Relative Efficiency of Pennsylvania Dairy Farms: New Data

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1 Data Description

In this note, we present an Data Envelop Analysis (**DEA**) of farms' production efficiencies using the DEA approach. The data we use is annual (2013, 2014, 2015) data of a small set of Pennsylvania dairy farms. The data was collected from around 50 dairy farms (depending on year) that participated in the study which we label as Decision Making Units (**DMU**). Of interest is to analyze the production efficiency of these **DMU**. We first describe our dataset.

Table 1: Summary of the Dataset

Year	Number of DMU	DMU included
2013	48	DMU 62 plus DMUs included in other years
2014	50	DMU 62, 161, 171 plus DMUs included in other years
2015	49	DMU 161, 171 plus DMUs included in other years

For the purpose of comparison, we include those DMU which appears in all three years (47 DMU in total) to conduct DEA.

2 Models

Now we define the input and output variables we use in the models. Of interest is to estimate dairy farms' efficiency based on a relatively comprehensive list of inputs and outputs (inputs: number of Cows, dry matter, CP, starch DM, pH, purchased feed, feed cost, corn silage etc.; outputs: Milk per Milk Cow, Fat, Protein, (negative) MUN, (negative) Fecal Starch)[1]. On the other hand, since there are missing values in some of the variates in our data, we use two models to evaluate the farms' efficiencies.

2.1 Model 1

In model 1, we select a small set of input and output variates with no missing values. In particular, the input variates are

Number of Cows, Purchased Feed, Feed Cost

And the output variates are:

DHI Average Milk per Milk Cow

And the production function can be written as

$$\text{Milk per Milk Cow} = f(\text{Number of Cows, Purchased Feed, Feed Cost}) \quad (1)$$

where $f(\cdot)$ is some production function form. For each of the three years, we analyze the farms' efficiency using DEA[2]. The results are summarized in table 2.

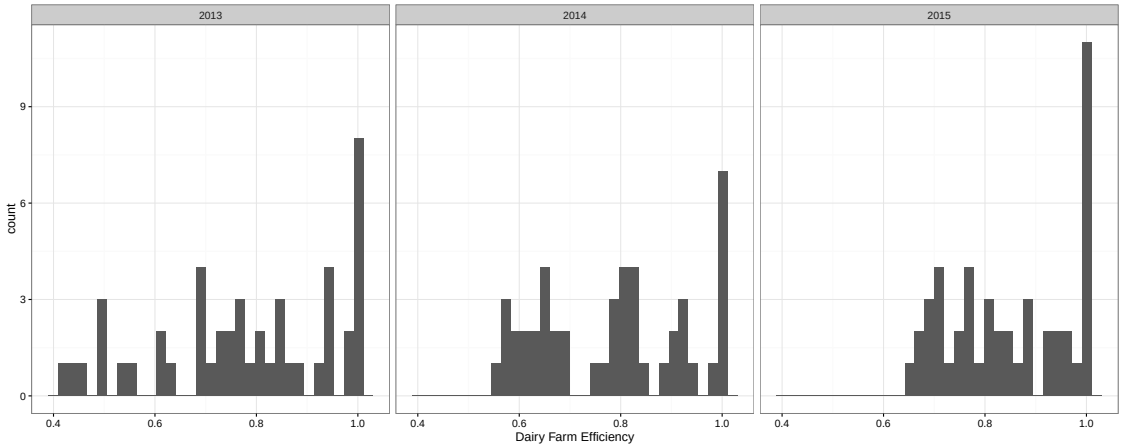
[1]See previous note for the choice of these variables.

[2]In contrast, instead of dividing data into sub-samples based on year, we can think the same DMU over different year as different DMUs. Using the latter approach, the efficiency scores for DMU will be generally significantly lower, since the production efficiency frontier will shift outwards (that is, a uniformly efficient frontier). The results using second approach is report in appendix 1.

Table 2: Dairy Farm Efficiency Scores over 2013 - 2015: Model 1

Farm ID	2013 Efficiency Scores	2014 Efficiency Scores	2015 Efficiency Scores
3	0.417	0.572	0.649
4	1.000	1.000	1.000
5	0.639	0.695	0.799
9	0.764	0.807	0.697
10	0.761	0.659	0.717
14	0.503	0.659	0.713
18	0.701	0.633	0.801
21	0.502	0.892	1.000
22	0.815	0.811	0.729
23	0.780	0.821	0.952
24	0.686	0.651	0.915
25	0.487	0.580	0.681
31	0.822	0.567	0.792
37	1.000	1.000	0.917
38	0.875	0.771	0.760
60	0.851	0.792	0.956
63	1.000	0.981	1.000
65	0.752	0.825	0.868
66	0.983	0.992	0.889
67	1.000	0.933	1.000
69	0.951	0.755	0.845
70	0.799	0.901	0.884
93	0.952	0.939	1.000
95	0.772	0.825	0.964
106	0.974	0.919	1.000
107	0.941	1.000	1.000
113	0.843	0.681	0.710
115	1.000	1.000	1.000
129	0.546	0.822	0.816
130	1.000	1.000	0.850
133	0.847	0.635	0.762
135	0.690	0.622	0.835
146	0.757	0.605	0.771
149	0.610	0.803	0.752
150	0.730	0.664	0.825
159	0.937	0.642	0.884
162	0.440	0.585	0.675
163	0.604	0.678	0.707
170	1.000	0.927	0.943
173	0.694	0.788	1.000
179	0.888	0.901	1.000
180	0.915	0.842	0.978
186	1.000	1.000	1.000
194	0.452	0.550	0.692
195	0.685	0.793	0.756
196	0.531	0.590	0.679
198	0.730	0.812	0.769

Figure 1: Histogram of Efficiency Scores of Dairy Farms over 2013 - 2015



As seen in table 2, there is a relatively large dispersion of production efficiency variations across dairy farms. We also note farms' production efficiency vary over time. To visualize the variation in both dimensions, we plot the results in figure 1. Figure 1 shows the number of efficient farms increases from 2013 to 2015[3].

2.2 Model 2

In model 2, we use a relatively large set of input and output variables. Most variates we choose in this model have missing value for year 2013. As a result, for model 2, we only use data with no missing values (2014 and 2015). In particular, the input variates are:

Number of Cows,Purchased Feed, Feed Cost
Dry Matter, CP, Starch DM, pH, Corn silage

The outputs variates are:

DHI Average Milk per Milk Cow, (negative) MUN, (negative) Fecal Starch

For each of output variates, we conduct production efficiency analysis. Thus the production functions we evaluate are:

$$\text{Milk per Milk Cow} = f_1(\text{Number of Cows, Purchased Feed, Feed Cost}) \quad (2)$$

$$-\text{MUN} = f_2(\text{Number of Cows, Purchased Feed, Feed Cost}) \quad (3)$$

$$-\text{Fecal Starch} = f_3(\text{Number of Cows, Purchased Feed, Feed Cost}) \quad (4)$$

where $f_i(\cdot)$ is some production function form $i = 1, 2, 3$. The results of efficiencies measured by milk per milk cow is reported in table 3.

As in table 3, most dairy farms are perfectly efficient. We suspect this is caused by the issue of missing values and the relative small sample (around 30 farms per year). We examine production efficiency using (negative) MUN and (negative) Fecal Starch. The efficiency scores reported in table 5 and 6 shows similar results. Thus we use the estimated efficiency from Model 1 in later section.

[3]Recall we can think the same DMU over different year as different DMUs. The results are reported in table 4 and figure 2. They are basically consistent with the result here.

Table 3: Dairy Farm Efficiency 2014 and 2015: Model 2

Farm ID	2014 Efficiency Scores	2015 Efficiency Scores
3	0.998	1.000
4	1.000	
5	1.000	1.000
9	1.000	0.987
10	0.982	
14	1.000	1.000
18	1.000	
21	1.000	1.000
22	1.000	0.996
23	1.000	1.000
24	0.958	
25	1.000	1.000
31		1.000
37	1.000	0.964
38	1.000	1.000
60		1.000
63		1.000
65	1.000	1.000
66	1.000	1.000
67	1.000	1.000
69	1.000	1.000
70	1.000	1.000
95		1.000
106	1.000	1.000
107	1.000	1.000
113	1.000	0.975
115		1.000
129	1.000	1.000
130	1.000	1.000
133	1.000	0.980
135	0.967	
146	1.000	1.000
149	1.000	
150		1.000
159	1.000	
162	1.000	1.000
163	1.000	1.000
170		1.000
179		1.000
180		1.000
194		1.000
198		1.000

Note: In this table, a blank entry means there is no efficiency score estimated. That could be caused by either a missing value in the output variate or one in the input variates.

3 Tobit Regression

In this section we conduct two step DEA on the data based on Model 1. The procedure is as follows: **Step 1**: We estimate efficiency score using Model 1.
Step 2: We run a tobit regression of efficiency score on two variates (Total Cows and Purchased Feed). The results are as follows.

```
Call:
censReg(formula = eff_Model1$Efficiency_Score ~ data$Total_Cows +
    data$Pur_Feed_Calc, left = 0, right = 1)

Observations:
         Total  Left-censored     Uncensored Right-censored
           141              0            128             13

Coefficients:
                      Estimate Std. error t value  Pr(> t)
(Intercept)          1.002e+00  5.542e-02  18.084  < 2e-16 ***
data$Total_Cows     -1.880e-04  5.314e-05  -3.538 0.000403 ***
data$Pur_Feed_Calc -2.912e-02  7.128e-03  -4.086 4.39e-05 ***
logSigma           -1.851e+00  6.403e-02 -28.918  < 2e-16 ***
---
Signif. codes:  0 ?**?0.001 ?*?0.01 ??0.05 ??0.1 ??1

Newton-Raphson maximisation, 8 iterations
Return code 2: successive function values within tolerance limit
Log-likelihood: 40.23596 on 4 Df
```

The results show both variates are significant in explaining farms' production efficiency. The coefficients of the tobit regression are:

```
   data$Total_Cows   data$Pur_Feed_Calc
     -0.000188          -0.029124
```

And the marginal effects $\frac{\partial \mathbb{E}(Y|X)}{\partial x_j}$ are

```
  data$Total_Cows     data$Pur_Feed_Calc
     -0.0001778          -0.0275450
```

4 Appendix

Table 4: Dairy Farm Efficiency Scores over 2013 - 2015: Model 1

Farm ID	2013 Efficiency Scores	2014 Efficiency Scores	2015 Efficiency Scores
3	0.41634	0.416794	0.556575
4	0.86936	1	0.857565
5	0.607902	0.630445	0.75091
9	0.729141	0.759382	0.694594
10	0.741756	0.480697	0.611422
14	0.502762	0.481112	0.595113
18	0.546834	0.578621	0.750793
21	0.502107	0.650542	0.877814
22	0.670057	0.674116	0.636015
23	0.766149	0.781702	0.936853
24	0.596913	0.525609	0.809911
25	0.475306	0.487883	0.582168
31	0.790984	0.540056	0.76862
37	1	1	0.851168
38	0.87472	0.712146	0.728793
60	0.819324	0.767522	0.876747
63	1	0.941101	0.969579
65	0.734778	0.678386	0.752969
66	0.85414	0.806581	0.726109
67	0.80975	0.807583	1
69	0.680305	0.747959	0.800318
70	0.703995	0.726691	0.774805
93	0.941486	0.913005	0.986758
95	0.751699	0.77831	0.901603
106	0.953957	0.880761	1
107	0.915191	0.98143	1
113	0.76634	0.636075	0.654516
115	1	1	1
129	0.532964	0.602408	0.700701
130	0.914988	0.982246	0.840954
133	0.730112	0.62282	0.693134
135	0.642591	0.475331	0.70551
146	0.756807	0.594687	0.74329
149	0.550464	0.660231	0.693097
150	0.6857	0.634153	0.747522
159	0.719626	0.61078	0.850911
162	0.439788	0.435843	0.585209
163	0.588361	0.562715	0.603708
170	1	0.852001	0.914381
173	0.690445	0.73627	1
179	0.851603	0.880369	0.995244
180	0.885808	0.801512	0.938807
186	1	0.810841	0.894309
194	0.438593	0.472274	0.588859
195	0.682405	0.730468	0.740073
196	0.530518	0.554897	0.612774
198	0.708857	0.715017	0.683977

Figure 2: Histogram of Efficiency Scores of Dairy Farms over 2013 - 2015

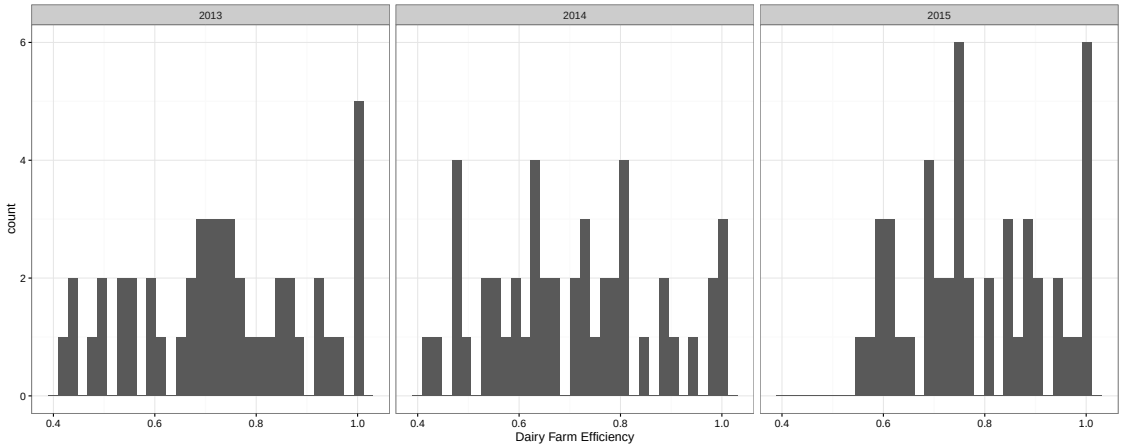


Table 5: Dairy Farm Efficiency 2014 and 2015: Model 2 Measured by MUN

Farm ID	2014 Efficiency Scores	2015 Efficiency Scores
3	0.991	1.000
4	1.000	
5	1.000	0.995
9	1.000	0.991
10	0.982	
14	1.000	1.000
18	0.990	
21	1.000	1.000
22	1.000	0.985
23	1.000	1.000
24	0.953	
25	1.000	1.000
31		1.000
37	1.000	0.964
38	1.000	1.000
60		1.000
63		1.000
65	1.000	1.000
66	1.000	1.000
67	1.000	1.000
69	1.000	1.000
70	1.000	1.000
95		1.000
106	1.000	1.000
107	1.000	1.000
113	1.000	0.975
115		1.000
129	1.000	1.000
130	1.000	0.983
133	0.988	0.967
135	0.966	
146	1.000	1.000
149	1.000	
150		1.000
159	1.000	
162	1.000	1.000
163	1.000	1.000
170		1.000
179		1.000
180		1.000
194		1.000
198		1.000

Table 6: Dairy Farm Efficiency 2014 and 2015: Model 2 Measured by Fecal Starch

Farm ID	2014 Efficiency Scores	2015 Efficiency Scores
3	0.991	1.000
4	1.000	
5	1.000	1.000
9	1.000	1.000
10	0.982	
14	0.993	1.000
18	1.000	
21	1.000	1.000
22	1.000	0.962
23	1.000	1.000
24	0.953	
25	1.000	1.000
31		1.000
37	1.000	0.965
38	1.000	1.000
60		1.000
63		1.000
65	1.000	1.000
66	1.000	1.000
67	1.000	1.000
69	1.000	1.000
70	1.000	1.000
95		1.000
106	1.000	1.000
107	1.000	1.000
113	1.000	0.987
115		1.000
129	1.000	1.000
130	1.000	1.000
133	1.000	0.976
135	0.960	
146	1.000	1.000
149	1.000	
150		1.000
159	1.000	
162	1.000	1.000
163	1.000	1.000
170		1.000
179		1.000
180		1.000
194		1.000
198		1.000