

# The impact of R&D and FDI on firm growth in emerging-developing countries: Evidence from Indian Manufacturing Industries\*

Adamos Adamou  
Subash Sasidharan

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## Abstract

This paper examines the impact of R&D and FDI on firm growth for a panel data of Indian manufacturing firms. We argue that besides age and size, FDI and R&D are essential determinants of firm growth. We use GMM estimation for fixed effects panel data models to control for endogeneity of R&D and FDI. We find that an increase in current R&D induces higher growth across all industries; where as the effect of increase in FDI is mixed - higher growth in some industries and lower growth in some others. Furthermore, Gibrat's law is not only rejected by our main model but it is also rejected by a unit root test for unbalanced panel datasets. This provides strong evidence in favor of our model. Finally, firm growth is negatively associated with its size and it is convex with respect to its age. The fact that firm growth is not diminishing convex – but just convex – with respect to age, contradicts the Jovanovic's argument that younger firms tend to grow faster than their older counterparts. With respect to firm growth, the absence of learning-effects appears to be the main difference between emerging-developing and developed countries.

Keywords: R&D; FDI; panel data; firm growth

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\* Author affiliations and contact:

Adamou: University of Cyprus; [adamos@ucy.ac.cy](mailto:adamos@ucy.ac.cy)

Sasidharan: Indian Institute of Technology Bombay; [subashs@iitb.ac.in](mailto:subashs@iitb.ac.in)

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# 1. Introduction

Studies based on the famous Gibrat's law have recently regained interest. According to this law, the growth rate of a firm can be represented as a random variable which is independent of its current size and its past growth history. Since the number of small firms in an industry outweighs the large firms, the firm size distribution is skewed. That is why Gibrat (1931) assumed that lognormal distribution was a good description of the observed firm size distribution.

Since then, a lot of work has been carried out in an attempt to verify empirical validity of this law. Most of the empirical studies were based on Galtonian regression models. This test however suffers from what is now famously known as Galton's fallacy. Empirically, most of these set of tests reject Gibrat's law. Recently however, following Klette and Griliches (2000), most of the research in this area fails to reject the law under some conditions. For example, Lotti et al. (2003) find that Gibrat's law fails to hold for small firms in the years immediately following start-up, while the law holds true when they achieve a size large enough to overcome the minimum efficient scale. In this study, given that we have an unbalanced firm level data of 26 Indian manufacturing industries, we consider the most appropriate unit root test proposed by Maddala & Wu (1999) designed specifically for unbalanced panels.

By rejecting that firm size growth is random, the size variable itself determines firm growth. However another variable that is commonly used is age. According to Jovanovic (1982) age can be used as a proxy of the learning-by-doing effect on the firm's dynamic path. The logarithm form of both of these variables as well as their interaction and squares were used by Evans (1987a, 1987b).

This study is an attempt to understand the role of R&D and foreign direct investment (FDI), besides age and size in determining firm growth. Consequently, we use an extension of the Evans model by augmenting with R&D and FDI variables. Empirical research on firm level data has revealed substantial heterogeneity between firms, so we include the latter two variables to control for its effects.

Until recently, the literature on firm growth did not include both the R&D and the FDI variables together, as determinants of firm growth. We were able to find only two papers which use FDI as a determinant of firm growth. However, neither of them has tried to capture the innovation effects through R&D intensity. In addition, both these papers impose the assumption that FDI has the same impact on firm growth for all the industries. We relax this restrictive assumption in order to allow for variation of the impact of FDI on firm size growth for each industry.

R&D and FDI are used as endogenous variables in this study. Ericson and Pakes (1995) developed the foundations of dynamic Markov-Perfect Nash Equilibria model. According to this model, investment decisions are made in each period depending on the current situation of each firm e.g. its profitability or its growth. Therefore, we use R&D intensity variable as endogenous in our model. Furthermore, FDI is also used as an endogenous variable. This is due to the fact that foreign companies tend to invest in industries whose companies grow more. Finally, in our data exit is negligible (about 3,8% over the sample period). Consequently, the effect of sample selection due to exit is likely to be unimportant.

The selection of India was made for many reasons. First of all, India is a member of the G8+5 which is a group of leaders consists of Presidents and Prime Ministers from the G8 nations (Canada, France, Germany, Italy, Japan, Russia, United Kingdom and the United States), plus the leaders from five emerging developing countries (Brazil, China, India, Mexico and South Africa). Additionally, it belongs to the category of newly industrialized countries (NICs) which contains countries that have outpaced their newly industrialized world counterparts. During the early nineties following severe economic crisis, several liberalisation measures was undertaken. It included deregulation of Industries and special policies to attract foreign direct investment. Since then India has become one of the major destinations of multinational firms and it is one of the highest recipients of FDI inflows in the Asian region. At present, FDI is allowed up to 100% in most of the sectors except for the reserved list of small scale industries and strategic sectors.

## II. Theoretical Framework

There exists a vast literature on firm growth and the determinants of the same. Large number of surveys of literature on the empirical studies on firm growth has appeared in recent years (Sutton 1997, Trau 1996, Caves 1997, Geroski 1999, Thurik et al 2006). Since our paper is dealing with issue of R&D and firm growth, we describe in detail below some of the theoretical models related to the same.

A number of theoretical papers have attempted to model the role of R&D in firm growth. Jovanovic (1982), in a seminal paper developed an optimizing model of firm behaviour which is now popularly known in the literature as “passive learning model” of firm growth. The model considers firm growth as a function of efficiency. According to Jovanovic’s model a new entrant is unaware of the distribution of productivity shocks. In each period the firms observe the efficiency and costs. As a result firms which are inefficient will exit the market. Therefore, the final outcome of the model is that the young and small firms are likely to grow faster (see Lotti et al 2003 for an extensive review).

Another type of model which describes firm growth deals with the “active learning” following Pakes and Erickson (1998). In this model, firms are aware of the productivity distribution shocks. Contrary to Jovanovic (1982) model, Pakes and Ericson (1998) emphasises the importance of learning by undertaking innovative activities R&D. Each firm has two options: to continue production or exit from the industry. It has to decide upon how much to be invested in the R&D, if it wants to continue in the industry. The firms try to maximize the expected net cash flows. Over a period of time the difference between initial size and present size of the firm tend to diminish. They also provide empirical support of their model in the paper.

Klette and Griliches (2000) construct a quality ladder model to incorporate firm growth and R&D. In their model firms are characterized by product differentiation. They compete among themselves to improve the quality of the product through cumulative innovations by investing in R&D. The rival firms also invest in R&D by paying a sunk cost. The incentive to invest in R&D is due to the increased profits due

to the improvement in product quality. Therefore, based on the theoretical foundations of the models by Pakes and Ericson (1998) we justify the inclusion of R&D variable in our empirical analysis.

### **Empirical Studies on Firm Growth and R&D**

The ‘stochastic approach’ (Simon and Bonini 1958; Hart and Prais 1956) considers firm size as the only influential factor in determining the firm growth. The empirical examination of other factors like R&D, finance, foreign direct investment in determining firm performance has been undertaken recently by some of the empirical studies. Along these lines, one set of literature has attempted to analyze the impact of R&D and foreign ownership on firm growth. These empirical studies are based on the theoretical models outlined in the previous section. In this paper, since we are dealing with the impact of R&D and FDI on firm growth, we review the related literature in detail below.

Mansfield’s (1962) study was one of the initial attempts at understanding the role of innovation activities in determining firm growth. The empirical analysis is based on the data obtained from steel and petroleum refining industries. He found that those firms which introduced innovations tend to grow faster than others. Small firms were found to be the main beneficiaries of the innovation activities.

Hall (1987) tested for Gibrat’s law on a sample of 1778 publicly traded manufacturing firms in the U.S. The empirical analysis was carried out for two sub-periods 1973-79 and 1976-83. The study corrected for the sample selection bias inherent in the firm growth regressions by estimating survival and growth equations in a two stage approach using maximum likelihood estimation (MLE) method. In addition to the analysis of firm size on growth, the study also investigated the role of R&D on the growth and survival of firms. The findings of the study clearly emphasise the positive effect of R&D on firm growth and survival.

Amirkhalkhali and Mukhopadhyay (1993) tested Gibrat’s law for a sample of 231 US manufacturing firms during 1965-87. The main objective of the study was to examine whether the size-growth relationship and the distribution of firms depend whether

they belong to the R&D intensive industries. The findings of the study indicate a positive relationship between R&D and firm growth.

Liu et al (1999) studied the impact of R&D on firm employment growth in Taiwanese electronics industries. The data coverage is for 915 plants operating during the period 1990-1994. They show that R&D (represented by a dummy) has a positive impact on employment growth. However, the effect of R&D on firm growth was more pronounced as a long-term effect. The impact of year to year investment in R&D was found to be of less importance.

Another study of Taiwanese electronics industry (Yang and Hung 2005) investigated the impact of R&D and size on firm growth. They test the Gibrat's law with a balanced panel data set of 3459 firms for the period 1992-1998. In consonance with the recent theoretical developments, the endogeneity of R&D was controlled using generalized method of moments estimation (GMM) procedure. The empirical results reveal a strong positive effect of R&D (R&D/Sales) on firm growth.

Del Monte and Papagni (2003) in a study of Italian manufacturing firms found that innovative activities exert positive effect on the firm growth. The study is based on a sample of 884 firms during 1992-1997. The empirical analysis was based on GMM methodology to control for the endogeneity of R&D as well as to avoid the problem of heteroskedasticity. The analysis was carried based on the sectoral classification based on Pavitt's taxonomy and employment size class. Both the GLS and GMM estimation results support the positive effect of R&D. An interesting finding of the is that, impact of R&D on firm growth was found to be greater in the case of traditional sectors as compared to the high tech sectors.

Nurmi (2004) analysed the firm growth (Gibrat's law) in Finnish manufacturing firms using an unbalanced panel data for the period 1981-1994. Firm size and age was found to be decreasing with the firm growth after controlling for unobserved plant heterogeneity and selection bias. Her study found that R&D has a positive effect on firm growth. However, the study did not attempt to endogenise the R&D variable as emphasized by the recent theoretical literature on microeconomic R&D based endogenous growth models (Thompson 2001).

Yasuda (2005) analyses the impact of R&D on employment growth based on a sample of 14000 Japanese manufacturing firms. The firms are observed during two periods namely 1992 and 1998. He found that age and size is negatively related to growth. R&D dummy was found to be significant in the growth equation. The positive effect on growth was found to be significant when the analysis was extended to a sub-sample of R&D spenders.

### **FDI and Firm Growth**

In this section we attempt to explain the spillover effects from foreign direct investment (FDI) and its effect on the firm growth, followed by a brief review related studies. The role of foreign firms in promoting industrial development in the host country is increasingly recognized. Of late, most of the fast growing developing economies like India, China, Brazil and other fast growing developing economies have devised special policies to attract foreign direct investment. The basis for such practice is based on the notion that foreign firms are carriers of superior technology and organizational practices (Dunning 1993). Increasingly it has been found that foreign firms are undertaking research activities in developing countries. Therefore, the presence of foreign firms can benefit the domestic firms through learning and spillover mechanism. The former argument has been subjected to rigorous theoretical and empirical testing. Therefore, we expect that the superior firm specific advantages of spillover effects from foreign firms may lead to improved performance of the domestic firms.

Large number of studies has appeared about the possible channels of spillovers effects (see Crespo and Fontura 2007; Gorg and Greenaway 2004; Blomstrom and Kokko 1994 for an extensive review of literature). From the literature on foreign direct investment and technology transfer, we are able to identify four main channels of spillover effects. *Demonstration effect*-The entry of foreign firms may lead to introduction of new products and technology which was previously unavailable in the host country. As a result, domestic firms imitate or adopt the same technology. *Labour turnover*- domestic firms can employ the workers who were with the foreign firms or the employee of a foreign firm may set up his own enterprise. The third important channel of spillover is the vertical spillover effects through *forward and*

*backward linkages*. The mechanism of backward linkages operates mainly through the procurement of inputs by the foreign firms from the domestic suppliers. Thereby the domestic firms are forced to improve the quality and productivity because of the stringent quality requirements of the foreign firm. In the case of forward linkages, domestic firms are able to obtain quality inputs or reduced price from the foreign firms. Another important channel of spillover mechanism is through learning by *exporting* from the foreign firms.

The entry of foreign firms is not without any negative consequences. Aitken and Harrison (1999) show that the presence of foreign firms can crowd out domestic firms. The domestic firms may be forced to move up along the average cost curve due to decline in the output. Reverse labour turnover can occur from domestic firms to foreign firms. Since the foreign firms pay higher wages compared to the domestic firms, some of the workers of the domestic firms leave domestic firms and join Multinational Companies (MNCs). Similarly, foreign firms may be reluctant to establish linkages with the domestic firms. It is often observed that entry of foreign firms may be followed by an entry of their international suppliers. This phenomenon is commonly referred to as “follow sourcing” (Humphrey 1999). Therefore, domestic firms may not benefit from the presence of foreign firms.

Much has written and said about the positive effects of FDI in the theoretical literature. However, the picture emerging from the empirical studies about the FDI spillover effects do not appear to be rosy. Due to the availability of large scale panel data, a large number of studies have appeared examining various aspects of spillover effects from FDI both for the developed and developing countries. However, there is no agreement about the results obtained from these studies. All of the studies have found positive, negative or even insignificant effects (see Crespo and Fontura 2007; Gorg and Greenaway 2004; Blomstrom and Kokko 1994 for the exhaustive list of studies).

Empirical studies dealing with FDI spillover effect and firm growth is scarce. We were able to find only a couple of studies carried out previously examining the role of spillover effects from FDI in determining firm growth. Fotopoulos and Louri (2003) study investigated the role of FDI in determining the firm growth based on a panel

data of 2640 Greek manufacturing firms. They also included other factors like finance, degree of foreign ownership and sunk costs. The firm size age relationship was estimated using a quantile regression approach. Empirical analysis provides support for the positive effect of foreign ownership and spillover effects from FDI on firm growth especially in the case of fast growing firms. Thus their study found strong support for the inclusion of FDI and foreign ownership as a determinant of firm growth.

Another study of Greek manufacturing firms (Dimelis 2005) used an augmented production function to explain the firm growth. In addition to the degree of foreign ownership, a sectoral FDI (the share of foreign fixed capital in total fixed capital of the sector) variable was included to capture the spillover effect. After controlling for endogeneity, she found that spillover effect has a positive influence on the firm growth. In the empirical model, she assumes that coefficient is the same for all the industries. However, in our empirical analysis we relax this assumption. The evidence from the two previous studies makes a strong case for including the FDI variable in our analysis.

### Section III: Methodology

**Gibrat's Model:** According to Gibrat's law, a firm's proportionate rate of growth is:

$$(S_t - S_{t-1}) / S_t = \varepsilon_t \quad (1)$$

where  $S_t$  is the firm size at time  $t$ , e.g. sales, employment or assets<sup>1</sup> and  $\varepsilon_t$  is a random variable that is independently distributed of  $S_{t-1}$ . Assuming that the initial size is  $S_0$  and there are  $n$  steps before the final size  $S_n$  is reached, then summing up gives:

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<sup>1</sup> We are using sales as a measure of size. Employment and assets are likely to be sticky. On the other hand, growth measures based on sales will demonstrate greater year-to-year change than the stickier measures of size such as assets or employment. Furthermore, as firms continually redefine their boundaries by engaging in activities such as outsourcing, sales are a better measure of firm size than assets or employment.

$$\sum_{t=1}^n (S_t - S_{t-1})/S_t = \sum_{t=1}^n \varepsilon_t \quad (2)$$

For short-time intervals the value of  $\varepsilon_t$  is probably small, and (2) can be approximated as:

$$\sum_{t=1}^n (S_t - S_{t-1})/S_t \approx \int_{S_0}^{S_n} dS / S \quad (3)$$

which gives:

$$\log S_n = \log S_0 + \sum_{t=1}^n \varepsilon_t \quad (4)$$

Having in mind that the  $\varepsilon_t$  is relatively small and combining that with the exponential expansion then equation (4) is approximately equivalent to

$$S_t = S_{t-1} (1 + \varepsilon_t) = S_0 (1 + \varepsilon_1)(1 + \varepsilon_2) \dots (1 + \varepsilon_n) \quad (5)$$

Assuming that  $\log S_0$  and  $\varepsilon_t$  are identically distributed with mean  $\mu$  and variance  $\sigma^2$ , then by the central limit theorem, it follows that  $\log S_t \sim N(\mu t, \sigma^2 t)$  as  $t \rightarrow \infty$ . Therefore, the distribution of  $S_t$  is lognormal with the implication that the expected value and variance increase over time.

Taking into consideration all the above and the fact that there are usually more small firms than there are large firms, Gibrat (1931) assumed that lognormal distribution was a good description of the observed firm size distribution. As there are more small firms, the firm size distribution is skewed. In a graph of probability density function, the probability mass is concentrated closer to the origin of the axes due to the many small firms and there is a long right tail due to the few large firms.

**Evans model:** According to Evans's model, the firm growth relationship for firm  $i$  in period  $t+1$  is a function of size and age:

$$\text{Size}_{it+1} = G(\text{Size}_{it}, \text{Age}_{it}) \text{Size}_{it} e_{it} \quad (6)$$

where  $e_{it}$  is a lognormally distributed error term. Equation (6) suggests the following regression framework:

$$\ln \text{Size}_{it+1} - \ln \text{Size}_{it} = \ln G(\text{Size}_{it}, \text{Age}_{it}) + u_{it} \quad (7)$$

where  $u_{it}$  is distributed normally with zero mean and possibly a non-constant variance, and it is independent of Size and Age.

**Evans extended model:** The empirical model used in this study is an extensive model of Evans (1987a, b). Using a second order logarithmic expansion of  $\ln G(\text{Size}, \text{Age})$  and adding the natural logarithms of FDI and R&D intensity that yield to the following extensive model:

$$\text{GR}_{it} = \beta_1 \ln \text{size}_{it} + \beta_2 \ln \text{age}_{it} + \beta_3 (\ln \text{size}_{it})^2 + \beta_4 (\ln \text{age}_{it})^2 + \beta_5 (\ln \text{size}_{it}) (\ln \text{age}_{it}) + \beta_6 \text{RDINT}_{it} + \beta_7 \ln \text{FDI}_{it} + u_{it} \quad (8)$$

In Eq. (8), firm size is measured by the number of sales in logarithmic terms. When Gibrat's law holds, this simple hypothesis asserts that the firm size is uncorrelated with firm growth. Age is measured in years since the firm was incorporated and is also in logarithmic form. It is used as a proxy for the learning-by-doing effect on the firm dynamics as suggested by Jovanovic (1982). Firms learn their efficiency level through production experience. When output is a decreasing convex function of managerial inefficiency, Jovanovic's (1982) model implies that younger firms tend to grow faster than their older counterparts. In addition, a complete set of size and age quadratic and interaction terms are also included. Natural logarithms of all the above variables are the main variables that Evans (1987) used.  $\text{GR}_{it}$  is the size growth of firm  $i$  at time  $t$  and is defined by  $\ln \text{Size}_{it+1} - \ln \text{Size}_{it}$ . In the section V we present the

results of a unit root test for unbalanced panel data as proposed by Maddala, G.S and Wu, Shaowen (1999). This test confirms that size variable is essential for our model. Age variable in our data is statistically significant. Therefore, we use an extension of this model to allow for quadratics and interaction too.

Based on the microeconomics of endogenous growth theories, R&D investment should play a key determinant of firms' dynamic. In fact, many researchers have emphasized the role of R&D on firm growth and find that more R&D-intensive firms tend to grow faster, even though the majority of them regard the R&D investment as an exogenous variable. To account for the effect of R&D activity on firm growth, there are potentially various measures on R&D activity. Term RDINT represents R&D intensity, which is measured as the R&D expenditure to sales ratio. This measure is a better proxy of R&D effort, because R&D intensity is independent of size. FDI is the foreign direct investment and we use it here in logarithmic terms. Unfortunately we could not find the actual FDI for each of our firms so we are using the FDI approved by the India government. As the FDI is approved per industry and not per firm, it is very strict to suppose that the coefficient  $\beta_7$  in Eq. 8 is the same among the industries. That is why we decide to use the equation 9 instead of the equation 8:

$$GR_{it} = \beta_1 \ln size_{it} + \beta_2 \ln age_{it} + \beta_3 (\ln size_{it})^2 + \beta_4 (\ln age_{it})^2 + \beta_5 (\ln size_{it}) (\ln age_{it}) + \beta_6 RDINT_{it} + \sum_{j=1}^J \gamma_j (\ln FDI_{ijt}) + u_{it} \quad (9)$$

Where  $j=1 \dots J$  and  $J=26$ . The 26 FDI coefficients  $\gamma_j$  determine the impact of FDI on firm growth for each of our 26 industries separately.

**Endogeneity of R&D and FDI:** Ericson and Pakes (1995) developed the foundations of dynamic Markov-Perfect Nash Equilibria model and Pakes and McGuire (1994) illustrated an algorithm for computing such equilibria. The algorithm provides insights into how markets operate and how firms make entry; exit and investment decisions in a dynamic environment<sup>2</sup>. In this model structural parameters are

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<sup>2</sup> Pakes, Gowrisankaran and McGuire (1993) provided a Gauss code to compute Markov Perfect Nash Equilibria.

numerically imposed. Based on that, entry, exit and investment decisions are made to maximize the expected discounted value of future net cash flow conditional on the current information set. Bajari, Benkard, and Levin (2005), present a two-step algorithm for estimating the structural parameters of Pakes and McGuire (1994). Both of these studies highlight the importance of heterogeneity and idiosyncratic uncertainty induced by the random outcomes of investment processes. In their model, investment is decided every period generating firm heterogeneity. Additionally in Ericson and Pakes (1995), investment decisions are made in each period depending on the current situation of each firm e.g. its profitability or its growth. Therefore, we use R&D intensity variable as endogenous in our model. Additionally, due to the fact that foreign companies tend to invest in industries whose companies grow more, FDI is also used as an endogenous variable in our model.

For the estimation of equation 9, panel data GMM method is needed<sup>3</sup>. We follow Wooldridge (2002) and Arellano (1987) to achieve that. Our results are given in the section V. The lags of R&D and FDI are used as their instruments<sup>4</sup>.

## **IV. Data Description**

The data source for this study is from the PROWESS electronic data base provided by the Center for Monitoring Indian Economy (CMIE). PROWESS provides information regarding around 10,000 firms registered with the Bombay Stock Exchange. The data is primarily drawn from the information in annual reports of the firms. Since our study is pertaining to the manufacturing industries, we obtain data regarding sales, age, R&D and foreign promoters share<sup>5</sup>. For our study, we have used an unbalanced panel data of nearly 1841 firms belonging to 26 three digit industries operating between the periods 1994 to 2005.

The FDI approval data is obtained from the various publications of Secretariat of Industrial Approvals (SIA). SIA is the sole data source in Indian providing data on the foreign approvals. We had to rely on the foreign approvals data since the actual

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<sup>3</sup> This is a fact because GMM estimation is more efficient in the case of two endogenous variables.

<sup>4</sup> First and second lagged for R&D and first lagged for FDI

<sup>5</sup> This was insignificant for our model and it is dropped.

inflow data are hard to come by. PROWESS provides data based on the NIC classification. Matching of the data between NIC with the SIA is necessary since the SIA is based on a different classification.

**Table 1: Summary Statistics**

Variable	lnAge	lnSize	Rdint	lnFdi	Size Growth
Mean	2.944	3.965	0.324	6.31	0.143
Median	2.942	3.886	0	7.19	0.111
Perc 1%	0.693	-0.511	0	0	-0.723
Perc 99%	4.564	7.643	4.45	10.58	1.59
Std. Dev	0.826	1.684	1.952	2.942	0.436
Skewness	-0.32	-0.33	30.26	-1.049	2.708
Kurtosis	3.133	4.024	1345.67	3.09	71.80
Obs	17120	17285	17285	17285	15426

**Table 2: FDI and R&D Statistics**

year	# of Companies	% of zero R&D Companies	% of zero FDI companies
1994	1039	73	42
1995	1222	71	42
1996	1308	69	6
1997	1380	65	4
1998	1462	67	13
1999	1589	68	12
2000	1684	71	9
2001	1687	71	12
2002	1675	66	7
2003	1597	65	3
2004	1429	62	0
2005	1213	62	2

As the concept of Evans model support elasticities as the interpretation of the coefficients, we transform all our variables to the logarithm form<sup>6</sup> (with exception the percentage variables). Consequently size, age and FDI are transferred into logarithms,

<sup>6</sup> Adding an extra variable in the model means that it enters as a multiplication variable in Eq.6 which means it enters as an additive log-variable in Eq.7.

R&D intensive remain as percentage<sup>7</sup>. In table 1 we provide our variable statistics. The size variable seems not following the normal distribution as Gibrat (1931) declaimed<sup>8</sup>. After testing it, Shapiro-Wilk normality test reject that hypothesis. This tells us that other variables can explain firm growth and not only the error term itself. In Table 2 we provide more statistics that explain the zero median of R&D and the zeros that our FDI variable contains.

## Section V: Testing and Results

### Testing

We start this section by testing Gibrat's law. In case that we accept the law, the size variable is valueless for our model. As some recent papers like Klette and Griliches (2000) lend support to this law, the need to test it is even greater. A lot of researchers use to test it with Galtonian regression models. Galtonian regression is a cross-section regression between the vectors of the logarithm of the size taken at two different and distant periods of time. This kind of inference that can be derived from the cross-section estimation, is subject to strong criticism known as Galton's fallacy: it is demonstrated that a non-positive value of the coefficient of the natural logarithm of size, in a growth equation that the natural logarithm of size is the only independent variable, can emerge from the estimates even when the cross-sectional distribution remains unchanged. The econometric strategy adopted in this testing attempt to explain the dimensional growth of firms on the basis of the properties of the time series of each firm. We can resort to the recent proposition of tests of unit root that extend the application from time series to panel data.

The usually Augmented Dickey Fuller (with one lag length) test is the following:

$$\Delta y_t = \alpha + \beta y_{t-1} + \gamma \Delta y_{t-1} + \varepsilon_t \quad (10)$$

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<sup>7</sup> As some industries have zero values in our FDI variable and as it varies from zero to 46000, we decide to create its logarithm as the natural logarithm of FDI plus one.

<sup>8</sup> Figures 2 & 3 in the appendix give more information about this. Additionally more FDI & R&D statistics can be found in the appendix.

The extending test for panel data is:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \gamma_i \Delta y_{it-1} \quad \forall i=1, \dots, n \quad (11)$$

Where  $y_{it}$  is the logarithm of the sales of firm  $i$  at time  $t$ ,  $\Delta y_{it}$  is the rate of sales growth and  $\Delta y_{it-1}$  the lagged rate of sales growth.

Levin and Lin (1992) proposed such a test with a major limitation that  $\beta$  is the same for all observations. Thus, if we denote by  $\beta_i$  the value of  $\beta$  for the  $i^{th}$  cross-section unit then the Levin-Lin test specifies the null  $H_0$  and alternative  $H_1$  as:

$$H_0: \beta_1 = \beta_2 = \dots = \beta_n = \beta = 0 \quad \& \quad H_1: \beta_1 = \beta_2 = \dots = \beta_n = \beta < 0$$

The null makes sense under some circumstances, but the alternative is too strong to be held in applied studies. The Im Pesaran Shin (IPS) (2003) relaxes that assumption under the alternative. However both tests are used only for balanced panel data. Maddala and Wu (1999) proposed a new test that it does not require a balanced panel as in the case of the IPS test. Also, one can use different lag lengths in the individual ADF regression below:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^m \gamma_{ij} \Delta y_{it-j} \quad \forall i=1, \dots, n \quad (12)$$

Where  $m$  is the lag length. This test basically use Fisher (1932) test based on the sum of the log- p-values. That p-values are derived from Monte Carlo simulations.

We perform the test for 1 and 2 lag length for logarithm of sales. In both cases the null of unit root is rejected<sup>9</sup>.

## Results

In table 4 we provide the results of our firm growth model regarding to the equation 9. Only the coefficients  $\beta_1$ ,  $\beta_6$ ,  $\gamma_9$ ,  $\gamma_{15}$ ,  $\gamma_{16}$ ,  $\gamma_{18}$  and  $\gamma_{20}$  are statistically significant in 10

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<sup>9</sup> The p-value is zero in both cases. As we have 12 years, 2 lags are more than enough for this testing.

percent<sup>10</sup>. Under the table 4 we present three important tests. Anderson test checks for underidentification, i.e. whether instruments are correlated with endogenous regressors. Rejecting the null means that the model is identified but the presence of weak instrument poses problem. With the Cragg-Donald F statistic we can identify whether we have weak instruments. Stock-Yogo (2005) provides the weak ID test critical values. Sargan-Hansen test is for overidentification purposes. The joint null hypothesis is that the instruments are valid instruments, i.e., uncorrelated with the error term, and that the instruments are correctly excluded from the estimated equation. Looking at the Cragg-Donald F statistic it is obvious that we have weak instruments.

**Table 3: Industry Classification**

Sl.No	Industry	Sl.No	Industry
1	Food Processing Industries	14	Glass
2	Vegetable Oil and Vanaspati	15	Ceramics
3	Sugar	16	Cement & Gypsum Products
4	Fermentation Industries	17	Metallurgical Industry
5	Textiles (including Dyed, Printed)	18	Prime Movers other than electrical+Boile
6	Paper and Pulp (incl Paper Product)	19	Industrial Machinery
7	Chemicals	20	Machine tools
8	Dye Stuffs	21	Earth Moving Machinery
9	Fertilisers	22	Commercial, Office and Household Equipme
10	Drugs & Pharmaceuticals	23	Electrical Equipments like lamps
11	Soaps, Cosmetic and Toilet preparations	24	Medical & Surgical Appliances
12	Rubber Goods	25	Scientific Instruments
13	Miscellan Mechanical & Engineering	26	Other Transportation Industry like Automobile ancillaries

Weak instrument problems tell us that a panel data fixed effects or random effects model would gives us better results than the ones we obtained. We performed a Hausman test which favours the panel data fixed effects method. The fixed effect results are presented in table 5a. All main variables except R&D intensity (excluding FDIs<sup>11</sup>) are statistically significant. The signs of the main variables are the same with our Table 4 results.

<sup>10</sup> All the \*, \*\* and \*\*\* in our tables denote statistical significant coefficients in 10%, 5% and 1% respectively.

<sup>11</sup> Table 3 decodes our industries. E.g. FDI1 denotes  $\ln FDI_{ijt}$  when  $j=1$  as it is specify in our basic model above.

**Table 4: Results based on panel data fixed effect model with GMM estimation  
(11512 # of obs)**

Variables	Model		Variables	Model (cont.)	
Rdint	0,016	(0,007)**	FDI11	0,028	(0,056)
Lnsize	-0,435	(0,079)***	FDI12	-0,021	(0,143)
Lnage	-0,093	(0,189)	FDI13	-0,393	(0,271)
Lnagesize	0,017	(0,025)	FDI14	-0,011	(0,354)
lnagesq	0,018	(0,078)	FDI15	-0,222	(0,107)**
lnsizesq	0,010	(0,008)	FDI16	0,063	(0,035)*
FDI1	0,030	(0,142)	FDI17	0,643	(0,560)
FDI2	-0,178	(0,123)	FDI18	-0,058	(0,021)***
FDI3	0,027	(0,035)	FDI19	-0,007	(0,025)
FDI4	0,021	(0,033)	FDI20	0,134	(0,078)*
FDI5	-0,089	(0,091)	FDI21	-0,029	(0,028)
FDI6	-0,764	(0,808)	FDI22	0,004	(0,084)
FDI7	0,040	(0,267)	FDI23	0,006	(0,120)
FDI8	-0,071	(0,347)	FDI24	0,026	(0,098)
FDI9	0,065	(0,035)*	FDI25	-0,152	(0,108)
FDI10	0,027	(0,054)	FDI26	0,058	(0,085)
Anderson canon. corr. LR stat Null: underidentification 6.38 chi-sq(1) p-val = 0.04					
Cragg-Donald F statistic (check for weak instruments) 0.23 (Stock-Yogo not available)					
Sargan-Hansen test (overidentification) Hansen J statistic 0.13 Chi-sq(1) P-val = 0.72					

**Table 5a: Results based on panel data fixed effects**

Variables	Standard Model plus lag size		Variables	Standard Model plus lag size (cont.)	
Rdint	0,002	(0,002)	FDI12	0,020	(0,015)
lnsize	-0,684	(0,011)***	FDI13	-0,051	(0,021)**
lnage	-0,412	(0,032)***	FDI14	-0,018	(0,030)
lnagesize	0,076	(0,005)***	FDI15	0,009	(0,016)
lnagesq	0,089	(0,009)***	FDI16	-0,016	(0,009)*
lnsizesq	0,016	(0,001)***	FDI17	-0,001	(0,003)
FDI1	-0,035	(0,043)	FDI18	-0,010	(0,006)
FDI2	-0,021	(0,009)**	FDI19	0,020	(0,013)
FDI3	0,002	(0,008)	FDI20	0,037	(0,025)
FDI4	-0,022	(0,005)***	FDI21	-0,016	(0,008)**
FDI5	-0,014	(0,003)***	FDI22	0,016	(0,020)
FDI6	-0,015	(0,016)	FDI23	-0,036	(0,017)**
FDI7	-0,031	(0,017)*	FDI24	-0,012	(0,012)
FDI8	-0,001	(0,012)	FDI25	-0,003	(0,025)
FDI9	-0,009	(0,008)	FDI26	-0,006	(0,003)**
FDI10	0,008	(0,012)	Constant	2,104	(0,046)***
FDI11	0,014	(0,016)			
Sigma_u: 0,647		Sigma_e:0,316		Rho:0,808	
Obs Num: 15274					

However by accepting the table 5a results, we somehow ignore the endogeneity of R&D and FDI which is consistent with our theory. In order to have results that support the theory, we are forced to impose the assumption that the FDI coefficient is

the same among the industries. Table 5b shows these results. R&D intensity is higher if we account for endogeneity and R&D intensity is statistically significant. Its coefficient is near to the one of Table 4. This tells us that the weak instruments were the 26 lagged industry-FDI variables. The coefficient of *lnfdi* is insignificant. As *lnfdi* is insignificant, there is no reason to continue forcing the endogeneity of FDI. We can relax the assumption that the FDI coefficient is the same among the industries and with that way we can have at least the endogeneity of R&D. The results are given in Table 5c.

**Table 5b: Results with the assumption of same FDI coefficient among industries. FDI and R&D are treated as endogenous (11512 # of obs)**

Variables	Model		Variables	Model (cont.)	
Rdint	0,017	(0,007)**	Lnagesize	0,026	(0,023)
Lnsize	-0,440	(0,071)***	lnagesq	0,128	(0,016)***
Lnage	-0,373	(0,095)***	lnsizesq	0,008	(0,008)
lnfdi	-0,022	(0,020)			
Anderson canon. corr. LR stat Null: underidentification 107.27 chi-sq(1) p-val = 0.00					
Cragg-Donald F statistic (check for weak instruments) 35.92 > 13.43 (Stock-Yogo 10% critical values)					
Sargan-Hansen test (overidentification) Hansen J statistic 0.17 Chi-sq(1) P-val = 0.68					

The coefficients of *lnsize* and *lnage* are negative and statistically significant. The squared term of age reveal a positive and significant effect on growth but the square term of size is statistically insignificant. The age/size interaction term is positive, but not statistically significant. These results show that the relationship between growth and age is convex. The relationship between growth and size is linear. This pattern is consistent with results in Evans (1987b), Das (1995) and Liu et al. (1999) in all except for the convexity of age in the firm growth which is not diminishing for our entire sample. The effect of FDI varies per industry. There are negative, positive and insignificant coefficients for our 26 industries. For Rubber goods, Metallurgical Industry, Industrial Machinery, Machine tools and Commercial, Office and Household Equipment<sup>12</sup>, there is positive effect of FDI on firm size growth. For all the others we have negative and zero effects.

<sup>12</sup> This category mainly includes computer and air-conditioning systems.

**Table 5c: Results without the assumption of same FDI coefficient among industries. R&D only is treated as endogenous (11512 # of obs)**

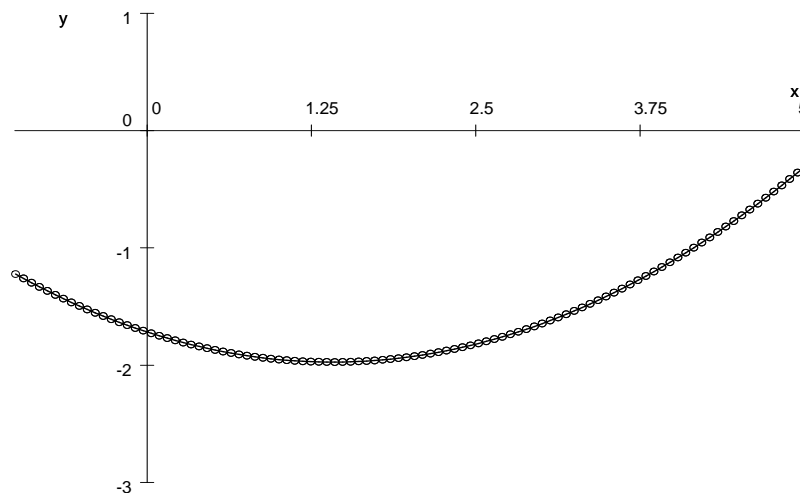
Variables	Standard Model plus lag size		Variables	Standard Model plus lag size (cont.)	
Rdint	0,017	(0,007)***	FDI11	0,017	(0,013)
Lnsize	-0,433	(0,070)***	FDI12	0,021	(0,008)**
Lnage	-0,364	(0,093)***	FDI13	-0,057	(0,019)***
Lnagesize	0,024	(0,023)	FDI14	-0,000	(0,021)
lnagesq	0,129	(0,015)***	FDI15	0,006	(0,013)
lnsizesq	0,007	(0,008)	FDI16	-0,013	(0,006)**
FDI1	-0,026	(0,032)	FDI17	0,069	(0,018)***
FDI2	-0,023	(0,007)***	FDI18	0,005	(0,005)
FDI3	0,000	(0,008)	FDI19	0,039	(0,010)***
FDI4	-0,025	(0,007)***	FDI20	0,038	(0,020)*
FDI5	0,002	(0,007)	FDI21	-0,011	(0,008)
FDI6	-0,005	(0,014)	FDI22	0,046	(0,023)*
FDI7	0,029	(0,023)	FDI23	-0,038	(0,020)*
FDI8	0,013	(0,009)	FDI24	-0,000	(0,023)
FDI9	-0,008	(0,009)	FDI25	-0,010	(0,025)
FDI10	-0,014	(0,009)	FDI26	-0,097	(0,017)***
Anderson canon. corr. LR stat Null: underidentification 3699.05 chi-sq(1) p-val = 0.00					
Cragg-Donald F statistic (check for weak instruments) 2237.98 > 19.93 (Stock-Yogo 10% critical values)					
Sargan-Hansen test (overidentification) Hansen J statistic 0.12 Chi-sq(1) P-val = 0.73					

Finally for comparison purposes among developed and emerging developing countries, we discuss a bit further the impact of age on firm growth. Figure 1 is constructed by taking zero impact of R&D intensity and FDI on growth<sup>13</sup>. The impact of the other significant variables except age (Lnsize) is evaluated at their sample mean values. Our results reject the Jovanovic argument that younger firms tend to grow faster than their older counterparts. As lnage varies from 0 to 5, we have a negative growth for all of our firms. The older firms have less negative growth than the younger ones. We would accept Jovanovic argument only if lnage varied from 0 to 1.41 for our entire sample. This is the range where age is convex and diminishing. E.g if some variables like R&D intensive cause the curve to shift upwards then indeed the younger firms will tend to grow faster. However, less than 5% of our sample lies within this range, so it is obvious that in our case the argument is rejected. A similar effect is found by Das (1995) for the computer hardware industry in India over 1983-1988. According to this paper, age found to have a strong positive impact on firm

<sup>13</sup> Since 15  $\gamma_j$ 's are insignificant and median of R&D intensity is zero.

growth, something that rejects Jovanovic argument and gives evidence about the absence of learning-effects in the specific industry.

Figure 1: The impact of age on growth



## Section VI: Conclusion

This paper is an attempt to understand the role of R&D and FDI, in determining firm growth. Empirical research on firm level data has revealed substantial heterogeneity between firms, so we include the latter two variables to control for it. Using fixed effects panel data models with GMM estimation to control for endogeneity of R&D and FDI, one of our major findings is that an increase in current R&D induces a higher growth, whereas, an increase in FDI induces higher growth in some industries and lower size growth in some others.

Furthermore, Gibrat's law is not only rejected by our main model but it is also rejected by an Augmented Dickey Fuller unit root test for unbalanced panel data. This provides strong evidence in favor of our model. Finally, firm growth is negatively associated with its size and it is convex with respect to its age. The fact that firm growth is not diminishing convex – but just convex – with respect to age, contradicts the Jovanovic argument that younger firms tend to grow faster than their older counterparts. As far as the firm growth is concerned, the absence of learning-effects appears to be the main difference between emerging-developing and developed countries.

**APPENDIX: More Data Statistics**

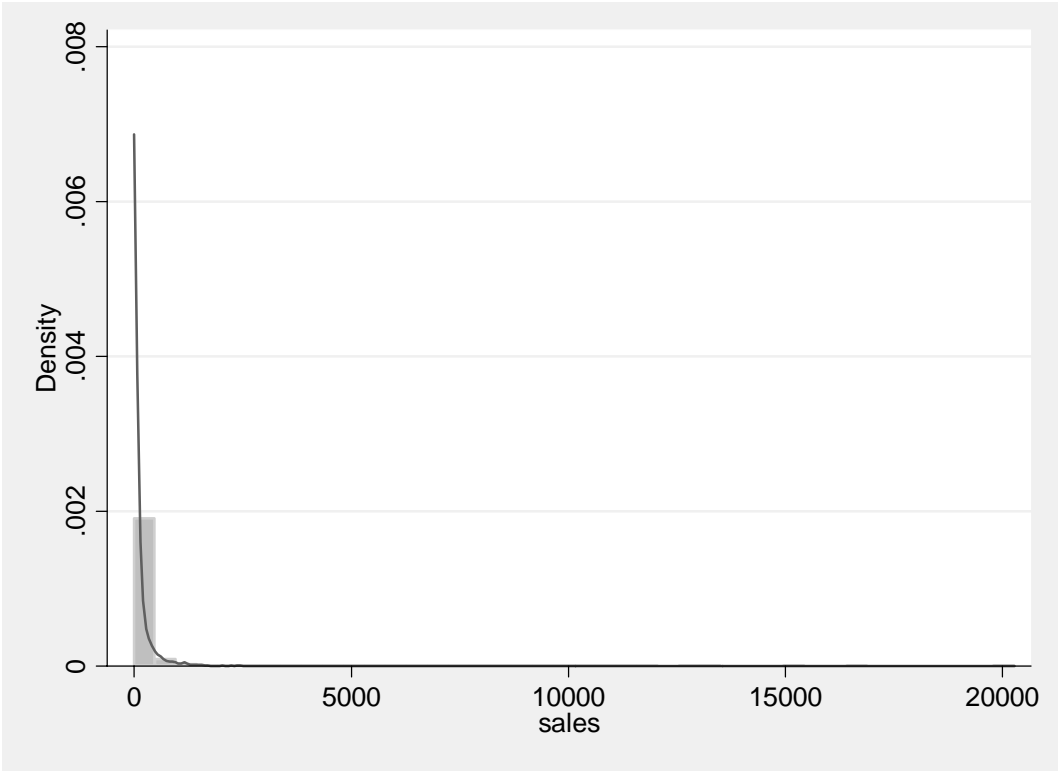
**Table 6: Percentage of zero R&D Companies per industry per year**

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
1	92	85	75	78	79	81	86	86	78	81	78	76
2	88	94	91	85	85	83	84	83	85	89	79	74
3	100	85	65	50	45	47	61	65	58	51	53	59
4	93	89	82	77	82	85	86	83	80	81	86	86
5	86	85	83	79	80	81	83	83	83	81	77	77
6	70	75	78	78	82	78	80	86	83	78	83	78
7	68	65	63	59	62	62	64	61	56	54	52	50
8	36	47	56	63	58	54	50	48	45	45	39	44
9	76	67	68	75	80	80	90	74	68	68	65	60
10	45	45	51	43	51	46	48	48	42	44	39	37
11	75	58	60	57	57	65	65	72	64	60	48	50
12	82	74	72	62	64	70	63	68	58	59	59	61
13	85	84	81	81	81	84	80	81	76	79	73	72
14	63	58	58	58	58	58	83	83	75	83	83	83
15	76	68	64	48	59	58	59	67	70	54	48	52
16	78	70	55	57	55	60	63	65	57	59	57	48
17	83	87	86	83	83	86	87	88	86	86	85	84
18	64	65	61	59	53	57	62	57	56	51	50	51
19	60	73	64	64	50	57	56	56	63	44	36	50
20	76	83	80	68	68	67	62	61	71	65	59	60
21	61	61	54	54	54	58	58	59	56	53	48	48
22	64	56	59	59	56	58	53	69	51	55	56	50
23	58	49	50	45	52	59	65	64	54	53	52	52
24	70	55	77	71	69	72	75	68	50	50	53	50
25	100	75	100	75	100	75	75	75	75	75	75	75
26	70	62	61	56	54	54	64	60	50	48	49	46

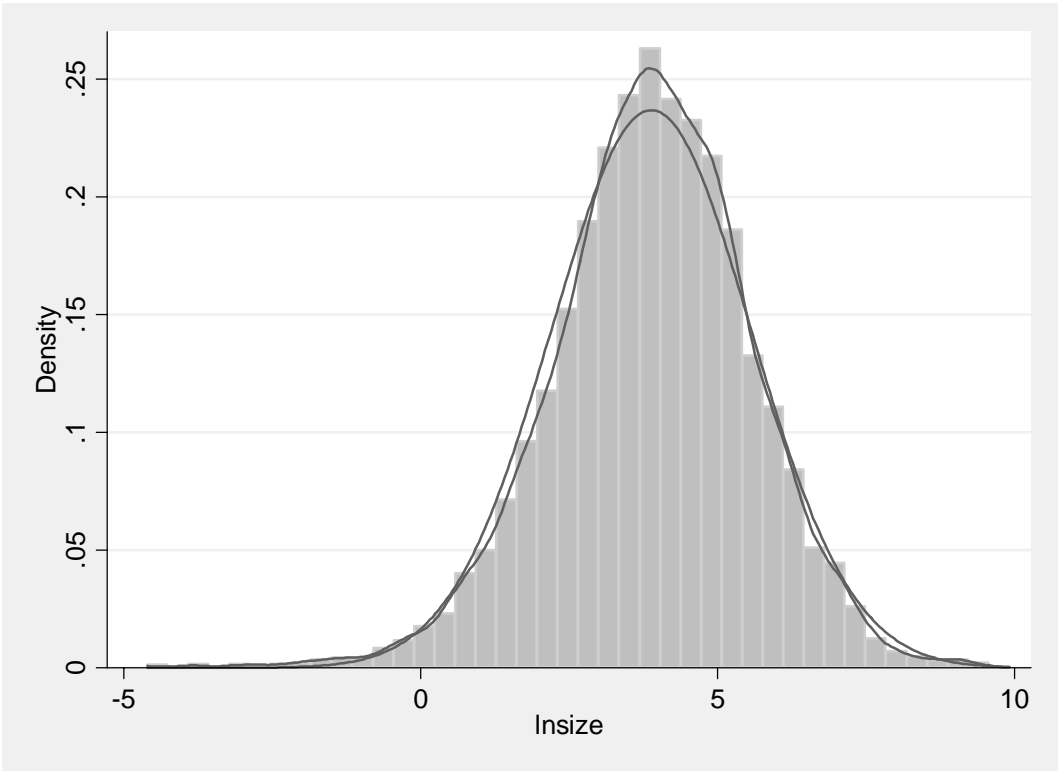
**Table 7: Percentage of zero FDI Companies per industry per year**

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
2	100	100	100	100	100	0	100	100	100	0	0	0
3	0	0	0	0	100	100	100	100	0	0	0	0
4	0	0	0	0	100	100	0	0	0	0	0	0
5	100	100	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	100	0	100	0	0	0	100
9	0	0	0	0	100	100	0	100	0	0	0	0
11	100	100	100	100	100	0	100	100	100	100	0	0
17	100	100	0	0	0	0	0	0	0	0	0	0
18	100	100	0	0	0	0	100	100	100	0	0	0
19	100	0	0	0	0	100	100	100	0	0	0	100
21	100	100	100	0	0	0	0	0	0	100	0	0
24	100	100	0	0	0	0	0	0	0	0	0	0
25	100	100	0	0	0	0	0	0	0	0	0	0
26	100	100	0	0	0	0	0	0	0	0	0	0

**Figure 2: Size Distribution**



**Figure 3: Natural Logarithm of Size Distribution**



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