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Cost and Productivity Experiences of Pakistan with Aggregate Learning Curve

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***Abstract*—**The principal focus of this study is on the measurement and analysis of labor learnings in Pakistan. The study at the aggregate economy level focus on the labor productivity movements and at large-scale manufacturing level focus on the cost structure, with isolating the contribution of the learning curve. The analysis of S-shaped curve suggests that learnings are only below one half of aggregate learning curve and other half shows the retardation in learning, hence retardation in productivity movements. The study implies the existence of learning economies in term of cost reduction that is input cost per unit produced decreases by 0.51 percent every time the cumulative production output doubles.

***Keywords*—**Cost, Inflection Point, Learning Curve, Minima, Maxima, and Productivity

I. Introduction

LEARNINGS from past experiences are a distinct phenomenon of economic growth. In literature these learnings have been captured through the learning curve [1]. The application of the learning curve concept has been well documented by Yelle [2]. It received attention during World War II as attempts were made to predict costs and time requirements of ships and aircraft used in conducting the war [3]. Later in post war era studies often used cost or price per unit instead of direct labor hours [4]—[7]. Nevertheless, Wright [3] was first who reported the learning curve phenomenon in the literature.

The theoretical and empirical literatures signify the strong relationships between productivity growth and the learning curve [8] cost and learning curve [2], [9], [10], [11]. The cost minimization through learning process attributed to experience has been the focus of many studies [12]—[14], [10], [15]—[17], it describes the well known phenomenon that as a product is produced over and over, the time and cost for that job or product becomes less and less in a pattern that is exponential in nature [3], [18], [2], [10], [8], [19]. This type of learning is capturing the traditional learning-by-doing phenomenon [20]. Similarly, productivity growth through learning by doing has also been studied [21]—[23].

The improvements in productivity and cost have been the target of government policies around the world. But, unfortunately, the same has been neglected in Pakistan. A number of earlier studies have analyzed productivity and cost in Pakistan with exception to learning curve phenomenon. Though most of these studies were based on CES (constant elasticity of substitution) production function or its variants [24]—[33]. A few studies have based their analysis on a flexible functional form, namely the Translog cost function [34]—[38] and a study related to Generalised Leontief cost function [39]. Studies based on the sources of growth of manufacturing in Pakistan [40]—[42], the computation of productivity indices for Pakistan has also been done [43], [44]. Mahmood and Siddiqui [45] analyzed the significance of the existing research and development capability, share of knowledge and human capital of Pakistan in explaining productivity growth. Khan and Burki [46] identified evidence of allocative inefficiency in the manufacturing sector of Pakistan. Wizarat [47] compared productivity differentials of Pakistan with UK, Europe, and Germany and concluded that the economies are diverging at an alarming rate.

This study focuses on examining the productivity trends via the aggregate learning curve. Since in the literature different shapes[1] of learning curves have been used but our focus will particularly be on the S-shaped aggregate learning curve for productivity and log linear model for cost. In this regard, this study intends to examine various aspects of learning in Pakistan by specifically focusing on labor learning. We also applied different diagnostic tests for each equation based on econometrics theory.

The organization of this study is as follows. Section 2 provides the more relevant overview of the literature. Section 3 describes the methodology and design of the aggregate learning curve by results obtained and their performance evaluation along with data sources. Section 4 reports diagnostic tests. Section 5 concludes the study with suggestions and future prospects for Pakistan economy.

II. Review of the Literature

We implicitly assumed that increase in individual productivity and skill result either from learning-by-doing on the job or improvements made in training [48], [49]. In the first case, productivity gains in human capital result from being able to increase the quality or speed of job performance as a result of previous exposure to a given set of task [50], [51], [52]—[54]. Similarly literacy can also cause growth in labor productivity. Khan et al [55] found that literacy does

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[1] for detail see Yelle (1979)

cause labor productivity in the manufacturing sector of Pakistan.

In the words of Argote and Epple [11] "Standard measure of organizational experience in the learning curve formulation is the cumulative number of unit produced a proxy variable for knowledge acquired through production. If unit costs decrease as a function of this knowledge, other variables being equal, organizational learning is said to occur."

Since the task differ in complexity, therefore according to Thurstone [56] performance of complex task take more time in approaching perfection as compare to the simpler ones. Thurstone supposed that if there are five or more homogeneous tasks with perfectly symmetrical S-shaped learning curves and if they are combined into a single heterogeneous task, how it will affect the learning curve. Moreover, Thurstone [56] suggested that due to heterogeneity in tasks learnings are normally below the inflection point or only in the first half of long-run attainable productivity and therefore make the aggregate learning curve less symmetrical vis-à-vis the individual learning curves. On similar grounds Renshaw [8] examined the post World War II increase in output per hour in the US economy from the perspective of an aggregate learning curve.

However, Carr [6] hypothesized an upper limit beyond which operations cannot be carried out at reduced man-hours and proposed that the long-run relationship between output per hour and cumulative production is most likely S-shaped curve with an upper limit of labor productivity. Such types of curves are more consistent with the growth curve examined in biology [57], [58] and the learning curves attained by psychologist [59], [60].

Similarly, Hayes [61] suggested that when there is a robust positive skew exist among the symmetrical S-shaped learning curve of different individuals with respect to time and the resulting average learning curve most probably be in the state of retarded growth. Due to the negative acceleration that may exist in relatively few individual learning curves that make a very low flex point for the aggregate learning curve. In the similar manner, Sriyananda and Towill (1973) model assumes and exploits the fact that the early stage of learning curves are almost horizontal and the curve as a whole on log-log axes is not linear but a reversed 'S' shape.

III. Methodological Issues

The study uses the aggregate productivity trends in Pakistan economy for the period of 1953–2008. Since productivity may likely to be cyclical, hence the time period of selection tends to be important. If we start from a recession than the productivity result are flattering [62] and if we start from a boom the productivity record is poor [63]. Therefore, to find an S-shaped curve we selected relatively prosperous years. Nevertheless the phenomenon of cost reduction or productivity improvement with experience has generally been regarded as a purely empirical one [17].

We know that the best measure for labor input is the number of hours worked but, since no such data are available, employment figures has be taken as the second best measure, known as the labor productivity or output per person employed. At national level it is refer to as the aggregate labor productivity ratio of gross domestic product to employed labor force in the economy.

In Pakistan primary source of manufacturing data is the Census of Manufacturing Industries (CMI) conducted by the Federal Bureau of Statistics which is available in for most years since 1955. For the years in which CMI were not conducted we interpolated the series. Data for the capital input has been borrowed from Wizarat [47] where the details regarding computation of this variable have been discussed (pp. 72-74). Pakistan Economic Survey (PES) is another source of data. Additional sources of data are Pakistan Statistical Year Books and State Bank of Pakistan's annual reports.

IV. The Aggregate Learning Curve

We link the learning curve to both productivity and cost estimation. However, the aggregate learning curve is assumed to be S-shaped may not be symmetrical; the simplest way to estimate such a curve is with a cubic polynomial. Sometimes only part of cubic polynomial equation or simple parabola is of relevance in estimating all or part of the learning curve [8].

We have selected 15 years[2] for the cubic polynomial equation. The selection for these years are based on two criterions, *first*, the selected year must be a prosperous year, as judged by the growth rates[3] and *second*, the year should be one in which Pakistan has not gone through any turmoil. The reason for taking cumulative GDP instead of simple GDP was because cumulative experience gained by the economy in the initial year enabled economic agents to enter next year of production processes of the economy with cumulative GDP [8].

For the estimation of cubic polynomial, the procedure consists of creating new variables $CGDP^2$, $CGDP^3$ through transformation and then regressing GDP per person employed against a constant term, CGDP and against these transformed variables [8]. Its OLS estimated functional form is denoted by equation-1 of table–I.

Since the S-shape curve has two curvatures, one is below the inflection point and other above it. Consequently we assumed that heterogeneous task will be located in the lower half of the learning curve [56], and the retarded portion of the learning curve is above inflection point [8]. Subsequently, we used the mathematical modus operandi to find the relative maximum, relative minimum and inflection point of the S-curve.

The resulting S-shaped curve for gross domestic product per employed person is demonstrated in Figure-I. On the

[2] Based on observations for 1953-1954, 1955-1956, 1958-1959, 1962-1963, 196
4-1965, 1967-1968, 1972-1973, 1975-1976, 1979-1980, 1981-1982, 1984-1985, 1987-1988, 1991-1992, 1995-1996 , 2003-2004.

horizontal and vertical axis we have taken cumulative GDP and output per employed person of the economy respectively. Since the S-shape learning curve is based on cubic polynomial, thus the graph presented in the figure is an estimated based on 15 years values. All the estimated coefficients of OLS equation-1 show the statistical significance, as can be seen by the t-values. Nevertheless, the Durbin-Watson (DW) statistic is also reasonably good (1.52) and much higher than R^2 which suggests that regression is not spurious (see Table I).

We took first derivative of estimated equation -1 and set it equal zero to find root points by applying the quadratic formula. Later, we Substitute the values of two real roots in second derivative to find maxima and minima. We again set second derivate equal to zero for inflection point and found concavity changes between CGDP = -31.28525429 and CGDP = 73.59763524, therefore the inflection point is at CGDP = 21.15619048. The aggregate learning curve (Figure – 1) shows different phases of learning rates in diverse production processes of the Pakistan economy. The curve has highlighted these learning rates, with the demarcation of minima, maxima and inflection point. The identification of inflection point (21.16, 56.41) along with relative maxima (73.60, 106.89) and minima (-31.9, 5.93) are calculated by mathematical modus operandi.

The positive squared term (the coefficient, β_3 = 0.011107of cumulative gross domestic product, entails that output per employed person increased at an accelerated rate on the average until about 1980[4], the year where the inflection point exists, though the curvature of the curve is hardly noticeable before 1997. This implies that at the pre-inflection point,

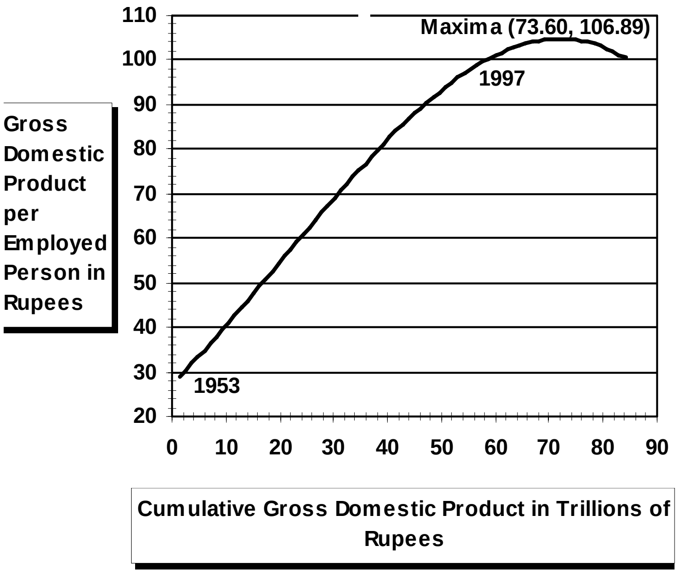

Fig. 1 Aggregate Learning Curves for Pakistan Economy 1953-2006 Rupees

Source: Computed from data given in the Pakistan Economic Various Issues

[4] The specialty of this year is that Pakistan switch form fixed to floating exchange rate and also the year of movement of Islamization of Commercial Banks.

TABLE I
LEARNING CURVES FOR GDP PER EMPLOYED PERSON IN 1999-2000 RUPEES

Explanatory Variables and Test Statistic	Regression Coefficients		
	Equation 1 (1953-2004)	Equation 2 (1981-1996)	Equation 3 (1981-1996)
Cumulated gross domestic product	1.208824 (7.893102)*	1.855227 (4.941299)*	
Cumulated gross domestic product squared	0.011107 (2.254074)**	-0.007950 (-1.62209)***	
Cumulated gross domestic product cube	-0.000175 (-4.380150)*		
Cumulated gross fixed capital formation			0.006635 (7.996465)*
Cumulated gross fixed capital formation squared			-1.17E-07 (-1.15390)
Annual percentage change in gross domestic product		0.644412 (2.023685)**	0.6422851 (2.012287) **
Constant term for the regression	27.52288 (25.48303)*	15.34100 (2.036662)**	49. 46995 (18.57641)*
R-square	0.9962	0.985045	0.984871
Durban-Watson statistic	1.52	1.688762	1.682110

Sources: Computed from data given in the Pakistan Economic Survey, and Census of Manufacturing Industry, various issues

Note: Values in parenthesis are t-values while Asterisk *, **, *** show level of significance at 1%, 5% and 10% respectively.

output per person employed increased at an accelerated rate on the average. Furthermore, this period revealed productivity has increasing returns as cumulative gross domestic product increases year by year. When we take the second derivate of the OLS equation 1, its sign changed from positive to negative (-0.00105) till 1980, revealing the presence of inflection point once again as the slope of the function changes. But eventually as we reach the coefficient of the cubed value which has a negative sign, demonstrating the fact that average output has been in the retarded portion of the learning curve since 1980. This is the phase which states that learning rates attached to production show decreasing returns, as productivity starts declining with higher level of output since 1980. We can conclude that the OLS equation is consistent with Thurstone [56] and Renshaw [8] hypotheses that the inflection point for a heterogeneous task are located in the lower half of the learning curve.

Moreover, the verification of inflection point is further judged by two ways, first to see the nearest two points at the inflection point (21.15619048) with a difference of ± 0.01, that are for pre-inflection (0.000010499) and post-inflection (-0.0000105) points in second derivative equation. Second, we put the value of inflection point again in the second derivative equation to see whether it is equal to zero or not. Hence it is proved that sign of the second derivative changes from positive to negative – the beginning of retardation in the productivity.

After reaching the inflection point, it is now possible to approximate the retarded portion of the learning curve with parabolic or polynomial of second degree equations. For this we added sequentially different variables along with the annual percentage changes in GDP in order to explore whether the relationship between productivity and growth trend is positive or negative. The selected variables for this are average annual percentage changes in GDP, and gross fixed capital formation.

V. The Parabolic Learning Curves

Since the inflection point (21.16, 56.41) starts from 1980, we can approximate the retarded portion of the learning curve with a simple parabola [8]. Furthermore, we have named it a parabolic learning equation of gross domestic product per employed person for the period started from the inflection point up till the curvature of the learning curve that is from 1980-81 to 1995-96.

The coefficients of the estimated equation 2, are given in table – 1, which do remarkably well in describing the behavior of gross domestic product per employed person. The squared term for cumulative gross domestic product has a negative coefficient that can be considered as statistically significant. This negative sign further strengthening our hypothesis that output per employed person was in a state of retarded growth well before the more noticeable slump in output per employed person since 1997. Here we added, average annual percentage change in GDP, because we know that output per person is cyclical and can be explained by including the average annual percentage change in GDP in our parabolic learning equations. The estimated coefficient for this variable is positive and also statistically significant. The implication is that it is much easier to increase output per employed person when the economy is perking up at a fast rate than when it is constricting or growing at a relatively slow rate [8].

We here again applied relative minima and maxima procedure for the parabolic equation-2. The real root of first derivative is 116.681, while the second derivative is negative (-0.0159) indicating that the function is relative maximum at value of 116.68. Now if we compare the values of relative maxima (106.89) of cubical equation with relative maxima (116.68) of parabolic equation, we find that the upper limit of parabolic equation is 9.16 percent greater than the upper limit of cubical equation for output per employed person. Hence, we again find that the economy was in the phase of retardation in post inflection period. The level of productivity in 1981 was 55.02 and this maximum (116.68) is about 112.07 percent greater.

The coefficients of the estimated equation-3, based on gross fixed capital formation (normalized by using the GDP deflators) as a proxy for investment do not explain the growth in labor productivity well during the fitted period 1981-1996. The negative sign of the coefficient on the square term indicates that one of the reasons for decrease in output per person employed during the fitted period is gross fixed capital formation. The growth in GFCF during the fitted period (1981-1996) was on average 5.45 percent compared to 3.98 percent for the period 1997-2008.

The better fit for the former period in terms of growth without any influence on productivity, shows that decline in investment in the later period and its possible effect on further slump in output per employed person. The most attractive difference between the two sub-periods is not on the decline in investment activity, but on the dramatic slump in the returns on many types of investment though the coefficient of the squared term is not highly significant[5]. The coefficient of annual percentage changes in gross domestic product is positive and statistically significant at the 10 percent level, indicating that the actual output during the period was rising and it is still easier to increase output per employed person when the economy is expanding. Therefore, retardation in productivity is not something that can easily be accredited to capital shortage or the paucity in investment opportunities in Pakistan.

During the 1960s in Pakistan the average growth rate of aggregate productivity was ever higher at 4.41 percent, even though there was significant shortage of highly educated and skilled people, most workers were able to obtain a substantial return on the given investment. In the later decades, aggregate productivity has declined. However, supply of educated and skilled workers have increased due to rise in demand in most specialized goods and services. All this shows there has been a noticeable drop in the average rate of return associated with their skills. Moreover, there has been a substantial reduction in the marginal rate of return in addition to the stock of human and business capital. This would help to explain the productivity slowdown since 1981 and it also suggests that it would not probably be possible to reverse the slowdown by simply investing more.

VI. Projected Percentage Changes in Output Per Employed Person

The column–2 of Table–II shows actual percentage changes in output per employed person (for the period 1996-97 to 2007-08) along with forecasted output per employed person (for the period 2008-09 to 2014-15) based on autoregressive order one model. On the other hand, the columns 2 and 3 show the projected increases in output per employed person for equation 2, and 3 respectively.

The projected values of equation-2 are based on the actual growth rates for gross domestic product and its cumulative sums. It will be noted that the actual increases in output per employed person have been a bit less than the projected increases, except for the years 1999-00, 2000-01, 2003-04, 2004-05, 2005-06, and 2007-08. The increases in other years were the recovery from economic recessions when productivity was probably not constrained by a shortage of productive capacity or by the existence of relatively unskilled labor force.

In more prosperous years, the increase in output per employed person has been consistently less than one would have expected on the basis of the parabola which best explains the behavior of labor productivity in the preceding 16 year period from 1980-81 to 1995-96. During the more recent 12 year period (1996-97 to 2007-08), the actual growth in labor productivity on the average is less by 0.07 percent than one

[5] The significances of the results are based on specification of the data which is not in our control.

would have expected on the basis of equation 3. This has also been the case with the projected time period values, that they will be lower than the actual forecasted on average by 0.12 percent.

Similarly, the projected values of equation–3 are based on the actual growth rates for gross domestic product along with the cumulative growth rates of gross fixed capital formation. It will be noted that the projected increases in output per

TABLE II
ACTUAL AND PROJECTED PERCENTAGE CHANGES IN GDP PER EMPLOYED PERSON (1996-97 TO 2014 -15)

Years	Actual Percentage Change in Output Per Employed Person (1)	Projected Percentage Changes in Output Per Employed Person	
		Equation-2 (2)	Equation-3 (3)
1996-97	-0.47	-1.45	-0.05
1997-98	-3.86	-1.06	-0.17
1998-99	-0.84	0.06	0.52
1999-00	1.58	0.59	0.74
2000-01	3.22	0.50	0.08
2001-02	0.90	1.10	0.59
2002-03	0.77	1.92	1.56
2003-04	4.68	3.04	2.54
2004-05	4.62	3.62	3.69
2005-06	4.19	3.30	3.32
2006-07	-2.35	3.07	3.14
2007-08	4.19	2.75	3.03
2008-09	1.56*	1.90	1.20
2009-10	1.54*	1.75	1.16
2010-11	1.51*	1.59	1.10
2011-12	1.49*	1.42	1.05
2012-13	1.47*	1.23	0.99
2013-14	1.45*	1.16	1.76
2014-15	1.43*	0.60	0.84

ource: Author's own calculations.
ote: The values of column 2 and 3 are estimated values based on equations 2, 3.

employed person (column – 4) have been less than the actual increases except for 1998-99, 2002-03, and 2006-07. These were the years when return on investment in terms of productivity increase was not high. The other reasons for the productivity shortfall might be the large influx of unskilled or inexperienced workers into the employed labor force since 1997, health of employed person due to increase in pollution and a rise in dishonesty, crime and lastly the under utilization of natural resources. Thus we cannot reject our hypothesis of retardation in the growth of labor productivity is due to its own law of diminishing returns.

The gross fixed capital formation averaged about 4 percent from 1996-97 to 2007-08 as compared with 5.45 percent for the preceding 16 year period (1980-81 to 1995-96). During the more recent 12 year period, the actual growth in labor productivity, on the average, has been almost 0.20 percent less vis-à-vis equation–3. The productivity increase, in other words, is something that can easily be attributed to capital availability or additional investment opportunities. This shows that there is still a possibility to increase productivity by effectively utilizing investment opportunities. But this will not be the case as suggested by the forecasted values that gross fixed capital formation will not help in increasing productivity in the future, that is on average it will be lower by 0.34 percent than the actual forecasted values.

In a nutshell, breadth of the slowdown in the growth of output per employed person would strongly suggest that the flex point in the aggregate learning curve for the Pakistan economy may not be much below one-half of the long run attainable output and that Pakistan's economy may now be much closer to the end of economic progress, unless care is taken to engage qualified and skilled people in research and development activities. The learning curve approach to productivity projections, however, does suggest that retardation in the growth of output per employed person may be subject to its own law of diminishing returns.

VII. THE LEARNING CURVE FOR COST

The learning curve for cost comprises average cost instead of total cost because average cost declining with cumulative experience across several years. Thus experience in the previous years enables the firm to revamp its production techniques in future years. Regression analysis that comprises costs and outputs of firms of varying sizes and experience, so it is important to use cumulative output rather than output during a given period to distinguish between learning effects and scale effects[6]. Thus the estimated equation 4 with double log functional form is [1] given in table – 3.

We used cost drivers other than cumulative production volume that affect average cost (e.g., capital stock, raw material), these other cost drivers included in equation (4) to distinguish between costs reductions that are due to learning and cost reduction that are due to economies of scale or favorable positions on the cost drivers. The variables vertical integration, capital stock, energy cost, raw material and wages have been normalized by using manufacturing, fuel and light, raw material and consumer price indexes respectively. Moreover, cost learning curve ensures the decrease in average costs per unit when the cumulative production level increases.

Similarly, economies of scale refer to the reduction in average costs attributable to increases in scale [10]. In other words, it is an ability to perform an activity at a lower cost when it is performed on a large scale at a particular point in time. According Besanko et al [1] economies of scale may be substantial even when learning economies are minimal, this likely be the case in simple capital intensive activities. Moreover, economies of scale also associated with marketing expense, research and development, and purchasing.

The results of regression analysis are mentioned in the Table–III, which is clearly indicating the existence of learning economies, i.e. the average cost declining with cumulative experience captured by cumulative output. This can be seen by the coefficient of cumulative output which is significant at the 1% level. The value of parameter (0.51) represents the

[6] Economies of learning differ from economies of scale. Economies of scale refer to the ability to perform an activity at a lower unit cost when it is performed on a larger scale at a particular point in time. Learning economies refer to reduction in unit costs due to an accumulated experience over time.

elasticity of average cost with respect to cumulative output, suggesting that cumulative output goes up by 1 percent, on average, the average cost goes down by about 0.51 percent explicitly there is a 0.51 percent learning rate in manufacturing sector of Pakistan.

Moreover, the negative sign helps in moving down the learning curve, so a firm enjoyed lower average cost level in year two of production. The level of average cost falls with cumulative experience across several years. Thus experience

TABLE III
LEARNING CURVES FOR AVERAGE COST

Log of Explanatory Variables and Test Statistic	Regression Coefficients	
	Equation 4	Equation 5 AR(1)
Cumulative Production Volume	-0.51 (-3.74)*	**-0.72** (-3.91)*
Wage Rate	1.30 (2.22)**	0.94 (1.07)
Energy Cost	-0.40 (-0.79)*	-0.02 (-0.04)
Raw Material	0.26 (0.62)	0.33 (0.59)
Capital Stock	0.08 (0.49)	0.15 (0.90)
Vertical Integration	0.64 (9.45)*	0.54 (6.52)*
Constant term for the regression	-6.70 (-2.56)**	-5.58 (-1.37)
R-square	0.94	0.95
F- statistic	109.49	121.16
Durban-Watson statistic	1.11	1.72

Note: Values in parenthesis are t-values while Asterisk *, ** show level of significance at 1%, and 5% respectively.

in the previous years enables the firm to revamp its production techniques in Pakistan. The initial model has the problem of autocorrelation as indicated by the value of Durban Watson test (1.11), thus in order to remove the problem of serial correlation we use the first order autoregressive iterative method selected on the basis of Schwarz information criterion. The result shows improvement in the learning rate, which is about 0.21 percent. Hence, the overall learning rate with autocorrelation corrected regression is about 0.71 percent. Moreover, the AR(1) procedure also indicates that the previous year average cost level does effect the current year's learning rate in term of lower average cost.

On the other hand, the variables for scale economies are included to check cost reduction due to economies of scale or favorable positions on cost drivers. The parameters of these variables are all insignificant except vertical integration and wage rate, which are significant at 5% and 1% levels respectively. The signs of these variables are also interesting, wage rate has a positive sign showing that wages increase the average cost of production and so does the raw material, capital stock and vertical integration. But surprisingly, the energy cost coefficient is negative showing that for every one percent increase in energy cost the average cost declines by 0.395774 percent on average. The reason of this might be that manufacturing has been using the energy efficient techniques of production along with more sophisticated machinery. Though t-value is showing the insignificance of the variable both with and without autocorrelation corrected regression.

All the results mentioned above give the impression that learning-by-doing phenomenon is very strong in Pakistan which even supersedes the conventional notion of economies of scale. The manufacturing sector some how manages to reduce the average cost with the joint efforts of managers and workers. The factors such as experience, motivation of workers, better organizational tactics, methods of manufacturing, etc, help firms to reap lower average cost in subsequent years. Two main reasons that contribute to economies of scale are indivisible inputs and factor specialization – specialized worker is a master of one task, one would say this is not true about the manufacturing sector of Pakistan. The other form of factor specialization in terms of work continuity and repetition is there, that is basically the learning-by-doing.

VIII. DIAGNOSTIC TESTS

TABLE IV
SPECIFICATION AND DIAGNOSTIC TESTS

Tests		Equation-1	Equation-2	Equation-3	Equation-4	Equation-5
Normality Test						
Jarque-Bera		1.749820 (0.416899)	1.186334 (0.552575)	1.404731 (0.495412)	0.918095 (0.631885)	0.984483 (0.611255)
Breusch-Godfrey Serial Correlation LM Test						
F-statistic	Lag 1	0.615854 (0.450783)	0.409162 (0.535490)	0.431379 (0.524816)	0.555509 (0.471701)	0.900719* (0.367376)
Observed R^2	Lag 1	0.870190 (0.350903)	0.573801 (0.448753)	0.603783 (0.437138)	0.769170 (0.380474)	1.364626* (0.242737)
F-statistic	Lag 2	0.874884 (0.449568)	2.335311 (0.147149)	2.275257 (0.153323)	2.439078 (0.137168)	1.664259* (0.248695)
Observed R^2	Lag 2	2.441589 (0.294996)	5.093851 (0.078322)	5.003825 (0.081193)	5.245980 (0.072586)	4.407263* (0.110401)
ARCH Test						
F-statistic	Lag 1	0.000039 (0.995143)	0.796858 (0.388260)	0.584530 (0.458196)	0.470630 (0.504749)	0.542653 (0.47440)
Observed R^2	Lag 1	0.000045 (0.994644)	0.866347 (0.351969)	0.645437 (0.421749)	0.524062 (0.469114)	0.601049 (0.43820)
F-statistic	Lag 2	0.571034 (0.582332)	0.292450 (0.752059)	0.216729 (0.808506)	0.186070 (0.832775)	0.569673 (0.58150)
Observed R^2	Lag 2	1.332507 (0.513629)	0.706835 (0.702284)	0.530759 (0.766915)	0.458135 (0.795275)	1.313979 (0.51840)
Ramsey's RESET Test						
F-statistic		0.928880 (0.357881)	0.341062 (0.570999)	0.314553 (0.586142)	0.091754 (0.767610)	1.674806 (0.222126)
Log Likelihood Ratio		1.332355 (0.248387)	0.488555 (0.484573)	0.451113 (0.501807)	0.132907 (0.715436)	2.267535 (0.132110)
White Heteroskedasiticity Test (Cross Terms)						
F-statistic		2.036694 (0.17320)	1.562532 (0.284974)	1.693828 (0.250734)	1.059946 (0.475939)	0.564924 (0.779643)
Observed R^2		9.065330 (0.16990)	10.25649 (0.247484)	10.55004 (0.228520)	8.764657 (0.362537)	6.277268 (0.616204)
Breusch-Pagan-Godfrey Heteroskedasiticity Test						
F-statistic		0.410478 (0.74870)	1.378566 (0.29660)	1.219250 (0.34510)	0.946206 (0.44900)	1.393938 (0.29230)
Observed R^2		1.510168 (0.67990)	4.100917 (0.25080)	3.737703 (0.29120)	3.060791 (0.38230)	4.134829 (0.24730)

Note: Values in parenthesis are pt-values.

In order to ensure that the estimated models are consistent with the standard OLS assumption, several diagnostic tests have been applied. Diagnostic tests were carried out for normality, serial correlation, model specification and for heteroskedasiticity. The results are reported in Table - IV.

In brief, the Breusch-Godfrey serial correlation LM Test, autoregressive conditional heteroskedasiticity (ARCH) and Ramsey RESET specification test overall verify the suitability of estimation and the normality test (Jarque-Bera) does show vigorous results. Likewise results also suggested by Breusch-Pagan-Godfrey test for heteroskedasiticity.

IX. Conclusion and Policy Implications

This study finds the learning pattern of Pakistan's economy at the aggregate level in general and the manufacturing sector in particular. For the aggregate economy we selected the S-shaped aggregate learning curve, which has been analyzed by the mathematical modus operandi of maxima, minima and inflection point. We found that learnings are below one half (pre-inflection point that is prior to 1980) of aggregate learning curve. The post inflection period (1981 to 1996) of aggregate learning curve suggests that retardation in productivity movements is due to reduction in labor learning. This finding suggests that irrespective of other factors labor learning is the key factor for improvement in productivity. Therefore learning should be high in order to improve the economy.

The learning curve approach to productivity projections, however, does suggest that retardation in the growth of output per employed person may be subject to its own law of diminishing returns. The policy implication of this finding is that the government along with private sector should concentrate on this by setting productivity targets on yearly basis, which can be possible only if the labor skill development factors are intact. Thus, it can be argued that the implementations of skill development policies in Pakistan are helpful in raising productivity.

The study finds 0.51 percent learning rate in the manufacturing sector of Pakistan, i.e. for every one percent increase in cumulative experience, on average, the average cost decreases by 0.51 percent. The empirical finding implies that learning-by-doing phenomenon has a significant role in the large scale manufacturing sector of Pakistan. The policy implication is that the employers must encourage workers in continual attainment of learning through training and development programs.

The potential areas of future research are indeed abundant in the learning curve area. Pakistan requires an urgent application of the learning curve in the areas delineated in the previous sections and also needs greater attention from academicians as well as practitioners.

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