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Measurement and Decomposition of Productivity Change in Pakistani Firms

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ABSTRACT

The main objective of this study is to measure and decompose changes in productivity and efficiency of firms using the annual data covering the period 2001-2020. It also observes whether the productivity and efficiency of firms have been increasing over time. The study employed the data envelopment analysis-based Fare-Primont total factor productivity (TFP) index developed by O'Donnell (2010). The estimates show that total factor productive efficiency (TFPE) progress is major component during the examined period which decreases the negative impact of technological regress. In addition, the estimates show that the TFP of firms increases over time in Pakistan except 2019 and 2020. Further, our results indicate that firms have to focus on technical efficiency because it is major factor that influencing the TFPE progress, and reducing the positive impact of mix efficiency and residual scale efficiency. Furthermore, the results demonstrate that on average, the TFP of automobile assembler industry is greater than automobile parts and accessories, cement, and sugar industry. Finally, the estimates show that changes in technology have significant impacts on the TFP. Overall, the findings recommend that the government is required to provide incentives and cost-effective technologies that enhance the productivity and efficiency of firms because productivity enhancement is a prerequisite condition for sustainable economic development.

1 Introduction

Efficiency and productivity growth investigation at firm level has fascinated substantial devotion in the economic growth literature by policymakers all over the world (Martinez Cillero et al., 2019; Dakpo et al., 2019; Ilyas & Rajasekaran, 2020). By improving productivity, firms can expand their market share and competitiveness. It is hard to manage for a state to achieve prosperity without achieving an extensive growth in productivity. Therefore, it is worthwhile to measure changes in efficiency and productivity of firms. In general, efficiency change and technological change may be used to decompose total factor productivity (TFP). The prior one can be fragmented into further three components, technical, mix and residual scale efficiency. Scrutiny of TFP subcomponent will assist to know when, why, and how changes in TFP. Moreover, the assessment of different sector concerning variations in efficiency and productivity will develop our perception regarding the vital function of different sectors in the growth of an economy.

Productivity is vital for all economic and financial sectors. Generally, it is claimed that productivity growth generates funds and increases government revenue, which subsequently results in an increased living standard and better public services for the people. From an economist's viewpoint, productivity is very significant for the economic development of the state and in creating employment levels and rising income for all segments of the society. From an enterprise perspective, productivity growth empowers the firm to convert into further competitive and to upsurge people's standards of living (Chen et al. 2022). Wright (2011) is of the view that a more productive firm has enough money and power to give higher remuneration to its workers, which increase their consumption ability and subsequently increases their standard of living. On the other side, at the same time, a productive and efficient firm can decrease the output prices of the firm's, hence escalating their products' utility (Giang et al. (2019).

Reviewing the empirical literature, we find that the prior empirical studies that scrutinized the efficiency and TFP change in the manufacturing sector enumerated without price data either implement Malmquist productivity index (MPI), Fare-Primont index (FPI), or Hicks-Moorsteen productivity index (HMI). These indexes may be described by using output or input-orientated distance functions. It compares ratios of outputs with inputs across units. It is observed that all the studies that evaluate the TFP improvement of the manufacturing, insurance, and banking sector frequently use the MPI. Raheman et al. (2009), Sufain (2010), Noreen and Ahmed (2016), Naz et al. (2017), Miao (2018), Martinez Cillero and Thorne (2019), Saleem et al. (2019), Wang et al. (2020), Abad and Arias (2022), and Chen et al. (2022), which demonstrates its prime supremacy in the literature to scrutinize TFP progress. Though, there are abundant studies in the literature demonstrating that the MPI has some drawbacks in its implementation. For instance, Grifell-Tatje and Lovell (1995) demonstrate in the variable return to scale (VRS) assumption, the MPI can not exactly evaluate a productivity change. Likewise, Glass and McKillop (2000) claim that there is the possibility of getting infeasible outcomes. Additionally, Coelli and Rao (2005) illustrate that the DEA approach, which uses MPI to evaluate distance functions, is flawed. The MPI decomposition proposed by Fare et al. (1994) is also shown by O'Donnell (2012) to be inconsistent. Lastly, Arjomandi et al. (2012) demonstrated that the MPI give rise to biased assessments.

Above insufficiencies, persuading in the MPI debate, two other indexes, Fare-Primont index recommended by O'Donnell (2012) and HMI suggested by Bjurek (1996) are used for measurement of TFP. They are more consistent and reliable as compared to MPI and can be further decomposed into recognizable components without requiring any restrictive assumptions regarding statistical noise and data on prices. However, amongst two indexes O'Donnell (2012) claimed that, concerning reliability, the HMI is less reliable than the FPI, because the latter may be adapted to estimate more reliable multi-temporal and multi-lateral evaluations. The HMI fails to pass the transitivity test. It may usually be used for a single binary comparison.

We utilize the Fare-Primont index to assess the efficiency and productivity of firms in Pakistan while keeping in mind the significance of TFP. The Fare-Primont index decomposes productivity into change in efficiency and technological advancement without suffering from the above-mentioned problems. After finding the prior one, we split efficiency into technical, mix and residual scale to conclude the most important components of productivity decline and advancement of firms working in Pakistan. Lastly, we do the assessment of different sector based on calculated productivity changes and different segments of efficiency and productivity.

The performance of enterprises has been attempted to measure by Naz et al. (2017), Saher et al. (2019), Khan et al. (2019), and Nasir and Nawaz (2021). To the best of our knowledge, no study has used the Fare-Primont index to analyze how productivity has changed in Pakistani enterprises. Yet, it is worthwhile to determine that whether the TFP of firms is growing over time. It is important to recognize the efficiency score of different firms belonging to different industries. It is advisable to identify whether total factor productivity changes are credited to technology changes and/or efficiency changes. Further, it is worthwhile to know that if there is a lack of productive efficiency in the firm what are their sources whether it will be attributed to technical inefficiency, mix inefficiency, residual scale inefficiency.

The main objective of this study is to conduct an empirical investigation of the manufacturing sector in Pakistan, to evaluate its productivity for the period 2001-2020. The study adds to the body of literature in a number of ways. Firstly, it is the first research to use the Fare-Primont index to measure efficiency of firms in Pakistan's manufacturing sector. Secondly, it adopts a latest linear programming approach that O'Donnell proposed in order to evaluate and separate the TFP into efficiency change and technical change. The first is divided into three categories: mix, technical and residual scale efficiency change. Thirdly, by examining the various TFP change and efficiency change components, this paper gives empirical evidence, that is extremely important to regulators and the firm's management for the effective use of available resources and capacities for the improvement of firms' efficiency and productivity. Decomposition analysis of productivity and efficiency also enables us to more clearly understand how changes in productivity and efficiency are brought about by business policies.

Our estimates show that TFPE progress is major component during the examined period, which decreases the negative impact of technological regress. Our results indicate that firms have to focus on technical efficiency because it is the major factor that decreases the TFPE progress, and lower the positive impact of mix efficiency and residual scale efficiency. Further, our estimates show that in general the TFP of firms increases over time in Pakistan except 2019 and 2020. Furthermore, the results demonstrate that on average, the TFP of automobile assembler industry is greater than automobile parts and accessories, cement, and sugar industry. Finally, the estimates show that technologies change has noteworthy impact on the TFP. Overall, the findings recommend that the government is required to provide incentives and cost-effective technologies that enhance the productivity and efficiency of firms because productivity enhancement is a prerequisite condition for sustainable economic development.

The rest of paper is structured as follows. Review of literature is presented in Section 2. Section 3 present the empirical framework and data. Section 3 presents the empirical results and their discussion.

2 Literature Review

To evaluate how well businesses are performing, several studies have been conducted. The majority of them used the Malmquist productivity index (MPI), Fare-Primont index (FPI), or Hicks-Moorsteen productivity index (HMI) to analyze the efficiency and productivity change in enterprises computed without pricing data. We note that the MPI is widely used in all research that assess the TFP improvement of the industrial, insurance, and banking sectors. Raheman et al. (2009), Sufain (2010), Noreen and Ahmed (2016), Naz et al. (2017), Kong et al. (2019), Shah et al. (2022), and Chen et al. (2022)), which demonstrates its prime supremacy in the literature to scrutinize TFP progress.

Fare et al. (1992) amalgamated the productivity measure proposed by Caves et al. (1982) as a theoretical index with the efficiency measure suggested by Farrell (1957), as a result, proposed the MPI which measures changes in productivity. Further, the easily decomposed the suggested TFP index into two components, technological and efficiency change. Subsequently, Fare et al. (1994) demonstrated that the measure efficiency changes can be further separated into different components, scale and technical efficiency changes. Ultimately, this development made MPI as a most popular index to evaluate productivity change.

Regardless the MPI status as a leading method and its fame for measuring productivity development, both its positive and negative elements has been vigorously debated. For instance, Grifell-Tatje and Lovell (1995) found that when we use variable return to scale (VRS), TFP modifications are not accurately evaluated using MPI. Hence, for the adoption of MPI the imposition of constant return to scale (CRS) become essential. If not, MPI's resulting approximation produces unworkable output. The MPI decomposition produced by Fare et al. (1994) was shown to be unreliable by Wheelock and Wilson (1999). Although it cannot evaluate the scale impacts at all, Ray and Desli (1997) emphasized the relevance of the execution of CRS technology, which illustrates the frontier shift under CRS and is symbolized by the phrase technological change. The VRS assumptions implementation, on the other hand, might not accurately capture the autonomous frontier change. Therefore, Ray and Desli (1997) suggested a different decomposition however the trouble with such decomposition is that it may not properly measures change in scale efficiency.

Coelli and Rao (2005) verified the importance CRS assumption to evaluate MPI, their investigation indicates that without CRS assumption in MPI we cannot correctly evaluate TFP change as a result of scale economies. Famous MPI, which is frequently used in literature, has been shown by Epure and Prior (2007) to be multiplicatively biased and incomplete. By demonstrating that, with few exceptions, the MPI cannot be utilized as a trustworthy metric to compute TFP changes, O'Donnell (2012a) cast more doubt on its ability to assess TFP. Similar opinions are held by O'Donnell (2010) and Kerstens et al. (2010) that trustworthy TFP indexes do not include the Malmquist index.

The above insufficiencies, existing in the MPI argument, there is an increasing trend for using Hicks-Moorsteen productivity index to evaluate productivity (Wright (2011), O'Donnell (2012), Arjomandi et al. (2014), Rashid and ur Rehman (2016), Wabuyabo (2017) and Hemathilake Weerasekara (2020)). Epure et al. (2011) showed that banks have been observed the increasing trend of TFP after the deregulation in the banking sector. Similarly, Arora and Arora (2012) compare productivity improvement results for banks in India. His finding shows that Indian banks have examined improvement in productivity, on average, after liberalization. With regard to productivity growth, his findings represent that, NBs have privileged productivity enhancement as contrast to SBIG, which is generally as a result of superior technological enhancement adopted by NBs.

In the same way, Arora and Arora (2013) measured productivity change for post liberalization period. His findings confirm that in three sub-period banks in India have no significant productivity change differences. Further, his findings show that scale efficiency is impacted by ownership differences in banks. Similarly, for Iran, Arjomandi et al. (2012) examined the consequences of reform on the productivity and efficiency covering the period 2003-2008 and find that after the reform overall TFP declines in Iranian banks which is generally credited to change in scale efficiency and shift in production possibility set. Further, their outcomes illustrate that after the reforms technical efficiency deteriorated which was improving over time. Arjomandi et al. (2014) by using operating method indicate that private banks are more mix and technically efficient. Hicks-Moorsteen index got popularity to measure productivity in different sectors of economy in last few years but they have to fail to satisfy the transitivity test.

The above inadequacies, existing in the MPI and Hicks-Moorsteen index, there is an increasing interest for employing the Fare-Primont index to measure productivity nowadays but mostly it is used in agriculture, water, energy, and insurance sector. (O'Donnell (2012, 2014), Balezentis (2015), Khan et al. (2015), Molinos-Senante et al. (2017), Nguyen et al. (2019), Thorne and Cillero (2019), Dakpo et al. (2019a, 2019b), Ilyas and Rajasekaran (2020), Thayaparan et al. (2022), and Temoso and Myeki (2023)).

The Fare-Primont index as suggested by O'Donnell (2012), is the ratio of two indices calculated by Fare and Primont (1995). It is perfect in the sense that it fulfills the entire test and relevant axioms associated to index number theory including a transitivity test and an identity axiom. All other indices generally used to make an assessment among two observations only and fail to do the transitivity test (O'Donnell (2012)). There is very little evidence in adopting this index, over the period, for computing the growth in productivity and the related components, so confirming the gap in the existing literature.

Khan et al. (2015) analyzed the total factor productivity for the period 1990-2011 for Australian agriculture. Their results indicate a progress in the average productivity of broadacre agriculture is very minor over the examined period. The main reason behind declining improvement in productivity growth appeared through technical regress comparative to efficiency change. Their results further indicate that mix and scale efficiency improvement is the main reason for efficiency and productivity improvement. Similarly, Molinos-Senante et al. (2017) looked at the productivity of the water business between 2001 and 2008 in both English and Welsh. Their findings recommend that concerning productivity water industry performance enhance in both countries, which can be attributed to efficiency gains. However, over time, the performance of the water industry declined in both economies, which can be credited to the dominant impact of regress in the change in technology in both economies which absorbed the impact of efficiency gains. In the same way, Dakpo et al. (2019) analyzed the productivity of cow farms by using data from 1990 to 2013. Their results illustrated that farms on average experienced pollution-adjusted productivity shrink which is fundamentally credited to technical efficiency and a little bite due to turn down in technological regress.

Cillero and Thorne (2019) attempted to explore the Irish beef sector over the period 2010 to 2016 by clustering it into seven clusters. They found that five of the classes out of seven concerning productivity, indicating enhancement in total factor productivity growth while the remaining two are indicating total factor productivity regress. Likewise, Dakpo et al. (2019) investigated the productivity change in the French beef production industry for three decades. Their results show productivity enhancement is frequently associated with technological improvement and various approaches have consistent in their results but with different magnitude. In the same way, Ilyas and Rajasekaran (2020) analyzed the productivity of non-life insurance sector. They found that overall, the level of productivity increase during the study period which is mainly attributed to the dominant impact of mix and scale efficiency enhancement. Their results further indicate that concerning productivity, privately insurers are performing well as compared to state-owned insurers.

3 Estimation Method

The definition of TFP employed in this study, is $TFP_{nt} = Q_{nt}/X_{nt}$, where TFP_{nt} represents the TFP of a firm 'n' in period t, $Q_{nt} = Q(q_{nt})$ indicates an aggregate output, and $X_{nt} = X(x_{nt})$ indicates aggregate input. This definition of TFP was adopted from preceding studies such as Jorgenson and Grilliches (1967) and O'Donnell (2010). In time s, the same equation can be maintained for a new firm called 'n'. In that case, the index quantity is said as the relationship between the TFP of firm 'n' in period 't' with the TFP of firm 'n' in period 's' is described as

$$TFP_{ns,nt} = \frac{TFP_{nt}}{TFP_{ns}} = \frac{Q_{nt}/X_{nt}}{Q_{ns}/X_{ns}} = \frac{Q_{nt}/Q_{ns}}{X_{nt}/X_{ns}} \quad (1)$$

where $Q_{ns,nt} = Q_{nt}/Q_{ns}$ and $X_{ns,nt} = X_{nt}/X_{ns}$ are output and input quantity index, correspondingly. This explanation permits us to describe the index that defines change in TFP as the fraction of an output to an input quantity index. The Fare-Primont TFP suggested by O' Donnell (2010) is the index that consisted with the above explanation and can be evaluated without price data.

Explicitly, the Fare-Primont index may be represented as

$$TFP_{ns,nt} = \left(\frac{D_o(x_o, q_{nt}, t_o)}{D_o(x_0, q_{ns}, t_o)} \times \frac{D_I(x_{ns}, q_o, t_o)}{D_I(x_{nt}, q_o, t_o\,)}\right) \quad (2)$$

where $D_O^T(x,q) = min(\delta > 0 : (x, q/\delta) \in P^T)$ output distance function, $D_I^T(x,q) = max(\rho > 0 : (x/\rho, q) \in P^T)$ represents input distance function, and P^T denotes the time T production possibilities set. For the purpose of calculating these distance functions, we use the non-parametric DEA method advocated by O'Donnell (2010a, 2012a, and 2010b), Khan et al. (2015), Maziotis et al. (2017), Ilyas and Rajasekaran (2019), Dakpo et al. (2019), Thayaparan et al. (2022), and Temoso and Myeki (2023). The DEA does not need any obstructive expectations about business behavior, and efficiency distribution.

According to O'Donnell (2010b), a firms total production efficiency (TFPE) is defined as the fraction of apparent TFP to utmost TFP that can be achieved by utilizing the technology available in period t. The TFPE of company 'n' in period t is therefore defined as:

$$TFPE_t = \frac{TFP_{nt}}{TFP_t^*} = \frac{Q_{nt}/X_{nt}}{Q_{nt}^*/X_{nt}^*} \quad (3)$$

As TFP_t^* signify the utmost TFP and Q_{nt}^* and X_{nt}^* represent maximum point of aggregate output and input, correspondingly. O'Donnell (2012) explains that diverse efficiency procedures can be adopted for TFP efficiency decomposition. However, the decomposition of TFP efficiency can be defined as

$$TFPE_{nt} = \frac{TFP_{nt}}{TFP_t^*} = ITE_{nt} \times IME_{nt} \times RISE_{nt} \quad (4)$$

This can be written as

$$TFP_{nt} = TFP_t^* \times ITE_{nt} \times IME_{nt} \times RISE_{nt} \quad (5)$$

where $ITE_{nt}, IME_{nt}, and\ RISE_{nt}$ signify the input-oriented technical, mix, and residual scale efficiency, while ITE_{nt} (Technical Efficiency) find out TFP growth, which have been attained by holding input mix, output mix and output level constant. IME_{nt} (Mix Efficiency) determine TFP growth achieved by comforting restrictions on output mix white holding input constant. Lastly, $RISE_{nt}$ (Residual Scale Efficiency) shows TFP growth which is mainly achieved by firm movement on the production frontier, from technically efficient spot to feasible maximum productivity point.

A new firm n in time s can use the same equation. In that case, the index quantity that connects the TFP of firm 'n' in time 't' with the TFP of firm 'n' in time 's' is described as

$$TFP_{nt} = \left(\frac{TFP_t^*}{TFP_s^*}\right)\left(\frac{ITE_{nt}}{ITE_{ns}} \times \frac{IME_{nt}}{IME_{ns}} \times \frac{RISE_{nt}}{RISE_{ns}}\right) \quad (6)$$

The first parenthesis of equation defines the technical change assessing the differences of the maximum TFP achievable with the technology achievable in period's t and s. correspondingly, dependent on whether TFP_t^*/TFP_s^* is greater or less than 1. We can evaluate the technical enhancement or technical retreat. The outstanding of the parenthesis evaluate technical efficiency, mix efficiency, and residual scale efficiency change.

3.1 Data and Sample

Regarding how to specify inputs and outputs for non-financial listed firms, the scholars do not agree. However, we have conducted a thorough assessment of the available literature to describe inputs and outcomes. (Raheman et al., 2009; Baležentis, 2015; Naz et al.; 2017; Miao, 2018; Nguyen et al., 2019; and Kong et al., 2021) among others. After reviewing the literature, we have selected those variables that have already been used in most of the researches. In this study, we use total sales of firms as a measure of output. Shareholders' equity, total assets, operating expenses, and cost of goods sold are used as input. This approach has been used by many pieces of research, for example, Raheman et al. (2009), and Naz et al. (2017). This approach includes four inputs and one output.

Four inputs include the cost of goods sold (X_1), we measured it by the cost of labor, raw material, and factory overhead; operating expenses (X_2), total assets (X_3), and shareholder's equity (X_4), we measured by the net worth of a firm. Our outputs variable is sale revenue (Y_1).

Data are acquired from firms' annual reports spanning a period 2001-2020. Our selection of firms depends upon the availability of data. We apply the software DPIN suggested by O'Donnell (2012) for achievement of all estimates.

4 Empirical Results

This section presents the results of the firms' measurements of TFP variation and its decomposition, which consist of technological variation and efficiency variation for manufacturing industry. Additionally, Efficiency change is separated into three components. First one is technical efficiency change, second one is change in mix efficiency change, and third is a change in residual scale efficiency. Table 4.1to 4.5 contains the estimations. The anticipated values less than 1 represent worsening in productivity, whereas, anticipated values greater than 1 represent productivity improvement.

Table 4.1

Changes in Total Factor Productivity for Automobile Assembler

	Period	dTFP	dTech	dTFPE	dITE	dIME	dRISE
Automobile Assembler	2001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	2002	1.0490	1.0024	1.0465	1.0061	1.0203	0.9991
	2003	1.1419	1.0575	1.0799	0.9921	1.0500	1.0348
	2004	1.2165	1.0609	1.1467	0.9879	1.0807	1.0723
	2005	1.2002	1.0325	1.1624	1.0082	1.0651	1.0801
	2006	1.1872	1.0160	1.1686	1.0096	1.0707	1.0789
	2007	1.1677	1.0146	1.1509	1.0042	1.0638	1.0749
	2008	1.1505	1.0110	1.1379	0.9978	1.0661	1.0665
	2009	0.9954	1.0505	0.9476	0.9884	0.9449	1.0067
	2010	1.0796	1.0535	1.0248	1.0057	1.0286	0.9738
	2011	1.0527	0.9821	1.0719	1.0009	1.1210	0.9601
	2012	1.0150	1.0261	0.9893	1.0062	1.0935	0.9145
	2013	1.0107	0.9541	1.0593	1.0018	1.1207	0.9611
	2014	1.0751	0.9708	1.1074	1.0005	1.1062	1.0019
	2015	1.0475	0.9996	1.0479	1.0056	1.1052	0.9588
	2016	1.0646	1.0144	1.0494	0.9981	1.1078	0.9674
	2017	1.0996	1.0513	1.0459	0.9940	1.0934	0.9829
	2018	1.0760	1.0199	1.0549	0.9936	1.1040	0.9855
	2019	1.0074	1.0440	0.9649	0.9894	1.0551	0.9769
	2020	0.9306	0.9120	1.0204	0.9658	1.2064	0.9836

Our results suggest that overall TFP improvement in Automobile assembler industry which is mainly attributed to TFPE improvement. However, during 2009 and 2020 TFP of Automobile assembler industry decrease. In 2009 TFP of firms decrease which is mainly attributed to decrease in total factor productive efficiency during 2009 and the reason behind this decrease in TFPE is mainly attributed to decrease in technical and mix efficiency during this period. Our result during 2020 point out that technological decline is a main reason behind the underperformance of TFP and it dominate the positive impact of TFPE. Further, our results are giving clear evidence that the role of technological progress during the examined period was negative which indicate that over the examined period it contributes negative role in total factor productivity. However, this negative impact of technological regress is dominated by the positive impact of efficiency in this industry during the study period.

Based on our empirical analysis, concerning automobile industry, our results shows productivity expansion throughout the study period, excluding the period 2009 and 2020 in which we finds productivity revert. This decrease is largely credited to TFPE during 2009 and in 2020 it is credited to technological decline. These results are in harmony to the findings of Shah et al. (2022), Kong et al. (2021), Miao (2018), Casu et al. (2013), and Figueria et al. (2009). These outcomes further show that most important rationale behind the productivity regress (growth) that is need to be highlighted is TFPE regress (progress). Further, our findings show an improvement in productivity has been noticed during study period and it emerges that the essential factor behind this was TFPE progress which dominates the negative impact of technological regress during the examined period. This result is consistent to the presented literature, for the most part Shah et al. (2022), Kong et al. (2021), Miao (2018), Arora and Arora (2012), and Sufain (2008). In particular, these researches found parallel outcomes for Saudi Arabian, Nepalese, Malaysian, Sri Lankan, Indian, Pakistanis, European, and Chinese firms. Therefore, the change in the environments could be resulted in to any change in the production possibilities set. Consequently, technological change expresses the consequences of technological modification as well as the impact of government regulations and policies.

Table 4.2

Changes in Total Factor Productivity for Automobile Parts and Accessories

	Period	**dTFP**	**dTech**	**dTFPE**	**dITE**	**dIME**	**dRISE**
Automobile parts and Accessories	2001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	2002	0.9823	0.9397	1.0453	1.0012	1.0027	1.0412
	2003	1.0304	0.9740	1.0579	1.0012	1.0255	1.0304
	2004	1.0375	1.0459	0.9919	1.0012	1.0136	0.9781
	2005	1.0049	0.9922	1.0129	0.9975	1.0033	1.0125
	2006	1.0168	1.0418	0.9760	0.9874	0.9872	1.0017
	2007	1.0043	1.0052	0.9991	0.9966	0.9857	1.0170
	2008	0.9751	0.9681	1.0072	0.9963	1.0038	1.0070
	2009	0.9621	0.9598	1.0024	0.9977	1.0262	0.9788
	2010	1.0011	1.0166	0.9848	1.0012	0.9975	0.9869
	2011	0.9882	0.9628	1.0264	1.0012	1.0245	1.0005
	2012	0.9999	0.9756	1.0249	1.0012	1.0098	1.0137
	2013	0.9761	0.9144	1.0675	1.0012	1.0337	1.0314
	2014	0.9766	0.9327	1.0470	0.9950	1.0364	1.0153
	2015	0.9988	0.9566	1.0441	0.9985	1.0298	1.0153
	2016	1.0407	1.0052	1.0353	1.0012	1.0194	1.0144
	2017	1.0260	0.9603	1.0684	1.0012	1.0293	1.0367
	2018	0.9771	0.9476	1.0312	0.9953	1.0159	1.0198
	2019	0.9499	0.9214	1.0309	1.0010	0.9934	1.0369
	2020	0.9096	0.8625	1.0546	0.9996	1.0167	1.0376

Based on our empirical analysis regarding automobile part and accessories industry, our results suggests that overall TFP improvement in automobile part and accessories industry is mainly attributed to TFPE improvement. Our results further giving clear evidence that the main reason behind the productivity regress in 2002, 2008, 2009, 2011, 2012, 2013, 2014, 2015, 2018, 2019, and 2020 is technological regress which dominates the positive impact of TFPE during these periods.

Table 4.3

Changes in Total Factor Productivity for Cement

	Period	dTFP	dTech	dTFP	dITE	dIME	dRISE
Cement	2001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	2002	1.0699	0.9904	1.0803	0.9978	1.0082	1.0724
	2003	1.0102	0.9298	1.0866	1.0203	1.0039	1.0597
	2004	1.1536	1.0986	1.0500	1.0037	1.0088	1.0363
	2005	1.1496	1.1002	1.0449	1.0070	1.0051	1.0316
	2006	1.2193	1.2524	0.9736	0.9913	1.0045	0.9783
	2007	0.9416	1.0371	0.9079	0.9966	0.9358	0.9747
	2008	0.9707	0.9512	1.0203	0.9937	0.9839	1.0446
	2009	1.1454	1.1224	1.0205	0.9977	0.9810	1.0418
	2010	0.9328	0.9943	0.9377	0.9520	0.8634	1.1823
	2011	1.0234	0.9931	1.0305	0.9820	0.9890	1.0620
	2012	1.1646	1.1561	1.0074	0.9968	0.9962	1.0168
	2013	1.2097	1.2397	0.9758	0.9871	1.0848	0.9945
	2014	1.1963	1.1779	1.0156	0.9919	1.0013	1.0282
	2015	1.1767	1.1367	1.0352	1.0020	1.0229	1.0097
	2016	1.2395	1.2272	1.0100	0.9961	1.0127	1.0033
	2017	1.1783	1.1741	1.0036	1.0010	0.9763	1.0301
	2018	1.0369	1.0481	0.9894	0.9919	0.9716	1.0282
	2019	0.9652	0.9771	0.9878	0.9849	0.9865	1.0087
	2020	0.7869	0.9225	0.8530	0.9871	0.8620	1.0050

Our results regarding Cement industry shows that overall TFP improvement in industry which is attributed to TFPE and technological improvement which absorb the negative impact, if in any year, of the counterpart component except in 2007 and 2008. However, during 2010, 2019, and 2020 TFP of a Cement industry decrease and the reason behind this decrease in TFP was TFPE regress and technological regress during these years.

Table 4.4

Changes in Total Factor Productivity for Sugar

	Period	dTFP	dTech	dTFP	dITE	dIME	dRISE
Sugar	2001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	2002	0.9875	1.0676	0.9245	0.9551	0.9636	1.0029
	2003	0.9851	1.0049	0.9803	0.9710	1.0106	0.9989
	2004	0.9875	0.9927	0.9948	0.9772	1.0128	1.0048
	2005	1.0128	1.0814	0.9366	0.9857	0.9927	0.9588
	2006	1.0067	1.0081	0.9986	0.9722	1.0231	1.0014
	2007	0.9476	0.9783	0.9686	0.9526	1.0025	1.0124
	2008	1.0081	0.9913	1.0170	0.9663	1.0182	1.0329
	2009	1.0421	1.0448	0.9973	0.9544	1.0128	1.0307
	2010	1.0254	1.0309	0.9947	0.9832	0.9915	1.0203

2011	1.0316	1.0060	1.0254	0.9955	1.0146	1.0154
2012	1.0091	1.0604	0.9517	0.993	0.9654	0.9937
2013	0.9932	0.9800	1.0135	0.9861	0.9886	1.0372
2014	0.9952	0.9817	1.0137	0.9761	1.0098	1.0267
2015	0.9697	0.9630	1.0069	0.9770	0.9994	1.0316
2016	0.9742	0.9656	1.0088	0.9767	1.0234	1.0071
2017	0.9379	0.9569	0.9802	0.9763	0.9994	1.0045
2018	0.9296	1.0383	0.8954	0.9658	0.9646	0.9666
2019	0.9575	1.0042	0.9535	0.9805	1.0047	0.9648
2020	0.9512	1.0078	0.9439	0.9654	0.9889	0.9909

Our results regarding Sugar industry shows that overall TFP regress in industry as compared to other industries which is attributed to TFPE regress during the study period which absorb the positive impact of the counterpart component except, 2004, 2007, and 2017 TFP of a Cement industry decrease, and the reason behind this decrease in TFP was TFPE regress and technological regress during these years. In all others year, our results shows that if one component of TFP is showing progress other component is showing regress.

Table 4.5

Changes in Total Factor Productivity for overall industry

	Period	dTFP	dTech	dTFP	dITE	dIME	dRISE
Overall industry	2001	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
	2002	1.0222	1.0000	1.0242	0.9901	0.9987	1.0289
	2003	1.0419	0.9916	1.0512	0.9962	1.0225	1.0310
	2004	1.0214	0.9972	1.0251	0.9954	1.0071	1.0200
	2005	1.0214	0.9972	1.0251	0.9954	1.0071	1.0200
	2006	1.0267	0.9965	1.0314	0.9943	1.0088	1.0249
	2007	1.0153	1.0088	1.0066	0.9875	0.9970	1.0198
	2008	1.0261	0.9804	1.0456	0.9885	1.0180	1.0378
	2009	1.0363	1.0444	0.9920	0.9846	0.9912	1.0145
	2010	1.0097	1.0238	0.9855	0.9855	0.9703	1.0408
	2011	1.0240	0.9860	1.0386	0.9949	1.0373	1.0095
	2012	1.0472	1.0546	0.9933	0.9993	1.0162	0.9847
	2013	1.0474	1.0221	1.0290	0.9941	1.0570	1.0061
	2014	1.0608	1.0158	1.0459	0.9909	1.0384	1.0180
	2015	1.0482	1.0140	1.0335	0.9958	1.0393	1.0039
	2016	1.0798	1.0531	1.0259	0.9930	1.0408	0.9981
	2017	1.0605	1.0357	1.0245	0.9931	1.0246	1.0136

2018	1.0049	1.0135	0.9927	0.9867	1.0140	1.0000
2019	0.9700	0.9867	0.9843	0.9890	1.0099	0.9968
2020	0.8946	0.9262	0.9680	0.9795	1.0185	1.0043

Based on our empirical analysis, our results for overall four industries suggests TFP progress during the study period, except 2019 and 2020, the major reason behind this progress was some time progress of TFPE and sometime due to technological progress and sometime due to both factors. Further, our results showing that in 2019 and 2020 TFP of firms decrease and the reason behind this decrease in TFP is mainly attributed to decrease in both TFPE change and technological change during this period.

5 Summary and Concluding Remarks

In this study we adopted the DEA-based Fare-Primont TFP index decomposition recommended by O'Donnell (2012). The benefit of using this method, which is better than HMPI and MPI is that it doesn't need any assumption concerning the market structure, the behavior of firms, return to scale in several input and output case.

The key findings can be summarized as follows. First, overall, the TFP of firms improve over time in Pakistan. Second, during the examined period no new technology is adopted by firms. Finally, the empirical findings show that variations in TFPE have considerable effect on TFP, and they are positively linked with one another.

Our study suggests that scale efficiency has a core presence behind efficiency improvement in automobile business sector. Hence, automobile sector would require expanding of their firm size to obtain persistent productivity rewards. Their performance could be more proficient during technological improvement. Further, administration should encourage firms to use latest cost-effective technologies for the assistance of automobile industry to reduce the issues concerning to inefficiency and enhance productivity further.

References

Abad, A., & Arias, M. (2022). Environmental Productivity Analysis: An Illustration with the Ecuadorian Oil Industry.

Arjomandi, A., Harvie, C., & Valadkhani, A. (2012). An emperical analysis of Iran's banking performance. *Studies in Economics and Finance, 29*(4), 287-300.

Arjomandi, A., Valadkhani, A., & O'Brien, M. (2014). Analysing banks' intermediation and operational performance using the Hicks-Moorsteen TFP index: The case of Iran. *Resarch in International Business and Finance, 30*, 111-125.

Arora, H., & Arora, p. (2012). Bank productivity measurement using Hicks-Moorsteen indices: Evidence from Indian public sector banks. *International Journal of Business Performance Management, 13*(3), 386-407.

Arora, H., & Arora, P. (2013). Measuring and decomposing productivity change using Hicks-Moorsteen index numbers: Evidence from Indian banks. *International Journal of Productivity and Quality Managment, 11*(1), 73-95.

Balezentis, T. (2015). The sources of the total factor productivity growth in Lithuanian family farms: A Fare-Primont index approach. *Prague Economic Papers, 24*(2), 225-241.

Bjurek, H. (1996). The Malmquist total factor productivity index. *The Scandinavian Journal of Economics, 98*(2), 303-313.

Casu, B., Ferrari, A., & Zhao, T. (2013). Regulatory reform and productivity change in Indian banking. *Review of Economics and Statistics, 95*(3), 1066-1077.

Caves, D. W., Christensen, L. R., & Diewert , W. E. (1982). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Journal of the Econometric Society, 50*(6), 1393-1414.

Chen, X., Liu, X., & Zhu, Q. (2022). Comparative analysis of total factor productivity in China's high-tech industries. *Technological Forecasting and Social Change*, *175*(C).

Coelli, T. J., & Rao, D. S. (2005). Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980-2000. *Agriculture Economics, 32*(1), 115-134.

Dakpo, K. H., Desjeux, Y., Jeanneaux, P., & Latruffe, L. (2019). Productivity, technical efficiency and technological change in French agriculture during 2002-2015: a Fare-Primont index decomposition using group frontiers and meta-frontier. *Applied Economics*, *51*(11), 1166-1182.

Dakpo, K. H., Jeanneaux, P., & Latruffe, L. (2019). Pollution-adjusted productivity changes: extending the Fare–Primont index with an illustration with French suckler cow farms. *Environmental Modeling & Assessment*, *24*(6), 625-639.

Epure, M., & Jimenez, D. P. (2007). Strategic path and productivity in the Spanish savings banks. In *Improving Business reporting: new rules, new opportunities, new trends, 1*(1), 661-689.

Epure, M., Kerstens, K., & Prior, D. (2011). Technology-based total factor productivity and benchmarking: New proposals and an application. *Omega-international Journal of Management Science, 39*(6), 608-619.

Fare, R., & Grosskopf, S. (1992). Malmquist productivity indexes and Fisher ideal indexes. *The Economic Journal, 102*(410), 158-160.

Fare, R., & Primont, D. (1995). Distance functions. *Multi-output production and duality: Theory and applications*, 7-41.

Fare, R., Grosskopf, S., Norris, M., & Zhang, Z. (1994). Productivity growth, technical progress, and efficiency change in industrialized countries. *The American Economic Review, 84*(1), 66-83.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of the Royal Statistical Society, 120*(3), 253-290.

Figueira, C., Nellis, J., & Parker, D. (2009). Banking performance and technological change in non-core EU countries: A study of Spain and Portugal. *Studies in Economics and Finance, 26*(3), 155-170.

Giang, M. H., Xuan, T. D., Trung, B. H., & Que, M. T. (2019). Total factor productivity of agricultural firms in Vietnam and its relevant determinants. *Economies*, *7*(1), 1-12.

Glass, J. C., & McKillop, D. G. (2000). A post deregulation analysis of the sources of productivity growth in UK building societies. *The Manchester School*, *68*(3), 360-385.

Grifell-Tatje, E., & Lovell, C. A. (1995). A note on the Malmquist productivity index. *Economics Letters, 47*(2), 75-169.

Hemathilake Weerasekara, S. (2020). *Impact of climate change induced disasters on technical efficiency and productivity: Evidence from Sri Lanka* (Doctoral dissertation, Queensland University of Technology).

Ilyas, A. M., & Rajasekaran, S. (2020). Productivity of the Indian non-life insurance sector: New evidence employing Fare–Primont index approach. *International Journal of Productivity and Performance Management*, *69*(4), 633-650.

Jorgenson, D.W. and Grilliches, Z. (1967). The explanation of productivity change. *The Review of Economic Studies, 34*(3), 249-283.

Kerstens, K., Hachem, B. A., & Woestyne , I. V. (2010). Malmquist and Hicks-Moorsteen productivity indices: An empirical comparison focusing on infeasibilities.

Khan, F., Salim, R., & Bloch, H. (2015). Nonparametric estimates of productivity and efficiency change in Australian Broadacre Agriculture. *Australian Journal of Agricultural and Resource Economics*, *59*(3), 393-411.

Khan, M. Q., Masood, S. A., & Qureshi, S. N. (2019). Analysis of low productivity in public sector automobile. *Technical Journal*, *24*(1), 51-62.

Kong, M., Wang, X., & Wu, Q. (2021). The development efficiency of China's innovative industrial clusters-based on the DEA-Malmquist model. *Arabian Journal of Geosciences*, *14*(7), 1-15.

Martinez Cillero, M., & Thorne, F. (2019). Sources of productivity growth using the Fare-Primont decomposition. An empirical application to the Irish beef sector. *Applied Economics*, *51*(36), 3982-3994.

Martinez Cillero, M., Thorne, F., Wallace, M., & Breen, J. (2019). Technology heterogeneity and policy change in farm-level efficiency analysis: an application to the Irish beef sector. *European Review of Agricultural Economics*, *46*(2), 193-214.

Maziotis, A., Molinos-Senante, M., & Sala-Garrido, R. (2017). Assesing the impact of quality of service on the productivity of water industry: A Malmquist-Luenberger approach for England and Wales. *Water Resources Management*, *31*(8), 2407-2427.

Miao, J. (2018). Study on Regional Efficiency and Productivity of Guangdong Province—Based on Hicks-Moorsteen TFP Index. *Modern Economy*, *9*(12), 2164-2180.

Molinos-Senante, M., Maziotis, A., & Sala-Garrido, R. (2017). Assessment of the total factor productivity change in the english and welsh water industry: A Fare-primont productivity index approach. *Water Resources Management*, *31*(8), 2389-2405.

Naz, F., Khan, H., & Sayyed, M. (2017). Productivity and Efficiency Analysis of Pakistani Textile Industry using Malmquist Productivity Index Approach. *Journal of Management and Research*, *4*(2), 1-23.

Nguyen, T. V., Simioni, M., & Le Van, D. (2019). Assessment of TFP change at provincial level in Vietnam: New evidence using Fare–Primont productivity index. *Economic Analysis and Policy*, *64*(C), 329-345.

Noreen, U., & Ahmad, S. (2016). Cost Efficiency and Total Factor Productivity: An Empirical Analysis of Pakistan's Insurance Sector. *The Lahore Journal of Economics*, *21*(1), 123-150.

O'Donnell, C. J. (2010a). Measuring and decomposing agricultural productivity and profitability change. *Australian Journal of Agricultural and Resource Economics, 54*(4), 527-560.

O'Donnell, C. J. (2010b). DPIN version 1.0: A program for decomposing productivity index numbers. Working Paper. Center for Efficiency and Productivity analysis, university of Queensland.

O'Donnell, C. J. (2012a). An aggregate quantity framework for measuring and decomposing productivity change. *Journal of Productivity Analysis, 38*(3), 255-272.

O'Donnell, C. J. (2012b). Nonparametric estimates of the components of productivity and profitability change in U.S. agriculture. *American Journal of Agricultural Economics, 94*(4), 873-890.

Raheman, A., Qayyum, A., & Afza, T. (2009). Efficiency Dynamics of Sugar Industry of Pakistan. *The Pakistan Development Review*, *48*(4), 921-938.

Rashid, A., & ur Rehman, Z. (2016). Measurement and Decomposition of Productivity Change in Banking: Islamic and Conventional Banks in Pakistan. *Journal of Islamic Business and Management*, *6*(2), 55-75.

Ray, S. C., & Desli, E. (1997). Productivity growth, technical progress, and efficiency change in Industrialized countries: Comment. *The American Economic Review, 87*(5), 1033-1039.

Saher, T., Malik, M. A. S., Ullah, S., & Ullah, A. (2019). Measuring firm and sector efficiency in Pakistan: An application of data envelopment analysis. *Studies in Business and Economics*, *14*(3), 239-257.

Saleem, H., Shahzad, M., Khan, M. B., & Khilji, B. A. (2019). Innovation, total factor productivity and economic growth in Pakistan: a policy perspective. *Journal of Economic Structures*, *8*(1), 1-18.

Shah, W. U. H., Hao, G., Zhu, N., Yasmeen, R., Padda, I. U. H., & Abdul Kamal, M. (2022). A cross-country efficiency and productivity evaluation of commercial banks in South Asia: A meta-frontier and Malmquist productivity index approach. *Plos one*, *17*(4), 1-17.

Sufian, F. (2008). Revenue shifts and non-bank financial institutions' productivity: Empirical evidence from Malaysia. *Studies in Economics and Finance, 25*(2), 76-92.

Sufian, F. (2010). Productivity, efficiency and technological change in banking: Empirical evidence from the Chinese banking sector. *International Journal of Economics and Business Research, 2*(5), 427-445.

Temoso, O., & Myeki, L. W. (2023). Estimating South African higher education productivity and its determinants using Fare-Primont index: Are historically disadvantaged universities catching up?. *Research in Higher Education*, *64*(2), 206-227.

Thayaparan, A., Neruja, N., & Godwin Phillip, P. M. (2022). Sources of total factor productivity and its determinants of paddy farming in Mullaitivu: A Fare-Primont index approach. *Sri Lanka Journal of Social Sciences and Humanities*, *2*(1).

Wabuyabo, E. O. (2017). *Institutional Efficiency and Sustainable Response to Hiv/aids in Nyanza and Western Kenya* (Doctoral dissertation, University of Nairobi).

Wang, C., Fan, Y., & Sun, K. (2020). Technology Progress and Energy Efficiency: An Empirical Analysis of Shanghai Industrial Firms. In *IOP Conference Series: Earth and Environmental Science, 526* (1).

Wheelock, D. C., & Wilson, P. W. (1999). Technical progress, inefficency, and productivity change in U.S. banking,1984-1993. *Journal of Money, Credit, and Banking, 31*(2), 212-234.

Wright, B. E. (2011). *Australian Defence Industry Productivity* (Doctoral dissertation, UNSW Sydney).