7. _____

Productivity Dynamics in the Indian Pharmaceutical Industry: Evidence from Plant-level Panel Data

Atsuko Kamiike, Takahiro Sato, Aradhna Aggarwal

1. Introduction

This paper uses a micro panel dataset of firms in the Indian pharmaceutical industry to analyse the impact of industry dynamics on total productivity growth across five selected regions over the period 2000-01 to 2005-06. Inspired by the 'creative destruction' process proposed by Schumpeter (1942), the study examines firms' strategic entry and exit behaviour and measures the contribution of new, continuing, and exiting firms to aggregate productivity growth in the pharmaceutical industry across the selected regions. These regions differ in terms of age and degree of agglomeration. Our hypothesis is that the productivity growth of continuing, entering, and exiting plants differs across regions depending on the degree and age of agglomeration. The empirical analysis is based on the decomposition methodology of aggregate productivity growth pioneered by Baily et al. (1992). Following the analysis of Aggarwal and Sato (2011), it uses three different methodologies: Griliches and Regev (1995), Foster, Haltiwanger, and Krizan (2001), and Melitz and Polanec (2009). The analysis is based on plant- or 'factory'-level data for the period 2000-01 to 2005-06 drawn from the Annual Survey of Industries (ASI). Given the data constraints, the analysis focuses on the large factory sector, the 'census sector'. The small sector, the 'sample sector' is beyond the purview of this study.

The Indian pharmaceutical industry has seen steady growth during the last three decades and has emerged as one of the leading global players in generics. It has also registered evolutionary dynamics driven by the survival, entry, and exit of firms and plants.

Economic reforms since 1991, which substantially relaxed barriers to business and trade, have progressively induced the new entry of firms and plants into the pharmaceutical industry. FDI has been permitted up to 100% for the manufacture of drugs and pharmaceuticals. Under the new WTO-compatible intellectual protection regime introduced in 2005, multinational pharmaceutical companies are creating research centres and manufacturing plants in India. They are also outsourcing drug discovery operations and clinical trials to Indian companies. The degree of price control on drugs has gradually been reduced. These factors contribute to increases in the competitive pressure on surviving firms and the rise in number of entering firms.

Generally speaking, while entry barriers are considerably relaxed, exit policy is still regulated in India. However, pharmaceutical industry is exceptional. India complies with the WHO Certification Scheme for Good Manufacturing Practice (GMP) on the quality of pharmaceutical products. The GMP, which is defined in Schedule M of the Drugs and Cosmetics Rules, has

become mandatory since 2005. According to official estimates, in 2001, 327 pharmaceutical manufacturing plants closed or had their licenses suspended or may have shifted to some other state. A total of 370 plants were not in a position to comply with GMP. Since GMP has been made mandatory from 2005, these units have been closed (Planning Commission 2002, par. 7.1.192). In addition to the increase in competitive pressure, GMP compliance has possibly induced the exit of small and inefficient firms and plants from the markets.

The Indian pharmaceutical industry thus makes a good case study for the process of 'creative destruction'' which Schumpeter (1942) proposed in order to explain the dynamics of industry evolution.

The rest of the study is organised as follows: In Section 2, we explain important policy changes to the Indian pharmaceutical industry which affect the new entry and exit of firms and plants, and focus on the formation of the industrial agglomerations in the Indian pharmaceutical industry. In Section 3, we present the empirical methodology and the data, and evaluate the entry and exit effects on region-wise productivity growth. In Section 4, we offer some concluding remarks.

2. The Formation of Industrial Agglomerations in the Indian Pharmaceutical Industry

2.1. Important Policy Changes to the Indian Pharmaceutical Industry

We will review important shifts in policies related to the pharmaceutical industry: (1) the introduction of pharmaceutical product patents and (2) the mandatory implementation of GMP (Good Manufacturing Practice).

(1)   The introduction of pharmaceutical product patents

In 2005, India had to amend the Patent Act of 1970 to comply with the TRIPS Agreement. Amendment of the Act changed the institutional factors which supported the growth of the Indian pharmaceutical industry.

The TRIPS Agreement forced not only the introduction of pharmaceutical product patents but also an assurance of a 20-year period for patent protection at the least. In March 2005, India completed the amendment of the Patent Act of 1970 to comply with the TRIPS Agreement. The new patent act came into force on April 4th, 2005. It introduced product patents for drugs, foods, and chemical products and the patent term was increased to 20 years. The Indian patent regime has become fully TRIPS compliant.

The introduction of pharmaceutical product patents brings new business opportunities to the Indian pharmaceutical industry. In the 2000s, pharmaceutical outsourcing business has been increasing in India. In the past, foreign pharmaceutical companies tended to hesitate to manufacture new drugs in India because of the Patent Act of 1970, which did not recognise product patents on pharmaceutical products. Recently, however, foreign companies have been increasing the outsourcing of manufacturing of their new drugs. The introduction of product patents by the amendment of the Patent Act of 1970 made it impossible for Indian companies

not licensed to manufacture patented drugs. The incentive of Indian companies to misappropriate the knowhow gained from contractors (foreign companies) was to be lowered. On the other hand, in terms of foreign companies, the amendment of the Patent Act of 1970 that introduces product patents in India lowered the risk of outsourcing to Indian companies.

Recently, contract research and manufacturing services (CRAMS) business has been growing rapidly in India. Many Indian companies entered into CRAMS, and the number of specialised CRAMS companies has increased. In addition to the liberalisation of FDI regulation in the pharmaceutical sector in 2002 that allows FDI up to 100% under the automatic route, the introduction of pharmaceutical product patents has also accelerated the advance of foreign companies into India, and several Indian companies have been taken over by foreign companies.

(2)   The mandatory implementation of GMP (Good Manufacturing Practice)

In India, the Drugs & Cosmetics Act of 1940 and the Rules of 1945 regulate drug regulatory affairs. The Act and Rules regulate drugs imported, manufactured, distributed, and sold. No pharmaceutical products can be imported, manufactured, stocked, distributed, or sold unless they meet the quality standards laid down in the Act. India decided to introduce Good Manufacturing Practice (GMP) in the Drug Policy of 1986. GMP was laid down in Schedule M of the Rules and came into force in 1987. The introduction of GMP has contributed to the enhancement of trust in Indian products in the global market. In addition, complying with the GMP standard of U.S. and Europe has increased exports to Western countries, and has tapped and expanded the opportunity for contract manufacturing.

In order to upgrade to the requirements of WHO-GMP standards and eradicate counterfeit drugs and substandard drugs, Schedule M was amended in December 2001. After the amendment of Schedule M in December 2001, it is mandatory for all manufacturers to comply with the new GMP. From 11th December, 2001, manufacturing facilities not complying with the new GMP have not been able to obtain any manufacturing license from each State Drug Control Administration office. Furthermore, the manufacturing facilities that received a manufacturing license before December 2001 had to implement the new GMP until 31st December, 2001. If they could not do so, their manufacturing licenses were revoked and their manufacturing facilities forcibly closed down.

While large, medium, and some small companies have upgraded their manufacturing facilities, most small companies have not upgraded. One of the reasons that small companies cannot upgrade their manufacturing facilities is that they do not have the capacity to raise the funds to upgrade. It requires more than Rs. 2.5 crore to comply with the new GMP. Even if they could afford to do so, they feared that they would lose the status of small-scale industry (SSI) once they invested in GMP. This is because the investment limit to be eligible to be a small-scale industry was Rs. 1 crore.

The Indian government made several concessions to support small companies to implement GMP. The deadline for implementation of GMP was postponed from 31st December, 2003 to 31st December, 2004, and the deadline was finally postponed for six months until 30th June,

2005. The government provides each State Drug Control Administration office with the authority to postpone the deadline. In addition, the investment limit to be eligible to be a small-scale industry was raised from Rs. 1 crore to Rs. 5 crore. Regardless of government support, a large number of small firms have been weeded out.

2.2. The Formation of Industrial Agglomerations in the Indian Pharmaceutical Industry
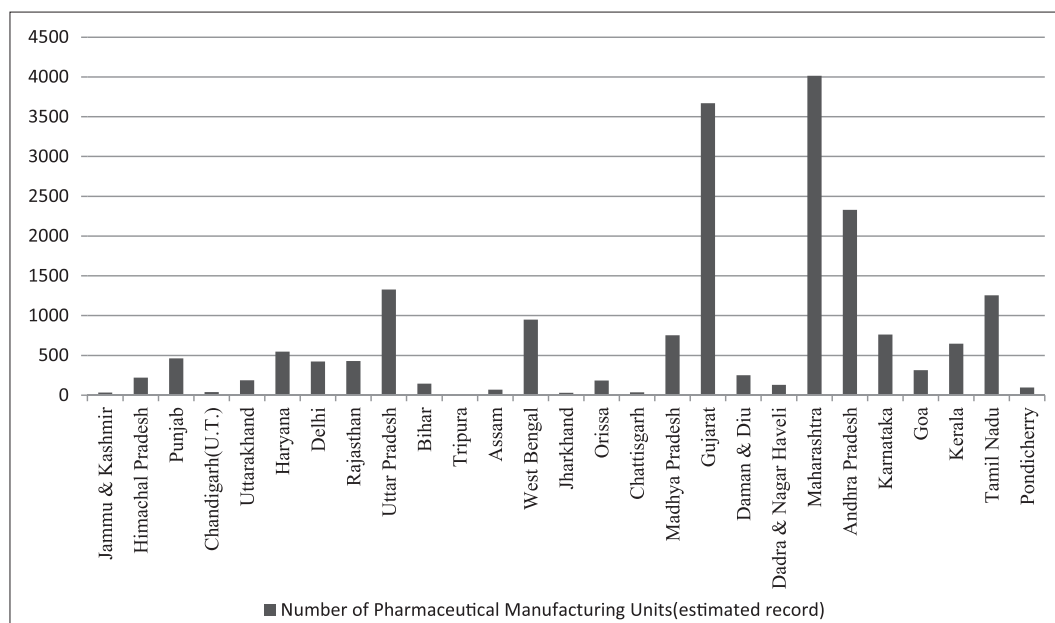
The Indian pharmaceutical industry has formed several industrial agglomerations in many parts of India. Major pharmaceutical industrial agglomerations are Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Haryana, Punjab, Delhi, Goa, Himachal Pradesh, Uttarakhand, Daman & Diu, and Dadra Nagar & Haveli. Table/Figure 2-1 shows the state-wise distribution of manufacturing facilities.

We point out three contributing factors in the formation of regional pharmaceutical agglomeration. These factors are (1) the linkage between public research institutions and private-sector companies, (2) the spin-off of engineers of public enterprises, and (3) the extensional development of large companies in India.

In the early stage of the development of the industry, public research institutions and public enterprises played an important role in the manufacturing of drugs and research and development activities.

The government established public research institutions and public enterprises in the early

Table/Figure 2-1: State-wise Number of Pharmaceutical Manufacturing Units in 2005 (Annual Survey of Industries)

Source: Central Statistical Organisation, Annual Survey of Industries, 2005-06, unit-level data.

1950s. The development of the industry is based on close linkage between public research institutions and private-sector companies. The technologies that public research institutions developed were transferred to private-sector companies and the private-sector companies then commercialised these technologies. Since the private companies had little of their own research capability in the early stage of development, cooperation with public research institutions was crucial. Therefore, pharmaceutical industrial agglomerations were formed around the public institutions. Agglomerations were also formed around public enterprises because the engineers of public enterprises started their own ventures. Dr. K. Anji Reddy, who is the founder of Dr. Reddy's Laboratories, is the most famous case where the engineer of a public enterprise, Indian Drugs and Pharmaceutical Limited (IDPL), started a venture. Hyderabad, which has the largest agglomeration of bulk drug manufacturers and the public research institution, the Indian Institute of Chemical Technology, Hyderabad (IICT-H), and the public enterprise, IDPL, is a good example of pharmaceutical industrial agglomeration.

The Patent Act of 1970 made manufacturing possible for pharmaceutical companies such as Cipla and Alembic which had been manufacturing drug-related chemical compounds before Independence and companies such as Ranbaxy which engaged drug-selling agents to manufacture drugs that were patented in other countries through reverse engineering. Since then, the Indian pharmaceutical industry has developed rapidly. In the process, pharmaceutical agglomerations have been formed around these companies.
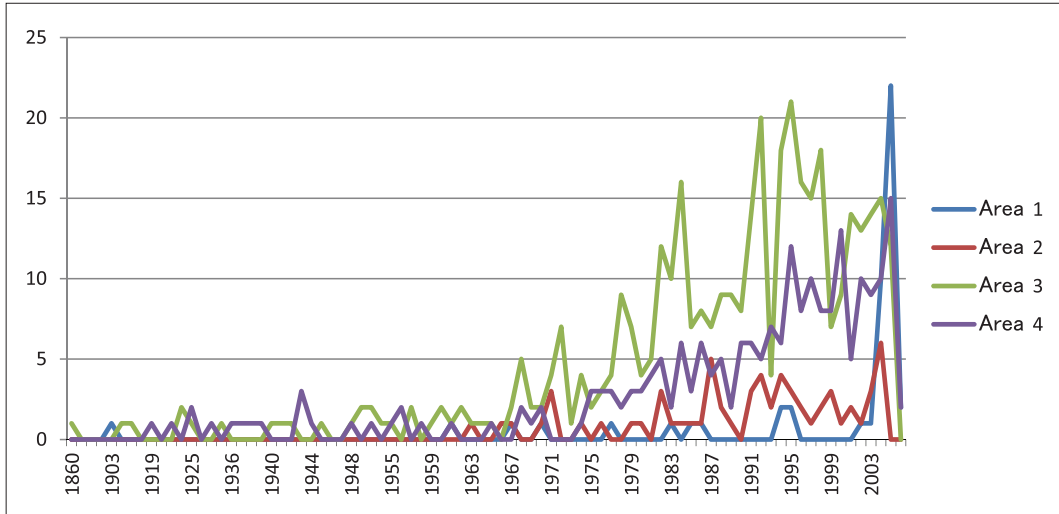
Recently, some state governments are conducting measures to promote industrial agglomeration. In April 2000, the Indian government released the Special Economic Zones Policy, and the state governments in the agglomerated areas then set to work on the building of SEZs. Now, 40 pharmaceutical and bio SEZs have been approved. All 40 SEZs are located in these agglomerations. Most state governments in agglomerated areas have attracted biotechnology industry aggressively and planned the building of biotech parks.

The Indian government implemented the Himachal-Uttaranchal Industrial Policy in Himachal Pradesh and Uttarakhand as a development policy for backward areas from 2003 to 2010 (DIPP, 2003a, 2003b). The policy classified industries into two categories—thrust industries and negative industries. While the industries identified as thrust industries were attracted, few industries indentified as negative industry were drawn. The pharmaceutical industry was identified as a thrust industry. In this industrial policy, fiscal incentives such as excise duty exemption, exemption of income tax for companies, and capital investment subsidy were granted to new industrial units and to existing units on their substantial expansion. This policy promoted industry agglomerations in both states.

In consideration of geographical location and the degree and age of agglomeration of the Indian pharmaceutical industry, we classify India into four areas.
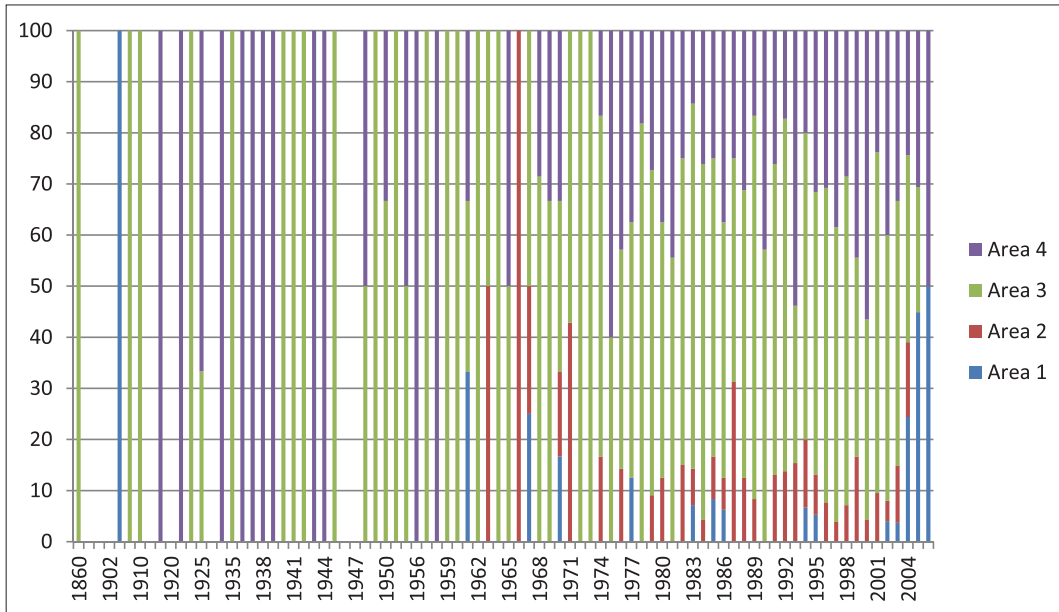
First of all, we classify India into two areas, the new (emerging) area and the established area, on the basis of the initial year of production of firms (Table/Figure 2-2, 2-3). The new area is Area 1 including Himachal Pradesh and Uttarakhand. The established area consists of three sub-areas, Area 2 (Delhi, Haryana, and Punjab), Area 3 (Gujarat, Maharashtra, Goa, Dadra & Nagar Haveli,

Table/Figure 2-2: Area-wise Distribution of the Initial Year of Production

Source: Central Statistical Organisation, Annual Survey of Industries, 2005-06, unit-level data.

Table/Figure 2-3: Area-wise Share of Newly Built Units

Source: Central Statistical Organisation, Annual Survey of Industries, 2005-06, unit-level data.

and Daman & Diu), and Area 4 (Andhra Pradesh, Karnataka, Tamil Nadu, and Pondicherry).

In this paper, Area 1 (new area: Himachal Pradesh and Uttarakhand), Area 2 (established area: Delhi, Haryana, and Punjab), Area 3 (established area: Gujarat, Maharashtra, Goa, Dadra & Nagar Haveli, and Daman & Diu), and Area 4 (established area: Andhra Pradesh, Karnataka, Tamil Nadu,

and Pondicherry) are identified as agglomerated regions of the pharmaceutical industry (Table/Figure 2-4). The rest of the states are included in Area 5 (non-agglomerated area). Thus, the regions are categorised as follows:
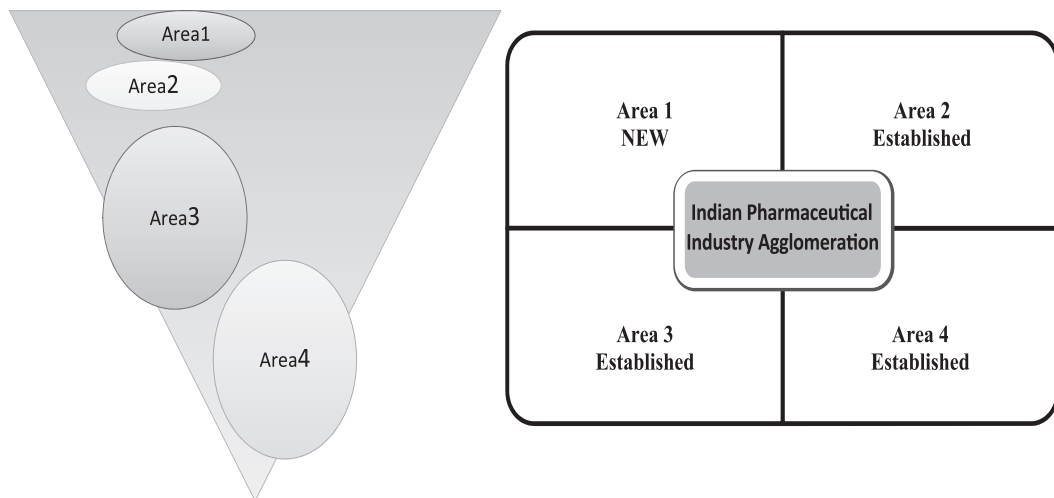
Agglomerated areas:

- Area 1: new area: Himachal Pradesh and Uttarakhand
- Area 2: established area: Delhi, Haryana, and Punjab
- Area 3: established area: Gujarat, Maharashtra, Goa, Dadra & Nagar Haveli, and Daman & Diu
- Area 4: established old area: Andhra Pradesh, Karnataka, Tamil Nadu, and Pondicherry

Non-agglomerated areas

The rest of the states included in Area 5

Table/Figure 2-4: Map of the Four Agglomerated Areas

3. Empirical Analysis of Business Dynamics and Productivity Growth

3.1. Empirical Method

Empirically, the dynamics of productivity growth are captured by productivity decomposition methodologies. Several decomposition methods are offered in the literature to assess sources of industry productivity growth. These methodologies decompose productivity growth between two points in time into the contribution from four broad factors:

- improvement in incumbents' productivity;
- reallocation of resources from less productive to more productive producers;
- entry of more productive firms; and
- exit of less productive firms.

These methodologies thus link macro productivity growth with micro firm and productivity dynamics.

Baily et al. (1992) was the first study to propose decomposition of productivity into the contributions of continuing, entering, and exiting plants (BHC methodology). They defined aggregate productivity as the output-weighted ($\theta_{f,t}$) average of the productivity of individual plants ($A_{f,t}$). The linear aggregation of productivity implies a geometric average of productivity levels:

$$A_t = \sum_f^{n_t} \theta_{f,t} A_{f,t}.$$

Difference in aggregate productivity is defined by

$$\Delta A_t = A_t - A_{t-1}.$$

Using this, they proposed the following methodology (BHC), to decompose aggregate productivity growth:

$$\Delta A_t^{BHC} = \sum_{f \in S} \theta_{f,t-1} \Delta A_{f,t} \quad + \sum_{f \in S} \left(\theta_{f,t} - \theta_{f,t-1} \right) A_{f,t}$$

$$+ \sum_{f \in N} \theta_{f,t} \left(A_{f,t} - A_{t-1} \right) + \sum_{f \in X} \theta_{f,t-1} \left(A_{t-1} - A_{f,t-1} \right).$$

In the above equation, Sets S, N, and X, respectively, represent the set of continuing, entering, and exiting plants during the period from *t-1* to *t*. The first term measures the effect of plant-level productivity changes, weighted by the initial share. The second term which sums changes in shares using a plant's productivity as weight captures the reallocation effect. The last two terms capture reallocation driven by new plants entering and others exiting.

An alternative is provided by Griliches and Regev (1995). Their methodology is as shown below.

$$\Delta A_t^{GR} = \sum_{f \in S} \overline{\theta}_f \Delta A_{f,t} \quad + \sum_{f \in S} \Delta \theta_f \left(\overline{A}_f - \overline{A} \right) + \sum_{f \in N} \theta_{f,t} \left(A_{f,t} - \overline{A} \right)$$

$$+ \sum_{f \in X} \theta_{f,t-1} \left(A_{f,t-1} - \overline{A} \right).$$

This methodology will be referred to as 'GR' throughout the text of this study. In this formula, a bar over a variable indicates the average of the variable over the base and end years. All productivity terms (except for within effects) are expressed as the average productivity of two years.

Foster et al. (2001) modify the BHC methodology. Like BHC, Foster et al. (2001) also

express all productivity changes as differences from aggregate productivity in *t-1*. In addition, they decomposed the second term of BHC into a 'pure between effect', weighing the change in shares by relative productivity in the initial period and a covariance term. This methodology will be called FHK in this study.

$$\Delta A_t^{FHK} = \sum_{f\in S} \theta_{f,t-1}\, \Delta A_{f,t} \quad + \sum_{f\in S} \Delta\theta_{f,t}\left(A_{f,t-1} - A_{t-1}\right) + \sum_{f\in S} \Delta\theta_{f,t}\, \Delta A_{f,t}$$

$$+ \sum_{f\in N} \theta_{f,t}\left(A_{f,t} - A_{t-1}\right) \quad + \sum_{f\in X} \theta_{f,t-1}\left(A_{t-1} - A_{f,t-1}\right).$$

This decomposition has five terms that show the contribution of various components of aggregate productivity change. The difference between the final two is called the net entry effect. In this formula, an entering plant contributes positively only if it has higher productivity than the initial average and an exiting plant contributes positively only if it exhibits productivity lower than the initial average. GR measures their distance from the average productivity of both the initial and the end years.

Olley and Pakes (1996) proposed an entirely different approach, referred to as 'OP' hereafter. They define aggregate productivity as the average of productivity levels and decomposed it into two terms as follows:

$$A_t^{OP} = \widetilde{A_t} \quad + \sum (\theta_{f,t} - \widetilde{\theta_t})\left(A_{f,t} - \widetilde{A_t}\right) = \widetilde{A_t} \quad + \mathrm{cov}(\theta_{f,t}, A_{f,t}).$$

Here, $\widetilde{A_t} = \frac{1}{n_t}\sum_{i=1}^{n_t} A_{f,t}$ and $\widetilde{\theta_t} = \frac{1}{n_t}\sum_{i=1}^{n_t} \theta_{f,t}$. The first term is the unweighted productivity average and the second term captures allocation efficiency, i.e., to what extent 'above average size' firms have 'above average productivity'. This decomposition distinguishes between the contributions of productivity improvements and reallocation but does not allow us to distinguish between contributions of surviving, entering, and exiting firms. Melitz and Polanec (2009) extended this decomposition to assess the contribution of entering and exiting firms to productivity growth. This methodology is termed the 'dynamic Olley and Pakes' method (hereafter referred to as 'DOP' in this study). They challenged the FHK and GR decomposition methodologies on the grounds that their choice of reference productivity values for entering and exiting firms, as well as the use of fixed weights in distinguishing between contributions of productivity improvements and market share reallocation of surviving firms, has confused various effects and hence introduced bias into the measurement. In order to eliminate these biases, they used the Olley-Pakes decomposition and modified it to capture firm dynamics. It is given by

$$\Delta A_t^{DOP} = \Delta \widetilde{A_{S,t}} + \Delta cov(\theta_{S,t}, A_{S,t}) + \theta_{N,t}(A_{N,t} - A_{S,t})$$
$$+ \theta_{X,t-1}(A_{S,t-1} - A_{X,t-1})$$

where $\theta_{g,t}$ and $A_{g,t}$ represent the aggregate market share and aggregate productivity of group g in period t.

There are two major differences between the components of the above methodology and those of FHK and GR. First, both entry and exit effects in this methodology are weighted by corresponding overall market shares. The other two decompositions compare the aggregate productivity of entering and exiting firms to either aggregate productivity of all firms in the initial period (FHK) or the unweighted time average of aggregate productivity of all firms (GR). Second, this methodology does not assign weights to productivity change of continuing firms (within-plant effects) as do the other two methods and follows instead the approach of Olley-Pakes decomposition, defining reallocation only when covariance between market share and productivity increases. Third, mathematically, the three methodologies may yield very different results depending on the features of firm dynamics in the data. In an industry where the productivity of continuing firms is growing, FHK decomposition yields a lower contribution of exiting firms than DOP, whereas the opposite holds for the GR decomposition. Furthermore, both FHK and GR decompositions yield a smaller contribution of surviving plants and a larger contribution of entering plants as compared with DOP. Finally, the within effects are inflated in FHK and GR due to the use of weights in measuring these effects, which according to Melitz and Polanec (2009) captures a part of the reallocation effect.

Clearly, there are a wide range of estimates in the literature. Foster et al. (2001) shows that the results are sensitive to the choice of methodology, time period, and productivity measure. The present study uses three methodologies of decomposition for robustness of results. These are GR, FHK, and DOP.

Hypothesis

The argument that firms benefit from being located in an agglomeration due to place-specific external economies of scale and increasing returns dates back to the early work of Marshall (1920), Ohlin (1933), and Hoover (1937). Marshall (1920) maintained that concentrations of firms in a similar industry give rise to localisation economies in the form of knowledge and information spillovers, labour pooling (advantages of thick markets for specialised skills), and backward and forward linkages. Over the years, the theoretical literature on agglomeration economies has been enriched by the emergence of new trade theories, new growth theories, and new economic geography theories (see Fujita and Thisse 2002 for a comprehensive up-to-date discussion of the theory). A vast body of empirical work, stretching back over many years, has sought to identify these externalities and to quantify their effects on productivity. There are a number of excellent up-to-date surveys of the empirical literature on agglomeration (see in particular, Rosenthal and

Strange, 2004; Eberts and McMillen, 1999). There is considerable evidence that agglomeration economies are associated with productivity enhancement, and we therefore hypothesise that productivity growth in agglomerated regions is likely to be higher than in non-agglomerated areas.

Furthermore, it is expected that entry effects are rather high in new agglomerations.

3.2. Methodology and Data

The most frequently applied measures of productivity are labour productivity (LP) and total factor productivity (TFP). As the latter accounts for the distinct effects of capital/labour inputs together with technological progress, it is often seen as favourable. The present study also uses both LP and TFP for the analysis.

Aggregate LP is measured as a weighted average of plant-level productivity. It is defined as:

$$LP_t \equiv \sum_f^{n_t} \theta_{f,t}\, LP_{f,t} = \sum_f^{n_t} \theta_{f,t} \left(\frac{GVA_{f,t}}{L_{f,t}} \right).$$

The aggregate TFP is defined as:

$$TFP_t \equiv \sum_f^{n_t} \theta_{f,t}\, TFP_{f,t} = \sum_f^{n_t} \theta_{f,t} \left(\frac{GVA_{f,t}}{K_{f,t}^{\hat{\alpha}} L_{f,t}^{\hat{\beta}}} \right).$$

Weight (θ): Different parameters have been used as weights in the existing literature. These are share of revenue, output, labour, value added, or costs. Foster et al. (2008) assert that the choice of weight is 'an open question'. The most common choices are either output (or revenue) weight or employment weight. Following the traditional literature, we have used 'gross value of output' weight in the present study.

Real gross value added (GVA): We obtain GVA using the double-deflation method as follows:

GVA= (gross value of output)/(wholesale price index)-(total input)/(input price index)

Gross value of output (GVO) is deflated by the wholesale price index of drugs and medicines, while inputs are deflated by the input price index. The input price index is constructed as the weighted average of fuel price, material price, and other input prices. Fuel price, material price, and other input prices are constructed using wholesale prices, implicit deflators of national account statistics, and weights from input-output tables. The data sources we use for constructing the input price index are the Reserve Bank of India's *Handbook of Monetary Statistics of India* and *Database on Indian Economy* and the Central Statistical Organisation's *Input-Output Transaction Table* and *National Account Statistics*.

Labour (L): Man-hours of workers are used to measure labour input.

Capital (K): Capital is defined as the initial value of net fixed capital deflated by the implicit deflator of net capital stock in the registered manufacturing sector. The data sources of implicit deflators are the Central Statistical Organisation and *National Account Statistics*.

Elasticity of production with respect to the production factor $(\widehat{\alpha}, \widehat{\beta})$: A semi-parametric estimation technique proposed by Levinsohn and Petrin (2003) which addresses the endogeneity problem is used in order to estimate the Cobb-Douglas production function defined as $\ln \mathrm{GVA} = a + \alpha \ln \mathrm{K} + \beta \ln \mathrm{L} + e$. The dataset that we use for the estimation is unbalanced unit-level panel data of six years from 2000 to 2005.

Our empirical application is based on plant- or 'factory'-level data for the period 2000-01 to 2005-06, which is collected by the Central Statistical Office of India in the Annual Survey of Industries (ASI). The primary unit of enumeration in the survey is a factory in the case of the manufacturing industries, and data are based on returns provided by factories. The present study uses data on various plant-level production parameters such as output, sales, labour, employees, capital, materials, and energy.

The ASI factory frame is classified into two sectors: the 'census sector' and the 'sample sector'. The sample sector consists of small plants employing 20 to 99 workers if not using electricity and 10 to 99 workers if using electricity. The census sector comprises relatively large plants. It covers all units having 100 or more workers and also some significant units which although having fewer than 100 workers contribute significantly to the value of the manufacturing sector's output. While the units in the census sector are approached for data collection on a complete enumeration basis every year, sample-sector units are covered on the basis of well-designed sampling. The present study focuses only on the census-sector data for the decomposition analysis. This is because productivity decomposition analysis requires a consistent and exhaustive database to distinguish between continuing firms, entrants, and exiters. A challenge was however posed by changes in the definition of the census sector in the recent past. For the years 1997-98, 1998-99, and 1999-2000, the census sector was limited only to factories employing 200 or more workers. From 2000-01 onwards again, factories employing 100 or more workers are under the census sector. For consistency in the analysis, we exclude the years prior to 2000-01 from our analysis and focus on the period 2000-01 to 2005-06.

Another important challenge was to distinguish between the categories of entering and exiting firms over the period of five years. Since our database comprises relatively larger units (100 employees or more), entry of new plants is accounted for by not only newly established plants but also by those plants that already existed in the sample sector but have expanded and subsequently shifted to the census sector during the study period. These two categories of entering firms need to be differentiated because of the different dynamics that they might have undergone. While the former are young firms and have later-coming advantages, the latter are successful factories which have undergone a learning process through passive learning or active exploration. The two categories of plants are thus expected to have very different outcomes. Newly established firms are

expected to make a much smaller contribution than the winners. Finally, an exiting firm is defined as a firm that has stopped functioning or has downsized its operations during the study period. It might not have wound up operations due to the tight exit policy but it might have become sick and downsized its production activity to join the small sector. In all, we define five categories of plants. Their definition and notations are provided in Table/Figure 3-1.

Table/Figure 3-1: Status of Plants

Status	Notation	Definition
Continuing survivors	S	Present in both the 2005 and 2000 period in the census sector
Entering survivors	ES	Present in 2005 in the census sector and in 2000 in the small sector
New entrants	EN	Present in the census sector and absent in 2000
Entering plants	N	ES+EN
Exiting plants	X	Present in 2000 in the census sector and dropped out in 2005

It required a careful examination of plants to identify different categories of productivity dynamics. Table/Figure 3-2 summarises definitions of the effects used in the study.

Table/Figure 3-2: Components of Productivity Decomposition

Effect	Category of plants	Clarification
Total entry effect	N= EN+ES	Effects of newly entering, expanding, and switching-in firms
Total exit effect	X	Effects of exiting and downsizing firms
Net entry effect	N+ X	Effects of the process of creative destruction
Within-plant effect	S	Effects of S
Reallocation effect (Between-plant effect + covariance)	S	Effects of improvement in allocation efficiency by S

The composition and number of plants are summarised in Table/Figure 3-3. The total number of plants increased over this period. Overall, the number of plants in our dataset increased from 352 in 2000 to 411 in 2005. Of the total 411 plants, a mere 138 (34%) plants are continuing survivors (S). The rest are either newly established plants (EN) or entering survivors (ES). The latter were originally small-sized plants classified into the sample sector but have expanded and upgraded to qualify to belong to the census sector. Their share varies from 20% to 55% across regions. The share of newly established plants of the total number of plants in 2005-06 varies from 11% in Area 4 (established area) to as high as over 77% in Area 1 (new area). Overall, the share of total entrants (N) ranges from 60 to 97%. Given the tight exit policy, the share of exiting plants (X) in 2001 is more remarkable. It varies from 56% in Area 4 (established area) and Area 5 (non-agglomerated area) to 86% in Area 1 (new area). Thus, there have been significant business dynamics taking place in the pharmaceutical industry across the regions.

Table/Figure 3-3: Plant Dynamics in the Indian Pharmaceutical Industry across the Regions during 2000-2005

Year: 2000		Area 1	Area 2	Area 3	Area 3	Area 5	Total
Continuing survivors (S)	Number	1	9	61	35	32	138
	Share	14%	41%	36%	44%	44%	
Exiting plants (X)	Number	6	13	110	44	41	214
	Share	86%	59%	64%	56%	56%	
S+X	Number	7	22	171	79	73	352
	Share	100%	100%	100%	100%	100%	

Year: 2005		Area 1	Area 2	Area 3	Area 4	Area 5	Total
Continuing survivors (S)	Number	1	9	61	35	32	138
	Share	3%	32%	36%	34%	40%	
Entering survivors (ES)	Number	6	12	86	57	33	194
	Share	20%	43%	51%	55%	41%	
New entrants (EN)	Number	23	7	22	11	16	79
	Share	77%	25%	13%	11%	20%	
Entering plants (N=ES+EN))	Number	29	19	108	68	49	273
	Share	97%	68%	64%	66%	60%	
S+N	Number	30	28	169	103	81	411
	Share	100%	100%	100%	100%	100%	

3.3. Empirical Results

A semi-parametric estimation technique proposed by Levinsohn and Petrin (2003) is used in order to obtain elasticity of production with respect to the production factor. Fuel cost is set as the proxy variable for unobserved productivity shock. Estimation results are shown in Table 3-4.

Both estimated coefficients are positive and statistically significant at the 1% level. The sum of coefficients is slightly higher than unity. But, according to the Wald test of constant returns, null hypotheses on constant returns to scale are not rejected. Econometric estimation of the Cobb-Douglas production function is satisfactorily conducted. Therefore, 0.3986463 as $\hat{\alpha}$ and 0.6402342 as $\hat{\beta}$ are employed in order to obtain TFP.

Table/Figure 3-4: Estimation of the Cobb-Douglas Production Function

(Dependent variable: ln GVA)

	Coefficient.	z-value
ln K	0.3986463	13.13
ln L	0.6402342	6.39
Wald test of constant returns	$\chi 2$=0.34 (p-value=0.5602)	
Number of observations	1927	
Number of groups	797	
Proxy variable for productivity shock	logarithm of fuel cost	

Table/Figure 3-5: Productivity Growth Rate across the Regions during 2000 to 2005
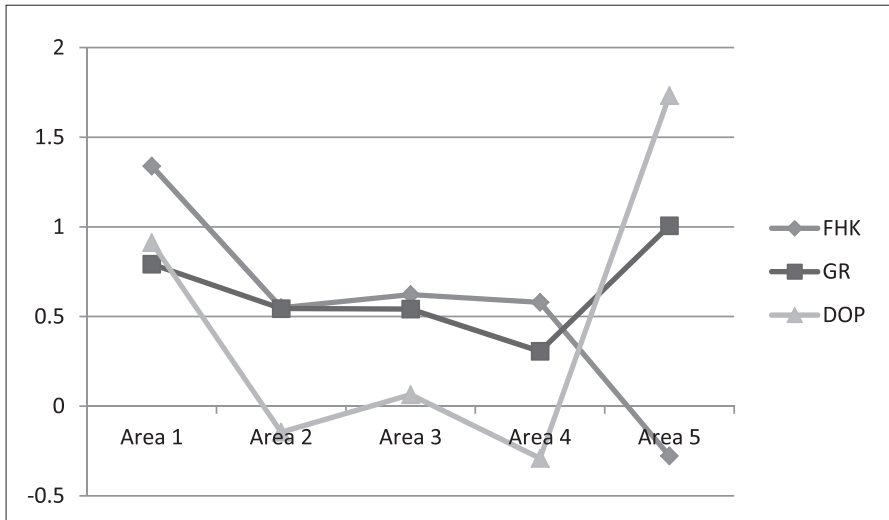

In this paper, Area 1 (new area: Himachal Pradesh and Uttarakhand), Area 2 (established area: Delhi, Haryana, and Punjab), Area 3 (established area: Gujarat, Maharashtra, Goa, Dadra & Nagar Haveli, and Daman & Diu), and Area 4 (established area: Andhra Pradesh, Karnataka, Tamil Nadu, and Pondicherry) are identified as agglomerated regions of the pharmaceutical industry. The rest of the states are included in Area 5 (non-agglomerated area). The region-wise results are shown in the following figures.

Table/Figure 3-5 presents the growth rates of labour productivity (LP) and total factor productivity (TFP) across five regions in the Indian pharmaceutical industry over the period from 2000 to 2005. It shows that both labour and total factor productivity have increased across all the regions over this period, with LP in Area 5 (non-agglomerated area) being the only exception. Nevertheless, productivity growth has been particularly strong in aggoromerated regions. Productivity grew by over 50% during this period.

The region-wise decomposition results based on FHK, GR, and DOP methodologies are presented in Table/Figure 3-6 to Table /Figure 3-10. Two points to be noted are that first, since the growth rate of LP in Area 5 (non-agglomerated area) is negative, the positive (negative) contribution of each effect in the following figures of LP in Area 5 (non-agglomerated area) essentially means a depressing (stimulating) effect on aggregate growth; second, as the decomposition results are sensitive to the choice of methodology, the present study regards the results with the same sign through the three methodologies, GR, FHK, and DOP, as robust.

Net entry effects: Table/Figure 3-6 presents the contributions of net entry to productivity growth based on the FHK, GR, and DOP methodologies. It is observed that the net entry effect is positive for LP in Area 1 (new area) and Area 3 (established area), and it is also positive for TFP in Area 1 (new area) and Area 5 (non-agglomerated area). In particular, the net entry effect in Area 1

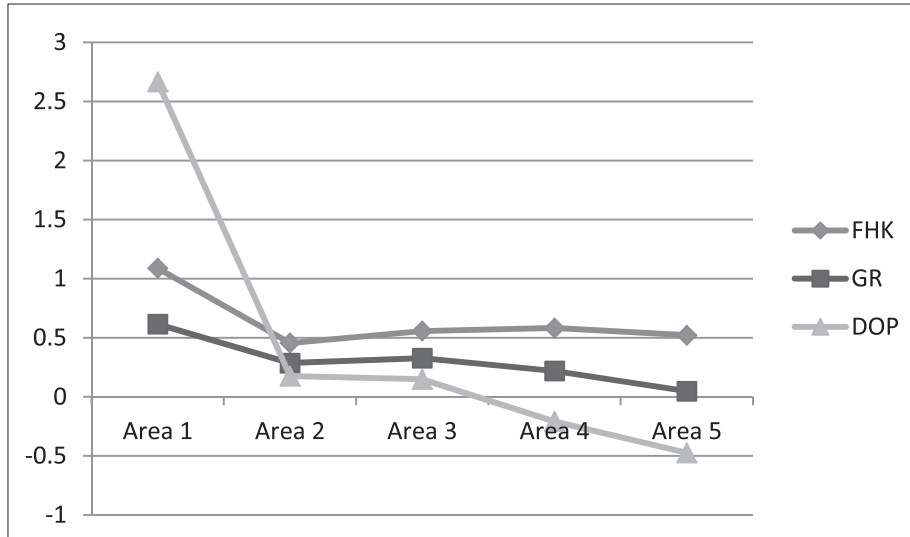**Table/Figure 3-6a: Net Entry Effects by Region: LP**

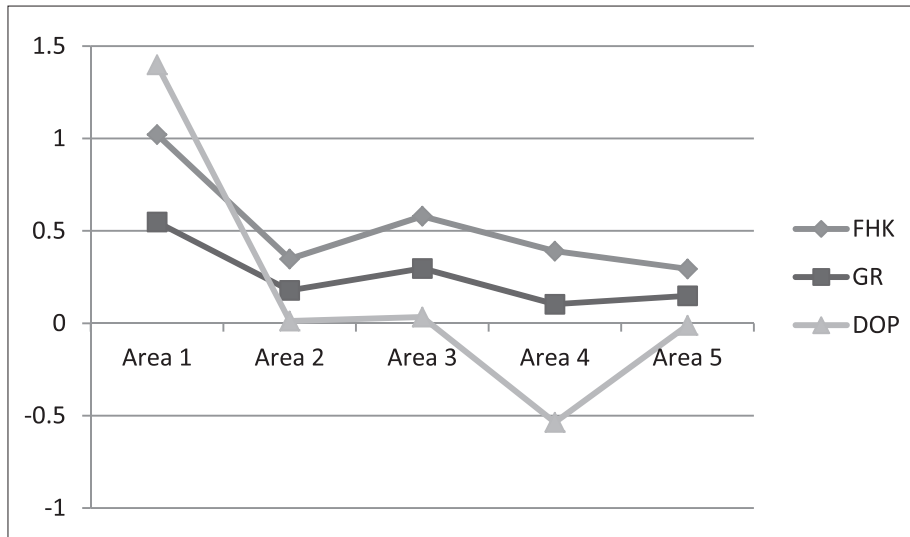**Table/Figure 3-6b: Net Entry Effects by Region: TFP**

(new area) accounts for 80% to 134% aggregate productivity growth.

Total entry effects: To tal entry effects are shown in Table/Figure 3-7. The total entry effect is positive for the both LP and TFP in Area 1 (new area), Area 2 (established area), and Area 3 (established area). The total entry effect in Area 1 (new area) is rather high, accounting for 55% to 267% of aggregate productivity growth.

Table/Figure 3-7a: Total Entry Effects by Region: LP

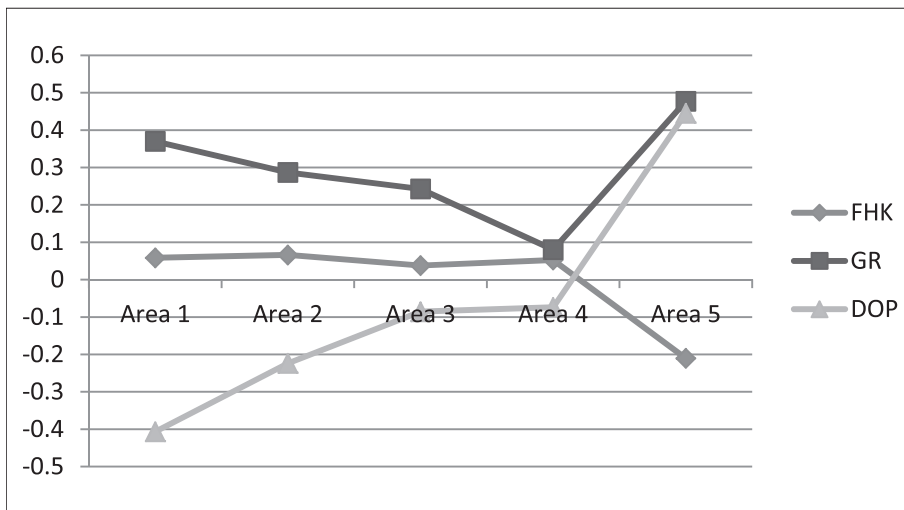**Table/Figure 3-7b: Total Entry Effects by Region: TFP**

Exit effects: Table/Figure 3-8 presents exit effects. It is observed that there are no robust results in terms of our empirical strategy. In particular, the exit effect varies considerably across the three methodologies.

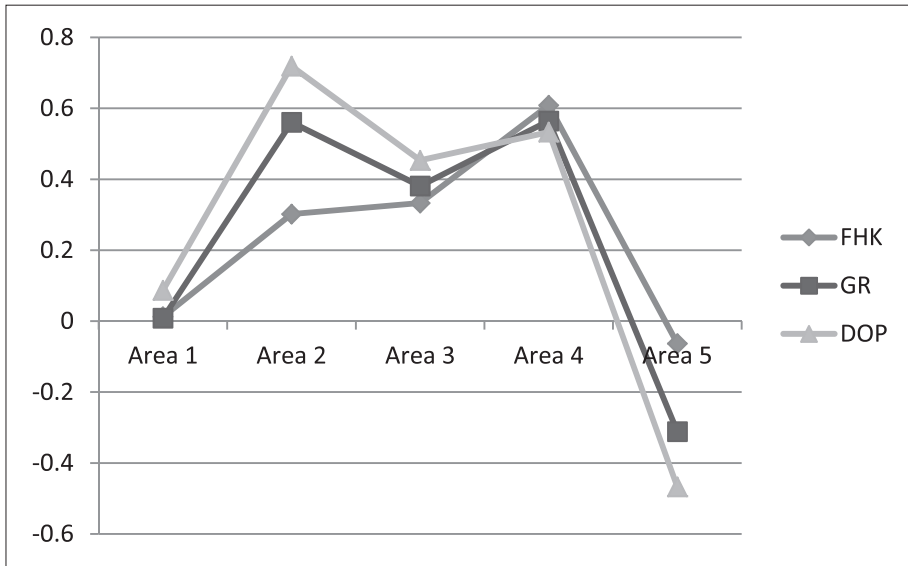**Table/Figure 3-8a: Total Exit Effects by Region: LP**

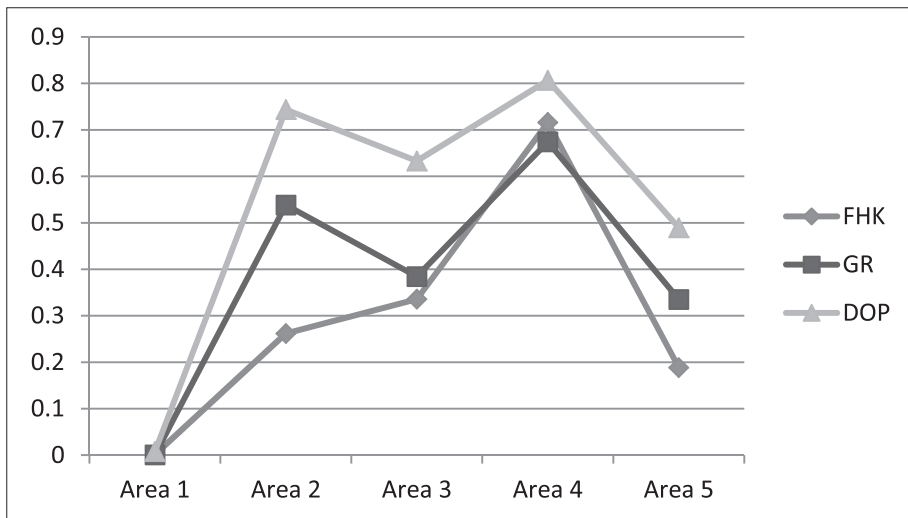**Table/Figure 3-8b: Total Exit Effects by Region: TFP**

Within effects: Within effects of surviving plants are presented in Table/Figure 3-9. For LP, the within effect positively contributes to productivity growth in all regions. But the within effect is negligible in Area 1 (new area). For TFP, the within effect is positive in Area 1 (new area) to Area 4 (established area) and is negative in Area 5 (non-agglomerated area). The within effect in Area 1 (new area) is still negligible. It is noted that within effects are positive and significant in Area 2 (established area), Area 3 (established area), and Area 4 (established area) accounting for 26% to 81% of productivity growth.

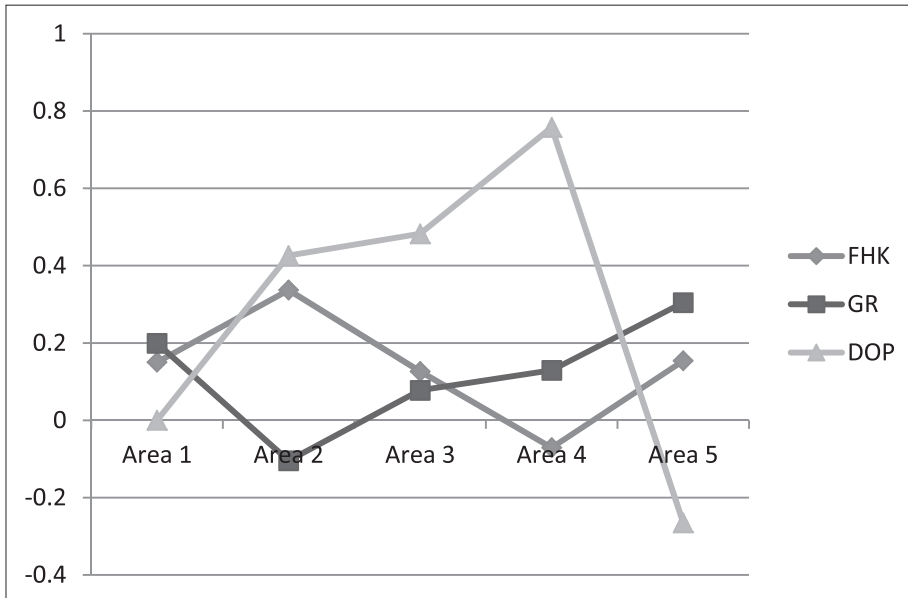**Table/Figure 3-9a: Within Effects by Region: LP**

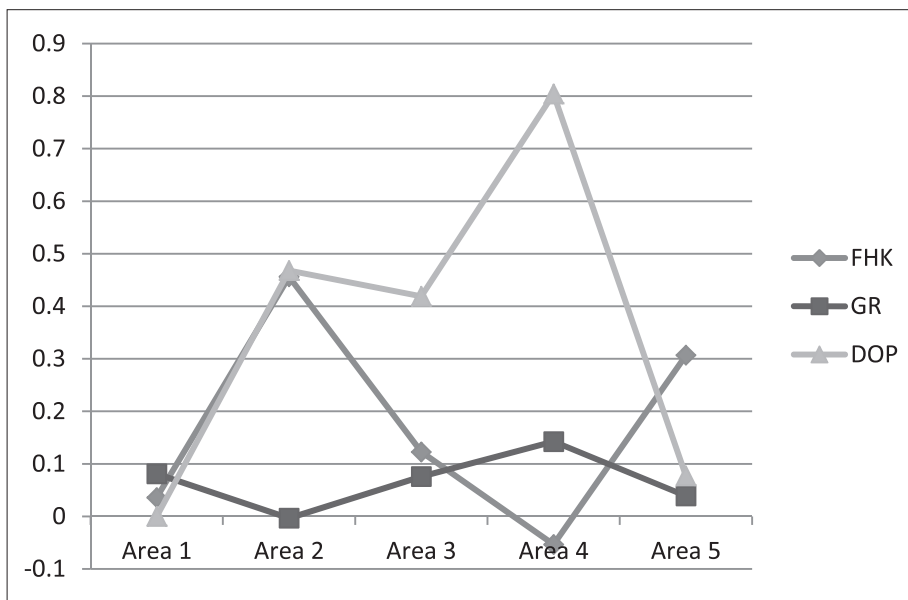**Table/Figure 3-9b: Within Effects by Region: TFP**

Reallocation effects: Reallocation effects as presented in Table/Figure 3-10 indicate that for LP, the reallocation effect is positive in Area 3 (established area) and for TFP, it is positive in Area 2 (established area) and Area 5 (non-agglomerated area).

Table/Figure 3-10a: Reallocation Effects by Region: LP

Table/Figure 3-10b: Reallocation Effects by Region: TFP

4. Concluding Remarks

This paper investigates the effects of plant dynamics on productivity growth in the Indian pharmaceutical industry across five regions, north, northwest, west, south, and the rest of India,

during the period from 2000-01 to 2005-06, using the unit-level panel database drawn from the Annual Survey of Industries. The selected regions differ in the degree and age of agglomeration of the pharmaceutical industry. The empirical analysis is based on the decomposition methodology of aggregate productivity growth. This methodology decomposes productivity growth between two points in time into the contribution from four broad factors: improvement in incumbents' productivity (within effect), reallocation of resources from less productive to more productive producers (reallocation effect), entry of more productive firms (entry effect), and exit of less productive firms (exit effect). This study used the methods developed by Griliches and Regeve (1995), Foster, Haltiwanger, and Krizan (2001), and Melitz and Polanec (2009). The analysis uses two commonly used measures of productivity, namely labour productivity and total factor productivity.

Our empirical findings reveal that productivity growth is relatively higher in the agglomerated regions: Area 1, Area 2, Area 3, and Area 4. Furthermore, the effects of plant dynamics on productivity growth differ depending on the age and dynamism of agglomeration. Rather large positive entry effects are found in Area 1 where the formation of agglomeration is a recent phenomenon. In Area 3, which has been a mature agglomeration, reallocation effects of surviving plants are large and robustly positive. In Area 2 and Area 4, however, 'within effects' of surviving plants are robustly positive. We have found no robust results regarding exiting effects in any region. There thus seems to be a systematic relationship between the maturity and dynamism of agglomeration and the composition of productivity growth. The contribution to TFP growth comes from within-firm efforts in mature agglomeration areas (Area 2, Area 3, and Area 4). Reallocation effects contribute in a major way to TFP growth in Area 3.　 In a new agglomeration, entering firms push the level of TFP in an upward direction.

In our study, there is a risk of underestimating the entry effect on industry productivity growth as the decompositions fail to account for indirect effects of entry on the productivity of incumbents. The measured within- and between-plant effects could in part be due to entry. But this indirect effect of entry is not captured in these methodologies. We plan to explore the indirect effects in the second stage of this research. However, the present analysis provides useful insights into the process of business dynamism taking place in the Indian pharmaceutical industry. This research thus calls for more research in this area.

References

Aggarwal, A., and T. Sato, "Firm Dynamics and Productivity Growth in Indian Manufacturing: Evidence from Plant Level Dataset," *RIEB Discussion Paper Series,* DP2011-07 [http://www.rieb.kobe-u.ac.jp/academic/ra/dp/English/DP2011-07.pdf.], 2011.

Baily, M. N., C. Hulten, and D. Campbell, "Productivity Dynamics in Manufacturing Plants," *Brookings Papers on Economic Activity: Microeconomics,* **2**, 187-249, 1992.

DIPP, "New Industrial Policy and Other Concessions for the State of Uttaranchal and the State of Himachal Pradesh," *Department of Industrial Policy and Promotion* [http://dipp.nic.in/ut_hp.htm], 2003a.

DIPP, "Central Grant or Subsidy for Industrial Units in the States of Uttranchal and Himachal Pradesh with a View to Accelerating the Industrial Development in the States," *Department of Industrial Policy and*

Promotion [http://dipp.nic.in/incentive/capinvsub_uthp.htm], 2003b.

Ebert, R., and D. McMillen, "Agglomeration Economies and Urban Public Infrastructure," in E. S. Mills, and P. Cheshire, eds., *Handbook of Regional and Urban Economics*, **3**. Elsevier Science Publishers, 1455-1495, 1999.

Foster, L., J. Haltiwanger, and C. J. Krizan, "Aggregate Productivity Growth: Lessons from Macroeconomic Evidence," in C. R. Hullten, E. R. Dean, and M. J. Harper, eds., *New Developments in Productivity Analysis.* Chicago and London: Chicago University Press, 303-363, 2001.

Fujita, M., and J. F. Thisse, *Economics of Agglomeration: Cities, Industrial Location, and Regional Growth*. Cambridge: Cambridge University Press, 2002.

Griliches, Z., and H. Regev, "Firm Productivity in Israeli Industry 1979-1988," *Journal of Econometrics,* **92**, 175-203, 1995.

Hoover, E. *Location Theory and the Shoe and Leather Industries*. Cambridge: Harvard University Press, 1937.

Levinsohn, J., and A. Petrin, "Estimating Production Functions Using Inputs to Control for Unobservables," *Review of Economic Studies*, **70**, 2:317-341, 2003.

Marshall, A., *Principles of Economics*. London: MacMillan, 1920.

Melitz, M. J., and S. Polanec, "Dynamic Olley-Pakes Decomposition with Entry and Exit," *MICRO-DYN Working Papers*, **03/09**, September, 2009.

Ohlin, B., *Interregional and International Trade*. Cambridge: Harvard University Press, 1933.

Planning Commission, *Eleventh Five Year Plan*. 2002.

Olley, G. S., and A. Pakes, "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica,* **64**, 6:1263-1269, 1996.

Rosenthal, S., and W. C. Strange, "Evidence on the Nature and Sources of Agglomeration Economics," in J. V. Henderson and J. F. Thisse, eds., *Handbook of Regional and Urban Economics,* **4**. 2119-2171, 2004.

Schumpeter, J., *Capitalism, Socialism and Democracy*. New York: Harper & Row, 1942.