Multinationals and Spillover

A Study of Post-reform Indian Industry

Patibandla, Murali; Sanyal, Amal

Murali Patibandla
Amal Sanyal

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Murali Patibandla[1]
Department of International Economics and Management
Copenhagen Business School
Institute of International Economics and Management
Copenhagen Business School
Howitzvej 60, 1.
DK 2000 Frederiksberg
Denmark
Tel: (+45) 3815 2532
Fax: (+45) 3815 2500
E-mail: mp.int@cbs.dk

Amal Sanyal
Commerce Division, Lincoln University, New Zealand

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[1] Corresponding author

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Abstract:

The paper looks for empirical evidence of spillover from multinational corporations who entered Indian industries since her recent economic reforms. Spillover in an industry, when it exists, has been empirically identified by temporal increase of the efficiency of local firms induced by the higher efficiency of MNCs in that industry. Efficiency has been estimated for individual firms by their closeness to the frontier production function of that industry. The study shows that in only two out of the nine industries studied, the hypothesis of spillover can not be rejected. In one other industry there is evidence of increase of efficiency as a result of competition rather than a direct spillover.

Keywords: Multinational Corporations; Local Firms; Technology Spillovers; Indian industries.

JEL Classification: F23; L20

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1 Introduction

Recent years have seen significant increase in the flow of FDI into developing economies[2]. Given its scale compared to host developing economies, FDI inflows produce observable change in the industrial structure of host countries. About these changes, the literature on MNCs observes that their ownership of assets such as technology, marketing, management, and networks benefit developing economies through a process of spill-over (Caves, 1996, Dunning, 1981). Property rights on intangible assets being underdeveloped, they are partially public goods and others can use assets developed by one firm at a small cost. If local firms, through deliberate effort or spillover, obtain the superior practices of MNCs, it would improve industrial efficiency in host countries. Often a dynamic process of growth is conceived from such a premise. The idea gets support from the observation that countries that opened to FDI on average have a record of higher growth rate among developing economies. It is also noted that the greater is the difference in relevant attributes between MNCs and local firms, higher is the expected gain to host economies, provided the process does not lead to exit of domestic firms (Kokko, 1994)[3].

A number of contributions have focussed on this spillover or catching-up[4] process resulting from the superiority of MNCs in specific attributes, eg Aitken and

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[2] Developing countries' share in global FDI inflow increased to 37 per cent ($ 87 billion) in 1994 from 18 per cent ($ 34 billion) in the period 1987-91 (World Investment Report, 1997).

[3] If the relative advantages of MNCs are very dominant, they might eliminate domestic firms which means the issue of spillover becomes irrelevant. In such a case, one possible benefit to the host country can be the training imparted to local workers. Contrarily, the entry of MNCs may create new markets, non-existent earlier. For example, the entry of Kellogs generated a market for breakfast cereals in India, which gave impetus to the entry of local firms into the market competing through lower price.

[4] We will use 'spillover' and 'catching- up' interchangeably, though the former is conceived of as a passive process while the latter entails active effort of local firms. For our empirical work whether the dynamics is active or passive does not make any difference.

Harrison (1993), Aitken, Harrison and Hanson (1994) and Kokko (1994). A good survey of this literature is available in De Mello. Jr (1997). The purpose of the present paper is to empirically look for the evidence of a spillover process in the case of the Indian economy where reforms initiated in mid 80s reduced the policy bias against MNCs, and led to their increasing presence (see Table.1).

A necessary condition for the spillover process is the existence of difference between local firms and MNCs in certain attributes at the time of entry of the latter. The difference then sets in motion a dynamic process that is expected to reduce the initial gap in the attributes. Thus the spillover hypothesis comprises a compound proposition: (i) MNCs differ from local firms at the time of their entry, and (ii) a process of catching up follows subsequent to the entry of MNCs. Even when the first proposition holds the second may not. The ideal way to explore it would be to estimate and test a dynamic model of this process with time series data. We can not avail that procedure because the entry of MNCs in post-reform Indian industries is recent and it is not possible to muster time series data of adequate length. Previous studies on MNCs in India have been based on cross-section data (eg Panth, 1993, Kumar, 1990) and therefore focus more on the first proposition. They also mostly use pre-reform information. In this paper we propose to use firm level panel data for nine Indian industries where new MNC subsidiaries started operation in post-reform times, and address both parts of the compound hypothesis.

In Section 2, we introduce a conceptual framework for the overall design of our empirical work. Section 3 discusses the attributes of firms that are of interest in this study, and reasons for interest in them. Section 4 introduces the data and empirical exercises. Section 5 discusses the empirical results from the perspective of the spillover question. The paper then ends with a brief concluding section. An appendix to the paper goes into the methodology of estimating technical efficiency that has been used in our empirical exercises.

2 An outline of the methodology

The spillover or catching up process is triggered off by a difference between local firms and MNCs in certain firm-specific features at the time of the entry of the latter. Technology is an important element of this set of features. Secondly, there is a view that MNCs tend to be present more in knowledge-intensive industries where intangible assets are more significant and they provide MNCs with relative advantage (Dunning, 1981, Caves, 1996)[5]. Possible assets in this category are managerial practice, patents, brand names, marketing networks, etc, which MNCs bring into the host economy. Most of these assets elude observation and measurement, and their existence needs to be inferred from observable quantities that they contribute to. We propose to evaluate them by their total effect on the technical efficiency of an MNC. Accordingly we use a measure of technical efficiency (TE) based on total factor productivity to explore the difference between MNCs and local firms. We should remark that this procedure implies that features or assets that an MNC brings to a host country are not reckoned in our account unless they contribute to their technical efficiency. This is a weakness of the procedure, because it may be argued that those assets may spillover into the industry regardless of whether they lead to greater recorded efficiency of MNCs or not. We discuss this issue in more detail in section 6.

Secondly, as opposed to these variables which we can call 'state variables', we also expect to observe differences in 'response variables' between MNCs and local firms. Difference in state variables lead to differential response to demand, product and factor market conditions. Response variables are either instruments of short run maximisation or strategic variables in the short run and medium run games.[6] Given the difference in state variables, MNCs and local firms are expected to choose different

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[5] Several recent foreign investments appear to fit the intangible assets model awkwardly. Examples are FDI in industries such as steel, glass and cement. However as Caves (1998) observes "The relevant proprietary assets may be the implicit contracts between suppliers and large customers located abroad, reflecting the foreign investor's ability to manage the logistics of continuous supply and adaptation to the customer's needs rather than general product-embodied assets."

[6] If we take a simple Cournot oligopoly case, low cost firms have higher market share and profits. MNCs have lower cost than local firms. Entry or threat of entry of multiantionals induces local firms to

levels for some or all of their response variables. A number of variables are expected to register the difference, eg, export and import intensity, extent of vertical integration, measures of advertisement and R&D efforts etc (see Section 3 below). For our purpose it is useful to look for differences in both TE as well as the response variables.

However, a comparison of TE or response variables is adequate only if conducted at the point in time when an MNC enters the host market. Later on, it can be argued that the difference narrows down because of catching up by local firms, and may leave no statistically significant difference after a number of periods.

Suppose S_t and s_t respectively denote a vector of state variables for an MNC and a local firm in period t, and R_t and r_t the vector of response variables. Assume that the choice of response variables depends only on the state variable of the firm given that of its competitor. All other market variables affect MNC and the local firm symmetrically, and can therefore be suppressed. Then the response vector for the MNC is:

$$R_t = g(S_t; s_t), \text{ and} \quad (1)$$

Likewise, that for the local firm is:

$$r_t = g(s_t; S_t) \quad (2)$$

Also the hypothesis of catching up by the local firm implies a process:

$$s_{t+1} - s_t = f(S_t - s_t), \text{ with } f' > 0$$

We augment this latter hypothesis by assuming $f' \geq 0$, to include the possibility that there may not be any catching-up during the sample period, eg if the local firm chooses to compete entirely using its response variables. The augmented equation can be written as:

$$s_{t+1} - s_t = f(S_t - s_t), \text{ with } f' \geq 0 \quad (3)$$

Note that if $f' > 0$, not only the gap $(S_t - s_t)$, but also $(R_t - r_t)$ narrows down over time. Initialise time by setting the period of entry of the MNC as 0. If $S_0 > s_0$, then from equations (1), (2) and (3) one of two possibilities is expected over the sample period:

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invest in research and development and advertising (response variables) to improve their production

(i) If $f' = 0$, then $S_t > s_t$, and $R_t \neq r_t$ for all t.

(ii) If $f' > 0$, then s_t increases with t over the sample period. In this case, $(S_t - s_t)$ and $|(R_t - r_t)|$ fall over time. This may lead to a situation where they may become statistically insignificant, and then $S_t > s_t$, and $R_t \neq r_t$ may or may not hold in a statistically significant sense over the sample period.

For our exercises below, S and s are scalars, and will stand for the TE of the MNC and the local firm respectively.

Given this model, we can examine how observations on a panel data would relate to the two parts of the compound proposition of spillover.

(1) Regarding the first part of the proposition, ie MNCs, at the time of entry, are superior to local firms in some attributes, we can have the following cases:

(i) If $S_t > s_t$, and $R_t \neq r_t$, the proposition is not rejected.

(ii) If $(S_t - s_t)$ and $|(R_t - r_t)|$ are not significantly different from zero, but s_t increases over the sample period, we can not reject the possibility of initial superiority of MNCs.

(iii) If $S_t^* < s_t$, the proposition is rejected.

(iv) If S_t and s_t are not significantly different, while $R_t \neq r_t$, we infer that difference exists between MNCs and local firms, but can not establish the superiority of either. This is because while a difference in TE results in different responses, we can not have unambiguous prior expectation about the sign of the difference (see section 3).

(2) Regarding the second part of the proposition, ie there is a spillover process, we can have the following relevant cases:

(i) If $S_t > s_t$, and/or $R_t \neq r_t$; and s_t increases in time, we may infer that there is a spillover process.

(ii) If $S_t > s_t$ does not hold but s_t increases over time, we can not reject the possibility of a spillover process. In this case the initial superiority of MNCs can be argued to have been eroded through spillover, and thus absent in the sample.

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efficiency and safeguad their market share.

(iii) If $S_t < s_t$ and s_t increases through time, the increase can not be attributed to spillover. It is however possible to suggest (or rather not reject) that the increase of s_t is the result of competition with MNCs rather than a spillover process.

(iv)If $S_t > s_t$, while s_t is invariant in time we conclude that MNCs have superiority but it has not spilled over during the sample period.

(v) If s_t decreases over time, there is no case for a spillover.

There may also be observations that do not fit any of the above categories. In some of the inconclusive cases, we will use the information of the estimated difference in response variables to speculate on the developments in that industry, which may be of some contextual interest.

3 Choice of Variables

We mentioned in section 2 that features like technology and intangible assets will be proxied by a measure of technical efficiency based on total factor productivity. The appendix to the paper discusses the TE index, estimation procedure and the estimates of industry production functions on which firm level efficiency measures have been based. The index is relative, and is based on the proximity of a firm to the production function of the 'best firm' ie the one with the highest factor productivity.

Secondly, we can identify a number of response variables that have been either observed to differ between MNCs and local firms, or are expected to differ on theoretical grounds. Response variables are either instruments of short run maximisation or strategic variables in the short run and medium run games. Given the difference in state variables, MNCs and local firms are expected to choose different levels for some or all of their response variables, though, as the following discussion shows, it may not be possible to have *a priori* expectation about the direction in which they would differ.

1. R&D: It is generally supposed that developing countries' technological institutions and skill endowments are inadequate for efficient R&D investment by MNCs. R&D investment by MNCs in host countries, if at all, is observed to be for adapting their products to local conditions, and would therefore be small (Bartlet and

Ghoshal)[7]. On the other hand, domestic firms often respond to MNCs' entry by increasing their R&D efforts. Consequently, domestic firms may exhibit higher R&D expenditure per unit sale compared to MNCs.

2. Import Intensity: MNC subsidiaries tend to be import-intensive in the beginning of their operations as they bring in technology and intermediates from the parent company. In course of time, for reducing transport and tariff cost and for possible cost advantage of location, they may start local production of certain intermediates. At the same time, for minimising technology spillover, they may not produce some intermediates locally. This latter may also be done for maintaining demand for specific intermediate products of the parent company or as a part of transfer pricing strategy.

As a result, the import intensity of MNC subsidiaries may vary with time. The evolving competition introduces further unpredictability. If domestic firms catch up technologically, an MNC may import more efficient technology from the parent company which is its R&D centre (Kokko, 1994). This may result in an unpredictable pattern of import intensity. While this discussion implies that import intensity is an important strategic variable, we can not form an *a prori* expectation about the difference in sign between MNCs and local firms.

Vertical Integration: Institutions of the host country determine market transaction costs, which are to be weighed against the economy of integrated production (Williamson, 1985, Dunning, 1981). Local firms, with more experience of domestic institutions may actually face lower transaction costs in some markets. This coupled with the preference of MNCs for using parent companies to source intermediate products tends to produce a relatively lower degree of vertical integration in their host country operations. However there are also contrary evidences where firms try to avoid transaction costs through vertical integration[8].

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[7] A couple of exceptions in India's case are softwares and pharmaceuticals. Some MNCs have been setting up R&D centres in India because of the availability of low-wage skilled labour.

[8] In garments industry, large scale integrated plants producing yarn, cloth, and garments are set up to reduce lead time and transaction costs associated with securing inputs, to avoid too many sub-contractors and to implement quality control (Ghemawat and Patibandla, 1999).

Both domestic firms and MNCs have to compare the economy of vertical integration with associated organisational costs[9]. When intermediate products can be sourced cost-efficiently from domestic vendor firms (for example, auto-components), local firms may opt for lower vertical integration and thus avoid organisational costs. Besides, domestic firms in order to compete with MNCs may increase import of intermediate products, which would reflect in a lower degree of vertical integration. Thus the degree of vertical integration is a strategic variable of some importance, but there is no prior expectation about the sign of its difference between local firms and MNCs.

Export Intensity: Export intensity also features in the literature as an important response variable. It has been observed that if local firms loose domestic market share to MNCs, they increase exports in the short run to maintain a reasonable scale of production (Patibandla, 1999). On the other hand those MNCs who produce mostly for export, would have higher export intensity than their counterparts in the host country.

Advertisement Intensity: MNCs are generally observed to have higher advertisement intensity aimed at popularising brand names and establishing consumer loyalty. Increasing presence of MNCs in the Indian market have led domestic firms to increase advertising intensity too. Apart from advertising, their general promotional expenditure has been also noted to increase with MNCs presence (Patibandla, 1999).

As is evident from the above discussion, it is not possible to have prior theoretical expectation about the sign of the difference of response variables between MNCs and local firms.

4 Data, variables and exercises

The data is based on nine Indian industries: Air-conditioners (A), Diesel Engines (D), Electronic Process Control (E), Light Commercial Vehicles (L), Motors and Generators (M), Motor Cycles (MC), Pumps and Compressors (P), Refrigerators (R),

[9] Organisational costs associated with integrated production could be high for large firms in India

Television Sets (T). The coverage, depending on the industry, is either 1988-96, or 1989-96 or 1990-96. Sources of the data are the publications of the Confederation of Indian Industry and the Centre for Monitoring the Indian Economy.

Firms with foreign equity above 50 per cent have been treated as MNC subsidiaries[10]. MNC firms in motor cycles and television sets are new entrants having entered in mid 80s or after, while in the other industries such as Light Commercial Vehicles and Electronic Process Control, the sample consist of both older and new entrant MNCs. This point is germane because new entrant MNCs may differ more from domestic firms than older MNCs (Patibandla, 1999; Sanyal and Patibandla, 1999).

Following is the list of variables used in the exercises:

1. TE: Relative technical efficiency of production. Firm level relative technical efficiency has been estimated by the production frontier approach. We adopt the 'within estimator' method by using Cobb-Douglas production function and derive plant specific and time variant technical efficiency indices[11]. The methodology and the estimates are briefly presented in the Appendix.

2. *VI*: Degree of vertical integration. It is defined as Value-added/ Value of output, $0 < VI \leq 1$.

3. *ES*: Export intensity, defined as Exports/Total Sales.

4. IM: Import intensity, defined as Import of intermediate goods and capital goods/ value of output.

5. RD: Research and development intensity, defined as research and development expenditure/value-added.

6. AD: Defined as promotional expenditure/Sales. Promotional expenditure includes advertisement, marketing, and distribution expenditure.

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because of the government's labour market policies and trade unions.

[10]Foreign equity holding has increased generally since the reforms started. In several industries (eg software and infrastructure) 100 per cent foreign owned subsidiaries are now permitted. In other industries, foreign equity is allowed up to 87 per cent.

[11] See Krishna and Sahota (1991) for a detailed explanation of this methodology.

7. D: Dummy variable that takes a value of '1' for MNC firms and '0' for domestic firms.

We report on two exercises. The first relates to the first part of the compound proposition about spillover. It explores if MNCs are significantly different from local firms in TE and response variables. A qualitative dependent variable (D) is used to distinguish between domestic and MNC firms, and we use Probit method of estimation (Maddala, 1983). A separate equation is estimated for each industry to capture industry specific factors explicitly. These exercises are to test for the likelihood of a firm being a domestic or a multinational firm as independent variables vary.

For this exercise, we estimated two Probit equations to avoid possible interdependence among variables. On *a priori* grounds, interrelation may exist between import intensity and the degree of vertical integration[12], and between efficiency and research and development intensity. Accordingly, in one of the equations the dichotomous variable is regressed on TE and vertical integration alone. In the second equation we regress it on the rest of the response variables.

The second exercise tests if TE of local firms in a given industry has increased over the sample period. Since efficiency is measured relative to the frontier firm in the industry, exogenous technical progress through time is not expected to interfere with this exercise, assuming that such progress affects all firms in an industry uniformly.

For this test we arrange the average TE of an industry in ascending order of calendar years, and divide them into two samples: the first and the second half. We assume that average TE in the two halves are normally distributed, independently of each other. On this assumption the difference of the means of the two samples has a *t*-distribution of appropriate degrees of freedom. We then test for the assumption of equal variance of the two samples. Depending on the outcome, we use an appropriate *t*-test for the significance of the difference in mean TE of the two samples.

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[12] Reduction of duties and easing of import controls has reduced both direct import cost as also import related transaction costs. Increase in import of intermediates can directly alter the extent of vertical integration.

5 Discussion of Results

Table 2 presents the Probit estimates that differentiate MNCs and domestic firms on the basis of relative technical efficiency and degree of vertical integration, while Table 3 presents the second Probit equation. Table 4 reports on *t*-tests on the average TE over two halves of the sample period. Below we comment on the findings taking account of the results of the three exercises together.

1. Technical efficiency of local firms increased significantly over the sample period in three industries: Air-conditioners (A), Light Commercial Vehicles (L) and Motor Cycles (MC). These increases can be attributed to spillover if in these industries the TE of MNCs is greater than that of local firms or if there is no significant difference between the two (see section 2). If local firms' TE is significantly higher than that of MNCs, then however the spillover hypothesis can not be accepted. On this basis, the hypothesis of spillover can not be rejected for MC and A because TE is not significantly different between local firms and MNCs.

In light commercial vehicles (L), the estimated coefficient of TE in Table 2 is negative and statistically significant which means local firms have performed more efficiently. Therefore in this industry the increase of TE of local firms over the sample period (Table 4) can not be attributed to spillover. Using anecdotal evidence and media reports, we can construct a possible sequence of events for this industry that may square with these findings. Out of the three MNC firms in L, two are new entrants. They have been reported to have difficulty competing with incumbent domestic firms, particularly, Tata Engineering and Locomotives (TELCO). Also, in response to MNCs' entry, TELCO increased technological efforts and invested large amounts in R&D[13]. This is also borne out by Table 3, where the coefficient for RD for this industry in the Probit equation is negative and significant. New entrants possibly had to operate at sub-optimal scale during the sample period, which kept their TE low. On the other hand their entry started an efficiency improving process in the industry, like

[13] As reported in the press, TELCO invested about Rs.1,700 million in R&D to design and develop a small car which appeared on the market in 1998.

the efforts of TELCO referred to above. This sequence would suggest an efficiency improving effect as a result of competition with MNCs, rather than a spillover process.

2. In Electronic Process Control (E), Pumps and Compressors (P), Refrigerators (R) and Television Sets (T), MNCs have significantly higher TE than local firms (Table 2). But as Table 4 shows, this has not produced efficiency spillover in any of these industries. In particular, local firms in E and T show a fall in TE during the sample period.

As Table 3 shows, local firms have coped with competition from more efficient MNCs in various ways. Local firms in Pumps and Compressors (P) appear to have higher export intensity than MNCs, which may support the idea that some firms try to maintain a reasonable scale of production by increasing exports when they lose domestic market share to more efficient firms (Patibandla, 1999). On the other hand local firms in Television Sets (T) show significantly higher import intensity than MNCs.

3. In a number of industries local firms show significantly lower TE for the second period. They are: Electronic process control (E), Motors and Generators (M), and Television Sets (T). It is of some interest to note that except for T, industries in this group have fewer new entrant MNCs than the group where TE of locals increased over time.

A few other observations on the results, which are not directly related to the question of spillover, but of some contextual interest are:

4. Except in the case of television and diesel engines, in the other industries MNCs have higher vertical integration (Table 2). This partially supports the argument that MNCs (especially, new entrants) that do not possess cumulative knowledge of dealing with domestic institutions may tend to operate with higher vertical integration.

5. Estimated coefficients of R&D (Table 3) is significantly positive only in pumps and compressors (P). By and large this may uphold the observation in the literature that MNCs do not incur significant R&D expenses in host countries. On the contrary, local firms respond to MNCs' entry by increasing R&D efforts. As

mentioned earlier, in light commercial vehicles (L), domestic firms such as TELCO increased R&D efforts in response to the entry of new MNCs[14].

6. As far as exports are concerned, only in the electronics process control (E), MNCs show significantly higher export intensity than local firms. Arguably, this is an industry where MNC investment is motivated by exporting rather than selling in India. It appears to be plausible in view of the skilled-labour intensity of production in this industry and low costs of skilled labour in India.

6 Conclusion

In India's post-reform period, entry of MNCs has not led to any notable exit of local firms. Furthermore, even in the case of labour intensive industries such as electronics and garments (not studied in this paper), a large and growing local market makes MNC investment more long term rather than purely focused on local production for the international market[15]. Entry of multinationals into semi-industrialized developing economies such as India results in two possible benefits: 1) it induces local firms to improve their production and marketing efficiency by increasing competitive conditions and 2) it results in technological and informational externalities (spillover) to local firms. The empirical exercises of this paper could detect possible spillover in two industries, and in another industry we have some evidence of efficiency improving effect of competition. As a bi-product of the study we have got the pattern of relative response of local firms and MNCs in different industries. Responses of local firms have led to increased efficiency in three industries, while in an equal number of other industries, we note significant fall in their efficiency.

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[14] In the case of Motor cycle industry (MC), a close look at the data reveals very large investment in R&D by one of the two domestic firms, Bajaj Auto. The second firm, Rajdoot lost out its market share significantly to new entrant MNCs and did not invest in R&D in any significant manner, pulling down the locals' average R&D.

[15] It has been observed that in industries where MNC investment is induced by low wage cost and for export to third countries, they relocate production once wages start increasing as a result of growth: examples are drawn from garments and electronic goods production. India's large and growing domestic market (unlike in smaller countries like Malaysia) provides incentive for MNCs not to shift location even if wage costs go up.

Several qualifications should be added to this general conclusion. First of all, conclusions of our exercises do not fit well with the general perception about the recent Indian industrial scene based on media reports and casual empiricism. The general perception is of dynamism whereby best international practices are becoming common among local firms after decades of stagnation. This casual observation is partly supported by our second Probit equation that shows local firms are spending no less and in most cases more on R&D. But it is also possible to argue that the observed dynamism is the result of a perception of threat from MNCs rather than direct spillover from them.

We can not make a conclusive point on this issue because it is possible to argue that our exercises take a somewhat restrictive view of the spillover process. Our methodology recognises the superiority of MNCs and resulting spillover only when they show up in terms of technical efficiency. Arguably, this represents a restricted vision of the process. It is possible that some new entrant MNCs are currently producing below optimal scale, leading to lower technical efficiency as measured by us. Yet their practices may start spilling over in the industry. Given our method, an improvement of efficiency of local firms in this situation will be attributed to increased contestability, while indeed it may be the result of spillover. It may be worthwhile to design a study with a more inclusive view of the spillover process.

Secondly, the focus on technical efficiency rules out the use of information on disaggregative features of response of both local firms and MNCs. This leaves out important features of the emerging competition like vertical product differentiation, strategic pricing etc[16]. Particularly in the presence of product differentiation, our measure of technical efficiency, which assumes a homogeneous product for each industry needs serious modification.

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[16] Product differentiation is an important feature of competition between MNCs and local firms in the post-reform Indian industries. See for example Sanyal and Patibandla (1999), who argue that MNCs tend to sell higher quality products at higher prices within the same generic product group. See also Patibandla (1999).

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Appendix: Measurement of Technical Efficiency

Firm level efficiency indices are based on Farrell's (1957) production frontier approach. More recent development in the efficiency frontier literature enables the derivation of firm-specific time-variant efficiency indices from panel data. The production function defines the maximum possible output a firm can realise for a given technology and vector of inputs. Relative technical efficiency is defined by the extent of closeness of output (for a given level of inputs employed) from the best practice in the industry.

The panel data technique of measuring efficiency overcomes several well-known shortcomings of the estimates based on cross-sectional data (Pitt and Lee, 1981). The panel data captures cross-sectional information of firms in an industry and also repeated observations over time for a given firm. This overcomes the shortcomings of strong distributional assumptions about composed error terms. Furthermore, this method does not impose the assumption that technical efficiency is independent of factor inputs.

By taking the Cobb-Douglas functional form, we can represent a technology as:

$$Y_{it} = \alpha + \beta X_{it} + v_{it} - u_i \qquad (1)$$

where Y_{it} is the observed output, X_{it} is a vector of K inputs: i indexes firms, t indexes time; α and β are the unknown parameters to be estimated; v_{it} represents random errors; u_i $(u_i \geq 0)$ represents technical inefficiency with a one-sided distribution which means that output must lie on or below the frontier.

The random error v_{it} is assumed to be identically and independently distributed across firms and time with identical zero mean and constant variance. It is also assumed to be uncorrelated with factor inputs. The other error component, u_i, is assumed to be independently and identically distributed across plants with mean m and variance σ_m^2.

We can rewrite equation (1) as

$$Y_{it} = (\alpha - u_i) + \beta X_{it} + v_{it} \qquad (2)$$

Cornwell *et al* (1990) introduce a parametric function of time into the production function to replace the coefficient of plant-specific technical efficiency. The functional form is

$$Y_{it} = X_{it}\beta + \alpha_{it} + \nu_{it} \qquad (3)$$

where

$\alpha_{it} = w'_{it} 0_i$, $w' = (1,t,t^2)$, $0_i = (0_{i1}, 0_{i2}, 0_{i3})$

and other variables are as defined before.

The model allows the rate of productivity to vary over time and firms. The production function can be estimated by OLS, which is referred to as the 'within estimator' in the literature. Residuals of the estimated function are used in deriving the efficiency indices. OLS estimation of the production function can be justified in terms of the Zellner-Kmenta-Dreze proposition that, under the assumption of maximization of expected profits, the explanatory variables and the disturbance term are uncorrelated. However, α'_{it} is not consistent as t goes to infinity if factor inputs are correlated with firm and time specific effects. Under these conditions, the consistent estimators of α'_{it}, as time goes to infinity, can be derived by estimating equation (3) using OLS directly (see Liu, 1993). The production function is estimated by the two input Cobb-Douglas functional form with value-added as output, and L and K as inputs. The estimated residuals are used in measuring the relative TE of firms. Table 5 presents the econometric results for the estimated production function for the nine industries.

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Table. 1

Foreign Collaboration Approvals by Industry Group, 1991 to 1996

Name of Industry	**Number of Approvals**		Amount of FDI approved, Rs.Million	Per cent of total approval
	Technical	Financial		
Basic Industries	966	766	278326	32.2
Capital goods	1992	1399	86111	10
Intermediate industries	170	286	15043	1.76
Consumer Non-durable industries	904	1292	120629	13.9
Consumer durable industries	27	42	26468	0.5
Services	258	1467	336712	39
Total	4317	5252	86329	100

Source: Research Foundation, Economic and Political Weekly

Table 2.

Probit Estimations (I)

Industry	Constant	TE	VI	-2(log-likelihood)	N
A	7.7	-4.4	-8.9	15	29
	(2.1)*	(1.0)	(2.2)*		
D	-0.2	3	-12	40	34
	(.03)	(0.9)	(2.3)*		
E	-5	5.5	2.8	24	30
	(2.7)*	(2.9)*	(1.2)		
L	7.3	-2.5	11	46	49
	(3)*	(1.67)*	(3.5)		
M	6	-5.8	-3.9	36	40
	(1.8)**	(1.4)	(1.36)		
MC	-19	1.5	28	18	51
	(2.8)*	(0.5)	(2.96)		
P	-4.0	7.0	-1.9	54	66
	(3.6)*	(2.0)*	(0.5)		
R	-7.3	0.85	16	18	24
	(0.9)	(1.97)**	1.9)**		
T	0.07	6.4	-13	36	52
	(0.3)	(1.5)**	(3.1)*		

Figures in brackets are *t* values. * Significant at 0.01; ** Significant at 0.05 levels

Table 3

Probit Estimations (II)

Industry	Constant	RD	IM	ES	AD	-2(log-likelihood)
A	9.0 (0.4)	12 (0.3)	-53 (1.0)	116 (0.9)	-28 (0.86)	8
D	-3.5 (1.95)**	15 (0.36)	49 (2.3)*	-23 (1.7)**	-138 (1.97)**	7.2
E	-8.1 (2.3)*	-64 (0.86)	19 (2.3)*	61 (2.5)*	48 (1.26)	10.8
L	-4.8 (1.78)**	-42 (2.8)*	0.7 (0.32)	-4.8 (0.77)	35 (2.5)*	36
M	1.7 (2.0)*	51 (1.3)	-33 (1.98)*	11 (0.5)	-10 (0.5)	14
MC	-3.5 (1.98)*	-30.9 (1.22)	36 (2.5)*	-24 (1.6)**	69 (2.24)*	22
P	-0.2 (0.2)	82 (1.5)**	4.3 (0.9)	-10 (2.4)*	28 (1.48)**	40
R	2.6 (0.4)	-49 (0.24)	21 (1.8)**	64 (1.48)	-72 (0.98)	2
T	0.15 (0.22)	-14 (1.3)	-8.7 (2.2)*	-4.5 (0.8)	7.2 (0.46)	46

Figures in brackets are *t* values. *Significant at 0.01; ** Significant at 0.05 levels.

Table 4

Difference in Technical Efficiency of Local Firms for two sample halves

	A	D	E	L	M	P	R	MC	T
Difference of Mean	0.088	-0.035	-0.061	0.037	-0.067	0.001	0.070	0.094	-0.098
Probability for estimated *t* value	0.024**	0.158	0.076***	0.079***	0.025**	0.458	0.113	0.079***	0.029**

* Significant at 0.05; ** Significant at 0.10 levels

Table 5.

Estimated Production Functions

Industry	Constant	Log L	Log K	Adjusted R^2	F
A	0.05 (0.1)	0.51 (3.1)*	0.71 (2.1)*	0.92	92
D	0.29 (2.9)*	1.0 (10)*	0.2 (1.6)**	0.94	150
E	0.75 (36)*	0.76 (7.5)*	0.27 (2.2)*	0.98	640
L	0.67 (6.6)*	0.67 (6.3)*	0.2 (1.67)**	0.96	230
M	0.12 (0.5)	0.62 (4.5)*	0.6 (7.7)*	0.92	89
MC	-0.02 (0.15)	0.61 (5.6)*	0.79 (7.8)*	0.93	0.93
P	0.98 (6.5)*	0.4 (2.78)*	0.45 (2.8)*	0.86	84
R	0.42 (2.9)*	0.67 (11)*	0.38 (6.6)*	0.95	181
T	0.6 (5.9)*	0.68 (4.4)*	0.25 (2.0)*	0.88	99

Figures in brackets are t values. *Significant at 0.01; ** Significant at 0.05 levels