**Title: The climate change and technical efficiency of pangasius farming in the Mekong Delta, Vietnam**

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**Abstract**

This study measures and compares technical efficiency for 195 pangasius farms in Vietnam using meta-frontier data envelopment analysis. The impacts of climate change on technical efficiency are also identified using bootstrapped truncated regression. The findings show that substantial technical inefficiency occurs in pangasius farming due to overuse of inputs. There are substantial differences in technical efficiency scores between farms and between different types of climate change. Technical efficiency scores are lowest for farms reporting to be impacted by both drought and unusual weather but highest for farms having no idea about the climate change and its impact. Technical efficiency is shown to be significantly impacted by the unusual weather and both drought and unusual weather.

Key words: climate change, technical efficiency, meta-frontier DEA, bootstrapped truncated regression, pangasius farming

1. **Introduction**

Vietnam has been one of the major producers of pangasius in the world with more than 75% of the global production (Thong et al., 2020). Pangasius farming has been the main livelihood of many laborers and households, especially in Mekong Delta region and contributed a lot to the Vietnamese economy (Thong et al., 2020; VASEP, 2020). Vietnamese pangasius products have been exported to more than 149 countries and territories in the world and earned a value of USD 2.2 billion (VASEP, 2020). However, at the same time, a decline in the profit margin of the growing-out farms has been frequently reported (Hasan and Shipton, 2021; Tho et al., 2021). Such economic performance of the sector was caused not only by the increase in production costs due to the increase in input prices but also by the lost in production due to climate change because Mekong Delta, where pangasius has been mainly cultivated, is one of the susceptible regions to climate change in Vietnam (Nguyen et al., 2017). Nguyen et al. (2014) found that upstream and midstream pangasius farms experienced larger inundation areas and longer flood periods while downstream farms faced higher salinity levels in a longer period. Many previous studies investigated the impacts of climate change on technical efficiency in agricultural systems such as studies by Oyekale (2012). Makki et al. (2012), and Hossain et al. (2013). However, up to now, the studies on the impacts of climate change on the performance of pangasius farming have been still limited. Only Nguyen et al. (2017) investigated the impacts of climate change on the technical efficiency of striped catfish farming in Mekong Delta, Vietnam. Nonetheless, they mainly focused on the impacts of floods and salinity intrusion (Nguyen et al., 2017) which related to the impacts of sea-level rise on upstream, midstream, and downstream farms. No one has studied the impacts of other types of climate change on the sector while the unusual weather or drought were also claimed to have negative impacts on the disease and mortality problems (Minh, 2020) and thereby affected on the performance of the sector. Therefore, this study aims to fill the gap by identifying the relationship between the current most common climate changes and the technical efficiency of pangasius farms in Vietnam.

1. **Research Methodology**
	1. **Meta-frontier data envelopment analysis**

Meta-frontier data envelopment analysis (meta-frontier DEA) is a non-parametric method introduced by O’Donnell et al. (2008). Meta-frontier DEA helps to compare efficiency scores between groups when the technology or production conditions are different between farms. This method is based on the traditional data envelopment analysis (DEA), which was proposed by Farrel (1957). The production frontier is built by the most efficient input-output combinations within the observed data. The production possibilities of groups of farms having the same production conditions or using sub-technologies are group frontiers. The meta-frontier is the boundary of the unrestricted condition or technology set (O’Donnell et al., 2008). Consider a set of farms producing M outputs$ y\in R\_{+}^{M}$ by N inputs $x\in R\_{+}^{N}$. The production set will be:

$$T=\{(xy)\in R\_{+}^{N+M}|x can produce y\}$$

Now a day, prices of inputs have been reported to increase continuously and sharply, using inputs efficiently is the objective of the paper. Therefore, the input-oriented DEA model for measuring technical efficiency (TE) is used in this paper:

$$TE\left(y,x\right)=\min\_{θ}\left\{θ|\left(θx,y)\in T\}\right.\right.$$

Where is the technical efficiency (TE) score. Given $x\_{TE}$ is the technically efficient input vector.

The group frontiers and meta-frontier used to estimate technical efficiency are illustrated in Figure 1.

Meta-frontier

$$x\_{1}$$

Group-frontier

B

M

N

Q

R

$$x\_{2}$$

O

Figure 1: The group frontiers and meta-frontier in estimating technical efficiency

The technical efficiency of farm B compared to its meta-frontier is:

$$TE={OQ}/{OB}$$

Moreover, in order to correct the bias estimators which are caused by the deterministic nature of the non-parametric method, this study uses the meta-frontier data envelopment analysis with smoothed bootstrap procedure introduced by Simar and Wilson (1998).

* 1. **Bootstrapped truncated regression**

To identify the relationship between climate change and technical efficiency in pangasius farming in Vietnam, this study applies a bootstrapped truncated regression with left trucation at $1-K\_{i}β$.

$$̿=α+K\_{i}β+ε\_{i}, i=1,….,n$$

where $K\_{i}$ is a vector of specific variables on climate change, α is a constant, β is a vector of parameters, and $ε\_{i}$ is the statistical noise, $ε\_{i}∼N\left(0,σ\_{ε}^{2}\right)$. $̿$ is the reciprocal of the bias-corrected technical efficiency scores.

* 1. **Data and variables**

In Vietnam, An Giang, Can Tho, and Dong Thap are the top provinces in pangasius farming (VASEP, 2020a). These provinces, therefore, were selected to do field survey in this study. In total, 195 farmers were interviewed using a structured questionnaire. The interviews include information on perception of the farmers on climate change, inputs and output the pangasius production cycle for the period 2020 – 2021.

Table 1: Description of the variables in the DEA model (per farm per production cycle)

|  |  |  |
| --- | --- | --- |
| Variables | Description | Unit |
| **DEA** |  |  |
| ***Outputs*** | Total quantity of pangasius produced | Tons |
| ***Inputs*** |  |  |
| Fingerling  | Total quantity of pangasius fingerling cultivated | Kilograms |
| Feed  | Quantity of feed | Ton |
| Labor  | Total working hours used for cultivating pangasius | Man-hours |
| **Bootstrapped truncated regression** |
| ***Dependent variable*** |
| Technical efficiency | Bias-corrected technical efficiency was estimated by DEA |  |
| ***Independent variable*** |
| Unusual weather | Being impacted by unusual weather | Dummy (0 = no, 1 = yes) |
| Drought and unusual weather | Being impacted by both drought and unusual weather | Dummy (0 = no, 1 = yes) |
| Flood and unusual weather | Being impacted by both flood and unusual weather | Dummy (0 = no, 1 = yes) |

In pangasius farming, feed, labor, and fingerling account for most of the production costs (Anh Ngoc et al., 2018). Therefore, fingerling (kilograms), feed (tons), and labor (man-days) are used as the main inputs in measuring technical efficiency in this study. The fish yield (tons) is used as the output.

In the truncated regression model, the reciprocal of the bias-corrected technical efficiency scores was regressed on a set of dummy variables of the most common climate changes including unusual weather (taking the value 1 if farmer reported to be impacted by unusual weather and 0 otherwise), drought and unusual weather (taking the value 1 if farmer reported to be impacted by both drought and unusual weather and 0 otherwise), flood and unusual weather (taking the value 1 if farmer reported to be impacted by both flood and unusual weather and 0 otherwise). The descriptive characteristics of these inputs and output per farm per production cycle are reported in Table 2.

Table 2 shows that the fish yield per hectare was highest for pangasius farms impacted by both flood and unusual weather (884.1 tons) and lowest for pangasius farms impacted by unusual weather (559.4 tons). Total quantity of pangasius fingerling per hectare was also highest for farms impacted by both flood and unusual weather (41232 kilograms) and lowest for farms not impacted by climate change (19818 kilograms). Conversely, total quantity of feed per hectare was highest for farms impacted by both drought and unusual weather (1559 tons) and lowest for farms impacted by unusual weather (936.7 tons). Total working hours per hectare used for cultivating pangasius was also highest for drought and unusual weather group (1291 hours) but lowest for having no idea group (795 hours).

Table 2: Descriptive statistics for some main inputs and output per farm per production cycle

|  |  |  |
| --- | --- | --- |
| **Climate change effect** | **Outputs** | **Inputs** |
| **Fingerling** | **Feed** | **Labor** |
| Unusual weather | Mean | 559.4 | 27247 | 936.7 | 930.7 |
| (n = 35) | Min | 50.0 | 2333 | 80.0 | 250.0 |
|  | Max | 2000.0 | 110000 | 3300.0 | 2600.0 |
|  | Median | 400.0 | 17143 | 620.0 | 800.0 |
| Drought and unusual weather | Mean | 749.5 | 36188 | 1559.2 | 1291.0 |
| (n = 11) | Min | 126.0 | 4571 | 200.0 | 300.0 |
|  | Max | 2500.0 | 140000 | 7410.0 | 3600.0 |
|  | Median | 450.0 | 15000 | 720.0 | 800.0 |
| Flood and unusual weather | Mean | 884.1 | 41232 | 1483.8 | 1227.0 |
| (n = 13) | Min | 130.0 | 7500 | 211.0 | 300.0 |
|  | Max | 6000.0 | 285318 | 10200.0 | 5175.0 |
|  | Median | 370.0 | 17143 | 600.0 | 900.0 |
| No idea | Mean | 616.9 | 19818 | 1008.8 | 795.2 |
| (n = 136) | Min | 48.0 | 900 | 78.2 | 200.0 |
|  | Max | 12000.0 | 194444 | 19200.0 | 8125.0 |
|  | Median | 250.0 | 10700 | 403.5 | 450.0 |

1. **Results and discussion**
	1. **Climate change**

The awareness of the farmers about climate changes and its impacts on pangasius farming were shown in Figure 1, 2, and 3.

Figure 1 shows that many people (more than 69% of the respondents) are still not aware of the climate changes and the impacts on their pangasius farming. These respondents did not give the answers when they were questioned about the climate change and the impacts of climate change on their farms because they might have no idea about this problem or their farms might not be impacted by climate change. To be easy to capture, the study names these respondents as “no idea” group from now on. Besides, some farmers acknowledge that the climate has changed a lot over time and impacted significantly on their aquaculture production. According to them, the weather has become unpredictable and has not follow any rules. They, therefore, named such weather phenomena as “unusual weather”. Many farmers reported to experience the unusual weather during the farming period. Almost 18% of the total farmers reported to be impacted by unusual weather. Meanwhile, 6.8% of respondents claimed to face the impacts of both unusual weather and flood. 5.6% of respondents reported to experience the impacts of both drought and unusual weather.



**Figure 1: The most common climate change affecting pangasius farming**

For those people responded to be impacted by climate change, some farmers (1.7%) have no idea about the frequency of climate change impact. However, more than 32% of respondents reported that their pangasius farms were frequently impacted by climate change. More than haft (59.3%) reported to be occasionally impacted and 5.6% was rarely impacted by such climate changes (Figure 2).



**Figure 2: The frequency of climate change impact**

According to pangasius farmers, severe and prolonged droughts, flood, and unusual weather degrade the water environment and adversely impact the health of farmed fish. This can lower the resistance of pangasius to disease and thereby reduce the output quality and productivity. Almost 97% of the respondents reported that disease outbreaks in pangasius farming increase significantly due to the climate change. 55% of farms claimed that the quality of pangasius products decreases and 88% experienced a reduction in productivity due to the climate change (Figure 3)

**Figure 3: Impacts of climate change on pangasius farming**

* 1. **Technical Efficiency**

Table 3: Technical efficiency scores by subgroups based on climate changes

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Climate change effect** | **Mean** | **Min** | **Max** | **Median** |
| Unusual weather | 0.858 | 0.487 | 0.981 | 0.879 |
| Drought and unusual weather | 0.806 | 0.489 | 0.883 | 0.850 |
| Flood and unusual weather | 0.858 | 0.734 | 0.980 | 0.852 |
| No idea | 0.879 | 0.738 | 0.972 | 0.888 |

Table 4: Kruskal-Wallis test for the difference in technical efficiency

|  |  |  |
| --- | --- | --- |
| Efficiency measure | Hypothesis | P-value of Kruskal test |
| TE | H0: $TE\_{1}=TE\_{2}=TE\_{3}=TE\_{4}$H1: $TE\_{1}\ne TE\_{2}\ne TE\_{3}\ne TE\_{4}$ | 0.02169\*\* |

1 = No idea, 2 = Unusual weather, 3 = Drought and unusual weather, 4 = Flood and unusual weather

Table 3 summarizes the technical efficiency scores of pangasius farms in Vietnam by subgroups based on climate changes. The results show that technical inefficiency occurs in pangasius farming in Vietnam. It also shows a large range in the technical efficiency scores among farms and between groups. There is difference in technical efficiency scores between different types of climate change farmers faced. On average, farms reporting to be impacted by both drought and unusual weather have the lowest technical efficiency score of 0.806 while farms not aware of the climate changes and its impacts on their pangasius farming have the highest technical efficiency score of 0.879. The technical efficiency for farms claiming to experience unusual weather and flood and unusual weather are both 0.858. Moreover, the results of Kruskal-Wallis test in Table 4 shows statistically significant differences in technical efficiency between groups. These results imply that the current level of input used for these groups are higher than those of the best practice farms. On average, farms having no idea about climate change and its impacts should reduce the current level of inputs by 12.1% to be efficient. Farms reporting to be impacted by both drought and unusual weather can further improve technical efficiency by up to 19.4%. Farms being impacted by unusual weather and by both flood and unusual weather should reduce the current level of inputs by 14.2% to be technical efficient.

* 1. **Impacts of climate change on technical efficiency**

**Table 5:**

|  |  |  |
| --- | --- | --- |
|  | Coefficient | Confident interval |
| Intercept | 0.82690561\*\*\* | 0.65950751 1.1033686 |
|  |  |
| Unusual weather | 0.17105476\* | 0.02715319 0.3039272 |
| Drought and unusual weather | 0.35708872\*\* | 0.15487068 0.5574267 |
| Flood and unusual weather | 0.08754377 | -0.09949864 0.3385866 |

∗, ∗∗, ∗∗∗ Indicate significance at 10, 5 and 1 % levels, respectively

According to pangasius farmers, although the weather phenomena such as drought, flood, and unusual weather have not occurred frequently, it might impact the quality of pond water thereby lowering the disease susceptibility of pangasius, impact on the quality of output, and reduce productivity. Therefore, the different types of climate change were hypothesized to have a different and negative effect on the technical efficiency of the sector. The impacts of different types of climate change on technical efficiency were identified using bootstrapped truncated regression. The results are shown in Table 5. Reciprocal of the bias-corrected DEA technical efficiency scores were used as the dependent variable. Meanwhile, dummy variables for different types of climate change were used as independent variables. Therefore, a negative coefficient shows a positive impact while a positive coefficient shows a negative impact on technical efficiency.

The results in Table 5 again confirm the statistically significant difference in technical efficiency between different types of climate change as in Table 3 and 4. The coefficient for the unusual weather was positive and statistically significant. This means that farms being impacted by unusual weather will be less technically efficient than those not. In other words, the unusual weather has negative impacts on technical efficiency. Table 5 also shows positive and statistically significant coefficient for both drought and unusual weather variable. This implies that farms being impacted by both drought and unusual weather will be less technical efficient than others. Put differently, drought and unusual weather also has negative impacts on technical efficiency of the sector. L. A. Nguyen et al. (2017) also found a negative relationship between salinity intrusion and scale efficiency when identifying the impacts of climate change on the technical efficiency of striped catfish farming in Vietnam.

1. **Conclusion**

This study used meta-frontier DEA to measure and compare the technical efficiency for pangasius farms in Vietnam. The impacts of climate change on the technical efficiency were identified using bootstrapped truncated regression. The results show that there are large rooms for improving technical efficiency in pangasius farming in the study area. The findings also show substantial differences in technical efficiency scores between farms and between different types of climate change. Technical efficiency scores are lowest for farms reporting to be impacted by both drought and unusual weather but highest for farms having no idea about the climate change and its impact. Unusual weather and both drought and unusual weather had negative and statistically significant relationship with the efficiency of the sector. These findings can be useful for the farmers and local authorities to improve the technical efficiency of the sector. For the farmers, reducing input used should be focused to improve the economic performance. This content should also be focused in extension service or training courses. Moreover, the results also give hints to local authorities in prioritizing to mitigate the impacts of drought and unusual weather on aquaculture.

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