Indian Journal of Applied Economics and Business
Vol. 3, No. 1, (2021), pp. 135-152

ARF INDIA
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Journal Home Page:
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Sources of Output and Total Factor Productivity Growth of the Organized Manufacturing Industries in Gujarat: A Stochastic Frontier Approach

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Received: 24 October 2020; Revised: 15 November 2020; Accepted: 14 December 2020; Publication: 1 January 2021

Abstract: *The paper estimates sources output and productivity growth of the 2-digit manufacturing industries as well as total manufacturing industry in Gujarat during the period from 1981-82 to 2010-11. The sources of output growth are input growth effect and total factor productivity growth (TFPG) and again TFPG is composed of adjusted scale effect (ASC), technological progress (TP) and technical efficiency change (TEC). A stochastic frontier model with a translog production function is used to estimate the growth attributes of output and productivity of the 2-digit manufacturing industries as well as total manufacturing industry in Gujarat during the entire study period (1981-82 to 2010-11), pre-and post-reform period (1981-82 to 1990-91 and 1991-92 to 2010-11) and also during two decades of the post-reform period (1991-92 to 2000-01 and 2001-02 to 2110-11). The empirical finding clears that input growth effect is the major contributor to output growth in Gujarat manufacturing and total factor productivity growth (TFPG) has also a positive and significant contribution on output growth of the same. Further, technological progress (TP) is found to be as the major contributor to TFPG but it fails to offset the strong negative scale effects (ASC) and as a result TFPG in the 2-digit manufacturing industries of the state declined during the post-reform period. The impact of technical inefficiency effect, however, remain absent as statistical test suggests. The relevant policy implication for the development of the organized manufacturing industries in Gujarat is the need to improve scale components of the 2-digit manufacturing industries of the state during the forth-coming years.*

Key Words: *Organized Manufacturing Industries in Gujarat, Stochastic Frontier Production Function, Total Factor Productivity Growth, Technological Progress, Technical Efficiency change and Adjusted Scale Effect*

JEL CODES: *C23, D24, L6, O47*

1. INTRODUCTION

Gujarat emerges as an industrial hub with India's most Industrialized State. The only state in India to emerge as 'investor friendly', it has achieved the significance of being the top most industrially developed state in respect of industrial growth. Many empirical studies tried to explore the sources of industrial growth.

Industrial growth overtime is usually attributed to growth in factor inputs and improvement in total factor productivity (TFPG). While measuring the sources of output growth, the contribution of TFPG is usually estimated as a residual, after accounting for the growth in factor inputs. If the industries operate on their production possibility frontiers producing the maximum possible output or realizing the full potential of the technology, then this implies that improvement in productivity arises from technological progress. Operation on the production possibility frontier can be achieved if industries follow the best practice methods of application of technology commonly referred to as technical efficiency. So productivity improvements can be achieved in two ways: improving the state of technology by innovation, and by implementing the programs such as improving workers' education, and ensuring that workers use the existing technology more efficiently. While the first approach is referred to as technological progress, the second one as technical efficiency.

The stochastic frontier production model as proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977) allow decomposing TFP growth into two components: technological progress (TP) and change in technical efficiency (TEC). The former reflects the improvement stemming from innovation and the diffusion of new knowledge and technologies, while the latter measures the movement of production towards the frontier. A notable advantage of the stochastic production frontier is the fact that the restrictive assumptions about firms operating with full efficiency are relaxed. Studies that assume that firms operate with full efficiency ignore the potential contribution of efficiency changes to TFP growth, which leads to biased and misleading results. This is because, in reality, producers are not always efficient (Kumbhakar et al 2015). Now a day the stochastic frontier model has been intensively used to decompose TFP growth at the firm, industry, state, and even more at the national levels. Although a vast number of empirical applications have contributed to identify the sources of TFP growth by focusing on its decompositions, representative studies are Nishimizu and Page (1982), Kumbhakar (1990), Fecher and Perelman(1992), Domazlicky and Weber (1998), to mention only a few. Some studies have extended their analysis to deal with the issues such as scale effects (SC) and allocative efficiency effects (ASC). Nishimizu and Page (1982) was the first to propose de-composition of TFPG into efficiency changes and technological progress. He used a deterministic translog production frontier to decompose productivity change in Yugoslavia into aforementioned two components. Bauer (1990) estimated a translog cost frontier using data on the US airline industry to decompose TFP growth into efficiency, technical progress, and scale components. By applying a flexible translog stochastic production function, Kumbhakar and Lovell (2000), Kim and Han (2001) and Sharma, Sylwester and Margono (2007) decompose TFP growth into four components: technological progress (TP), technical efficiency change (TEC), allocative efficiency change (AEC) and scale changes (SC). Sangho Kim and Gwangho Han (2001) applied a stochastic frontier production model to Korean manufacturing industries to decompose the sources of total productivity (TFP) growth into TP, TEC, AEC, and SC. Empirical results based on data of Korean manufacturing industries from 1980 to 1994 he showed that productivity growth was mainly driven by TP, that TEC had a significant positive effect, and that AEC had a negative effect. They recommended that specific guidelines are needed to promote productivity growth in each industry, and provided additional perceptions into understanding the recent discussion of TFP growth in Korean manufacturing industries.

Li and Liu (2011) in their study examine and apply the theoretical foundation of the decomposition of output and productivity growth to China's post-reform economy. Their theoretical discussion follows that of Solow (1957), Denny, Fuss, Everson and Waverman (1981), Bauer (1990), and Kumbhakar and Lovell (2000) and they show that cost information is not required in estimating the components of decomposition and the production function approach is sufficient for the empirical work. Output growth is then decomposed by them into input growth effect, adjusted scale effect (ASC), technological progress (TP), and growth in technical efficiency (TEC). With this decomposition, the TFP growth simply contains the last three components: ASC, TP, and TEC (Kunbhakar and Lovell, 2000). The growth of aggregate input is the weighted sum of each input growth and the weights being the cost share of each input. The ASC depends on the size of returns to scale. This effect is zero for constant returns to scale, but is adjusted by the aggregate input growth for increasing or decreasing returns to scale. TP in the decomposition represents the shift of the production function over time. The TEC component can be measured and derived from stochastic frontier model.

The objective of our study is to decompose the sources of output and total factor productivity growth of the 2-digit manufacturing industries in Gujarat by using stochastic frontier model assuming that the industries are not able to fully utilize their existing resources and technology because of various non-price and organizational factors that might have led to technical inefficiencies in production. The manufacturing industries of Gujarat considered in our study are: (1) manufacture of food, beverages and tobacco products (20-22), (2) manufacture of textile and textile products (23+24+25+26), (3) manufacture of wood and wood products; furniture and fixtures (27), (4) manufacture of paper and paper products (28), (5) manufacture of chemicals and chemical products (30), (6) manufacture of rubber, petroleum and coal products (31), (7) manufacture of non-metallic mineral products (32), (8) manufacture of basic metals and alloys industries (33), (9) manufacture of metal products and machinery equipments (34-36), (10) manufacture of transport equipments (37) and total manufacturing of the state. Using panel data of the afore-mentioned industries in Gujarat over a period from 1981-82 to 2010-11 (entire study period), and during the pre-reform period (1981-82 to 1990-91), post-reform-period (1991-92 to 2010-11) and also during two decades of the post-reform period, i.e., during 1991-92 to 2000-01 and during 2001-02 to 2010-11], we decompose output growth of the organized manufacturing industries in Gujarat into input growth effect and TFPG. TFPG is again decomposed into adjusted scale effect (ASC), technological progress (TP) and technical inefficiency effects (TEC) in order to examine the trend and variations in the TFPG and its different components. To the best of our knowledge, none of the existing studies has decomposed output and TFP growth of the organized manufacturing industries in Gujarat at the disaggregated level as we propose to do.

The paper is organized as follows. The next section outlines the stochastic frontier production function and the methodology that involve decomposition of output and TFP growth. The econometric specifications of the stochastic frontier production function and the time-varying technical inefficiency function have also been made in this section. Data sources and the measurement of variables are presented in Section 3. Section 4 presents the results of the estimation and tests of hypotheses and other relevant empirical results. The final section contains concluding remarks.

2. METHODOLOGY

The existence of technical inefficiency in the production process can be explained by using a stochastic frontier model (Aigner, Lovell and Schmidt and Meeusen and Van den Broeck, 1977; Battese and Coelli, 1988 and 1992; Greene, 2005) as given by

$$Y_t = F(X_{1t}, X_{2t}, \ldots, Xnt, t)\, e^{-u_t} \tag{1}$$

where Y is the actual level of output; F is the potential production function with 'n' inputs; Xit is i^{th} input; and 'u' is a half-normally distributed random variable with a positive mean. The inclusion of't' in 'F' allows for the production function to shift over time due to technological progress. The last term e^{-} measures technical inefficiency.

Taking logs and totally differentiating (1) with respect to 't' and after some algebraic manipulation we get

$$\dot{Y}_t = \sum_i s_{it}\,\dot{X}_{it} + (e_t - 1)\sum_i s_{it}\,\dot{X}_{it} + \dot{A}_t + T\dot{E}_t \tag{2}$$

Equation (2) shows that output growth can be decomposed into four components: weighted sum of input growth (weights being the expenditure share of inputs), adjusted scale effect (ASC), technological progress (TP), and growth of technical efficiency (TEC).

Where components of TFP growth becomes

$$T\dot{F}P_t = (e_t - 1)\sum_i s_{it}\,\dot{X}_{it} + \dot{A}_t + T\dot{E}_t \tag{3}$$

Thus TFP growth has three components: adjusted scale effect (ASC), technological progress (TP), and growth of technical efficiency (TEC) (Bauer, 1990; Kumbhakar and Lovell, 2000, pp. 284).

2.1 Model Specification

A time-varying stochastic production frontier in translog form with two inputs labour (L) and capital (K) is given as:

$$Lny_{it} = \beta_0 + \beta_L \ln L_{it} + \beta_K \ln K_{it} + \beta_t t + 1/2\beta_{LL}L_{it}^2 + 1/2\beta_{KK}K_{it}^2 + 1/2\beta_{tt}t^2 + \beta_{LK}\ln L_{it}\ln K_{it} + \beta_{Lt}L_{it}t + \beta_{Kt}K_{it}t + v_{it} - u_{it} \tag{4}$$

where y_{it} is the level of output, u_{it} represents production loss due to industry-specific technical inefficiency; thus it is always greater than or equal to zero ($u_{it} \geq 0$) , and it is assumed to be independent of the statistical error, v_{it}, which is assumed to be independently and identically distributed as $N(0, \sigma^2_v)$.

The distribution of technical inefficiency effects, u_{it}, is taken to be non-negative truncation of the normal distribution N (µ,ì²u), modelled, following (Battese & Coelli 1992, Greene 1997: pp119) to be the product of an exponential function of time as

$$u_{it} = \eta_t u_i = u_i \exp(-\eta\,[t - T]),\ i = 1,\ldots, N;\ t = 1, \ldots, T \tag{5}$$

The unknown parameter 'η' represents the rate of change in technical inefficiency, and the non-negative random variable u_i, is the technical inefficiency effect of the i^{th} industry in the last year of the data set. That is, the technical inefficiency effects in earlier periods are deterministic exponential function of the inefficiency effects for the corresponding forms in the final period (i.e., $u_{it}=u_t$), given the data for the i^{th} industry are available in the final period. So the production unit with a positive 'η' is likely to improve its level of efficiency over time and vice-versa. A value of $\eta = 0$ implies technical inefficiency is time invariant in nature. Since the estimates of technical efficiency are sensitive to the choice of distributional assumption, we consider truncated normal distribution for general specifications of one-sided error u_{it}, and half - normal distribution can be tested by LR test.

Technical efficiency of the i^{th} industry at time t (TE_{it}), defined as the ratio of the actual output to the potential output determined by the production frontier, can be written as

$$(TEit) = \exp(-u_{it}) \quad (6)$$

and technical efficiency change is the change in TE, and the rate of technological progress (TPit) is defined by,

$$TP_{it} = \partial \ln f(x_{it}, \beta, t) / \partial t = \beta t + \beta_{tt} t + \beta_{Lt} \ln L_{it} + \beta_{kt} \ln K_{it} \quad (7)$$

where βt and β_{tt} are 'Hicksian' parameters and β_{Lt} and β_{Kt} are 'factor augmented' parameters. It is noted that when technological progress is non-neutral, the change in TP will vary for different input vectors. To avoid this problem, Coelli, Prasada Rao and Battese (1998) suggest that the geometric mean between the adjacent periods be used to estimate the TP component. That is, geometric mean between time't' and t+1 is defined as

$$TPit= [1 + \partial \ln f(x_{it}, \beta, t) / \partial t] * [1+ \partial \ln f(x_{it+1,} \beta, t+1)/\partial t+1]^{1/2}-1 \quad (8)$$

So that both TE_{it} and TP_{it} vary over time and across industries. The associated input elasticities of output can be defined as

$$\text{Labour Elasticity of Output } (\varepsilon_L) = \partial \ln f(x_{it}, \beta, t) / \partial \ln L_{it} = \beta_L + \beta_{LL} \ln L_{it} + \beta_{LK} \ln K_{it} + \beta_{Lt} t \quad (9)$$

$$\text{Capital Elasticity of Output } (\varepsilon_K) = \partial \ln f(x_{it}, \beta, t) / \partial \ln K_{it} = \beta_K + \beta_{KL} \ln L_{it} + \beta_{KK} \ln K_{it} + \beta_{Kt} t \quad (10)$$

These two factor elasticities are then used to estimate returns to scale component (RTS). The scale elasticity of output, i.e. the change in output with respect to change in scale, is given by the formula:

$$\epsilon = \varepsilon_L + \varepsilon_K \quad (11)$$

If scale elasticity exceeds unity, then the technology exhibits increasing returns to scale (IRS); if it is equal to one, the technology obeys constant returns to scale (CRS), and if it is less than unity, the technology shows decreasing returns to scale (DRS).

3. DATA AND VARIABLES

The study is based on panel data collected from various issues of Annual Survey of Industries (ASI) and National Accounts Statistics (NAS) published by, Central Statistical Organization (CSO), Ministry of Statistics and Program Implementation, Government of India, New Delhi. The variables used in this study are output and labour and capital inputs. Deflated gross value added has been taken as the measure of output. The ratio of nominal and real GDP, the values of which are obtained from different volumes of NAS is treated as deflator. Total number of persons engaged in production is used as the measure of labour input. Since working proprietors, owners and supervisory, managerial staff have a significant influence on the productivity of industries, total number of persons engaged is preferred to number of workers. Price of labour is obtained by dividing the total emoluments by the total persons engaged. Net fixed capital stocks at constant prices have been taken as the measure of capital input. The net fixed capital stock series has been constructed from the series on gross fixed capital formation (at constant prices) using the perpetual inventory accumulation method (PIAM) [Goldsmith, 1951]. The annual rate of depreciation of fixed assets has been taken as 5 per cent. Rental price of capital equals the ratio of interest paid and capital invested (Jorgenson and Griliches, 1967) is treated as price of capital.

4. EMPIRICAL RESULTS

4.1. Estimation of the stochastic production frontier

The maximum likelihood estimates for the parameters of the stochastic frontier model, defined by equations (4) and (5), are obtained using the program FRONTIER 4.1, in which the variance parameters are expressed in terms of $\gamma = \sigma^2_u/\sigma^2$ and $\sigma^2 = \sigma^2_u + \sigma^2_v$ (Coelli, 1996) which are also reported in the result table (Table 1). These are associated with the variances of the stochastic term in the production function, and the inefficiency error term u_{it}. The parameter γ must lie between zero and unity. If the hypothesis $\gamma = 0$ is accepted, this would indicate that σ_u^2 is zero and thus the inefficiency error term, u_{it} should be removed from the model, leaving a specification with parameters that can be consistently estimated by OLS. On the other hand, if the value of γ is one, we have the full-frontier model, where the stochastic term is not present in the model. The μ parameter determines the distribution the inefficiency effects have, either a half-normal distribution or a truncated normal distribution. The ç parameter determines whether inefficiencies are time varying or time invariant.

Table 1 shows the results of the estimation of translog stochastic frontier production function in which the technical inefficiency effects, u_{it}, have the time varying structure and follow truncated normal distribution. The estimate of γ which is the ratio of the variance of industry-specific performance of technical efficiency to total variance of output is statistically significant at 1 per cent probability level. This implies that the variation in productivity performances among the industries is not due to statistical chance factor but principally to individual technical efficiency differences.

The estimated average technical efficiency of the 2-digit industries in Gujarat is as high as 0.94 which implies that the industries in Gujarat are operating at 94% of their potential output determined by the frontier technology. But statistical test (Table 2) suggests that technical inefficiency in the 2-digit manufacturing industries in Gujarat remains absent and/or it is time invariant in nature, i.e. overtime changes in technical efficiency are not statistically significant in spite of a moderate level of technological progress taking place in the industry. So it can be inferred from this result that each year or within a range of years the innovating manufacturing industries in Gujarat keep on or shifting for better technologies; however, for various reasons, such as insufficient knowledge of the best practice and other administrative factors, they are unable to follow the best practice techniques of the chosen technology. As a result, the industries fail to achieve 100% technical efficiency and the level of efficiency seems to be more or less at the same percentage level over the year. On the other hand, non-innovator manufacturing industries, due to technology spill over, are also moving towards the best practice frontier i.e. they are catching up with the frontier and thereby keeping up the same distance from the frontier set by the best practice techniques. The possible reasons, for which none of the 2-digit industries is able to follow the best practice techniques and thereby attaining 100 % efficiency, are as follows. Due to inadequate number of domestic machinery suppliers, most of the machineries and equipment used in the 2-digit manufacturing industries in Gujarat are borrowed from abroad. There exist certain factors which lead to poor absorption and adaptation capacities of the borrowed technology. Firstly, poor infrastructure of the receiving companies; Secondly, very limited R&D activities of the recipient companies; thirdly, inadequate technology support services of the manufacturing industries and lastly, absence of any long term training programme for the local personnel.

Table 1
Parameter Estimates of the Stochastic Production Frontier and Technical Inefficiency Model in the Manufacturing Industries in Gujarat

Variables	*Parameters*	*Coefficients*
Constant	β_0	5.20** (2.97)
lnL	B_L	0.045 (0.74)
lnK	β_K	0.112 (0.40)
t	β_t	0.13*** (0.04)
lnL^2	β_{LL}	-0.00037 (0.056)
lnK^2	β_{KK}	-0.033** (0.022)
t^2	β_{tt}	-0.0007* (0.0005)
lnL*lnK	β_{LK}	0.060 (0.062)
lnL*t	β_{Lt}	-0.024*** (0.006)
lnK*t	β_{Kt}	0.019*** (0.006)
Sigma squared	σ^2	1.56 (1.64)
Gamma	γ	0.94*** (0.06)
Mu	μ	0.55 (1.23)
Eta	η	-0.0065* (0.005)

Log-Likelihood -105.58
Standard errors are mentioned in the parenthesis
***,** & * denote statistical significance at the 1%, 5% and 10% levels, respectively
Source: Authors' own calculation

4.2. Tests of hypotheses of the parameters

In this study various tests of hypotheses of the parameters in the stochastic frontier production function are carried out using the generalized likelihood ratio-test statistic, defined by

$$\lambda = -2\,[L\,(H_0)-L\,(H_1)]$$

where L (H_0) is the log-likelihood value of a restricted frontier model, as specified by a null hypothesis, H_0; and L (H_1) is the log-likelihood value of the general frontier model under the alternative hypothesis, H_1. This test statistic has approximately a Chi-Square distribution (or a mixed chi-square) with degrees of freedom equal to the difference between the parameters involved in the null and alternative hypotheses. If inefficiency effects are absent from the equation, as specified by the null hypothesis H_0: $\gamma = 0$, then the statistic λ is approximately distributed according to a mixed chi-square distribution. Table 2 presents the test results of various null hypotheses as mentioned below:

The first likelihood test is conducted to test the null hypothesis that the translog stochastic frontier production function can be reduced to a Cobb-Douglas. The test statistic H_0: $\beta_{LL} = \beta_{KK} = \beta_{LK} = \beta_{tt} = \beta_{Lt} = \beta_{Kt} = 0$ as shown in Table 2 has a likelihood ratio value 24.48, which implies rejection of the null hypothesis at 1% significance level. In other words, the translog model could not be reduced to a Cobb-Douglas model and is, hence, the ideal model.

Table 2
Generalized Likelihood Ratio Tests of Hypotheses for Parameters of the Stochastic Frontier Production Function in Gujarat Manufacturing

Null Hypothesis	*Log-likelihood Value*		*Test statistics*	*Critical value*		*Decision*
	$L(H_0)$	*$L(H_1)$*	*$\lambda = -2[L(H_0) - L(H_1)]$*	*At 1% level*	*At 5% level*	*Reject H_0/ Accept H_0*
Cobb-Douglas production function $H_0: \beta_{LL}=\beta_{KK}=\beta_{LK}=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-117.82	-105.58	24.48	16.81	12.59	Reject H_0
No technological change H_0: $\beta_t=\beta_{tt}=\beta_{Lt}=\beta_{Kt}=0$	-132.70	-105.58	54.24	13.28	9.49	Reject H_0
Neutral technological change H_0: $\beta_{Lt}=\beta_{Kt}=0$	-112.81	-105.58	14.46	9.21	5.99	Reject H_0
No technical inefficiency effects H_0: $\gamma = \mu = \eta = 0$	-106.44	-105.58	1.72	11.34	7.81	Accept H_0
Half-normal distribution of technical inefficiency H_0:$\mu = 0$	-105.63	-105.58	0.10	6.63	3.84	Accept H_0
Time invariant technical inefficiency H_0: $\mu=0$	-106.33	-105.58	1.50	6.63	3.84	Accept H_0

Source: Authors' own calculation

The second test we have conducted in this study consists of testing the null hypothesis that there is no technological change over time i.e. H_0: β_t=β_{tt} =β_{Lt}=β_{Kt}=0. The value of the test statistic as shown in Table 2 is 54.24 which is significantly larger than the critical value of 13.28 at 1% probability level. As a result, the null hypothesis of 'no technological change over time' is rejected.

The third null-hypothesis is that technological progress is neutral i.e., H_0: β_{Lt}=β_{Kt}=0. The value of the test statistic in this case becomes 14.46 which is greater than the critical value of 9.21 at 1% probability level. This indicates that the translog parameterization of the stochastic frontier model does not allow for neutral technological progress.

Fourth, null-hypothesis that technical inefficiency effects are absent (H_0: $\gamma = \mu = \eta = 0$) is accepted. This implies that the traditional production function is an adequate representation for the organized manufacturing industries in Gujarat.

The fifth null-hypothesis, specifying that technical inefficiency effects have half-normal distribution (H_0: $\mu = 0$) against truncated normal distribution, is accepted at 1% level of significance.

The final null-hypothesis, that technical inefficiency is time-invariant (H_0: $\eta = 0$) is accepted at 1% level of significance. This implies that technical inefficiency in the organized manufacturing industries in Gujarat is time-invariant in nature.

4.3 Components of Output and Productivity Growth

Based on the translog production function estimates shown in Table 1 we obtain the following measures: the input growth effect, the adjusted scale effect and the rate of technological progress. As the translog specification is used because of its superiority over the traditional production function, (this has been established above) the performance of these measures varies across industries and over the years. These measures are then used to derive output and total factor productivity growth. As statistical tests (Table 2) suggest that the industries under study do not suffer from technical inefficiency, the rate of TFPG of the 2-digit industries of the state is the sum total of adjusted scale effect and the rate of technological progress and the rate of output growth of the same is the sum total of input growth effect, adjusted scale effect and the rate of technological progress. For the sources of the output and productivity growth, Tables (3) – (7) in the Appendix show that: the major contributor to the output growth is input growth effect, while technological progress is the major contributor to TFPG of the organized manufacturing industries in almost all the 2-digit industries in Gujarat as well as that of the state's total manufacturing during the whole study period, pre-reform and post-reform periods, and during the two decades of the post-reform period. Further, whereas increase in output growth in most of the 2-digit industries in Gujarat during the post-reform period is responsible for the increase in input growth effect of the same during that period, the decline in scale effect in most of the 2-digit industries of the state during the same period of time is responsible for the decline in TFPG of them during that period.

Be it mentioned that scale effects in most of the 2-digit industries of the state are found to be very low or even negative with high values during that period. However, the finding clears that although factor accumulation may lead to TFP growth through increasing returns to scale in case of a few industries, the most important factor of TFP growth in almost all the 2-digit manufacturing industries in Gujarat is technological progress. It is found that the rate of TFPG becomes the lowest (negative) in case of wood and wood products (27) and manufacture of transport equipments (37) and this is mainly due to huge negative scale effects in the two industries.

5. SUMMARY AND CONCLUSION

The paper estimates the sources of output and productivity growth of the 2-digit manufacturing industries in Gujarat during the period from 1981-82 to 2010-11, during the entire study period, pre-& post-reform period and also during two decades of the post-reform period. Our theoretical discussion follows that of Solow (1957), Denny *et al.* (1981), Bauer (1990), and Kumbhakar and Lovell (2000) and it shows that cost information is not required in estimating the components of output growth and the production function approach is sufficient for that empirical work. Output growth is then decomposed into input growth effect, adjusted scale effect and technological progress (technical efficiency change is absent as statistical test suggests). The growth of aggregate input is the weighted sum of each input growth and the weight being the cost share of each input. The adjusted scale effect depends on the size of returns to scale. This effect is zero for constant returns to scale, but is adjusted by the aggregate input growth for increasing and decreasing returns to scale. Technological progress in the decomposition represents the shift of the production function over time. For our empirical work on the production function, we have derived the series of capital stocks data using the perpetual inventory accumulation method for the 2-digit manufacturing industries in Gujarat and for the total manufacturing industry of the state during the period from 1981-82 to 2010-11.

We have actually followed the decomposition of output and TFP growth of Liu and Li (2011) using stochastic frontier approach. We have estimated the translog stochastic frontier production function using the maximum-likelihood estimation method. Our empirical findings show that the two primary inputs (labor and capital) are important for output performances of the 2-digit manufacturing industries in Gujarat. Further, among the two inputs, capital is the most important factor in the post-reform industrial growth in Gujarat. This conclusion is consistent with the earlier studies. Increase in capital will increase productivity of labour thereby increasing the labour share of total output. When the sources of TFPG of the 2-digit manufacturing industries in Gujarat are concerned, it is found that the major contributor to the TFP growth of the said industries of the state is technological progress. The contribution of adjusted scale effect is very negligible or even negative with very high values during the entire study period. Thus, although factor accumulation cannot lead to TFP growth through increasing returns to scale, the most important factor of TFPG of the 2-digit manufacturing industries in almost all the states under study are the technological progress. Economies of scale are advantageous no doubt. But scale should be increased not by growing networks but by building factories.

APPENDIX

Table 3
Average Annual Rates of Output Growth of the 2-Digit Manufacturing Industries in Gujarat

I/P	*1981-82 To 2010-11 (Entire Study Period)*	*1981-82 to 1990-91 (Pre-reform Period)*	*1991-92 To 2010-11 (Post-reform Period)*	*1991-92 to 2000-01 (Post-reform Period-Decade 1)*	*2001-02 to 2010-11 (Post-reform Period-Decade-2)*
20-22	6.50	3.84	7.84	7.54	8.13
23-26	5.25	2.20	6.77	8.27	5.25
27	9.83	5.54	11.97	10.22	13.71
28	8.42	7.18	9.03	11.27	6.81
30	14.65	23.4	10.28	13.85	6.71
31	14.54	11.57	16.02	11.35	20.69
32	9.56	8.97	9.85	10.06	9.65
33	12.15	6.13	15.17	18.84	13.06
34-36	9.06	6.74	10.22	9.63	8.74
37	11.38	4.80	14.66	12.32	17.02
TOTAL	7.92	4.83	9.48	8.73	10.23

Source: Authors' own calculation
I/P-Industries/Periods

Table 4
Average Annual Rates of Input Growth Effect of the 2-Digit Manufacturing Industries in Gujarat

I/P	*1981-82 To 2010-11 (Entire Study Period)*	*1981-82 to 1990-91 (Pre-reform Period)*	*1991-92 To 2010-11 (Post-reform Period)*	*1991-92 to 2000-01 (Post-reform Period-Decade 1)*	*2001-02 to 2010-11 (Post-reform Period-Decade-2)*
20-22	4.40	0.27	6.47	5.50	7.44
23-26	2.37	-1.46	4.28	6.00	2.56
27	11.51	2.66	15.94	11.83	20.04
28	5.54	2.85	6.88	9.70	4.07
30	11.27	22.92	5.45	9.67	1.23
31	10.62	6.65	12.6	5.76	19.44
32	6.71	5.94	7.09	6.96	7.23
33	8.64	1.49	12.22	12.58	11.86
34-36	7.59	3.90	9.43	6.79	12.07
37	11.59	0.13	17.32	13.52	21.12
TOTAL	4.31	0.49	6.23	4.76	7.70

Source: Authors' own calculation

I/P- Industries/Periods

Table 5
Average Annual Rates of Total Factor Productivity Growth (TFPG) of the 2-Digit Manufacturing Industries in Gujarat

I/P	*1981-82 To 2010-11 (Entire Study Period)*	*1981-82 to 1990-91 (Pre-reform Period)*	*1991-92 To 2010-11 (Post-reform Period)*	*1991-92 to 2000-01 (Post-reform Period-Decade 1)*	*2001-02 to 2010-11 (Post-reform Period-Decade-2)*
20-22	2.10	3.57	1.37	2.04	0.69
23-26	2.88	3.66	2.49	2.27	2.69
27	-1.68	2.88	-3.97	-1.61	-6.33
28	2.88	4.33	2.15	1.57	2.74
30	3.38	0.48	4.83	4.18	5.48
31	3.92	4.92	3.42	5.59	1.25
32	2.85	3.03	2.76	3.10	2.42
33	3.51	4.64	2.95	6.26	1.20
34-36	1.47	2.84	0.79	2.84	-3.33
37	-0.21	4.67	-2.66	-1.20	-4.10
TOTAL	3.61	4.34	3.25	3.97	2.53

Source: Authors' own calculation

I/P- Industries/Periods

Table 6
Average Annual Rates of Technological Progress (TP) of the 2-Digit Manufacturing Industries in Gujarat

I/P	*1981-82 To 2010-11 (Entire Study Period)*	*1981-82 to 1990-91 (Pre-reform Period)*	*1991-92 To 2010-11 (Post-reform Period)*	*1991-92 to 2000-01 (Post-reform Period-Decade 1)*	*2001-02 to 2010-11 (Post-reform Period-Decade-2)*
20-22	3.62	3.65	3.60	3.73	3.47
23-26	3.61	3.33	3.75	3.91	3.58
27	3.98	4.09	3.92	4.07	3.77
28	4.97	5.32	4.79	5.24	4.35
30	6.74	7.27	6.47	6.99	5.95
31	8.07	7.31	8.45	7.69	9.21
32	5.11	4.65	5.34	5.47	5.21
33	6.66	4.98	7.51	7.84	7.17
34-36	3.84	3.83	3.85	3.96	3.74
37	4.61	4.55	4.64	3.80	5.49
TOTAL	4.57	4.43	4.64	4.84	4.44

Source: Authors' own calculation
I/P- Industries/Periods

Table 7
Average Annual Rates of Scale Effect (SC) of the 2-Digit Manufacturing Industries in Gujarat

I/P	*1981-82 To 2010-11 (Entire Study Period)*	*1981-82 to 1990-91 (Pre-reform Period)*	*1991-92 To 2010-11 (Post-reform Period)*	*1991-92 to 2000-01 (Post-reform Period-Decade 1)*	*2001-02 to 2010-11 (Post-reform Period-Decade-2)*
20-22	-1.52	-0.08	-2.23	-1.69	-2.78
23-26	-0.73	0.33	-1.26	-1.64	-0.89
27	-5.66	-1.21	-7.89	-5.68	-10.1
28	-2.09	-0.99	-2.64	-3.67	-1.61
30	-3.36	-6.79	-1.64	-2.81	-0.47
31	-4.15	-2.39	-5.03	-2.10	-7.96
32	-2.26	-1.62	-2.58	-2.37	-2.79
33	-3.15	-0.34	-4.56	-1.58	-5.97
34-36	-2.37	-0.99	-3.06	-1.12	-7.07
37	-4.82	0.12	-7.30	-5.00	-9.59
TOTAL	-0.96	-0.09	-1.39	-0.87	-1.91

Source: Authors' own calculation
I/P- Industries/Periods

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