are dealing with a sample of quoted firms, it is natural to follow the second course of action and use the first difference in (the log of) a firm's market value, V_t, as a direct measure of current changes in expectations about future profitability. However, the conditions under which a firm's stock market valuation fully embodies all currently available information on its future profitability are fairly strong, and it is not unreasonable to suppose that the influence of other factors, W_t, may not be fully reflected in V_t. Thus, using both V_t and W_t to proxy ΔZ_t yields an empirical model of corporate growth which can be written as

$$G_t = \alpha V_t + \beta W_t + \phi(L)G_{t-1} + \epsilon_t, \tag{5}$$

where ϵ_t is a white noise residual.[10]

The observables W_t which we wish to include in (5) are those which may be responsible for the unpredictable variability we see in the data but have been neglected in previous work, namely: net industry and aggregate growth rates (reflecting changes in the firm's market environment), and the number of major innovations and patents produced by the firm and by its rivals (measuring both the firm's competitive strength and changes in the technological environment which it operates in).[11] Given (3), the correct interpretation of the estimated co-efficients on these variables is that they reflect influences of the W_t which are not captured by V_t; that is, a lack of significance on the co-efficient of a particular W_t does not mean that it has no influence on corporate growth. Indeed, to the extent that stock market values fully capture all of the determinants of expected future profitability, then $\beta=0$ and, what is more, V_t will be unpredictable. In this case, (5) can be collapsed to a simple AR model of growth. If, in addition, $\phi(L)=0$, then (5) reduces to a Gibrat process in which firm size follows a random walk over time. We will take this to be our null hypothesis.

(c) the results

Regression (i) on Table I shows our baseline estimate of equation (5). It contains a single constant and twenty explanatory variables: V_t, three lagged values of the dependent variable and current and three lagged values of aggregate growth (AG), the number of innovations produced by each firm (INN), the number of patents produced by each firm (PAT), and net industry growth (IG). Equation (i) is itself a simplification of a more general model which included a full set of fixed effects and a range of spillover variables (current and lagged values of the net number of innovations and patents produced in each industry). Surprisingly (in view of the low ratio of between to within firm variation in corporate growth rates) conventional F tests reject the null that the fixed effects can be simplified to a single constant, although they had little effect on R^2. However, this conventional test procedure is certain to reject all point null hypotheses when sample sizes become large (as often happens in panel data for instance). Indeed, using alternative critical values computed from a Bayesian flat prior leads us to accept uniformly the simplification of fixed effects to a single constant.[12] Further, none of the eight spillover variables made an individual or a collectively significant contribution to explaining corporate growth rates, and their inclusion also had little effect on the other estimates.[13]

Although less general than our starting point, (i) is nevertheless less parsimonious than it need be. Neither the current or any lagged number of innovations nor patents produced by each firm made much of a direct impact on the growth of firms, and dropping either or both sets of variables had very little impact on the other estimated co-efficients.[14] Similarly, net industry growth rates had very weak and extremely imprecisely estimated effects on corporate growth rates (the t-2 lag aside), and dropping these four terms also had no effect on the other estimates. Indeed, dropping all twelve variables associated with innovations, patents and net industry growth rates turns out to be a statistically acceptable simplification of regression (i), and this regression is shown as (ii) on Table I.

Regression (ii) shows that changes in current market value, previous growth and current and recent past macroeconomic shocks make a significant but collectively unimpressive contribution to explaining corporate growth rates.[15] The simple fact is that even our most general regression (which included 28 observables and a full set of fixed effects) only accounted for about 18.6% of the variation in G_t, and it is, therefore, hard to resist the conclusion that Gibrat's Law is not a bad description of the evolution of firm size. Nevertheless, corporate growth rates are affected by macro economic shocks (above and beyond any effects conveyed via V_t), and (ii) suggests that the large manufacturing firms who comprise our sample lose (gain) market share to (from) smaller manufacturing firms during upswings (downswings) in the cycle.[16] Current period corporate growth rates also depend on recent past growth rates. The estimates shown on (i) imply that the long run responses of growth rates to exogenous shocks are larger than short run responses, exactly what one would expect if adjustment costs dampen the rate at which firms adjust production and sales levels in response to unforeseen changes. However, the ratio of long to short run responses is about 1.27, suggesting that adjustment costs have only a modest effect on growth rates.[17]

Both regressions (i) and (ii) show small but very precisely estimated effects of changes in market value on corporate growth rates, and this was a feature of virtually every variant of (i) and (ii) that we examined. Further, the estimated size of α was not very sensitive to decisions about which of the variables in W_t were included in the regressions. In fact, the effects of current changes in expectations seem to persist some way into the future. Several experiments with (i) and (ii) which included lagged values of V_t produced a statistically significant improvement in fit, and a set of relatively precisely estimated co-efficients. Regression (iii) on Table I shows a generalisation of (ii) involving three lagged values of V_t (it was possible to omit higher order lags without significantly worsening the fit). It suggests that a 10% revaluation in current expectations about future profitability had a positive short run effect on growth of less than 1%, cumulating to about 2.7% in the long run.[18] These effects are considerably larger than those shown in (i) and (ii), and they suggest that managers' reactions to changes in the long-term prospects of their companies take perhaps as many as five years to fully implement.

What is puzzling about (iii) is the fact that distributed lags in both V_t and G_t make important contributions to explaining current period growth. Equation (5) suggests that any lag in the reaction to changes in expected future profits should be captured by the co-efficients on lagged growth (which reflect adjustment costs). The apparent direct effect (i.e. above and beyond the effects of adjustment costs) that lagged changes in expectations have on current growth suggests the existence of a second source of delay in response, corresponding (perhaps) to perception or reaction lags. That managers were still directly responding in period t to new information that is three or four years old must mean that they discount many of the changes in the market values of their firm which occur over time, treating them as if they were mainly transitory. Indeed, were there no other influence on growth rates other than V_t, regression (iii) suggests that corporate growth rates would be considerably less variable than changes in market values. This is, of course, completely consistent with the spirit of the adjustment cost model that we are using to interpret the data, even if it does raise some doubt about whether it is the perceptions of shocks or the response to them which is smoothed out over time.[19]

(d) some caveats and extensions

The most obvious caveat to the results displayed on Table I is that V_t may be jointly determined with G_t, and, thus, that the co-efficient on V_t may be biased. The main difficulty we faced in exploring this issue was that of generating legitimate instruments for V_t. There are no variables in our data which unambiguously identify V_t, and, indeed, V_t is - like G_t - primarily driven by lagged V_t, lagged G_t, and changes in aggregate demand. Equations explaining changes in V_t usually displayed a fairly strong autoregressive pattern, with lagged aggregate growth rates and, less clearly, lagged own rates of growth and lagged rates of industry growth producing R^2s two and three times larger than were found for corresponding growth equations. As noted above (in footnote #13), innovations, patents and technological spillover variables had little effect on changes in V_t in this sample. Virtually all of the equations which we used to construct instruments for V_t were poorly determined.[20] Regression (iv) on Table I replicates (iii) using a GMM estimator with innovations, patents and lagged profits as instruments for V_t. It yields an estimate of α somewhat higher than (iii) does, and a very similar pattern of co-efficients on the other variables. This is typical of what we found in repeated experiments. Further, reduced form estimates of (i), (ii) and (iii) on Table I produced very similar co-efficient estimates on the exogenous variables, this inclines us to believe that simultaneity bias may not be too serious a problem (it may, if anything, lead to underestimates of α).

We also computed predicted and surprise values of V_t from a wide range of reduced form regressions and included both in (i)-(iii). In virtually all cases, both variables were statistically significant, and the co-efficient on the surprise variables was usually slightly larger than that on the predicted V_t variables. That firms appear to be responding to predictable changes in V_t as well as to apparent surprises is puzzling, but it undoubtedly reflects the fact that V_t is not a white noise series. Further, firms are likely to have rather different information sets than econometricians, and what surprises us may not surprise them.

A second caveat concerns the sample, which consists of survivors and includes some firms reporting extremely high or extremely low values of growth in particular years. To examine the impact of outliers, we replicated these regressions using robust estimation methods and excluding all observations further than ±2 standard deviations from the mean. These regressions displayed qualitatively similar results to those reported on Table I. Sample selection bias is probably of more concern, since current expectations of future profitability ought to be a major determinant of whether a firm fails (or is taken over). To explore this problem, we compared the estimates of (i)-(iii) shown on Table I (which is a balanced panel) with estimates of (i)-(iii) obtained from an unbalanced panel of 615 firms yielding 3315 observations (out of a maximum of 4305). The results using the unbalanced panel were almost indistinguishable from those shown on Table I, yielding co-efficient estimates of very similar sizes and the same pattern of significance. Neither of these exercises seems to suggest that our conclusions cannot be generalized to beyond our sample of survivors.[21]

One obvious extension of the work reported above is to encompass the traditional literature in (5) by including a measure of firm size in the regression. Adding log(sales) to each of the three regressions on Table I yielded significant co-efficients (for both the balanced and unbalanced panels) of 0.011 (with t-statistics of about 4.5). None of the other co-efficient estimates where much affected by the inclusion of firm size in the regression, and they remained collectively significant. This is probably because the fixed effects in the original specification picked up effects associated with scale. In any case, it follows that the traditional regressions of size on growth typical of the literature are not statistically acceptable simplifications of the regression shown on Table I.

A second extension is to examine the possibility that the process of growth differs between larger and smaller firms by re-estimating all the equations shown on Table I on sub-samples of firms ordered by quartiles based on pre-sample period turnover.[22] All of these experiments led us to reject the view that the co-efficients $\phi(L)$, α and β in (7) were the same across firms of different sizes. Three main differences emerged between large and small firms (that is, small within the sample of quoted firms that we are considering). First, mean growth rates were slightly higher for larger firms, and the variability of growth was lower. Second, the "effect" of changes in current expectations of future profitability (i.e. α) on current growth rates was somewhat smaller (but still quite significant) for larger firms. Third and finally, larger firms were noticeably less sensitive to macroeconomic shocks than smaller firms.

IV. CONCLUSIONS

It is hard to dispute the conclusion that corporate growth rates are (very nearly) random. Although it is possible to think of many reasons why this might be true, one rather natural way to interpret the data is to use a standard model of an intertemporal profit maximizing firm that forms rational expectations about its future prospects and builds them into its current output choices. One implication of this model is that corporate growth rates contain forward and backward looking components: at any time, firms will try to anticipate future shocks and begin the costly process of adjusting to them, all the while responding to past shocks that are still working their way through the system. A second implication is that the unpredictability of future shocks means that corporate growth rates are likely to be relatively unpredictable. These conjectures find ample support in our data. Corporate growth rates are highly variable, and differences in growth rates between firms over time do not persist for very long. Further, although the fortunes of many firms are sensitive to macroeconomic conditions, most of the times series variation in corporate growth rates is highly idiosyncratic. All of this said, it is also the case that there is some systematic variation in growth rates, and both forward and backward looking components are evident in the data. Of most interest is the relatively clear and very robust association which seems to exist between growth and changes in the market value of firms. This is, of course, consistent with a third implication of the model, namely that there should exist a link between current growth rates and changes in expectations about future profitability.

However, our results also contain (at least) two puzzles. The first is the question of why Gibrat's Law is not a more accurate description of the data than it actually is. If expectations are formed rationally, then changes in expectations should be unpredictable, and this means that growth rates should be unpredictable; i.e. that Gibrat's Law should hold (or, at the least, growth rates should follow a simple AR process). In fact, changes in market value do not appear to capture all of the exogenous determinants of growth, not least because aggregate growth rates have an independent direct effect on growth. Further, annual changes in market values are not completely unpredictable, and they appear to have direct effects on growth for several periods into the future. These observations are slightly difficult to interpret, although they may simply be the consequence of temporal aggregation from daily to average annual market valuations (which can induce serial correlation in a white noise series). The important point, however, is that standard theories of the firm coupled with the assumption of rational expectations suggest that Gibrat's Law should be an accurate description of the process of corporate growth, and, very roughly speaking, it is.

The second puzzle in all of this is why managers might be interested in trading off profits for growth. This is usually thought to be the result of managers' desires to preside over large firms (and pocket the perks which that brings), but the data suggest that it may actually be a rather risky choice for managers to make. Growth rates are very much more variable and idiosyncratic than profits. A manager who sacrifices current profits for increased growth rates (say, by acquiring a rival) is, in effect, sacrificing a relatively steady stream of returns for a highly variable set of outcomes over time. Indeed, any manager who chooses to stake his/her reputation on the growth performance of his/her companies is bound to underperform on an unpredictably regular basis. Possibly more fundamentally, for managers to trade profits off for growth, there must (at least at some stage) be a negative relationship between the two. We have found absolutely no trace of this kind of trade-off in our data; that is, we have found no evidence at all which suggests that actions which genuinely contribute to growth over the long run (many acquisitions do not fall into this category) do so at the expense of profits. This is not to say that managers do not dissipate some windfall profit increases in the pursuit of growth (many acquisitions do fall into this category), but, rather, that they do not do so very systematically. As a consequence, the data suggest that high (low) current period growth rates are reasonable (if very noisy) predictor of increases (decreases) in long run profitability.

NOTES

1. Most of the attention given to Gibrat's Law has focused on its consequences (mainly for increasing industrial concentration). However, some recent work has begun to explore economic interpretations of reversion to the mean; see Cabral, 1995.

2. There are many possible sources of adjustment costs, including the managerial constraints suggested by Penrose, 1959. Many dynamic relationships have effects which are formally very similar to the effects of adjustment costs. If, for example, the rivals of a firm respond to it's current period output choices in the future, or if current prices affect demand or the possibility of entry in the future, then current period output choices will have future consequences that a profit maximizing firm will wish to take into account.

3. Note that (2) collapses to the conventional static profit maximizing firms level of output, $x = \{(p - c)/p\}\eta/\theta$, if there are no costs of adjustment and $\lambda = 0$ (η is the elasticity of demand).

4. Equation (3) can also be written in the form $x_t = \gamma[x^*_t - x_{t-1}]$, where $x^*_t = [\xi_0/\psi(1-\xi_0)] \Sigma(1/\xi_1)^\tau\{m_t\}$ and $\gamma = 1 - \xi_0$. This looks like a familiar partial adjustment model, except that the "target", x^*_t, depends on current expectations of future profitability (and, as a consequence, is likely to vary over time).

5. Previous work in the UK has found the firm size-growth link to be sensitive to sample composition and rather unstable over time: the evidence seems to suggest a rejection of Gibrat's Law in the 1950s because large firms grew relatively faster than small firms, but data drawn from the 1960s or early 1970s seems to be more consistent with the Law. It also seems to be the case that departures from Gibrat's Law are much less noticeable for large than small firms, an impression reinforced by work on samples containing small firms by Hall, 1987, and Evans, 1987a and 1987b, Dunne and Hughes, 1994, Hart and Oulton, 1995, and others. For work testing Gibrat's Law, see also Hart and Prais, 1956. Mansfield, 1962, Hart, 1962, Samuels, 1965, Singh and Whittington, 1968,Samuels and Chesher, 1972, Hymer and Pashigian, 1962, Prais, 1976, Singh and Whittington, 1975, Cantwell and Sanna-Randaccio, 1993, and others. For a survey and assessment of this work, see Scherer and Ross, 1990, pp. 141-146.

6. We choose sales turnover because of its availability, and because it is much less prone to measurement errors than other commonly used measures of firm size (like net assets). It is hard to assess the effect of potential measurement errors on all of the parameters which we estimate, but Hall, 1987, has shown that measurement errors do not seem to generate biased estimates of the firm size-growth relationship (probably because the enormous variation in growth rates seems to dwarf reasonable estimates of these measurement errors).

7. Our data are not rich enough to allow us to distinguish growth through acquisition from organic growth. It is possible that the lumpy expansion and contraction in firm size induced by acquisition or divestment will make the growth process appear excessively variable and unpredictable. However, the data shows that the growth of small firms is no less erratic than that of large firms, suggesting that the process of internal growth may not be terribly smooth

either. See also Samuels, 1965, and Kumar, 1984 and 1985, who have examined growth by acquisition and by investment using UK samples.

8. By contrast, levels of profitability are stationary, and show a reasonably rapid convergence to long run profitability levels following an exogenous shock. This is consistent with a large literature on the "persistence of profits": see Mueller, 1986 and 1990, amongst others.

9. Equation (4) is not identical to the first difference of (3), since the latter describes a relation between the first difference in the level of output (not the log of turnover), it's value lagged once and ΔZ_t. Note that any formal test of (3) is unlikely to be persuasive unless allowance is made for variations in fundamental parameters like θ and η across firms and over time.

10. Equation (5) is a straightforward generalization of the model typically used to test Gibrat's Law. Some tests estimate $X_t=\alpha_0+\psi_0X_{t-1}+\epsilon_t$ (where X_t is the log of firm size) and test if $\psi_0=1$, others estimate $G_t=\alpha_1+\psi_1G_{t-1}+\epsilon_t$ and test whether $\psi_1=0$ and, finally, others estimate $G_t=\alpha_2+\psi_2X_{t-1}+\epsilon_t$ and test whether $\psi_2=0$ (for example Singh and Whittington, 1975, do all three). As Chesher, 1979, has noted, these tests are very sensitive to the dynamic specification of the estimating equation.

11. Unlike R&D spending, these two variables measure innovative output, and ought to have a direct effect on a firm's costs and demand, and, thus, on its performance. The major problems with both variables is that they are counts of innovations that may have very different values, and both only measure new technology based innovations.

12. For regressions (i), (ii), and (iii) F-tests of the joint significance of fixed effects give $F_{270,1606}$ = 1.303 (.002), $F_{270,1618}$ = 1.302 (.002) and $F_{270,1615}$ = 1.189 (.027) respectively. However, adjusted R^2 measures for each regression change very little whether fixed effects are included or not: for regression (i), $\bar{R}^2$ (constant) = .1589 and $\bar{R}^2$ (fixed effects) = .1941; for regression (ii), $\bar{R}^2$ (constant) = .1572 and $\bar{R}^2$ (fixed effects) = .1607; for regression (iii), $\bar{R}^2$ (constant) = .1821 and $\bar{R}^2$ (fixed effects) = .2036. Moreover, the values of estimated coefficients are robust to the simplification of fixed effects to a single constant. Coefficients in regressions (i), (ii) and (iii) are generally within the standard errors of their counterparts in fixed effects specifications. Further, 5% critical values for the F distribution based upon a Bayesian flat prior (see Leamer, 1978) are given by 11.468, 11.554 and 11.532 for regressions (i) to (iii) respectively, all of which are comfortably greater than the F test statistics.

13. This is not a new result. Geroski, 1991, and Geroski et al, 1993, failed to observe spillovers on industry productivity growth or on the accounting profits of firms using this data on innovations. The obvious interpretation of these results is that what spills over is disembodied knowledge (as measured, say, by R&D expenditures), while knowledge embodied in particular new products (as reflected in innovation counts) is too specific for underspread use.

14. Innovations and patents also did not have much effect on growth rates when V_t was omitted from (7), and neither had much effect in regressions explaining V_t. This may be an artifact of the relatively short time over which the effects of innovations are measured in our

regressions, it may be because most of the innovations in our data were not used by the firm which produced them (we have no record on the usage of innovations by the firms in our sample), and it may be because many patents are valueless (e.g. see Pakes and Shankerman, 1986). These results stand in contrast to those obtained by Mansfield, 1962, who found that innovating firms grew significantly faster than non-innovators (by 4-13 percentage points) over the 6-10 years immediately post innovation.

15. However, none of the three regressions shown on Table I can be simplified to an AR(3) or lower order process: the test statistics are F(17,1876) = 15.1, F(5,1888) = 49.21 and F(8,1885) = 35.36 respectively. In all cases, they are high enough to reject the null hypothesis that growth rates are purely random.

16. One way to interpret the effects of industry and aggregate growth rates on corporate growth rates is to argue that they reflect changes in market opportunities occasioned by changes in demand or in labour market conditions. Following Caballero and Lyons, 1992, they might also be interpreted as reflecting agglomeration or external effects. Either way, the fact that most of the firms in our sample are not specialised in a particular 3-digit industry makes it somewhat easier to accept the otherwise puzzling result that aggregate effects are much larger than industry effects.

17. It is not possible to simplify (i)-(iii) by dropping the lagged dependent variables without significantly worsening the fit. Our experiments suggested that including fourth and higher order lags in the dependent variable could be simplified to the three lag structure displayed on Table I.

18. We replicated these results using accounting measures of profitability and, in particular, changes in profits on sales. Accounting profits and stock market returns were not highly positively correlated in levels (.2103) or first differences (.0035), but accounting profits were far less variable than stock market returns (and displayed a much lower ratio of "within" to "between" variation). The first difference of profits on sales produced positive and significant estimates of α in (i)-(iii). For work on the relationship between growth and profits in the UK, see Singh and Whittington, 1968, and others; for a broader survey, see Hay and Morris, 1991.

19. Although some people use the market value of a firm as a size measure, this does not mean that the correlation between G_t and V_t discussed in the text is a tautology. In fact, it is easy to find many examples where $G_t > 0$ while $V_t < 0$. This often occurs, for example, when a firm makes a particularly large acquisition, and there is a large literature on managerial theories of the firm which suggests that G_t and V_t ought to be negatively correlated at the margin.

20. The instruments which we used were the log level of firm market value (taken from the London Business School Share Price Database), accounting rates of return (profits and sales taken from Datastream) and the first difference of accounting rates of return, amongst others. Sargan tests on the overidentifying restrictions of instrumenting for V_t were always substantially above their χ^2 critical values.

21. This is consistent with results reported by Evans, 1987a, Hall, 1987, and Dunne and Hughes, 1994, which suggests that sample selection bias (arising from the exit of slow growing firms) does not account for the negative size-growth relation which they observe in their data.

22. We used pre-sample period classifications to avoid endogeneity problems. In fact, the composition of the quartiles was very stable through the period (not surprising since the rank correlation between firms ranked by (log) sales in 1976 and 1982 is .9434). Rerunning the regressions using quartiles defined by ranking in each year produced almost exactly the same results as those reported in the text using 1976 rankings. For instance, Wald tests of equality of coefficients over 1976 and 1982 (log) sales ranks produce χ^2 test statistics of 18.318 (.629), 15.880 (.776), 13.765 (.879) and 4.136 (.999) for the quartiles in regression i). Similarly, for regression ii), 17.869 (.037), 11.195 (.263), 5.309 (.807) and 3.655 (.933) - and for regression iii) 18.329 (.106), 14.459 (.272), 4.925 (.960) and 3.777 (.987). In each case Wald tests are reported for quartiles increasing in size. Of course, Wald tests are sensitive to variants of the Behrens-Fisher problem if these samples are not independent.

DATA APPENDIX

Both the balanced and unbalanced samples were built primarily from three sources: the DATASTREAM on-line firm accounts service, the Science Policy Research Unit's (SPRU) innovations database and the SPRU patents database. DATASTREAM financial data covers the population of firms listed on the London Stock Exchange from 1972 onwards. Firms with fewer than six continuous time series observations of our principal variables were dropped, as were firms whose principal operating industry (defined by sales) was outside manufacturing. Firms who were involved in large scale merger activity were also excluded from the samples.

The final year of the SPRU innovations database is 1983, but this year was dropped from both samples because there appears to be a serious falloff in reported innovative activity for this year which may be the result of the data collection process as the survey was conducted mid-year. The database consists of over 4370 major innovations, defined as "the successful commercial introduction of new or improved products, processes and materials introduced in Britain between 1945 and 1983". The aggregate innovations data displays discernible peaks and troughs at roughly five yearly intervals. The distribution of industry innovations across time appears broadly stable with the bulk concentrated in four two-digit (SIC) industries: mechanical engineering, electrical engineering, vehicles and chemicals. Pavitt, Robson and Townsend (1987) describe the data more fully. Innovations are enumerated by *innovating unit* - the parent or subsidiary relationship (if applicable) of each innovation holding firm has been ascertained using annual editions of Dun and Bradstreet's *Who Owns Whom* for the UK and the Republic of Ireland. An aggregate yearly innovation count has then been generated at the parent company (DATASTREAM) level for firms which are not "independent". When matched to firms accounts we have captured about one third of all SPRU innovations in the period 1972-1982. The remaining innovations accrue mainly to smaller "independent" firms who are not listed on the London Stock Exchange.

The SPRU patents database consists of an aggregate annual count of the number of patents awarded to UK registered firms by the US Patents and Trademarks Office in the period 1969-1988. The decision to use US as opposed to UK patents was motivated by the desire to "screen out" the numerous very low value patents taken out each year. There are over 7450 UK firms in receipt of US patents in this period. The parent or subsidiary relationship (if applicable) of each patent holding firm has been ascertained using annual editions of Dun and Bradstreet's *Who Owns Whom* for the UK and the Republic of Ireland. An aggregate yearly patent count has then been generated at the parent company (DATASTREAM) level for firms which are not "independent". When matched to firms accounts we have captured about 30% of all SPRU patents in the period 1972-1982. The remaining patents accrue mainly to smaller "independent" firms who are not listed on the London Stock Exchange.

One problem with the patents data is that they are enumerated at the date granted rather than the application date. Most patents granted are applied for within the preceding three years, with the mode at *t-3*. By way of example, in 1977 of the population of (approximately) 2700 US patents granted to UK firms, 73% were applied for in the preceding three years (2% in 1976, 30% in 1975 and 41% in 1974). We are grateful to Sam Kortum (Boston University) for the data upon which these calculations were made.

For this reason we have included lags of terms in patents to capture correlation which is not contemporaneous. First differencing and lagged values of our other principal variables mean that of the 640 firms from 1972 to 1982 with which we were left after cleaning, 615 are observed continually sometime from 1976 to 1982 and 271 are observed in every year. The unbalanced panel of 615 firms with $1<t<8$ time series observations produces 3315 observations in total, 77% of the potential size of a balanced panel of these (maximum) dimensions. The balanced panel of 271 firms has 1897 observations in total.

Our principal variables are as follows. *AG* is the first difference in the natural log of manufacturing gross value added. Its mean and standard deviation (between and within components) are $m_b=.089$ and $s_b=.062$ ($s_{bb}=.000$, $s_{bw}=.062$) for the balanced panel and $m_u=.074$ and $s_u=.080$ ($s_{ub}=.048$, $s_{uw}=.066$) for the unbalanced panel. This series is taken from annual editions of the *Business Monitor: Report on the Census of Production (Summary Tables)* series (PA1002, HMSO, London), Table 1 *Gross value added at factor cost (Total)*.

G is the first difference in the natural log of firm sales [$m_b=.109$, $s_b=.168$ ($s_{bb}=.069$, $s_{bw}=.154$), $m_u=.091$, $s_u=.184$ ($s_{ub}=.095$, $s_{uw}=.162$)]. This series is taken from DATASTREAM. *IG* is the first difference in the natural log of net three digit SIC industry sales [$m_b=.094$, $s_b=.096$ ($s_{bb}=.033$, $s_{bw}=.091$), $m_u=.083$, $s_u=.094$ ($s_{ub}=.047$, $s_{uw}=.083$)]. Gross three digit SIC industry sales are taken from annual editions of the *Business Monitor: Report on the Census of Production (Summary Tables)* series (PA1002, HMSO, London). Table 1 *Sales and work done (Total)*. Firm sales are subtracted from industry sales to obtain net industry sales. There is likely to be mismeasurement of this variable because of the presence of large, multi-industry firms in the data, but controls for fixed effects should deal with this if the mismeasurement is stable over time.

INN is a count of the number of innovations produced by each firm [$m_b=.144$, $s_b=.797$ ($s_{bb}=.669$, $s_{bw}=.436$), $m_u=.081$, $s_u=.598$ ($s_{ub}=.444$, $s_{uw}=.323$)]. This series is taken from the SPRU innovations database, which is described above. *PAT* is a count of the number of patents produced by each firm and registered in the US [$m_b=2.421$, $s_b=13.630$ ($s_{bb}=13.131$, $s_{bw}=3.729$), $m_u=1.445$, $s_u=10.417$ ($s_{ub}=8.887$, $s_{uw}=2.814$)]. This series is taken from the SPRU patents database, which is described above. *V* is the first difference in the natural log of firm market value [$m_b=.141$, $s_b=.529$ ($s_{bb}=.145$, $s_{bw}=.509$), $m_u=.104$, $s_u=.402$ ($s_{ub}=.186$, $s_{uw}=.363$)]. This series is taken from the London Share Price Database (LSPD). The LSPD is maintained by the Institute of Finance and Accounting at the London Business School and contains data for approximately 6000 companies, comprising several different samples. As well as a random sample of 33% of the companies quoted on the London Stock Exchange between 1955 and 1972 and samples containing the largest companies quoted in 1955 and 1972, there is a complete history for all UK companies quoted in London since 1975, including those companies traded on the Unlisted Securities Market. Market value is the product of the firm's outstanding shares and the price of these shares on December 31st. This date was chosen to obtain the best possible match between the dating of the firm's innovations and patents and its market value. An average price for the three months preceding the firm's accounting year was also constructed from monthly observations (last trading day) of share prices to iron out atypical fluctuations but this had little effect on results.

TABLE I: Estimates of Equation (7)[*]

Independent Variables	(i)	(ii)	(iii)	(iv)
V_t	.0629 (7.019)	.0612 (7.433)	.0774 (8.799)	.1000 (4.201)
V_{t-1}			.0551 (5.092)	.0636 (1.559)
V_{t-2}			.0368 (4.119)	.0547 (2.126)
V_{t-3}			.0117 (1.746)	-.018 (.695)
G_{t-1}	.1088 (3.421)	.1086 (3.524)	.0646 (2.235)	.0539 (2.244)
G_{t-2}	.0015 (.039)	-.0005 (.01)	-.0324 (.665)	-.0462 (1.169)
G_{t-3}	.0962 (3.333)	.1014 (3.065)	.0844 (2.572)	.0913 (2.915)
AG_t	.6971 (9.644)	.7202 (10.311)	.7547 (9.893)	.6484 (4.879)
AG_{t-1}	.0272 (.294)	.0335 (.395)	.0211 (.257)	-.0119 (.134)
AG_{t-2}	-.0057 (.055)	-.0608 (.52)	-.1685 (1.507)	-.1416 (1.221)
AG_{t-3}	-.2631 (2.348)	-.3044 (2.556)	-.5031 (3.918)	-.6529 (3.264)
INN_t	-.0007 (.129)			
INN_{t-1}	-.0005 (.099)			
INN_{t-2}	.0093 (1.517)			
INN_{t-3}	-.0048 (.619)			
PAT_t	.0011 (1.669)			
PAT_{t-1}	.0002 (.348)			
PAT_{t-2}	-.0015 (2.449)			
PAT_{t-3}	.0004 (.855)			
IG_t	.024 (.589)			
IG_{t-1}	.0734 (1.776)			
IG_{t-2}	-.1083 (2.772)			
IG_{t-3}	-.0251 (.543)			
R^2	.1678	.1608	.1868	N/A
SE of Regression	.1543	.1545	.1522	.3150
Hausman FE/RE	21.940 (.001)	23.309 (.001)	26.272 (.001)	83.645 (.185)[***]
F(zero slopes)	18.915 (.000)	45.203 (.000)	39.363 (.000)	346.007 (.000)[**]
White hetero	125.76 (.000)	74.705 (.000)	139.98 (.000)	N/A
m_1 AR/MA(1)	.307	.491	1.079	.039
m_2 AR/MA(2)	1.2	1.204	.694	.610

[*] Dependent variable is G_t. Method of estimation is Ordinary Least Squares for regressions (i) to (iii). Generalised Method of Moments for regression (iv). Standard errors are robust to heteroscedasticity. Instruments used in regression (iv) are firm innovations, firm patents and firm profits dated t-3 or earlier. Absolute values of *t* statistics in parentheses. V=Δlog(firm market value); G=Δlog(firm sales); AG=Δlog(manufacturing gross value added); INN=number of firm innovations; PAT=number of firm patents, and; IG=Δlog(net three digit industry sales). Data sources are described in the Appendix. The Hausman χ^2 test of fixed against random effects is based on the comparison of a random effects estimator which is (more) efficient under the null of random firm effects but inconsistent under the alternative of fixed firm effects, with a fixed effects estimator which is consistent and less efficient under both hypotheses. m_1 and m_2 are autocorrelation tests described in Arellano and Bond (1991) and asymptotically standard normally distributed. All equations contain a constant. A simple AR(3) model yields coefficients of (*t*): .155 (4.82), .072 (1.61), .161 (4.52) with a constant of .054 (5.34) and R^2 = .054. The number of observations is 1897.[**] Wald test of joint significance. [***] Sargan test of overidentifying restrictions.

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