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A STOCHASTIC FRONTIER ANALYSIS OF COST EFFICIENCY IN TURKISH CEMENT INDUSTRY

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ABSTRACT
Purpose - The main focus of this paper is to measure cost efficiency in Turkish Cement Industry using firm level data over the period 2008-2016. The measurement of cost efficiency in the industry in which there can seem usually competition infringement is of great importance regarding effective allocation of resources. The ineffective allocation of resources can bring about cost inefficiency.
Methodology - In this study, efficiency is measured using a frontier analysis approach, which quantifies efficiency as the gap between the best achievable performance and actual performance. The Stochastic Frontier Analysis (SFA) method is employed to assess cost efficiency of each firm in this manner. By incorporating both statistical error and inefficiency, the SFA method recognizes that deviations from optimal performance can arise from both random errors and inefficiency factors.
Findings- Empirical results show that cost efficiency scores vary between 82% and 93% by different models. The results also indicate a wide range of cost efficiencies across different size cement firms. The lowest cost efficiency score is estimated by TFE, BC95, and PL81 models in 2015.
Conclusion- Average cost efficiency score varies between approximately 93% and 82%, which means that the firms can potentially achieve at least 7% and a maximum of 18% reduction in input costs.

Keywords: Stochastic frontier analysis, cement industry, cost efficiency, efficiency estimation, time-varying, invariant efficiency.
JEL Codes: D24, C51, L61

1. INTRODUCTION

Cement industry is of great importance for Türkiye since construction sector has been an engine of the economy for years. The industry has been sufficiently met domestic and foreign demand, increased revenues of the country through exports. Moreover, the sector offers employment opportunities. According to the October 2022 report of Republic of Türkiye Ministry of Trade, cement is one of the most exported product segments. In the January-October 2022 period, the sector achieved an increase of 14.1% in export revenue with 3.2 billion dollars compared to the same period of the previous year (2.8 billion dollars).[1] While there are 66 enterprises in cement manufacturing in 2020, this sector has provided employment to 19 thousand people in the field of production.[2]

[1]See October foreign trade statistics tables of Republic of Türkiye Ministry of Trade, the table of the most exported 20 product segments.
[2]See Turkish Statistical Institute (TurkStat)-Business Records Statistics and Cement Industry Report (2020) of Republic of Türkiye Ministry of Industry and Technology.

In cement sector, 38% of the total cost is fuel, and %21 is electricity in the process of cement manufacturing in Türkiye. Primary materials and labor costs are 10% and 9% of the total cost, respectively. It is seen that private housing construction have the highest share in cement demand in Türkiye. Türkiye ranks first in Europe in terms of ready mixed concrete production. Although the increasing uncertainties in the Middle East in recent years have negatively affected Türkiye's cement exports, the highest exports are made to the Middle Eastern countries (Çevik, 2016).

Efficiency is basically an indicator of success in achieving the goal. Therefore, a firm is efficient the extent to which it is successful in the field where it is active (Aydın and Kök, 2013). The word of efficiency is used in many fields besides economics and business literature and is defined as "the capacity to achieve maximum return with minimum effort or cost". Economic efficiency is formed of productive efficiency and allocative efficiency including conditions related to Pareto optimum. That's why, the concept of economic efficiency is also defined as allocative efficiency and static efficiency (Kök and Deliktaş, 2003: 43-44). Technical efficiency is the degree to which the output of the related sector is being maximized for a given amount of inputs or the degree to which average production costs are minimized in the long run. Allocative efficiency is the degree to which resources available to the sector are being supplied to the use with the highest expected value (Falkena et. al., 2004). Lovell (1993) states that if the goal of the production is cost minimization, an estimation of cost efficiency is ensured by the ratio of minimum cost to observed cost. And the researcher stresses that a firm is cost efficient if, and only if, it is technically and allocatively efficient.

Our main focus is to measure cost efficiency in Turkish Cement Industry using firm level data over the period 2008-2016. The measurement of cost efficiency in the industry in which there can seem usually competition infringement is of great importance regarding effective allocation of resources. As Abel and Marire (2021) pointed out, the ineffective allocation of resources can bring about cost inefficiency. In addition, the expansion of the related literature is another source of motivation for the study.

This study is organized as follows. Section 2 presents related literature review and Section 3 provides details on the data set and methodology. Section 4 discusses empirical results. Finally, Section 5 provides concluding remarks.

2. LITERATURE REVIEW

The concept of efficiency refers to the relationship between input and output. Efficiency can be classified as technical, allocation, scale and scope efficiency. Technical efficiency refers to whether the input produces the amount of input that it is capable of producing. For example, if a hospital can produce 800 units with an input that has the potential to produce 1000 units of output, then it is 20% inefficient or 80% efficient. Allocative efficiency measures whether the firm chooses the less costly input combination to produce the output. Finally, scale efficiency is used to target the size at which the firm can produce most efficiently (Rosko and Mutter, 2011).

Farrell defined technical efficiency as the ratio of the observed output of the firm to the output at the frontier, which is the maximum output that can be achieved. According to this framework, a hospital can be characterized as technically efficient if it operates above the best practice production frontier of its sector. In the original Farrel study, all observations had the same technology access level (Farrel, 1957). Farrell was the first to use the frontier method in 1957 by determining the efficiency of each firm according to its distance from the best practice production frontier formed by the firms in the sector. Thus, Farrell can be considered the father of boundary analysis.

It is possible to come across many studies in the literature regarding cost efficiency. Within the scope of this study, cost-effectiveness studies, are briefly included in the literature review. Holló and Nagy (2006) try to explain the efficiency differences of banks operating in 25 EU countries and their reasons. Using the stochastic frontier approach (SFA), the X-efficiency (cost-efficiency) of 2459 banks over the period 1999-2003 and the alternative profit-efficiencies were estimated in two different models, controlling for country-specific variables and non-controlling. The authors added environmental variables to the second model to reduce the distorting effect of size and other operational deviations on efficiency estimates. According to the first model, in which environmental factors are not considered, the average cost effectiveness in 25 EU countries was found to be 85%. In addition, it has been observed that the average cost efficiencies in the old EU countries are higher than the cost efficiencies in the new EU countries during the period under consideration. However, a significant catch-up process has emerged over time in the new member states, as their cost-effectiveness has increased significantly and the efficiency gap with the former member states has narrowed. On the other hand, when environmental factors are taken into account, similar results were obtained except for the lower cost-efficiency gaps between the old and new states. According to the results of the snow efficiency model, in which environmental factors are not considered, the authors reached an average of 69% snow efficiency level in all EU countries. Although it is slightly higher in the old member countries, no significant difference has been reached in the average snow efficiency scores between the old and new member countries.

Weill (2007) makes a comparison between banking activities in eastern and western EU countries. The study measures cost-efficiency in 11 Western and 6 Central and Eastern European countries (CCE) between 1996 and 2000. Cost-efficiency results using stochastic frontier analysis show that banks in Western European countries are more efficient than banks in Central and Eastern European countries. According to the author, this result means that there is a cost-efficiency gap between the banking systems in the two regions. Weill (2007) included different environmental factors in the cost model in order to see whether the said deficit was caused by environmental factors. According to the predicted inefficiency effects model, the author concluded that the weak managerial performance especially in Eastern European banks and the efficiency gaps between them and Western European banks are due to differences in risk preferences.

Kasman and Yıldırım (2006) analyzed the cost and profit efficiency of European banks in their studies. Cost and profit efficiencies of 190 commercial banks operating in 8 Eastern and Western European countries between 1995-2002 were obtained with the help of stochastic frontier analysis. In addition, using Battese and Coelli's (1995) single-stage SFA model, the effect of foreign ownership on bank efficiency was examined along with different country-specific variables. According to the results obtained, the average cost inefficiency of banks is 20.7%; the average profit inefficiency was found to be 36.7%. On the other hand, the fact that the cost efficiency of the banking system in the countries included in the sample is higher than the profit efficiency shows that the banks are more effective in controlling their costs rather than making a profit. According to the authors, the cost and profit inefficiencies of banks vary between countries and groups of banks of different sizes. However, foreign banks were found to be more efficient than domestic banks on average. Ekinci (2018) examines the cost efficiency and determinants of 156 commercial banks operating in European Union countries. As far as the study is concerned, cost efficiency of banks falls with the global crisis and European debt crisis.

3. DATA AND METHODOLOGY

3.1. Data

We define total cost as a dependent variable, an output variable and three input prices, the price of capital, wages, and the price of the primary materials and supplies in *Table 1*.

Table 1: Definition of the Variables

Variables	Symbol		Definition
Independent variable	tc	Total cost	Total costs associated with the production
	p_k	Price of capital	Deprecation / tangible fixed assets + interest rates of the government debt securities
Input Prices	p_l	Price of labor	Total personnel expenditure / number of employee
	p_r	Price of primary materials	(Total cost of the primary materials + other production expenses) / cement
Output	q	Quantity of production	Quantity of the cement produced

Summary statistics are also provided for the mean values of the firms' key variables in the *Table 2.* Our quarterly data set covers the period from 2008q1 to 2016q4.

Table 2: Summary Statistics

Variables	Unit	Mean	SD	Min	Max
tc	million tl	33.4	27.5	5.1	93.4
Share of personnel expenses in tc	%	12.2	3.2	7.6	18.5
Share of primary material costs in tc	%	85.4	5.4	76.4	92.7
q	thousand tons	601.8	436.5	114.6	1600.0
Tangible fixed assets	million tl	162.4	117.0	36.8	385.6

3.2. Methodology

Although the stochastic frontier was originally proposed for the estimation of the production functions, it has also been used in exclusive efficiency analyses such as input, profit, and cost. Assuming firms minimize their cost, we can estimate cost efficiency if the price data are available. The general form will be the following.

$$c_{it} \geq c(w_{1it}, w_{2it}, \dots, w_{Nit}, y_{1it}, y_{2it}, \dots, y_{Mit}) \tag{1}$$

where c_{it} is the actual cost of firm i at period t, w_n's are the input prices, y_M denotes the output, and $c(.)$ is a cost function which is non-decreasing and linearly homogeneous in input prices.

If we suppose $c(.)$ has a Cobb-Douglas form, the cost frontier can be written as follows.

$$\ln c_{it} \geq \beta_0 + \sum_{n=1}^{N} \beta_n \ln w_{nit} + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + v_{it} \tag{2}$$

or

$$\ln c_{it} = \beta_0 + \sum_{n=1}^{N} \beta_n \ln w_{nit} + \sum_{m=1}^{M} \alpha_m \ln y_{mit} + v_{it} + u_{it}, \tag{3}$$

where v_{it} accounts for the random errors and u_{it} is a non-negative variable that represents inefficiency. Note that u_{it} has a positive sign in the cost frontier, implying that observed cost increases with inefficiency. In addition, to estimate technical inefficiency in this model, certain distributional assumptions for the error terms are necessary, including half-normal, truncated-normal, exponential, and gamma distributions.

Since cost efficiency is defined as the ratio of best practice (minimum cost) to observed cost, it is given by

$$CE_{it} = \frac{c(.)}{c_{it}}. \tag{4}$$

If we plug the Eq. (3) into Eq. (4), we have

$$CE_i = \frac{\exp(\beta_0 + \sum_{n=1}^{N} \beta_n \ln w_{ni} + \sum_{m=1}^{M} \alpha_m \ln y_{mi}) * \exp(v_i)}{\exp(\beta_0 + \sum_{n=1}^{N} \beta_n \ln w_{ni} + \sum_{m=1}^{M} \alpha_m \ln y_{mi}) * \exp(v_i) * \exp(u_i)} = \exp(-u_i). \tag{5}$$

Hence, we have

$$CE_{it} = \exp(-u_{it}). \tag{6}$$

For detailed explanations and derivations associated with cost frontiers, see Kumbhakar and Lovell (2000) and Coelli et al. (2005).

The stochastic frontier model, initially introduced by Aigner et al. (1977) for cross-sectional data, was later adapted to panel data by Pitt and Lee (1981). Subsequently, various methods have been proposed in the literature to estimate the inefficiency term. Time-invariant models (Pitt and Lee, 1981; Battese and Coelli, 1988) have been developed, along with models that assume time-varying inefficiency (Cornwell et al., 1990; Kumbhakar, 1990; Battese and Coelli, 1992; Lee and Schmidt, 1993; Battese and Coelli, 1995; Greene, 2005). Additionally, there are studies that explore the relationship between the inefficiency parameter and exogenous variables. For the purpose of comparison, we employ some of these methodologies.[3]

[3] sfpanel STATA routine is used.

Considering transcendental cost function (TCF), empirical framework incorporates three inputs (capital, labor, and raw material) and one output (quantity of cement) in cement production. Therefore, TCF, formed by three inputs and one output, is modeled as in *Equation (7)*.

$$\begin{aligned} lnTC_{it} = {} & \alpha_0 + \alpha_1 lnQ + \beta_1 lnPk_{it} + \beta_2 lnPl_{it} + \beta_3 lnPh_{it} + \delta_{11}\frac{1}{2}(lnQ)_{it}^2 \\ & + \frac{1}{2}\big(\gamma_{11}(lnPk)_{it}^2 + \gamma_{12} lnPk_{it} lnPl_{it} + \gamma_{13} lnPk_{it} lnPh_{it} + \gamma_{21} lnPl_{it} lnPk_{it} + \gamma_{22}(lnPl)_{it}^2 \\ & + \gamma_{23} lnPl_{it} lnPh_{it} + \gamma_{31} lnPh_{it} lnPk_{it} + \gamma_{32} lnPh_{it} lnPl_{it} + \gamma_{33}(lnPh)_{it}^2\big) + \rho_{11} lnQ_{it} lnPk_{it} \\ & + \rho_{12} lnQ_{it} lnPl_{it} + \rho_{13} lnQ_{it} lnPh_{it} + v_{it} + u_{it} \end{aligned} \tag{7}$$

where i represents firm and t represents the period. The other variables are as follows. TC: Total cost of sales, Pk: Price of capital (%) [(deprecation/real asset) +deposit interest rate], Pl: Price of labor (expanse of labor/number of personnel), Ph: Price of raw material (expanse of raw material/quantity), Q: Output (Quantity).

The cost function given in *Equation (7)*, is assumed homogeneous of degree one in input prices and symmetric. So, the following constraints are imposed on the model.

$$\begin{gathered} \sum_{i=1}^{n} \beta_i = 1;\ \sum_{i=1}^{n} \gamma_{ij} = 0; j = 1 \dots n;\ \sum_{i=1}^{n} \rho_{ij} = 0; j = 1 \dots n\ (homogeneity) \\ \gamma_{ij} = \gamma_{ji}, \qquad \rho_{ij} = \rho_{ji}, \qquad i \neq j\ (symmetry) \end{gathered} \tag{8}$$

When we impose the restrictions given in the equation system (6), we get the TCF to be estimated as follows.

$$\begin{aligned} ln\left(\frac{TC}{Pk}\right)_{it} = {} & \alpha_0 + \alpha_1 lnQ_{it} + \beta_2 ln\left(\frac{Pl}{Pk}\right)_{it} + \beta_3 ln\left(\frac{Pr}{Pk}\right)_{it} + \delta_{11}\frac{1}{2}(lnQ)_{it}^2 + \gamma_{22}\frac{1}{2}\left(ln\left(\frac{Pl}{Pk}\right)\right)_{it}^2 + \gamma_{23} ln\left(\frac{Pl}{Pk}\right)_{it} \\ & * ln\left(\frac{Pr}{Pk}\right)_{it} + \gamma_{33}\frac{1}{2}\left(ln\left(\frac{Pr}{Pk}\right)\right)_{it}^2 + \rho_{12} lnQ_{it}\left(ln\left(\frac{Pl}{Pk}\right)\right)_{it} + \rho_{13} lnQ_{it}\left(ln\left(\frac{Pr}{Pk}\right)\right)_{it} + v_{it} + u_{it} \end{aligned} \tag{9}$$

Since the cost efficiency is estimated in terms of this equation, it has an output and three inputs: labor, capital, and primary materials. Therefore, there are three input price such as price of labor, price of capital and price of primary materials. Cement production level is used as an output.

4. FINDINGS AND DISCUSSIONS

We estimate translog cost function by using stochastic frontier analysis as in equation (9). Specifically, we utilize the Pitt and Lee (1981) model (PL81) as a time-invariant and half-normal model, the Battese and Coelli (1995) model (BC95) as a time-varying and truncated normal model, and the Greene (2005) model (TFE) as a time-varying and exponential model.[4]

Table 3 summarizes the estimation results obtained for cost efficiency of Turkish cement industry for three different models. According to Table 3, the coefficient of output (lnQ) are positive and statistically significant at 1% in TFE. Additionally, the coefficient of labor price ($ln\frac{p_l}{p_k}$) is positive and significant at 1% in both BC95 and PL81. On the other hand, the price of primary materials ($ln\frac{p_r}{p_k}$) is positive and statistically significant at 5% in only True Fixed Model.

The *lambda* parameter shows the existence of inefficiency in the models. According to the Table 3, all values of *lambda* are statistically significant and it proves the existence of inefficiency.

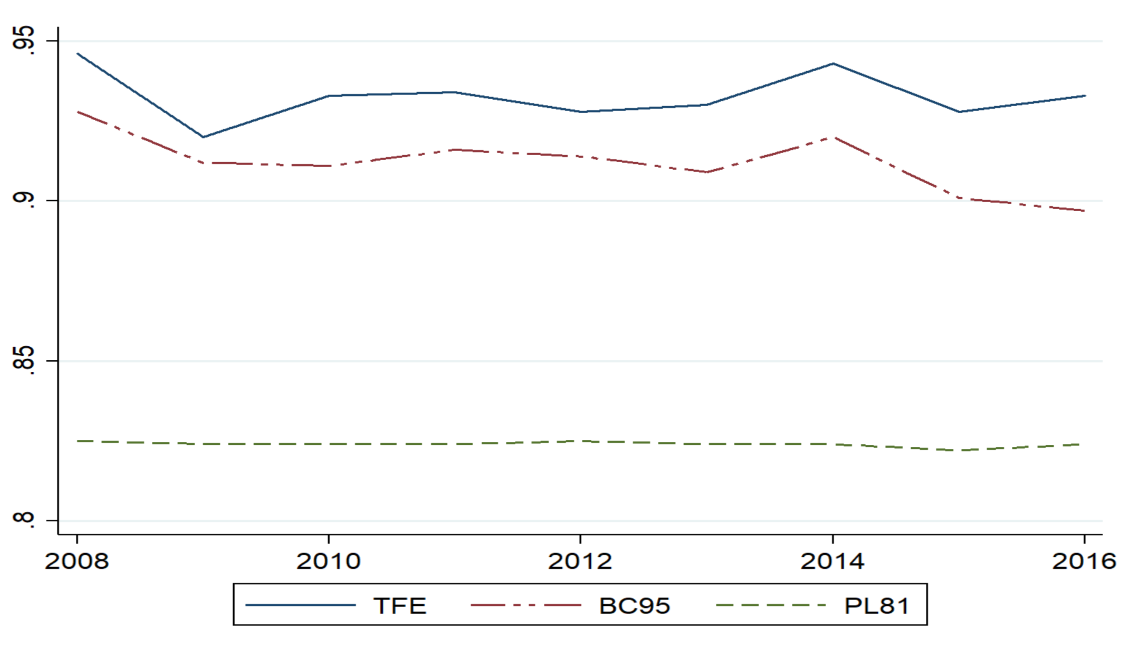
Table 3: Estimation Results of Cost Efficieny

		TFE	BC95	PL81
Variables	**Parameters**	**Coefficient**	**Coefficient**	**Coefficient**
lnQ	α_1	2.310 [0.345]***	14.920 [3.648]***	8.518 [2.598]***
$ln\frac{p_l}{p_k}$	β_2	-0.211 [0.367]	1.394 [0.412]***	2.485 [0.329]***
$ln\frac{p_r}{p_k}$	β_3	1.095 [0.466]**	-0.128 [0.437]	-0.221 [0.351]
$lnQ\left(ln\left(\frac{Pl}{Pk}\right)\right)$	ρ_{12}	-0.107 [0.029]***	1.683 [0.633]***	1.019 [0.448]**
$lnQ\left(ln\left(\frac{Pr}{Pk}\right)\right)$	ρ_{13}	0.146 [0.050]***	0.043 [0.026]*	-0.105 [0.029]***
$0.5(lnQ)^2$	δ_{11}	0.034 [0.031]	0.099 [0.060]*	0.182 [0.027]***
$0.5ln(\frac{Pl}{Pk})^2$	γ_{22}	0.093 [0.043]**	-0.014 [0.026]	0.031 [0.029]
$0.5ln(\frac{Pr}{Pk})^2$	γ_{33}	0.131 [0.053]**	-0.110 [0.048]**	0.086 [0.044]**
$ln\frac{Pl}{Pk}ln\frac{Pr}{Pk}$	γ_{23}	-0.086 [0.052]	0.142 [0.072]**	0.156 [0.050]***
Inefficiency Parameters				
$Sigma\_u$		0.071 [0.008]***	1.932 [0.556]**	0.273 [0.057]***
$Sigma\_v$		0.089 [0.017]***	0.107 [0.013]***	0.118 [0.000]***
$lambda$		0.801 [0.021]***	18.111 [0.562]***	2.312 [0.000]***
Average Cost Efficiency Scores				
2008		0.946	0.928	0.825
2009		0.920	0.912	0.824
2010		0.933	0.911	0.824
2011		0.934	0.916	0.824
2012		0.928	0.914	0.825
2013		0.930	0.909	0.824
2014		0.943	0.920	0.824
2015		0.928	0.901	0.822
2016		0.933	0.897	0.824

Notes: TFE: True Fixed Effects model (Greene, 2005). BC95: Battese and Coelli (1995). PL81: Pitt and Lee (1981). Significance levels: *** 1%, ** 5%, * 10%. Convergence is achieved in all three models.

Our main interest lies with the calculated cost efficiency scores, which are presented towards the bottom of *Table 3*. The cost efficiency scores of the firms in the cement industry varies between 93% and 82% according to the models. Figure 1 also provides an information about the scores.

Figure 1: Average Cost Efficiency Scores



Notes: TFE: True Fixed Effects model (Greene, 2005). BC95: Battese and Coelli (1995). PL81: Pitt and Lee (1981).

In Figure 1, average cost efficiency scores estimated from BC95, TFE, and PL81 are given by years. As seen in the figure, one can infirm that the efficiency scores of TFE model and BC95 model are varies but in parallel to each other. On the other hand the scores of PL81 model are almost stable. In first two models, there is a decline in around 2009 because of 2008 crisis. In 2015, the efficiency score was upward in TFE and BC95 models because both macroprudential policies implemented in the country and the uncertainties in the global capital movements caused the cement sector to shrink (Çevik, 2016).

Possible competition infringement as cartel agreements can be seen in the cement industry. Kulaksizoglu (2004) and Çelen and Günalp (2010) reveal that the cement industry in Türkiye has slowly become more competitive over time. Çalmaşur and Daştan (2015) show that Turkish cement industry has oligopolistic characteristics. Ekinci (2018) points out less competitive markets are more cost efficient than highly competitive markets.

5. CONCLUSION

In this study, we employed the stochastic frontier analysis to measure cost efficiency scores of Turkish cement industry including 14 firms over the period from 2008q1 to 2016q4. We can say that cost efficiency scores above the 80% although it varies by the method we used. Although there are some fluctuations, it can be said that the efficiency followed a nearly horizontal path throughout the period. The results also indicate a wide range of cost efficiencies across different size cement firms. The lowest cost efficiency score is estimated by BC95 and PL81 in 2015. In this year, both macroprudential policies implemented in the country and the uncertainties in the global capital movements caused the cement sector to shrink. Average cost efficiency score varies between approximately 93% and 82%, which means that the firms can potentially achieve at least 7% and a maximum of 18% reduction in input costs.

There may be many reasons for the horizontal efficiency during the period under review. The first of these may be insufficient observations to monitor efficiency changes. Due to the high initial investment to enter the cement sector, new investments may spread over time. This may cause no significant changes to be seen in 9 years. Another factor may be that firms use close technologies in their production process. Relatively higher efficiency scores also support this. Although efficiency-enhancing technologies are accumulated in the capital stock, this accumulation may be similarly experienced in almost all firms.

Although this study makes significant contributions to the potential increase in efficiency in the cement sector, it also has limitations. First, the number of observations may be regarded as inadequate due to the data availability. With more producers making their data available, reaching a deeper understanding of efficiency would be possible. It can also be said that efficiency scores are affected by the analysis method. Therefore, performing comprehensive analyzes will yield more robust results. Finally, in the SFA approach, the influencing factors of efficiency could also be examined. After determining the potential increase in efficiency, exploring which factors play a key role in boosting efficiency would also make significant contributions. This part is left for future work.

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