The Profitability Dynamics of Indian Firms

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Abstract

We assess the relative importance of firm and industry effects on corporate profitability in India for a sixteen year period and evaluate the changing balance between these effects as a regime of control and regulation, pre 1985, gave way to partial liberalization between 1985 and 1991 and to more decisive liberalization after 1991. We test the significance of the variance components, the differences between them and their changes over time. We find that firm effects are significant in all periods, when rent seeking opportunities proliferated, as well as when the scope for strategic decisions increased under competition brought about by institutional change. These effects become more pronounced over time. While the industry effect does statistically matter, in general, it is significantly large in the period after comprehensive liberalization, relative to other periods, suggesting that industry choice also matters within competitive markets for firms to enjoy above average profitability.

Key words: firm and industry effects; institutional change; transition economy; profitability; Indian industry; liberalization.

1. Introduction

In this article, we report the results of a study that examines the determinants of profitability of firms in India. Using a proprietary dataset on Indian firms, we evaluate the relative importance of firm versus industry effects in impacting the levels of profitability of a balanced panel of firms over a sixteen year period from 1980-81 to 1995-96. The overall period straddles the most important period in the recent history of the Indian economy, as the opening up of markets took place with the liberalization of industrial policies in 1991, and each period covers a unique phase in the contemporary history of India. Our analysis covers three well-defined institutional eras for contemporary India.

The issue of firms' profitability is important, and the search for superior profits is the primary objective of firms' management since relatively higher profits mean the availability of greater amounts of cash to invest for future growth. One view posits that industry effects matter the most in explaining profitability differences between firms. Firms are lucky to have gotten into a profitable industry by chance or politics. Once in then they take advantage of opportunities for exploiting market power.[1] An alternative school of thought posits that firm effects matter the most in explaining profitability differences between firms. Firms have idiosyncratic skills enabling them to become profitable.[2]

[1] The mainstream literature (Bass, Cattin and Wittink, 1978; Cubbin and Geroski, 1987) has dealt with assessing market structure related factors influencing firms' profitability levels, though Mueller (1977), reporting significant firm level profitability persistence over time, first highlighted the validity of the firm effect. According to the mainstream paradigm, an explanation for the empirical relationship between concentration and industry profits is market power. Higher concentration, predicated by industry specific factors (Sutton, 1991), facilitates the exercise of market power by large firms, thereby generating superior profits.

[2] The alternative perspective on industrial organization and performance (Demsetz, 1973; Mancke, 1974) has suggested that the positive relationship between size, market structure and profitability arises because larger firms are more efficient. They increase industry concentration and earn higher profits.

In line with establishing the credentials of alternative perspectives, a literature has evolved to derive the theoretical foundations underlying firms' specific competencies that predicate profitability (Nelson, 1991). While early work of Schmalensee (1985) established industry effects to be dominant in explaining profit variations across firms, other studies (Scott and Pascoe, 1986; Rumelt, 1991) have pointed to firm effects as being primary in explaining profit variations. The literature has generated debate, not only because there were large variation between studies on the estimated importance of firm-effects, but also on the related question of appropriate econometric methodology.

Yet, a balanced approach, that both firm and industry effects are important, is suggested in other work (Kessides, 1990; Waring, 1996). Several important contributions (McGahan and Porter, 1999) have also established industry effects and firm effects to be both important in explaining profit variations across firms, and a contention is that differences in the resource and competence bases of industries arise while structural differences in the environment can give rise to firm effects.

While the above contributions sharpen our understanding of why some firms have profit levels superior to others, and why profits persist, the work has been carried out under the assumption that institutional conditions may not matter. This is not surprising given the context has been the Western economies enjoying stable institutional regimes. Yet, even in such economies institutional factors vary and are important for economic growth, and for the performance of economic agents in an economy (North, 1991; Olson, 1996; Parente and Prescott, 2002).

If the performance of firms in an emerging economy are to be evaluated, assuming institutional absence is untenable, given the rapid institutional changes taking place within these economies. Institutional factors matter greatly in influencing economic performance in emerging economy contexts (Amsden, 2001; Hall and Jones, 1999; Rodrick, Subramanian and Trebbi, 2004;

Wade, 1990), and the inclusion of institutional effects is important in evaluating the long-run performance of firms in emerging economies.

We evaluate the importance of firm versus industry effects for an important economy, India, against the backdrop of economic reforms in the late 1980s and early 1990s. We address the issues of whether industry effects are important in emerging markets such as India, the extent to which firm effects are significant, both in an absolute sense and in relation to industry effects, and if the relative and absolute magnitudes of firm and industry effects have changed over the period of institutional transition.

India is a large and important economy today, but little as yet is known about Indian firms' strategies and performance (Luce, 2006). On the other hand, institutional conditions have been extremely important in influencing industrial performance in India (Bardhan, 1984; Jalan, 2005) and in extensively shaping the contours of firms' strategic decision making (Das, 2002; Haksar, 1993; Marathe, 1989; Mohan and Aggarwal, 1990). We take into account the prevalent institutional conditions by introducing institutions as a key profit impacting element.

In addition, there is the issue of method. Studies using time series data often assume that the various effects remain constant over time. This assumption is linked to the natural belief that institutions remain stable as they do in developed economies. We evaluate the validity of this assumption by incorporating a different method. Analyses in this branch of literature have involved the decomposition of the variance of business-unit profitability, using components of variance (COV) and nested ANOVA techniques, apportioning it into elements attributable to year, industry, firm, and business units. Conclusions are drawn based on the sizes of estimated firm and industry effects, but statistical inference is not carried out.

There have yet been no attempts to test whether any of the variance components are statistically significant, whether one component is significantly larger than another and whether any

of the components have changed significantly over time. Some of the effects may be large and yet insignificant, thus being immaterial for drawing conclusions. In this article we redress this by testing for the significance of all of the estimated effects.

In the next section we review the existing literature briefly. Thereafter, we describe the Indian context and state our expectations for the periods studied. We follow the section with a data description. The section after that goes into details of the econometric procedures. This is followed by the description of the results and the findings. The final section contains a discussion and concludes the article.

2. Literature

Commencing with the contributions of Schmalensee (1985) and Rumelt (1991) several researchers have studied the determinants of corporate profitability in the United States. Industry specific factors include the concentration level of an industry, consolidated versus fragmented industries, minimum capital requirements, an important entry barrier in some industries, or product differentiation, also an entry barrier. Firm specific characteristics include firm resources, capital, technology and human resources, marketing, management or production skills, and strategies.

For one school of thought, inter industry differences are the main sources of variance in performance, while firm specific characteristics are regarded as less important. For the other, the orientation of a firm's behavior towards making choices and firm characteristics, such as resources, capabilities and strategies, determine firm performance. Even in weak industries, stars consistently outperform the others, and in high-profit industries failures occur due to mistakes by firms.

Over two decades of research, based on US corporate data, consensus has emerged, that industry factors explain a relatively small proportion of the variations and a larger proportion of profit variations are attributable to firm or business specific characteristics. Macroeconomic factors, identified by time effects, and interaction between industry and time, representing different cyclical

patterns in different industries, also contribute to profit variations significantly. Substantial remainder in variations cannot be attributed to any of these factors.

In the conceptual domain, theoretical developments postulate that underlying firms' specific competencies that predicate profitability also lead to changes in industry conditions. Thus, differences in the resource and competence bases of industries can arise, influencing profitability, while simultaneously structural differences in the environment, including country-specific factors, can give rise to firm effects (Nelson, 1991).

A central concern in the literature on decomposition of firm performance into its various determinants relates to empirical analysis. Both approaches have conducted variance decomposition analyses to evaluate quantitatively the roles of industry and firm specific factors on performance variations. The results of these studies have been varied, the variations being largely attributed to differences in sample composition, period of study, definitions of firm, industry and business segment effects, and methods of analysis.[3]

3. Institutional Details and Hypotheses

3.1 The Indian Context

Institutions determine the distribution of resources (Hayami and Ruttan, 1985), shape the incentives of competitors (North, 1991), influence the level of investments (Acemoglu, Johnson and

[3] While both Schmalensee (1985) and Rumelt (1991) use COV and nested or sequential ANOVA approaches, the two studies have differed in the importance placed on the two methodologies. The COV assumes random effects. The nested ANOVA approach, in contrast, assumes that the effects are fixed. Schmalensee (1985) has used the COV estimates of variance components for evaluating the relative importance of the different effects but suggested an ANOVA test for significance as a prerequisite to COV estimation. In contrast, Rumelt (1991) argues that COV analysis is a statistical description of the data, and recommends its use based on its independent merit as a method for estimating the importance of effects. We adopt the COV approach in our analysis, but augment the analysis with a battery of new tests to evaluate the significance of effects, relative to each other as well as over time, and these tests have not hitherto been used in the literature.

Robinson, 2006), shape the power structure (Bardhan, 2005), influence the allocation of property rights and can be interfering deterrents or facilitators for firms to achieve best outcomes (Andersson and van Laerhoven, 2007). Thus, they significantly influence firms' behaviour. Nevertheless, formal institutions can be changed. Institutions evolve and are formed by incremental change of earlier institutions. If the institutional changes that take place are truly 'policy switches' (Flood 1992), they can destroy the path-dependencies engendered in the past.

Our analysis covers the sixteen-year period from 1980-81 to 1995-96. The period is divided into two equal phases of five years each and one of six years. Each phase is distinct in terms of its political economy and attention paid to institutional features of the economy during the time period. The first five-year phase, one of regulation and control, is from 1980-81 to 1984-85. The second five-year phase, one of partial liberalization, runs from 1985-86 to 1990-91. The third five-year phase, one of full liberalization, runs from 1991-92 to 1995-96.

The year 1980 is associated with the commencement of attempts to liberalize the Indian economy. In 1980, Mrs. Indira Gandhi returned to office and commenced liberalization (Bhagwati, 1993). But severe political turmoil intervened, nothing much happened, the period remained one of regulation and control (Marathe, 1989), with severe policy distortions (Srinivasan, 2003), and she was assassinated in 1984.

In 1985, Rajiv Gandhi took office as head of government and commenced industrial reform activities with a new slate, but very soon the government was involved in the 'Bofors' corruption scandal involving the purchase of artillery guns. In 1991, a new government took office, and one its first acts was to liberalize the economy, by removing past distortions, so as to promote economic growth (Das, 2002; Srinivasan, 2004).

3.2 Theoretical Importance of Institutional Context

Existing studies based on Western economies concentrate on economic factors as determining firm performance. Yet, even in Western societies the fundamental difference in comparative growth between different countries has been the differences in institutions (North and Thomas 1973; Parente and Prescott, 2002). In transition economies, such as India, and in other emerging markets, institutions have mattered more for economic performance (Amsden, 2001; Bardhan, 2005; Easterly, 2002).

While countries may have access to the same stock of initial ideas about institutions, the way they are designed and implemented across countries can lead to policy distortions and barriers being put up that affect economic performance (Parente and Prescott, 2002). These institutions, and barriers if any, influence the level of investments in physical and human capital, technology and the organization of production within firms (Acemoglu, Johnson and Robinson, 2006). Since one of the primary functions of a firm is the acquisition of resources, and their organization into modules of productive skills, it is axiomatic that firm performance will be affected by institutional context.

Other than shaping the context for resource acquisition, institutions shape the power structure in an economy and the primary category of institutions are political institutions (Bardhan, 2005). For example, with respect to the distribution of property rights, an important feature influencing capital productivity (de Soto, 2000), their allocation is a function of the institutional context. The institutional context alters the inalienability characteristics of property rights and impacts on capital productivity levels.

In addition, government agencies can either use institutional rules to interfere in day-to-day activities of firms or provide facilitation for firms to achieve best outcomes (Andersson and van Laerhoven, 2007). Also, if policy distortions are severe, firms may just not adopt the requisite technologies or work practices to work effectively and profitably (Parente and Prescott, 2002).

Similarly, in an institutional environment with strong barriers to entry and specification of detailed rules for the conduct of business, firm behavior will be oriented towards political rent-seeking (Krueger, 1974) and politician management (Das, 2002). Large amounts of resources are directed towards political as opposed to commercial relational activities (Becker, 1985). Firm effects picked up may predominantly relate to political and rent seeking tasks (Tullock, 2005).

An institutional legacy that hinders an efficient market for outputs and resources will engender increasing returns to political behavior carried out within a non-market oriented institutional framework. The importance of firm effects, in an economy such as India, will be strongly tempered by the degree to which firms will have operated within a controlled environment with strong barriers to entry and conduct of business (Parente and Prescott, 2002). Firm performance will be determined both by newly emergent market forces, economic factors and the legacy of economic planning and control (Bardhan, 2005; Jalan, 2005).

3.3 Hypotheses

We discuss how institutional characteristics relate to our periods and link shifts in institutional policy to the dynamics of firm competition, possible industry structure and profit impact. In India, the institutional framework till the mid 1980s is characterized as one of detailed administrative day-to-day direction (Marathe 1989), even though 'reforms by stealth' were attempted to set in motion some liberalization (Bhagwati, 1993). Controls over all facets of operations of firms, for example, on activities such as pricing and acquisition of raw materials, distribution of the final product, and allocation of foreign exchange within projects, remained all pervasive, not just control over strategic issues such as whether firms could enter certain sectors of industry (Weiner, 1986).

Government policy during a pre-liberalized regime dictates who can enter and compete in a given industry, thus serving as an industry barrier and leading us to expect that during such controlled periods industry effects would be stronger and not weaker. By managing entry, firms

would enter and secure a position in the industry rent chain. Government can also mandate that totally inexperienced firms enter a particular sector[4] and even if industry rents are available these firms may not have the capacity to enjoy them. Additionally, capacity licensing policies can be such that demand shortfalls are chronic and price controls can operate in many industries (Mohan and Aggarwal, 1990; Srinivasan, 2004). These eradicate profit possibilities for firms present in industries with adequate demand. Presence within an industry may not be material for profits.

Firms, by virtue of their capabilities, contribute to the resource base of industries and help define industry structure (McGahan, 2004). Yet, the way resources are distributed, incentives shaped and investments influenced, this can be infeasible. Control means markets and were supply options closed and so were.[5] If on the production side, firms of inappropriate scale are allowed to operate the concept of minimum efficient scale is abandoned.

The exact number of firms that can operate in a particular industry, the size of each firm and the technology mix that firms can deploy can also be also laid down by institutional authorities. These institutional features can hold any industrial sector hostage to a backward technological era with no grounding in the concept of efficiency and firms. Industry-specific characteristics that might have dictated efficiency growth are simply unable to be exploited by firms within industries (Little, Mazumdar and Page, 1987).

[4] For example, cigarette makers were mandated to become hoteliers, battery manufacturers became shrimp exporters and engineering companies traded commodities (Haksar, 1993).

[5] Industries were given directions as to the areas they could enter, and the amount of investments possible. There were quantity controls and capacity management. Control over resources became the policy. Strategic and operational decisions were taken away from firms (Marathe, 1989). There were little incentives for enlarging production as a result of competitive market pressures. Raw material inputs, foreign exchange, foreign technology purchases, types of collaborations, and the amount of domestic capital made available to any unit, were decisions which the state controlled, apart from controlling capacity dispensations.

Where price, quantity and technology controls operate, the impact of industry levels factors on firms performance disappear (Bhagwati, 1993). Market and supply option closure policies instead influence firms to heavily engage in rent-seeking activities (Goswami, 1985; Mohan and Aggarwal 1990), and the critical competencies that firms develop are in the sphere of political and government activities management. A focus on such activities by firms would also be in consonance with the rent-seeking literature (e.g. Becker, 1985; Bhagwati, Brecher and Srinivasan, 1984; Krueger, 1974; Tullock, 2005). Thus, managing the political economy becomes more important than managing the market or the industrial economy.

Rent seeking has been an important in the past history of Indian business (Ray, 1979). It remained an all-important and all-consuming activity of firms, so as to pre-empt licensed capacity to serve a market, by manipulating the approval process, and acquire other resources that were in short supply so as to undertake business activities (Das, 2002).[6] Managing the political economy was the activity that most corporate managers undertook in the *"license raj"* regime (Haksar, 1993; Ray, 1999). This phase is termed as one of 'continuation.' Pre-1980 policies were the dominant institutional features of the Indian economy in the 1980-81 to 1984-85 phase.

Das (2002) specifically highlights how the attention of top managers of that time was primarily given to dealing with the senior administrative personnel of various government departments and agencies rather than in managing the business properly. Any company wanting to succeed economically

[6] Bhagwati (1993: 49) has written "Few outside India can appreciate in full measure the extent and nature of India's controls until recently. The Indian planners and bureaucrats sought to regulate both domestic entry and export competition, to eliminate product diversification beyond what was licensed, to penalize unauthorized expansion of capacity, to allocate and prevent the reallocation of imported inputs, and indeed define and eliminate virtually all aspects of investment and production through a maze of *kafkaesque* controls. This all-encompassing bureaucratic intrusiveness and omnipotence has no rationale in economic or social logic; it is therefore hard for anyone who is not a victim of it even to begin to understand what it means."

devoted substantial resources, and its best people, in institutional management activities that included a full-fledged office solely given to institutional liaison work and manned by the senior-most staff or family members. In view of India's institutional context we hypothesize that:

H1A: Firm effects will be an important determinant of profitability in the pre-liberalization period of 1980-81 to 1984-85;

H1B: Firm effects in the pre-liberalization period of 1980-81 to 1984-85 will dominate industry effects in the same period;

H1C: Industry effects will be an inconsequential determinant of profitability in the pre-liberalization period of 1980-81 to 1984-85.

The control regime described above continued till 1985, when a new prime minister, the late Rajiv Gandhi, sought to modernize the Indian economy and introduced partial liberalization, or 'reforms with reluctance' (Bhagwati, 1993). Liberalization policy after 1985 involved the supply routes for competencies and capabilities. Limited permissions to purchase foreign technologies,[7] allowing the establishment of plants at economic scale and encouraging the establishment of sunrise industries would affect both firm effects and industry effects (Government of India, 1985: 7.42).

As quantity controls generally diminish, the economic and technological logic that underlies different industry contexts can come to the fore. Thus, capacity restrictions are relaxed, permitting firms to enjoy the benefit of scale economies that might have been feasible in certain industries. Also, some capacity that might have been surreptitiously added by entrepreneurs can be regularized so that production according to market conditions can proceed. Thus, the ability of firms to shape the dynamics of industry structure via appropriate investment and market development activities are made feasible by the institutional changes.

[7] Import restrictions, particularly for capital goods, were significantly lessened.

The transition from a regulated and controlled environment to a liberalized environment requires that credible commitments by the government (Spiller, 1996). This is so that firms can then alter their behaviour and adapt to the new environment with certainty. The initial implication of the transition for the corporate sector is that past practice of managing the labyrinths of bureaucracy are less critical than skills needed in managing operations, production processes, marketing strategies, and facing the onslaught of potential competition. In other words, proper strategic management can take place. A transition from rent-seeking and bureaucracy management to strategic management implies that: the premium on efficiency increases.

In India, the phase of partial liberalization turned to one of confusion. Initial efforts to permit firms to enjoy the benefits of industry-driven economies fell by the wayside as the government got embroiled in the *Bofors* scandal and attempts at liberalization foundered. Constraints on the freedom of choice to tackle interesting market segments remained. Therefore, industry effects were still suborned to institutional whims. The credible commitments required to be made by government were not forthcoming in India during this period. The Indian markets were not made truly contestable till the reforms of 1991 (Das, 2002). Based on the above, we expect that:

H2A: Firm effects will be an important determinant of profitability in the pre-liberalization period of 1985-86 to 1990-91;

H2B: Firm effects in the pre-liberalization period of 1985-86 to 1990-91 will be larger than those in the pre-liberalization period of 1980-81 to 1984-85;

H2C: Firm effects in the pre-liberalization period of 1985-86 to 1990-91 will dominate industry effects in the same period;

H2D: Industry effects will be an inconsequential determinant of profitability in the pre-liberalization period of 1985-86 to 1990-91.

The trigger for the 1991 reforms was a severe financial crisis. Under pressure from the *World Bank* and the *International Monetary Fund*, the government agreed to several macro-economic reforms. It was realized then that a process of micro-economic reforms could be implemented, and several of these reforms effectively ended the policy of industrial licensing the regulatory system had been built on (Ahluwalia, 2002). These 'reforms by storm' (Bhagwati, 1993) brought in competition and made Indian markets contestable (Panagariya, 2004; Srinivasan, 2003). We term this phase as one of 'competition.'

In consonance with the evidence for comparable Western economies, such as the United States, once markets are contestable then superior profits accruing from an attractive industry position are dissipated away because of the presence of several new entrants. The lowering of entry barriers will ensure that this happens. Therefore, as market contestability increases, enhancing industry fragmentation, the importance of firm effects will increase and the importance of industry effects will decrease. Firms will need to differentiate their products and services for a contestable market environment. These requirements will, in turn, generate a premium for the firm-specific capability investments required to do so, and the acquisition of these capabilities will be reflected in the higher magnitudes observed for the firm effects.

The enhancement of market contestability also changes individual psychology (Ellerman, 1985) and sets in motion an explosion of entrepreneurial experimentation (Eliasson, 1991), as well as increasing the discernment of customers who can become choosy and demanding, thereby rapidly altering the composition of industry structure (Sutton, 1991). In such circumstances, managing the market economy, and choosing which industry to be in, can turn out to be material.

As new entrepreneurs enter an industry, because a policy switch (Flood, 1992) alters the rules of the game and institutional mandates no longer hold, in a dynamic matching process many firms find that their resources and capabilities are not matched with the characteristics of the

industry chosen to enter. There will be shakeout. Firms that have chosen the right industries, segments and niches will enjoy superior levels of profits accruing from participating in these segments and industries. With an explosion of entrepreneurial experimentation, there will also be numerous exits, as failure becomes well-accepted and institutionally difficult to evade, so that industry structure can attain its natural equilibrium of firms rather contain a number of firms artificially dictated by institutional fiat.

Within an industrial economy, once an industry is relieved of the artificial constraints that have forced operations within it to be conducted in particular ways, because of prior micro-management a process of liberalization re-establishes the natural economic rhythm that is specific to each industry (Reid, 1987). If there are specific industry-levels forces, which will have been created by the cumulative actions of firms, that are germane to firms' profits, these assert themselves and their impact is felt on firms' performance. Thus, industry effects also become consequential to economic performance.

One of the characteristics after the 1991 liberalization has been a recovery of self-confidence for the enterprising class, letting go of the mental path-dependencies of the control era (Guha, 2007; Khilnani, 1999), and a large surge of entrepreneurship (Luce, 2006; Majumdar, 2007). This surge of entrepreneurship will have influenced significant investments in firm level capability building, so as to obtain the requisite efficiencies for growth and survival, as well as capabilities in the identification of particular niches that yield superior profits. Under such conditions, the logic of corporate success is dominated by economic and not political or regulatory forces, and both firm and industry effects will matter in influencing profit generation after liberalization. We expect that:

H3: Firm effects will remain consequential and as compared with the pre-liberalization periods 1980-81 to 1984-85 and 1985-86 to 1990-91, will be more important in the post-liberalization period of 1991-92 to 1995-96, indicating increased accumulation of firm-specific capabilities and improved efficiency.

H4: Industry effects will be consequential in the post-liberalization period of 1991-92 to 1995-96 and will be higher in the post-liberalization period of 1991-92 to 1995-96 as compared with those in the pre-liberalization periods of 1985-86 to 1990-91, reflecting the emergence of a competitive market with positive performance outcomes accruing to firms because of appropriate industry and segment choices.

4. Empirical Analysis

4.1 Basic Model

We test the hypotheses, using variance decomposition, based on the following model of profitability of company c in industry i at time t:

$$r_{cit} = \mu + \alpha_c + \beta_i + \gamma_t + \delta_{it} + \varepsilon_{cit}, \quad (1)$$

where the μ is the overall mean, and α's, β's, γ's, δ's and ε's are the firm or company effects, industry effects, time effects, industry × time interaction effects and random errors and disturbances respectively.

To infer the relative importance of the different effects, we assume independence between the different effects, and between error and the effects. Since unconditional independence can be an unreasonable assumption, it is convenient to assume independence conditional on, or subject to, the inclusion of either an adequate choice of interaction effects, as in the COV and ANOVA approaches, or an adequate selection of regressors as in the regression approach.[8]

Under the above assumptions, the variance of r_{cit}, denoted σ_r^2, can then be represented as:

$$\sigma_r^2 = \sigma_\alpha^2 + \sigma_\beta^2 + \sigma_\gamma^2 + \sigma_\delta^2 + \sigma_\varepsilon^2 \quad (2).$$

[8] For example, in the model for corporate profitability, equation 1, it is unreasonable to assume that the industry effects are independent of the year effects, because firms in different industries are affected differently by changes in the macroeconomic environment. This dependence is incorporated in the model by including an industry × year interaction effect. Inclusion of this interaction effect is independent of the subsequent choice of methodology, whether the model is estimated using the nested ANOVA, COV or regression approach.

This linear split of the variance of r_{cit}, i.e. σ_r^2, into components corresponding to distinct sources of variation, enables assessment of the relative importance of the various effects in explaining overall variability in r_{cit}.

Our modeling choice is guided by our hypotheses. Given these hypotheses, we choose a method robust to sampling fluctuations and violations of assumptions, for moderate sample sizes, and that allows the following kinds of inference, first, we estimate the contribution of each factor to the overall variation in profitability, variance components, both in absolute terms (σ_α^2, σ_β^2, σ_γ^2, σ_δ^2 and σ_ε^2) and in relative terms (e.g., $\sigma_\alpha^2 / \sigma_r^2$ or $\sigma_\alpha^2 /(\sigma_r^2 - \sigma_\varepsilon^2)$). The, we then infer on the significance of each variance component by testing hypotheses of the form $H_0 : \sigma_a^2 = 0$ against the alternative $H_1 : \sigma_a^2 > 0$ for $a = \alpha, \beta, \gamma$ or δ. Third, we assess the relative importance of different effects by testing hypotheses such as $H_0 : \sigma_\alpha^2 = \sigma_\beta^2$ versus $H_1 : \sigma_\alpha^2 > \sigma_\beta^2$. Fourth, we test for transition over the period of liberalization by testing hypotheses such as $H_0 : \sigma_{\alpha,t}^2 = \sigma_{\alpha,t-1}^2$ against the alternative $H_0 : \sigma_{\alpha,t}^2 > \sigma_{\alpha,t-1}^2$.

Thus, in the context of understanding the relative importance of firm and industry effects within the Indian environment, we use a method allowing us to estimate the variance components robustly while conducting hypothesis tests on the magnitude of these variance components. We use maximum likelihood estimates in our analysis. These maximum likelihood estimators (MLE) are among the most robust estimators of variance components (Brown and Mosteller, 1991) and their asymptotic standard errors are easy to compute. The method has the advantage it does not produce negative variance components estimates. We also compare these against robust methods available in the literature such as the estimator proposed by Huggins (1993).

5. Data and Empirical Analysis

5.1 Data Description

To test our hypotheses we use data drawn from the Reserve Bank of India (RBI) database on financial accounts of non-government public limited companies. The choice of the data is driven by two important factors. First, since the analysis spans sixteen years, it has been imperative to select a database with good and consistent coverage over this entire period.

The RBI database is an elaborate and consistent database on Indian companies maintained by the RBI since the financial year 1950–51 onwards, based on balance sheets, profit and loss accounts and annual reports of the companies. Aggregates based on these accounts inform policy and are used for compilation of national accounts. They are also used for estimating the growth and performance of the real sector of the economy. The data we use relate to companies that are public limited, according to the definitions of the Companies Act, 1956, and some of these may be listed on stock exchanges. The Reserve Bank of India also collects similar data on private limited companies, as defined in the Companies Act, 1956, but these data are not released to outsiders.

The overall data set comprises a pooled cross-section, where a different sample of companies is included each year. The data are widely perceived to have representative coverage of most sub-segments of the Indian corporate sector.[9] It was important that the coverage be not only representative of the population in each year, but that it was consistent over the long period of time covered in the study. Second, it was necessary to use a database taking adequate care of changes in accounting norms over this period.

[9] The RBI public limited company data represents approximately 85 per cent of the paid-up capital of 86 3-digit industries (Feinberg and Majumdar, 2001). The consistent coverage over a long period has contributed to database quality. Additionally, the data are standardized into a common format across companies and time to maintain consistency. While proprietary, the RBI database has been commonly used for empirical work related to policy on the Indian corporate sector by government bodies. Private use of it is rare.

We first begin with a balanced panel of firms. To construct the panel we used data on a balanced number of firms for the period 1980-81 to 1995-96. Thus, every firm is represented every year in our base-line data sample. Between 1,600 and somewhat over 3,000 companies are surveyed each year. However, while the RBI systematically collects data on large public limited firms, its coverage of smaller public limited companies is sporadic. Entries and exits in and out of the sample are the smaller firms that may not submit data rather than actual entries and exits. At the maximum for any year of our series, there are 3,187 firms in the sample. We initially use a balanced panel to negate firm specific sample selection issues. The total number of observations initially used is 7,200.

Next, while studies in the literature attempt to distinguish between business, corporate parent and industry effects, our focus is only on firm and industry effects. This is because most of the firms in the sample are single business firms. The RBI database includes several diversified firms. However, profits and other financial characteristics for the different business units of these firms are not separately recorded in the data base. Hence, we omit diversified firms from our analysis. We cannot consider business and corporate level effects separately.

In addition to diversified firms, we exclude state owned enterprises and privately held limited companies from our sample. Further, we confine our analysis to the manufacturing sector. The effect of the business cycle and institutional factors such as credit availability, impact of fiscal policy and fluctuations in interest and exchange rates will be similar for publicly held firms in the manufacturing sector. These are captured in our analysis by the time and industry and time interaction terms. We initially commence analyses with data on a balanced panel of 450 firms for the period 1980-81 to 1995-96. These data are classified into 22 industries, ensuring that each industry has at least 6 companies in each year.

5.2 Variables and Descriptive Statistics

Following the major focus in the literature, we choose return on assets (ROA) as our profit measure. We also used the operating profit margin, the ratio of profits before depreciation, interest and tax to net sales (EBIDTA), as an alternative measure of profitability. Since the implications of the latter measure are similar to that ROA, we report only the results for ROA.

Table 1 presents a summary of the cross sectional distribution of ROA in various industries and over the period of the study. There are substantial differences in profitability across industries in 1980-81 and 1995-96 and in intervening years. Yet, the time-series of average ROA is approximately stationary across all the industries validating the use of linear models. Also, the change in average profitability over time dominates the change in standard deviation of profitability in most industries.

The cross sectional distribution of ROA is negatively skewed for most industries and has high kurtosis. Therefore, the normality assumption, important to estimation methods for variance components, may not be valid. Because of the non standard distributional characteristics of the cross-section of profitability ratios, we pay attention to robust inference techniques.

5.3. Maximum Likelihood Estimation Procedures

We estimate a linear model where firm-level profitability, r_{cit}, is linearly related to the firm effect, the industry effect, time effects, industry × time interaction effect and an error term, in equation 1. Making the random effects assumption that the various fixed effects and interaction effects included in the model arise randomly and independently of each other, the variance of firm-level profitability can be linearly decomposed into the constituent variances of the various fixed and interaction effects and the variance of the error, in equation 2.[10]

[10] An important issue regarding the components of variance method employed is the validity of the random effects assumption. This is judged by the standard test of Hausman (1978) where the consistent fixed effects estimator is compared with an estimator, the random effects estimator, which is efficient when the random effects assumption holds. In all cases, we find overwhelming support for the random effects assumption, in that the null hypothesis that the fixed effects

Traditionally, the analysis of firm and industry effects has taken the form of comparing shares of components of variance. We use the components of variance approach in estimating the component variances by maximum likelihood methods. In addition, we propose tests of hypothesis to determine: whether the variance components are in fact significantly different from zero, whether any one effect dominates another, and whether the effects have changed significantly over time.

Because of the problems usually associated with ANOVA, the maximum likelihood method (ML) and the related restricted maximum likelihood (REML) method are popular methods in estimating variance components. We estimate components of variance using maximum likelihood estimators. This marks a departure from other studies in the economics and strategy literatures.

The ML estimator of variance components has several merits. First, the ML method of estimation is well defined and the resulting estimators have well known large sample properties in that they are normally distributed and their sampling variances are easily estimated. Second, ANOVA estimators can be negative, which ML precludes. Further, the distributions of ANOVA estimators and in many cases their variances are unknown (Searle, 1984). Third, the ML estimator is robust to distributional assumptions. The third reason is important given the non-normal nature of the cross-sectional distribution of profitability ratios.[11] The derivation of the ML estimator for COV analysis is set out in the appendix.[12]

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estimator is the same as the random effects estimator cannot be rejected at the 5 percent level of significance.

[11] Robust ML estimators have been developed by Huggins (1993). These estimators are computation intensive, and their sampling distributions have not yet been studied well in the literature. However, due to the non-normal nature of the data, we have also tried out these estimators, and satisfied ourselves that these robust estimates are numerically not very different from the ML estimates.

[12] An important robustness issue relates to variance components analysis of firm level profitability. A large part of the firm effects may be due to a relatively small number of firms. To address this issue we remove firms with higher influence function values from the analysis. We

5.4. Tests of Hypotheses to Evaluate Significance of Effects

The description of the ML method shows how standard error estimates for the variance components can be computed. These standard error estimates can be routinely used for tests of hypotheses on the variance components, when the null hypothesis lies away from the boundary of the parameter space. However, testing for significance of random effects is a non-standard problem, since the null hypothesis of zero variance of one or more random effects lies on the boundary of the parameter space.[13] In this case, standard techniques of testing hypotheses, like the likelihood ratio test and Wald's test, break down since the asymptotic χ^2 distributions of the test statistics do not hold.[14]

Following Breusch and Pagan (1980), we use a test of the hypothesis $H_0 : \sigma_a^2 = 0$ versus the alternative $H_1 : \sigma_a^2 > 0$ for $a = \alpha, \beta, \gamma$ or δ which is asymptotically equivalent to the Lagrange multiplier test. This test statistic is given by:

$$LM = \left. \frac{\left(\frac{\partial \ln L}{\partial \sigma_a^2} \right)^2}{-\frac{\partial^2 \ln L}{\partial \left(\sigma_a^2 \right)^2}} \right|_{\sigma_a^2 = 0} \sim \chi^2(1)$$

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follow the statistical inference route, by verifying that the ML parameter estimates are similar in magnitude to robust estimates (Huggins, 1993), and that the ML standard error estimates are similar to jacknife estimates of the same variance components.

[13] From the point of view of method, existing works in strategy limit themselves to statistical estimation of variance components, a computationally cumbersome process. Testing for the significance of variance components is an extremely sophisticated statistical exercise, because the null hypothesis, that a component is zero, places the true value of the parameter on the boundary of the parameter space (Stram and Lee, 1994).

[14] In fact, Verbeke and Molenberghs (1997) caution that the *p* values given by many statistical and econometric packages are not accurate in these situations.

where $\ln L$ is the log-likelihood function, as in equation 3. The above test is more robust to departures from normality compared to the traditional Lagrange multiplier test (Koenkar, 1981).[15] We used this test to examine the statistical significance of the estimated variance components, as stated in our various hypotheses.

In addition to this, we also test the hypothesis that the firm effects dominate industry effects, or vice-versa. Relying on the asymptotic normality of the maximum likelihood estimates, we test hypotheses about the equality of the firm and industry effects, against one sided alternatives: $H_0 : \sigma_\alpha^2 = \sigma_\beta^2$ versus $H_1 : \sigma_\alpha^2 > \sigma_\beta^2$. The statistic

$$T = \frac{\hat{\sigma}_\alpha^2 - \hat{\sigma}_\beta^2}{\sqrt{I^{11} + I^{22} + 2I^{12}}} \sim N(0,1)$$

is used, where $\hat{\sigma}_\alpha^2$ and $\hat{\sigma}_\beta^2$ are the maximum likelihood estimates of the respective parameters, as in equation 4, and $I = \begin{bmatrix} I^{11} & I^{12} \\ I^{12} & I^{22} \end{bmatrix}$ is their asymptotic variance covariance matrix, as in equation 5.

Given institutional change, it is important to go beyond an examination of each time phase to determine whether the effects have changed significantly between the different phases of liberalization. This involves tests of hypotheses about the temporal stability of firm and industry effects: $H_0 : \sigma_{\alpha,t_1}^2 = \sigma_{\alpha,t_2}^2$ versus $H_1 : \sigma_{\alpha,t_1}^2 > \sigma_{\alpha,t_2}^2$. These tests are based on the test statistic:

$$T = \frac{\hat{\sigma}_{\alpha,t_1}^2 - \hat{\sigma}_{\alpha,t_2}^2}{\sqrt{I_{t_1}^{11} + I_{t_2}^{11}}} \sim N(0,1),$$

[15] Like the Lagrange multiplier test, this test exhibits local asymptotic efficiency, and its asymptotic distribution is not affected by the fact that the null hypothesis lies on the boundary of the parameter space.

where $\hat{\sigma}^2_{\alpha,t_1}$ and $\hat{\sigma}^2_{\alpha,t_2}$ are the maximum likelihood estimates of the firm-effect variance components for periods t_1 and t_2 respectively.

6. Results

6.1 Primary Findings

The ML estimates of COV, along with standard error estimates, for the entire period under analysis, 1980-81 to 1995-96, and for the three regimes, pre liberalization, partial liberalization and post liberalization, separately are presented in the panel A of table 2. In panel B, we report the variance components as percentages of the total variance in return on assets.[16] In panel C, we report the variance component estimates for the three regimes, as percentages of the explained variance $(\hat{\sigma}^2_r - \hat{\sigma}^2_\varepsilon)$.

********** INSERT TABLE 2 HERE **********

Table 2 reveals that firm effects were important determinants of differences in profitability, in congruence with much of the findings from other countries as reported in the literature, in the Indian manufacturing sector during all the three regimes. In the overall period, firm effects accounted for 29.42 percent of the variations in profitability among the firms, while industry effects were 7.61 percent. Year and industry × year effects were much smaller, and the unexplained portion of the variance in profitability was 58.04 percent.

The estimates clearly reveal the changing balance between firm effects and industry effects as the Indian economy has moved from a regime of regulation, before 1985, to partial liberalization between 1985 and 1991, and finally to a phase of comprehensive liberalization in the post 1991 period. The proportion of the variation in ROA explained by firm effects was higher in the partial

[16] The results for the other profitability ratio, gross profit margin on sales, are very similar and not reported separately.

liberalization period, at 49.49 percent, perhaps as were trying to make adjustments to a well established institutional environment that was finally changing relative to the regulated period when it was 33.84 percent. It was somewhat lower, at 38.72 percent, in the post 1991 period.

The presence of industry effects under a command and control regime, at 3.48 percent, may be partially explained by special regulations for selected industries. With the partial liberalization of the Indian economy, these special regulations were somewhat eroded and the share of industry effects was indeed the lowest in the partial liberalization period, at 1.08 percent. The size of industry effects, however, has sharply increased to 11.75 percent in the post liberalization period. In an open and competitive market place, which the institutional changes have brought about in India, the choice of industry also has an impact in explaining firms' profitability.

Panel C shows that firm effects comprise 78 percent, 91 percent and 73 percent of the explained variance in the three periods while industry effect comprise 8 percent, 2 percent and 22 percent of the explained variance. Thus, in a contestable markets environment, industry effects begin to assume a greater role in explaining profit variations.

6.2 Statistical Test Results

While past analyses of firm and industry effects have compared shares of the components of variance, we test the significance of these estimates. This exercise reveals whether just a process of random sampling, with zero variance, of the respective fixed effects or interactions could have contributed to values as large as the estimates themselves. The results of the tests, that the variance of firm effects and industry effects are zero against the alternative hypothesis of positive effects, are reported in Table 3. We also report on the test that firm effects and industry effects are equally important against the alternative that firm effects are more important than industry effects. The tests are conducted separately for the three regimes.

********** INSERT TABLE 3 HERE **********

Column (I) of table 3 lists the results of the test where the null hypothesis is that firm effects are zero versus the alternate hypothesis that firm effects are positive. The test is of the form: H_0: $\sigma_\alpha^2 = 0$ vs. H_1: $\sigma_\alpha^2 > 0$.

The test results provide strong evidence in favour of the alternate hypothesis, that firm effects are positive, validating hypotheses *H1A*, *H2A* and *H3*. These results are obtained for the overall period as well as for the three sub periods. The significant firm effects in all the three periods, suggest that managerial capabilities have mattered at all times in Indian industry, both under a controlled regime when rent seeking was rewarded, and under liberalization, both partial and more comprehensive, when productive performance was rewarded.

Column (II) of table 3 lists the results of the test where the null hypothesis is that industry effects are zero versus the alternate hypothesis that industry effects are positive. The statistical test is of the form: H_0: $\sigma_\beta^2 = 0$ vs. H_1: $\sigma_\beta^2 > 0$.

The test results provide mixed evidence of the alternate hypothesis, that industry effects are positive. These results were obtained for the overall period but only for one of the three sub periods, the post liberalization period. The null hypothesis could not be rejected in the first and second periods. These results support hypotheses *H1C, H2C* and *H4*.

These significant industry effects, in the post-liberalization period, as industry factors began to influence firms' profitability, show that in the controlled and regulated environment of Indian industry, prior to liberalization, it might not have entirely mattered which industry a firm belonged to. This contingency, however, no longer holds after the opening up of markets. The choice of industry, and subsequent positioning within it, matters significantly in influencing profits.

Finally, we evaluate whether firm effects and industry effects were equal or if firm effects dominated industry effects. The test is of the form: H_0: $\sigma_\alpha^2 = \sigma_\beta^2$ vs. H_1: $\sigma_\alpha^2 > \sigma_\beta^2$.

These results are in Column (III). We find that firm effects are larger than industry effects under all policy regimes, as well as overall, as given in last column of table 3. Our null hypothesis is rejected on all occasions, and these results support much of what is established. The results support our hypotheses *H1B, H2B* and *H3*.

6.3 Statistical Test Results of Changes in Effects over Time

Given the context of a liberalizing economy, it is important to assess if firm and industry effects have changed monotonically and significantly over different phases of liberalization. Table 4 reports tests of the null hypothesis that the variances of firm effects, industry effects and the sum of industry fixed effects and industry × year interaction effects remained unchanged in the transition from the pre-liberalization regime to partial liberalization, given in column (I), and from the transition from partial liberalization to the post liberalization period, given in column (II).

The alternative hypothesis is that the variances of firm effects, industry effects and the sum of industry fixed effects and industry × year interaction effects have increased, monotonically, in the transition from the pre-liberalization regime to partial liberalization, and in the transition from the partial to the full liberalization era. The test takes the form: H_0: $\sigma_{\alpha,t}^2 = \sigma_{\alpha,t-1}^2$ vs. H_1: $\sigma_{\alpha,t}^2 > \sigma_{\alpha,t-1}^2$.

********** INSERT TABLE 4 HERE **********

Table 4 shows that firm effects have increased significantly as the Indian economy has moved from a command and control to a partially liberalized regime, and again increased when that regime gave way to a comprehensively liberalized regime. This evidence also validates *H2B* and *H3*. Managerial competence and practice have become relevant with progressive phases in liberalization. The evidence is consistent with the view that increased accumulation of firm specific capabilities and increased efficiency follows market opening institutional changes. These then positively impact profitability.

While there were no significant changes in industry effects between the command and control and partial liberalization periods, as given by the test results for the hypothesis: H_0: $\sigma_{\beta,t}^2 = \sigma_{\beta,t-1}^2$ vs. H_1: $\sigma_{\beta,t}^2 > \sigma_{\beta,t-1}^2$, the increase was significant as the economy moved into the comprehensive liberalization regime. Results are similar for the sum of industry fixed effects and industry × year interaction effects tested by: H_0: $\sigma_{\beta,t}^2 + \sigma_{\delta,t}^2 = \sigma_{\beta,t-1}^2 + \sigma_{\delta,t-1}^2$ vs. H_1: $\sigma_{\beta,t}^2 + \sigma_{\delta,t}^2 > \sigma_{\beta,t-1}^2 + \sigma_{\delta,t-1}^2$.

These are further evidence that the choice of industry matters in the liberalized Indian institutional climate. This result further validates *H4*, and highlights that liberalization has brought about the emergence of a competitive market in India where market concentration, entry barriers and other similar industry level effects affect excess or low profitability among firms.

6.4 Additional Estimation using Sub-sampling

We carry out additional tests on the data set using powerful recent sub-sampling methods. Of the total of 3,187 firms that appear in the data set, 2030 of these have been in the data set for at least six years. First, we draw 100 sub-samples of 675 of these firms, so that each of the 2,030 firms appears at least once in the sample. Second, for these 100 sub-samples of 675 firms we estimate firm, industry and time effects. Standard error and covariance estimates are based on the above 100 sets of parameter estimates and recent literature (Bickel, Götze and van Zwet, 1997; Politis and Romano, 1994) shows that this sub-sampling methodology works well and requires minimal assumptions.[17]

[17] It is more powerful than the non-parametric bootstrap (Efron, 1979) and can be applied in almost any setup. Ever since its introduction, the bootstrap has provided a powerful set of solutions for practical statisticians and applied researchers across different disciplines (Hall, 1992). However, while bootstrap procedures possess compelling second-order accuracy properties in many settings, they are inconsistent in other settings unless problem-specific regularity conditions hold. The failure of the bootstrap in these situations has recently spurred researchers to broaden the applicability of the original sampling scheme (Davison et al., 2003). In this context, the development of a sub-

The idea underlying sub-sampling is simple, entailing calculation of a statistic for sub-samples of the data selected without replacement. The values of the statistic for the different sub-samples are then used to estimate the asymptotic mean of the statistic and to construct an approximation to the appropriate sampling distribution. In particular, the sample mean based on a large number of sub-samples can be used to estimate an unknown population parameter, and the sample standard deviation provides an estimate of the standard error (Politis et al., 1999).

A related re-sampling methodology is the *m* out of *n* bootstrap, where one typically draws samples, with replacement, of size much smaller than the available data (Booth, et al. 1994; Davison, et al, 2003). Both the methods are not only powerful but extremely easy to use, often contributing to significant efficiency gains and reduced computational intensity. By choosing sub-sampling over the *m* out of *n* bootstrap approach, we ensure than no company is included twice in any of the sub-samples. Besides maximum likelihood or restricted maximum likelihood estimation of random effects models with a large number of firms is extremely computation intensive.

Sub-sampling is a general method of inference in econometric and statistical models that approximates the sampling distribution of a statistic based on the values of the statistic computed over smaller subsets of the data (Politis and Romano, 1994; Shao and Wu, 1989; Wu, 1990; Sherman and Carlstein, 1996; Politis, et al, 1999). In the case where the data are *n* independent and identically distributed observations, the true sampling distribution of the statistic computed based on the entire data set can be approximated by the realized distribution of statistics, normalized appropriately, re-computed over all $\binom{n}{b}$ data sets of size *b*. The notion of a statistic sequence is implicit, so that the statistic is defined for samples of size *n* and *b*.

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sampling methodology (Politis and Romano, 1994; Bickel et al., 1997) providing asymptotic consistency under extremely weak conditions, even where the conventional bootstrap fails, is an important contribution (Politis et al., 1999).

A related idea is that of "*bagging*" (**b**ootstrap **agg**regat**ing**) based on sub-sampling, where sample means based on a finite number of random sub-samples drawn without replacement from the original n observations are used to estimate the unknown population parameter. Bagging estimators based on sub-sampling have three main advantages. First, only minimal conditions are needed for sub-sample tests and confidence intervals to have desirable asymptotic properties, such as asymptotically correct rejection rates and coverage probabilities. This is true even for many non-regular cases where a bootstrap may not work (Bickel *et al.*, 1997; Andrews, 2000; Politis et al., 2001).

Second, bagged estimators based on sub-sampling, m-out-of-n cases without replacement re-sampling, have asymptotic properties similar to bagging based on the regular bootstrap with m-out-of-n with replacement re-sampling, but require a much smaller sample size (Friedman and Hall, 2007). This means that bagged estimators are much less computation intensive in problems where computational complexity increases sharply with sample size. Third, it is intuitively more appealing to use sub-sampling, without replacement, rather than bootstrap with replacement, since the same observation is not wished to be included more than once in any particular re-sample.

The above reasons motivate the use of the sub-sample bagging estimator for the data. Sub-samples without replacement are selected from the entire sample of distinct firms, and include all years for which data on these selected firms are available. In the present case, a sub-sampling proportion of about one-third of the total firms provides credible inference since this produces estimators similar to a full bootstrap. This can be viewed against the traditional preference for half-sampling in the sample survey literature (Mahalanobis, 1946; McCarthy, 1966; Hall, 2003) and is supported by theoretical results (Friedman and Hall, 2007).

Friedman and Hall (2007) compare bagging estimators for m-out-of-n with- and without-replacement re-sampling under a very general setup. In particular, they show that asymptotic properties of a bagged estimator based on an usual re-sample of size n is similar to that of half-

sampling, or one-half *n*-out-of-*n* sub-sample, without replacement, re-sampling. Similar methods can be used to evaluate sub-sample bagging in the present case. The analytical foundations for sub-sampling are given in appendix 2.

The industry × year interactions are not included because the maximum likelihood, as well as restricted maximum likelihood, procedure fail to converge to estimates within the parameter space. Further, iterations of the expectation-maximization algorithm for maximum likelihood estimation indicate that the variance component for industry × year was zero in each case. In addition to providing inference similar to usual bagging, the approach based on sub-sampling also vastly facilitates computation. In fact, the high computation intensity associated with the full bootstrap approach makes computations based on 2030 firms unachievable.

In each implementation of the re-sampling plan, we estimate the model based on data on 675 randomly chosen firms. We check that 100 such sub-samples drawn, taken together, cover each of the 2030 companies with more than six years of data at least once. The sample mean over the 100 re-samples are used as the point estimates of variance components, and standard error and covariance estimates are based on the sampling distribution of these estimates. We have 10,800 observations in each of our 100 sub-samples. The choice of each sub-sample size at 675 offers credible coverage and efficient computation. In total, we evaluate over 1,000,000 observations.

Table 5 shows that firm effects continue to be important determinants of differences in profitability. Panel A shows the variance magnitudes; panel B shows the proportion of each effect as a percentage of the total variance and panel C shows the proportion of each effect as a percentage of the explained variance. Panel C shows that firm effects comprise 80 percent, 90 percent and 87 percent of the explained variance in the three periods while industry effect comprise 10 percent, 8 percent and 12 percent of the explained variance. Thus, in a contestable market environment, industry effects still retain a relatively greater role in explaining profit variations.

********** INSERT TABLE 5 HERE **********

Table 6 shows the results evaluating whether firm and industry effects are inconsequential and whether firm effects are greater than industry effects. The first hypothesis, that firm effects are inconsequential, is rejected for all three periods. Now, however, industry effects are consequential in all three periods. Our a-priori hypotheses, that industry effects would be inconsequential in periods of command and control and partial liberalization, now do not hold up in the new analysis.

Thus, whether by luck, or by politically and institutionally managing industry entry, firms have also gained from being in the relevant industry even in periods when market contestability was absent. It also raises questions about the political economy of industrial policy during the partial liberalization period since it was neither a control regime nor was the market environment contestable. Firms present in the market could have used this period of confusion to assert their skills in strategic management.

********** INSERT TABLE 6 HERE **********

Since we have added more data in the sub-sampling procedures, these confirmatory results are robust and point to the importance of the industry effect even when markets are not contestable. Firms lucky to have gotten into an industry with profit-generating potential will have reaped the benefits of industry-specific rents influencing profits. If entry barriers have precluded other firms from entry, then such firms as are already present within an industry will enjoy the benefits of industry presence. As transition to contestability occurs, and as entry barriers are lowered, the entry of new firms will whittle the industry-specific rents away and industry effects will cease to have any worth. Is this borne out by further evidence? We tackle this next.

Table 7 shows monotonicity tests of the firm and industry effects for the sub-sample results. Firm effects monotonically increased significantly, while industry effects did not statistically increase between the first and middle periods but have increased significantly after Indian markets were made

fully contestable over the prior period. The increase in the magnitude of the industry effect between the first period and the final period is also substantial, as was noted in the results for the balanced sample. These results, based on the sub-sampling procedure, are consistent with earlier results and validate the notion that liberalization leads to the emergence of market contestability where concentration, entry barriers and other industry level factors affect profit variations among firms.

********** INSERT TABLE 7 HERE **********

7. Discussion and Conclusions

7. 1 Discussion

This research makes several points. First, in the analysis of profitability variations among firms, institutional factors have to be accounted for. In transition economies and emerging markets, it is important to understand the role of government policy in influencing the strength of the effects. We do so by separating out our data for Indian firms into three periods, each capturing a different institutional regime in Indian industry.

The Indian economy went through two stages of liberalization in the 1980s and early 1990s. Hesitant and partial domestic reforms were instituted in 1985, but political difficulties intervened. Financial difficulties forced the administration into comprehensive reforms only in 1991. We have used this opportunity to assess the shifts in the relative balance of firm effects and industry effects across the two distinctly separate liberalization regimes that have unfolded in India, an economy now getting world attention.

We find evidence from Indian firms that liberalization significantly affects the relative importance of firm and industry effects in shaping the profitability of firms. Firm effects are always important, whether in a command and control regime, with potential benefits accruing from protectionism and political rent seeking, or in the fully liberated period where firm specific capabilities and efficiency are valued. This accords with the main findings for US firms. For the US,

it has also been noted that firm effects dominate industry effects which dominate time effects. We find this same pattern to be prevalent in India.

We find that inter-temporally firm effects get stronger over time as the institutional forces enhance market contestability. As the market becomes more dominant in the resource allocation process, relative to the role of government, so does the role of managerial competence, which is implicitly one of the factors captured by the firm effects, become more important in explaining profit variations. By altering the distribution of resources, shaping the incentives of competitors, influencing the level of investments and the allocation of property rights, institutional changes alter firms' landscapes to achieve best outcomes. Firm effects become vital in managing the market economy as compared to managing the political economy.

With respect to the role of industry effects in India, while we find that they do not matter in our smaller balanced sample, in a broad-based sub-sampling procedure they do matter but not as much as the firm effects. In a restricted sample of firms and industries, the specific industry effects may have been dampened by the estimation process. Specific macro-economic factors related to these industries, as captured in the industry × year interaction terms, will have been isolated leaving the residual industry effect to be immaterial. In the broad-based sub-sampling estimation, only firm, industry and time effects were included and the industry effects would include an element of industry-related macro-economic factors that we were capturing separately.

In the command and control and partial liberalization regimes, there were many industry-specific macro-economic policies implemented (Jalan, 2005) and the impact of these policies, captured within the industry effect, will have led to the industry effect mattering, as we found that they did. Of course, as the partial liberalization period has given way to one of total liberalization, or conditions of full market contestability, the industry effect has strengthened significantly over that of the previous period and we reiterate that this effect is possibly indicative of firms in India choosing

the right industries and segments to enter, do business in and enjoy industry-specific economic returns.

Also, while movements of the shares of firm effects and industry effects may not tell us anything about the changes in the absolute magnitudes of firm and industry variance components over the different stages of institutional change. Inference procedures help draw sharper conclusions about phenomena and whether they matter. The standard practice involves the decomposition of the variance of firm profitability, apportioning it into elements attributable to year, industry and firm effects. Conclusions are drawn based on the relative sizes of estimated firm effects and industry effects, most often generated within a random effects estimation framework. An evaluation of the significance of these statistics also requires attention.

Previous studies have used components of variance (COV) and nested ANOVA techniques, but statistical inference has not been attempted. There have been no attempts to test whether any of the variance components are statistically significant, if they matter, whether one component is significantly larger than another, and whether any of the components have changed significantly over time, or, if there is a dynamic trajectory in the way that a particular effect behaves. These are important considerations in the assessment of the dynamics of firms' profitability.

7. 2 Future Research Issues

There are a number of way researchers can take this line of research forward to decompose profits in more detail. From a theoretical viewpoint of evaluating performance in transition economies, the capabilities required to manage the market economy are distinctly different compared to those required to manage the political economy. Particularly, when command and control processes constrain resource flows, and dilute the scope for strategic decisions in competition, firm level abilities may not matter. One might simply expect to see firms that have entered particularly profitable industries to have higher profit rates, and thereby industry effects will

be seen to prevail. Conversely, managerial efforts at attending to procedures, and playing by the rules of the political game, can lead to firms doing well under the command and control regime. If so, such competencies can ensure that firm effects are also visible in analysis.

We find that firm effects have been important in all phases of India's economy, yet as the environment has changed so will have the innate capabilities within firms. Follow-up research tracking the changes in specific capability investments within firms, and then evaluating their impacts on firm profits, will provide a much more micro-granular view on performance in one of the world's leading economies of the 21st century, and which is yet a context that is seriously under-researched. Patterns of performance changes noted in India can be generalised toward understanding performance change in other transition economies.

In extending such research across countries, prior work has found that, on average, correlation between countries in average industry profitability is zero. Yet, as more countries liberalize their economies, and adopt similar institutional policies, industry profit rates across countries may converge, just as economic growth rates are expected to converge across countries. Whether such converge has occurred or not is an important question at the heart of cross-country performance research, especially as countries classified as emerging economies, such as China, India, Malaysia, Thailand and Vietnam, become important players on the global economic stage. If industry profits do converge, then it is prima-facie evidence that institutional changes put through have had the expected outcomes. The results of such research will be important in the policy domain.

There are dynamic aspects to performance analysis in a transition context. These aspects lead to several research questions. One might expect that market forces unleashed by liberalization will accelerate shakeout and profits will converge to the industry specific level of returns. This suggests that industry effects will eventually diminish. Industry effects become less important with liberalization, as a more competitive market emerges and a concentrated market structure

disappears. Thus, results observed from our data may not hold as we add more time-series data.

Two questions emerge. First, do industry effects dissipate over time or do they stay similar across time periods? Second, if they do dissipate, what is the rate of decay? In other words, what is the lag length with which an industry effect may decay? As such, there is no theory to suggest the average lag length for an industry effect to become unobservable or insignificant. Addressing the questions will need theory development, particularly as countries, such as India, transform toward Western-style economies, catch up and then forge ahead. To examine the issue will also require time-series data.

At the same time, major institutional changes, such as comprehensive liberalization of the industrial economy, increases the volatility of the business environment. Shocks of various types will be numerous and business conditions can be continuously cyclical. Increased volatility will impact the decisions and performance of firms. Thus, the role of the time effect can also become important. The time effect captures several elements related to business cycles, macro-economic factors and specific political events that affect the economy as a whole but are not firm or industry specific. Decomposition of the time effect into several constituent parts is an important research exercise within the overall performance research agenda.

Another issue relates to analysis across economic sectors. Many emerging economies are shifting emphasis from manufacturing to the services sector. Countries such as India, Israel, and many in Central and Eastern Europe, have a full complements of service as well as manufacturing industries. Industry categorizations into various sectors will shed light on particular sector specificities. In addition, inter-sector linkages matter. For example, a robust agriculture sector is necessary for the manufacturing sector to succeed. Sector-oriented profitability analysis, conditioned on institutional factors, evaluating how inter-sector linkages impact the composition and importance of firm, industry and time effects is an important way to take research further.

7. 3 Conclusion

We use data for the period 1980-81 to 1995-96, to evaluate the impact of firm versus industry effects in impacting the profitability, measured as return on assets, of firms in India's manufacturing sector. Our aim has been to assess the relative importance of firm and industry effects within a setting of institutional change, which Indian industry has experienced because of a transition from a regulated and controlled to a competitive regime over a decade and a half.

In addition to the comparison of shares of variance components, we carry out hypotheses tests to evaluate the significance of individual effects, the relative significance between different effects, and inter temporal changes in individual effects between one policy regime and another. We have found that firm effects are always significant and have dominated industry effects. Firm level abilities have mattered both when rent seeking proliferated, as well as when the scope for strategic decisions has increased within a competitive environment. The magnitude of firm effects monotonically increases with time. Monotonic increases in the industry effect over time are also noted. With comprehensive liberalization after 1991, industry effects have come to significantly matter, relative to previous periods, in influencing profits in India's manufacturing sector.

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Table 1: Average Return on Assets in Major Industries

Major industries are industries with at least 20 firms in each of the years. For each industry, we report average ROA, standard deviation and skewness in the years 1980-81 and 1995-96. These are the end points of our analysis. We also report the year in which average ROA were the maximum or the minimum of all years. Number of observations: 7,400.

	For the Year 1980-81			*For the Year 1995-96*			*For the Entire Period*	
Industry	Mean	Standard deviation	Skewness	Mean	Standard deviation	Skewness	Minimum (Year)	Maximum (Year).
Automobiles	4.19	11.94	1.21	6.24	6.80	-1.77	-1.49 (87-88)	6.24 (95-96)
Cement	-0.12	10.65	-1.75	5.62	11.02	-0.52	-6.65 (88-89)	7.28 (95-96)
Ceramics	3.66	16.58	-2.61	2.76	9.94	-1.08	-6.36 (90-91)	7.01 (81-82)
Cotton Textiles	3.89	7.97	-1.50	-4.13	16.60	-5.15	-6.83 (84-85)	4.59 (90-91)
Electrical Machinery	4.71	8.57	-2.50	3.39	8.37	-1.32	-0.76 (84-85)	4.71 (80-81)
Metals	3.07	12.86	-1.41	3.67	15.38	1.67	-2.00 (87-88)	4.94 (81-82)
Paper	2.81	7.95	-1.38	8.42	9.94	2.17	-7.99 (87-88)	8.42 (95-96)
Pharmaceuticals	2.67	8.38	-2.33	4.88	12.40	-2.34	1.08 (88-89)	6.79 (94-95)
Rubber	0.82	11.79	-1.17	6.81	14.23	4.66	-0.52 (87-88)	6.81 (95-96)
Sugar	3.22	13.20	-0.36	-0.44	9.94	-2.29	-3.39 (84-85)	5.38 (93-94)
All industries	2.96	11.48	-0.50	3.44	12.87	-0.97	-1.41 (87-88)	3.92 (94-95)

Table 2: Statistics from the Components of Variance Analysis of Return on Assets – Balanced Panel (Number of observations 7,200)

	Firm Effects	Industry Effects	Year Effects	Industry × Year Effects	Residual Variance
Panel A. Estimates of the Variance of Different Components					
Overall Period: 1980-81 to 1995-96	0.00273 (2.1e-4)	0.00071 (3.2e-4)	0.00012 (5.4e-5)	0.00034 (8.7e-5)	0.00539 (1.0e-4)
Command and Control: 1980-81 to 1984-85	0.00213 (2.0e-4)	0.00022 (1.6e-4)	0.00022 (1.5e-4)	0.00017 (6.1e-5)	0.00355 (1.2e-4)
Partial Liberalization: 1985-86 to 1990-91	0.00394 (3.1e-4)	0.00009 (8.0e-5)	0.00011 (8.1e-5)	0.00018 (7.3e-5)	0.00365 (1.1e-4)
Post Liberalization: 1991-92 to 1995-96	0.00537 (4.8e-4)	0.00163 (7.7e-4)	0.00005 (6.1e-5)	0.00031 (3.1e-4)	0.00651 (3.1e-4)
Panel B. Share of Variance Explained by each Component Expressed as Percentage of Total Variance					
Overall Period: 1980-81 to 1995-96	29.42 percent	7.61 Percent	1.29 percent	3.63 Percent	58.05 percent
Command and Control: 1980-81 to 1984-85	33.84 percent	3.48 Percent	3.48 percent	2.70 Percent	56.51 percent
Partial Liberalization: 1985-86 to 1990-91	49.49 percent	1.08 Percent	1.41 percent	2.23 Percent	45.79 percent
Post Liberalization: 1991-92 to 1995-96	38.72 percent	11.75 percent	0.38 percent	2.24 Percent	46.92 percent
Panel C: Share of Variance Explained by each Component Expressed as Percentage of Explained Variance					
	Firm Effects	Industry Effects	Year Effects	Industry × Year Effects	
Overall Period: 1980-81 to 1995-96	70.13 Percent	18.14 Percent	3.08 Percent	8.65 Percent	
Command and Control: 1980-81 to 1984-85	77.81 Percent	8.00 Percent	8.00 Percent	6.21 Percent	
Partial Liberalization: 1985-86 to 1990-91	91.29 Percent	1.99 Percent	2.60 Percent	4.11 Percent	
Post Liberalization: 1991-92 to 1995-96	72.95 Percent	22.14 Percent	0.72 Percent	4.22 Percent	

Table 3: Results of Tests of the Significance of Firms and Industry Effects - Balanced Panel (Number of observations 7,200)

	Column (I)	Column (II)	Column (III)
	Null Hypothesis: Firm Effects are Zero	*Null Hypothesis:* Industry Effects are Zero	*Null Hypothesis:* Firm Effects Equal Industry Effects
Regime	H_0: $\sigma_\alpha^2 = 0$ vs. H_1: $\sigma_\alpha^2 > 0$	H_0: $\sigma_\beta^2 = 0$ vs. H_1: $\sigma_\beta^2 > 0$	H_0: $\sigma_\alpha^2 = \sigma_\beta^2$ vs. H_1: $\sigma_\alpha^2 > \sigma_\beta^2$
Overall Period: 1980-81 to 1995-96	Reject H_0 (0.000)	Reject H_0 (0.035)	Reject H_0 (0.000)
Command and Control: 1980-81 to 1984-85	Reject H_0 (0.000)	Do not reject H_0 (0.166)	Reject H_0 (0.000)
Partial Liberalization: 1985-86 to 1990-91	Reject H_0 (0.000)	Do not reject H_0 (0.279)	Reject H_0 (0.000)
Post Liberalization: 1991-92 to 1995-96	Reject H_0 (0.000)	Reject H_0 (0.029)	Reject H_0 (0.000)

Note: Figures in parentheses are *p*-values

Table 4: Tests Results Evaluating Change over Time in the Magnitude of the Variance Components for Firm, Industry Effects, and Industry and Industry and Year Effects – Balanced Panel (Number of observations 7,200)

	Column (I)	*Column (II)*
	Transition Stage	**Transition Stage**
	Command and Control Period to Partial Liberalization Period (1980-81 to 1984-85 period and 1985-86 to 1990-91 period)	*Partial Liberalization Period to Post Liberalization Period* (1985-86 to 1990-91 period and 1991-92 to 1995-96 period)
Null Hypothesis: No Difference in Firm Effects between One Period and the Next *Alternate Hypothesis:* Subsequent Period Firm Effects Larger than Prior Period Firm Effects H_0: $\sigma_{\alpha,t}^2 = \sigma_{\alpha,t-1}^2$ vs. H_1: $\sigma_{\alpha,t}^2 > \sigma_{\alpha,t-1}^2$		
Firm effects (α)	Reject H_0 (0.000)	Reject H_0 (0.006)
Null Hypothesis: No Difference in Industry Effects between One Period and the Next *Alternate Hypothesis:* Subsequent Period Industry Effects Larger than Prior Period Industry Effects H_0: $\sigma_{\beta,t}^2 = \sigma_{\beta,t-1}^2$ vs. H_1: $\sigma_{\beta,t}^2 > \sigma_{\beta,t-1}^2$		
Industry effects (β)	Do not reject H_0 (0.772)	Reject H_0 (0.023)
Null Hypothesis: No Difference in Industry and Industry × Year Effects between One Period and the Next *Alternate Hypothesis:* Subsequent Period Industry and Industry × Year Effects Larger than Prior Period Industry and Industry × Year Effects H_0: $\sigma_{\beta,t}^2 + \sigma_{\delta,t}^2 = \sigma_{\beta,t-1}^2 + \sigma_{\delta,t-1}^2$ vs. H_1: $\sigma_{\beta,t}^2 + \sigma_{\delta,t}^2 > \sigma_{\beta,t-1}^2 + \sigma_{\delta,t-1}^2$		
Industry and Industry × Year effects ($\beta + \delta$)	Do not reject H_0 (0.731)	Reject H_0 (0.023)

Note: Figures in parentheses are *p*-values

Table 5: Statistics from the Components of Variance Analysis of Return on Assets – Sub-sampling Results for 100 Random Sub-samples on Unbalanced Panels (Number of observations per sub-sample approximately 10,800; total observations approximately 1,000,000)

	Firm Effects	Industry Effects	Year Effects	Residual Variance
Panel A: Estimates of the Variance of Different Components				
Command and Control:				
1980-81 to 1984-85	0.00235 (3.3e-4)	0.00031 (1.1e-4)	0.00026 (3.9e-5)	0.00359 (3.3e-4)
Partial Liberalization:				
1985-86 to 1990-91	0.00327 (7.0e-4)	0.00030 (1.5e-4)	0.00008 (1.9e-5)	0.00355 (4.1e-4)
Post Liberalization:				
1991-92 to 1995-96	0.00479 (7.4e-4)	0.00065 (1.3e-4)	0.00005 (1.7e-5)	0.00596 (8.9e-4)
Panel B: Share of Variance Explained by each Component Expressed as Percentage of Total Variance				
Command and Control:				
1980-81 to 1984-85	36.09 percent	4.70 percent	4.05 percent	55.17 percent
Partial Liberalization:				
1985-86 to 1990-91	45.41 percent	4.16 percent	1.05 percent	49.38 percent
Post Liberalization:				
1991-92 to 1995-96	41.83 percent	5.64 percent	0.48 percent	52.06 percent
Panel C: Share of Variance Explained by each Component Expressed as Percentage of Explained Variance				
	Firm Effects	Industry Effects	Year Effects	
Command and Control:				
1980-81 to 1984-85	80.50 percent	10.48 percent	9.02 percent	
Partial Liberalization:				
1985-86 to 1990-91	89.71 percent	8.22 percent	2.07 percent	
Post Liberalization:				
1991-92 to 1995-96	87.25 percent	11.75 percent	1.00 percent	

Table 6: Results of Tests of the Significance of Firms and Industry Effects – Sub-sampling Results for 100 Random Sub-samples on Unbalanced Panels (Number of observations per sub-sample approximately 10,800; total observations approximately 1,000,000)

	Column (I)	Column (II)	Column (III)
	Null Hypothesis: Firm Effects are Zero	*Null Hypothesis:* Industry Effects are Zero	*Null Hypothesis:* Firm Effects Equal Industry Effects
Regime	H_0: $\sigma_\alpha^2 = 0$ vs. H_1: $\sigma_\alpha^2 > 0$	H_0: $\sigma_\beta^2 = 0$ vs. H_1: $\sigma_\beta^2 > 0$	H_0: $\sigma_\alpha^2 = \sigma_\beta^2$ vs. H_1: $\sigma_\alpha^2 > \sigma_\beta^2$
Command and Control: 1980-81 to 1984-85	Reject H_0 at 1% level (0.000)	Reject H_0 at 1% level (0.001)	Reject H_0 at 1% level (0.000)
Partial Liberalization: 1985-86 to 1990-91	Reject H_0 at 1% level (0.000)	Reject H_0 at 1% level (0.004)	Reject H_0 at 1% level (0.000)
Post Liberalization: 1991-92 to 1995-96	Reject H_0 at 1% level (0.000)	Reject H_0 at 1% level (0.000)	Reject H_0 at 1% level (0.000)

Note: Figures in parentheses are *p*-values

Table 7: Tests Results Evaluating Change over Time in the Magnitude of the Variance Components for Firm and Industry Effects – Sub-sampling Results for 100 Random Sub-samples on Unbalanced Panels (Number of observations per sub-sample approximately 10,800; total observations approximately 1,000,000)

	Column (I)	*Column (II)*
	Transition Stage	**Transition Stage**
	Command and Control Period to Partial Liberalization Period (1980-81 to 1984-85 period and 1985-86 to 1990-91 period)	*Partial Liberalization Period to Post Liberalization Period* (1985-86 to 1990-91 period and 1991-92 to 1995-96 period)
Null Hypothesis: No Difference in Firm Effects between One Period and the Next *Alternate Hypothesis:* Subsequent Period Firm Effects Larger than Prior Period Firm Effects H_0: $\sigma_{\alpha,t}^2 = \sigma_{\alpha,t-1}^2$ vs. H_1: $\sigma_{\alpha,t}^2 > \sigma_{\alpha,t-1}^2$		
Firm effects (α)	Reject H_0 at 5% level (0.029)	Reject H_0 at 10% level (0.092)
Null Hypothesis: No Difference in Industry Effects between One Period and the Next *Alternate Hypothesis:* Subsequent Period Industry Effects Larger than Prior Period Industry Effects H_0: $\sigma_{\beta,t}^2 = \sigma_{\beta,t-1}^2$ vs. H_1: $\sigma_{\beta,t}^2 > \sigma_{\beta,t-1}^2$		
Industry effects (β)	Do not reject H_0 (0.528)	Reject H_0 at 1% level (0.001)

Note: Figures in parentheses are *p*-values

Appendix 1: Maximum Likelihood Estimation of Components of Variance Analysis

The likelihood based methods assume normally distributed random effects and errors. The ML and REML estimators of variance components are not available in closed form but there are efficient iterative algorithms to obtain the estimates (Hartley and Rao, 1967; Gilmour et al., 1995).

The components of variance model are represented in matrix form as: $\underline{r} = \mu\underline{1} + \sum_{\theta=A}^{K} X_\theta \underline{b_\theta} + \underline{e}$,

where $\underline{r}$ is the vector of r_{cit}'s, $\theta \in \{\alpha, \beta, \gamma, \delta\}$ are the random effects, X_θ is that part of the design matrix corresponding to random effect θ, $\underline{b_\theta}$ is the vector of levels of the random effect θ, $\underline{e}$ is the vector of random errors ε's, $\underline{1}$ is the vector (1 1 … 1)′, and we have $E(\underline{r}) = \mu\underline{1}'$.

Define $\eta_\theta = \sigma_\theta^2 / \sigma_\varepsilon^2$, for $\theta = A, B, \cdots, K$, and **H** as $\mathbf{H} = \mathbf{I}_N + \sum_{\theta=A}^{K} \eta_\theta \mathbf{X}_\theta \mathbf{X}_\theta'$.

Then, the variance-covariance matrix of $\underline{r}$, **V**, can be written as $\mathbf{V} = \sigma_\varepsilon^2 \mathbf{H}$.

If we further assume that

$$\underline{b_\theta} \sim N(\underline{0}, D_\theta)$$
$$\underline{e} \sim N(\underline{0}, \Sigma)$$

and the components of $\underline{b_\theta}$ and $\underline{e}$ are independent, the log-likelihood is given by:

$$\ln L = -\frac{1}{2} n \log(2\pi) - \frac{1}{2} n \log(\sigma_\varepsilon^2) - \frac{1}{2} \log|\mathbf{H}| - \frac{1}{2\sigma_\varepsilon^2} (\underline{y} - \mu\underline{1})' \mathbf{H}^{-1} (\underline{y} - \mu\underline{1}). \quad (3).$$

Then, equating the derivatives of this with respect to σ_ε^2 and the η_θ's to zero, the ML estimates are given by:

$$\hat{\sigma}_{\varepsilon}^{2} = (\underline{y} - \mu\underline{1})'\hat{\mathbf{H}}^{-1}(\underline{y} - \mu\underline{1})\Big/N$$

$$\mathbf{tr}\left(\hat{\mathbf{H}}^{-1}\mathbf{X}_{\theta}\mathbf{X}_{\theta}'\right) = (\underline{y} - \mu\underline{1})'\hat{\mathbf{H}}^{-1}\mathbf{X}_{\theta}\mathbf{X}_{\theta}'\hat{\mathbf{H}}^{-1}(\underline{y} - \mu\underline{1})\Big/\hat{\sigma}_{\varepsilon}^{2}, \quad \mathbf{for}\ \theta = A, B, \cdots, K. \tag{4}$$

Iterative algorithms like the steepest descent method are frequently employed to obtain the ML estimates. While the maximisation process itself does not guarantee non-negativity of the estimates of variance components, the estimation strategy of equating negative variance components to zero is quite adequate. Large sample variances of these estimates are given by:

$$\mathbf{Var}\left(\underline{\hat{\sigma}^{2}}\right) = I^{-1} = \begin{bmatrix} I^{11} & I^{12} & \cdots & I^{1q} \\ I^{21} & I^{22} & \cdots & I^{2q} \\ \vdots & \vdots & \ddots & \vdots \\ I^{q1} & I^{q2} & \cdots & I^{qq} \end{bmatrix}$$

$$= 2\left\{\mathbf{tr}\left(\mathbf{V}^{-1}\frac{\partial\mathbf{V}}{\partial\sigma_{i}^{2}}\mathbf{V}^{-1}\frac{\partial\mathbf{V}}{\partial\sigma_{j}^{2}}\right)\ ;i, j = 1,\cdots,q\right\}^{-1}, \tag{5}$$

where $\underline{\sigma^{2}}$ is the q × 1 vector of the variance components.

Appendix 2: Sub-sampling Framework

Let $M_i \quad (i = 1,\ldots,n)$, be the number of years of data (out of a total of *T* years) available for firm i, have binomial distribution $M_i \sim Bin(T, \rho)$ independent of the other firms. Here ϱ denotes the probability of inclusion in the sample in any given year. Based on Friedman and Hall (2007), we compare without replacement sub-sampling against with-replacement bootstrap in terms of amount of effective sizes of the re-samples. In the second case, the number of times a firm is included in any bootstrap resample of size n, $N_i \quad (i = 1,\ldots,n)$ has a binomial distribution $N_i \sim Bin(n, \frac{1}{n})$ independent of M_i.

Following Friedman and Hall (2007), the effective size of an *n*-out-of-*n* with-replacement bootstrap resample, in terms of the amount of information it contains, is given by the ratio $\frac{\left[\sum_{i=1}^{n} Z_i\right]^2}{\sum_{i=1}^{n} Z_i^{\,2}}$, where $Z_i = M_i N_i$. Since sample means are consistent for population means under simple random sampling with replacement, and since

$$E[Z_i] = E[M_i]E[N_i] \text{ and } E\left[Z_i^{\,2}\right] = E\left[M_i^{\,2}\right]E\left[N_i^{\,2}\right],$$

we have $\frac{1}{n} \cdot \frac{\left[\sum_{i=1}^{n} Z_i\right]^2}{\sum_{i=1}^{n} Z_i^{\,2}} \xrightarrow{P} \frac{1}{2} \cdot \frac{T^2\varrho^2}{T\varrho\left[T\varrho + (1-\varrho)\right]} = \frac{1}{2} \cdot \frac{1}{1 + \frac{1}{T} \cdot \frac{1-\varrho}{\varrho}}.$

This follows since $\lim_{n\to\infty} \frac{\left[\sum_{i=1}^{n} N_i\right]^2}{\sum_{i=1}^{n} N_i^{\,2}} = \frac{n}{2}$ (Friedman and Hall, 2007) and $\frac{\left[E(M_i)\right]^2}{E\left(M_i^{\,2}\right)} = \frac{T^2\rho^2}{T\rho\left[T\rho + (1-\rho)\right]}.$

The above derivation is illustrated numerically. In our data, 2030 of the total of 3187 firms have at least 6 years of data out of 16 years. This is consistent with a selection probability of between

0.3 and 0.4. With $T = 5$ and $\rho \approx 1/3$, which is consistent with our application, we have: $\frac{1}{n} \cdot \frac{\left[\sum_{i=1}^{n} Z_i\right]^2}{\sum_{i=1}^{n} Z_i^{\,2}} \xrightarrow{P} \frac{1}{2.8}$.

In other words, we expect sub-sampling bagging with an asymptotic sampling fraction of about one-third to provide inferences similar to *n*-out-of-*n* bootstrap bagging. Based on the above reasoning, we base our unbalanced panel results on 100 sub-samples of 675 firms, which is approximately a third of 2030, each firm drawn randomly from firms with at least 6 years of data.