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Dynamic efficiencies and determinants under investment: an application to the Norwegian Dairy Farms

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Outline

1. Background
2. Literature review
   - method
   - empirical model used
3. Data

4. Main results

5. Conclusion

Background

- Since the introduction of **one-sided inefficiency** within the context of **Stochastic Frontier** (SF) models
  - Several models have been developed based on different

Two categories

1. assumptions on the model specification
   - about the temporal behavior of the inefficiency (e.g. persistent and transit)
   - model specifications and distribution (exponential, normal, truncated …)
   - estimation techniques (GMM, ML, GlS), etc.

(see e.g. Greene (2008), and Kumbhakar et al. (2015).

2. assumptions on the behavior of the input use (static and dynamic)

a **static framework** assumption in which an input is used for the production process, it **immediately** contributes to production at the maximum possible level.

Background

- However, once the input is introduced in the production process, it might take some **time for adjusting** within the system (Minviel and Sipiläinen, 2018).
  - **investment in new technology and improved** capital can enable lower costs in the future.
  - The firm’s decision on the use of inputs depends on the farmer's ability to make an efficient decision over time.
  - Thus, comparing the performance of firms using technical efficiency scores obtained based on in the static framework is likely to **produce misleading results.**

Literature on Dynamic analysis

- we can find important contributions on dynamic efficiency modelling
- the model advances have taken place in the framework of the **nonparametric approach** using data envelopment analysis (**DEA**). **e.g.** Silva and Stefanou (2003 and 2007).

Parametric

- Ahn and Sickles (2000) examine a potential link between **technical innovation** and productive efficiency level using a parametric dynamic approach. (GMM)

- Recently, we can find important contribution a dynamic efficiency modelling from **the parametric approach** e.g. Bhattacharyya, A. (2012)
  Serra, Oude, & Stefanou, (2011)
  Minviel and Sipiläinen, (2018)

  use different methods

Literature –dynamic parametric methods

Two approaches: **a reduced** and a **structural** approaches (Minviel and Sipiläinen, 2018).

1. The **reduced dynamic** model approaches mainly the extension of the standard SF model through an **autoregressive process** of order for the inefficiency component

That is

the actual productive efficiency in any period depends on the actual product in the **previous period**.

$\boldsymbol{y_{it}} = f(x_{it}; \beta) + (1 - \theta)\boldsymbol{y_{it-1}} + \varepsilon_{it}$ θ be the speed of adjustment of outputs.

y_{it} and y_{it-1} which both are the function of the error term (ε_{it}). The lagged dependent variable is an endogenous regressor by Construction …. **ENDOGENITY PROBLEM**

Literature –dynamic parametric methods

$$\boldsymbol{y_{it}} = f(x_{it};\beta) + (1 - \theta)\boldsymbol{y_{it-1}} + \varepsilon_{it}$$

Bhattacharyya, 2012 suggested that

- the **first differences of the two outputs** $(y_{it} - y_{it-1})$ or
- Use more-period lagged dependent and independent variables **as valid instruments**
- Estimate the Generalized Method of Moments (**GMM**) or SYSTEM GMM

e.g. Bhattacharyya, A. (2012) use this apprach and …

Shortcoming

- When you use the flexible functional form like Translog …….there will be more parameters to estimate
- It might not converge
- we can find more variables insignificant in our model and
- difficult to interpret the parameters

Literature –dynamic parametric methods

2. The structural dynamic model approach is mainly based on two methods
   - shadow cost method (Rungsuriyawiboon and Stefanou, 2007) and
   - distance function method (Serra, Lansink & Stefanou, 2011).

- A shadow cost method that relates **actual observed costs** obtained from the optimization programs.
  - This method does not specify the production technology directly (Serra, Oude, & Stefanou, 2011) .

- The dynamic distance function approach (Serra et al., 2011) is derived from the duality between input distance functions and cost functions which provide a complete characterization of **production technology**

Thus, this paper is based on the dynamic distance function approach.

Conceptual framework (graph)

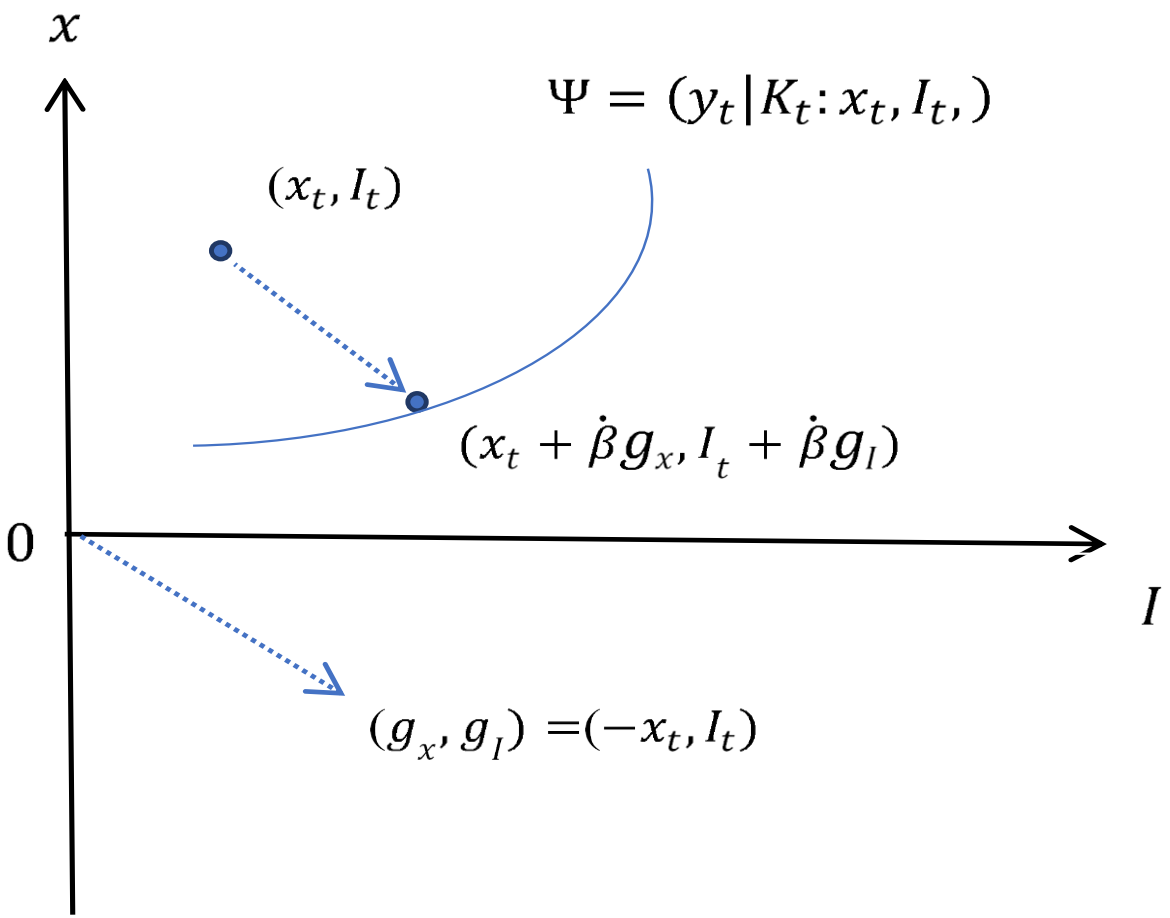


Fig. 1. Illustration of Dynamic Directional Input distance function

Conceptual framework (mathematical expressions)

The dynamic production **technology set** (Ψ) for period ***t*** can be represented by an input requirement set (L) in the following manner

$$\Psi = \{(y_t | K_t : x_t, I_t,) : x, I \ can \ produce \ y_t \ given \ K_t\}$$

The producers **transform the inputs to outputs** using some Ψ

Where

$x_t \in \Re_+^K$ denoted a 1 x K vector of **variable inputs**,
$y_t \in \Re_+^M$ stands for a 1 x M vector of **output**,
$I \in \Re_{++}^H$ represents 1 x H vector of **gross investment** and
$K \in \Re_+^P$ represents a 1 x P vector of **quasi-fixed inputs**.

(Serra, Lansink,, & Stefanou., 2011):

.

Dynamic Input distance function

- The dynamic input distance function $\boldsymbol{D_I}$ ( ) at any period, t is defined as the maximum possible reduction of input x ($\boldsymbol{\lambda}$) while retaining a given level of output vector, y, and farm characteristics, z

$$\boldsymbol{D_I(y_t, x_t, I_t, k_t; Z, t, \omega) = max\{(\lambda: {}^{x_t}/_{\lambda}) \in L(y_t, x_t, I_t, k_t; Z, t, \omega)\}} \qquad (2)$$

Where

$L(y_t, x_t, I_t, k_t; Z, t, \omega)$ is the **feasible input set**, and

ω denotes unobserved heterogeneity like individual effects

λ is a scalar ($\lambda \geq 0$) measuring possible reductions in inputs

The dynamic input distance function (DIDF) in (2) must fulfil the following **properties**

a) It is non-decreasing in outputs: $D_I(\lambda y_t, x_t, I_t, k_t; Z, t, \omega) \leq D_I(y_t, x_t, I_t, k_t; Z, t, \omega), 0 \leq \lambda \leq 0$

i.e. **monotonicity** condition

b) It is **homogeneous**: $\lambda D_I(y_t, x_t, I_t, k_t; Z, t, \omega) = \mathrm{L}(\lambda y_t, \lambda x_t, \lambda I_t, \lambda k_t; Z, t, \omega), \lambda > 0$

c) It is non-increasing in inputs: $D_I(y_t, \lambda x_t, I_t, k_t; Z, t, \omega) \leq D_I(y_t, x_t, I_t, k_t; Z, t, \omega), \lambda \geq 0$

d) It is non-decreasing in investment: $D_I(y_t, x_t, \lambda I_t, k_t; Z, t, \omega) \leq D_I(y_t, x_t, I_t, k_t; Z, t, \omega), 0 \leq \lambda \leq 0$

Monotonicity requires that the first derivatives of the distance function with respect to **all inputs** be greater than or equal to zero. We can **check** it after estimation

homogeneity condition

A convenient way of **imposing the homogeneity** condition is following Lovell et al. (1994) to divide **all inputs by one of the inputs.**

$$D_I(y_t, x_t, I_t, k_t; Z, t, \omega) / x_1 = L(y_t, ln\breve{x}_{nt}, ln\dot{I}_t, ln\dot{k}_t; Z, t, \omega) \quad (3)$$

where $\breve{x}_{nt} = \frac{x_{kt}}{X_1}, \forall n = 2, \dots, N; \dot{I}_t = \frac{I_t}{x_1}$; and $\dot{K}_t = \frac{K_t}{x_1}$

$$lnD_I(y_t, x_t, I_t, k_t; Z, t, \omega) - lnx_1 = TL(lny_t, ln\breve{x}_{kt}, , ln\dot{I}_t, ln\dot{k}_t; Z, t, \omega) \quad (4)$$

$$-lnx_1 = TL(lny_t, ln\breve{x}_{kt}, , ln\dot{I}_t, ln\dot{k}_t; Z, t, \omega) + v_{it} - lnD_I(y_t, x_t, I_t, k_t; Z, t, \omega) \quad (5)$$

where

- v_{it} is the white noise error term
- $lnD_I() = u_{it} \geq 0$ is a non-negative error term capturing the effects of technical inefficiency.

Empirical model

$$
\begin{aligned}
-lnx_1 = \alpha_0 &+ \sum_{k=1}^{K} \beta_k ln\breve{x}_{k,it} + \sum_{p=1}^{P} \beta_p \ln\dot{k}_{p,it} + \sum_{h=1}^{H} \beta_h \ln\dot{I}_{h,it} + \sum_{m=1}^{M} \beta_m \ln\dot{y}_{m,it} + \beta_t D_t \\
&+ \frac{1}{2}\sum_{K=1}^{K}\sum_{K=2}^{K} \beta_{kk} \ln x_{k,it} \ln x_{k,it} + \frac{1}{2}\sum_{p=1}^{P}\sum_{p=2}^{P} \beta_{pp} \ln k_{p,it} \ln k_{p,it} + \frac{1}{2}\sum_{h=1}^{H}\sum_{h=2}^{H} \beta_{hh} \ln\dot{I}_{h,it} \ln\dot{I}_{h,it} \\
&+ \frac{1}{2}\sum_{m=1}^{M}\sum_{m=2}^{M} \beta_{mm} \ln\dot{y}_{m,it} \ln\dot{y}_{m,it} + \sum_{K=1}^{K}\sum_{p=1}^{P} \beta_{kp} \ln x_{k,it} \ln\dot{k}_{p,it} + \sum_{K=1}^{K}\sum_{h=1}^{H} \beta_{kh} \ln x_{k,it} \ln\dot{I}_{h,it} \\
&+ \sum_{K=1}^{K}\sum_{m=1}^{M} \beta_{km} \ln x_{k,it} \ln\dot{y}_{m,it} + \sum_{p=1}^{P}\sum_{h=1}^{H} \beta_{ph} \ln\dot{k}_{p,it} \ln I_{h,it} + \sum_{p=1}^{P}\sum_{m=m}^{M} \beta_{pm} \ln\dot{k}_{p,it} \ln\dot{y}_{m,it} \\
&+ \sum_{h=1}^{H}\sum_{m=1}^{M} \beta_{hm} \ln\dot{I}_{h,it} \ln\dot{y}_{m,it} + \sum_{k=1}^{K} \beta_{kt} ln\breve{x}_{k,it} D_t + \sum_{p=1}^{P} \beta_{pt} \ln\dot{k}_{p,it} D_t + \sum_{h=1}^{H} \beta_{ht} \ln\dot{I}_{h,it} D_t \\
&+ \sum_{m=1}^{M} \beta_{mt} \ln\dot{y}_{m,it} D_t + \frac{1}{2}\beta_{tt} D_t^2 + \omega_i + v_{it} - u_{it}
\end{aligned}
$$

Greene (2005) TFE model

(TRE … Durbin–Wu–Hausman test)

$$-lnx_1 = \alpha_i + TL(lny_t, ln\breve{x}_{kt}, ln\dot{I}_t, ln\dot{k}_t; Z, t, \omega) + \varepsilon_{it}$$

$$\varepsilon_{it} = v_{it} - u_{it}$$

$$\alpha_i = \alpha_0 + w_i$$

ML imposing distributional assumptions

- $v_{it} \overset{iid}{\sim} N(0, \sigma_v^2)$
- $u_{it} \sim N^+(\mu_{it}, \sigma_u^2)$
- $w_i \sim N[0, \sigma_w^2]$

μ_{it} is a function of a vector of firm characteristics (z_{it}) i. e.

$$u_{it} \sim N^+(\partial z_{it}, \sigma_u^2)$$

Estimated also the static model for comparison

Technical inefficiency and marginal effects

- **Technical efficiency (TE)** estimated following **Battese and Coelli (1988)**

TE= $\boldsymbol{E(exp(-u_{it}|\varepsilon_{it})}$ where $\boldsymbol{\varepsilon_{it}} = v_{it} - u_{it}$

  - Technical inefficiency Jondrow et al. (1982)

$$\boldsymbol{E(u_{it}|\varepsilon_{it})}$$

- **Marginal effects (ME)** of the exogenous variables estimated following **Wang (2002)**

$$\textbf{ME=} \frac{\boldsymbol{\partial E(exp(-u_{it}|\varepsilon_{it})}}{\boldsymbol{\partial z_{itk}}}$$

Data Source

- We used farm-level survey data
- The data collected by Norwegian Institute of Bioeconomy Research (NIBIO).

Data collected from farms in

different regions

different farm size and

different farm type

- We select those farms whose dairy sales represent at least **80%** of total farm income.
- Minimum of years **3** years
- For the year 2000-2018
- unbalanced panel of **5327** observations on 663 Norwegian dairy farms

Variables specification

Output (2)

- **Dairy output (y_1)** -total farm revenue from dairy products (milk, beef/cattle, and other livestock)
- **Other output (y_2),** total farm revenue from include crop and other outputs the farm produced

input

- **labour (x_1)=** total labor hours used on the farm, including hired labor, owners' labor, and family labor
- **Farm land (x_2)** = both owned and rented in hectares.
- **Materials (x_3)** =including fertilizers, feed, oil and fuel products, electricity, expenses for crop and animal protection, construction materials and other costs; and
- ***Capital assets*** (K)= including the implicit quantity index that is obtained by deflating the value of machinery, building, and **livestock at** the beginning of the year

❑ **Gross investment** (I) represent the flow of investments during the respective year in NOK

All values are measured in NOK adjusted to 2015 values.

Exogenous variables

- Exogenous variables selected based on
  - literature and
  - data availability

- The following exogenous variables included in the model

  i) the financial structure of the farm measured as **debt to an asset ratio**

  ii) government support in NOK (subsidy)

  iii) farm experience measured in a year, and

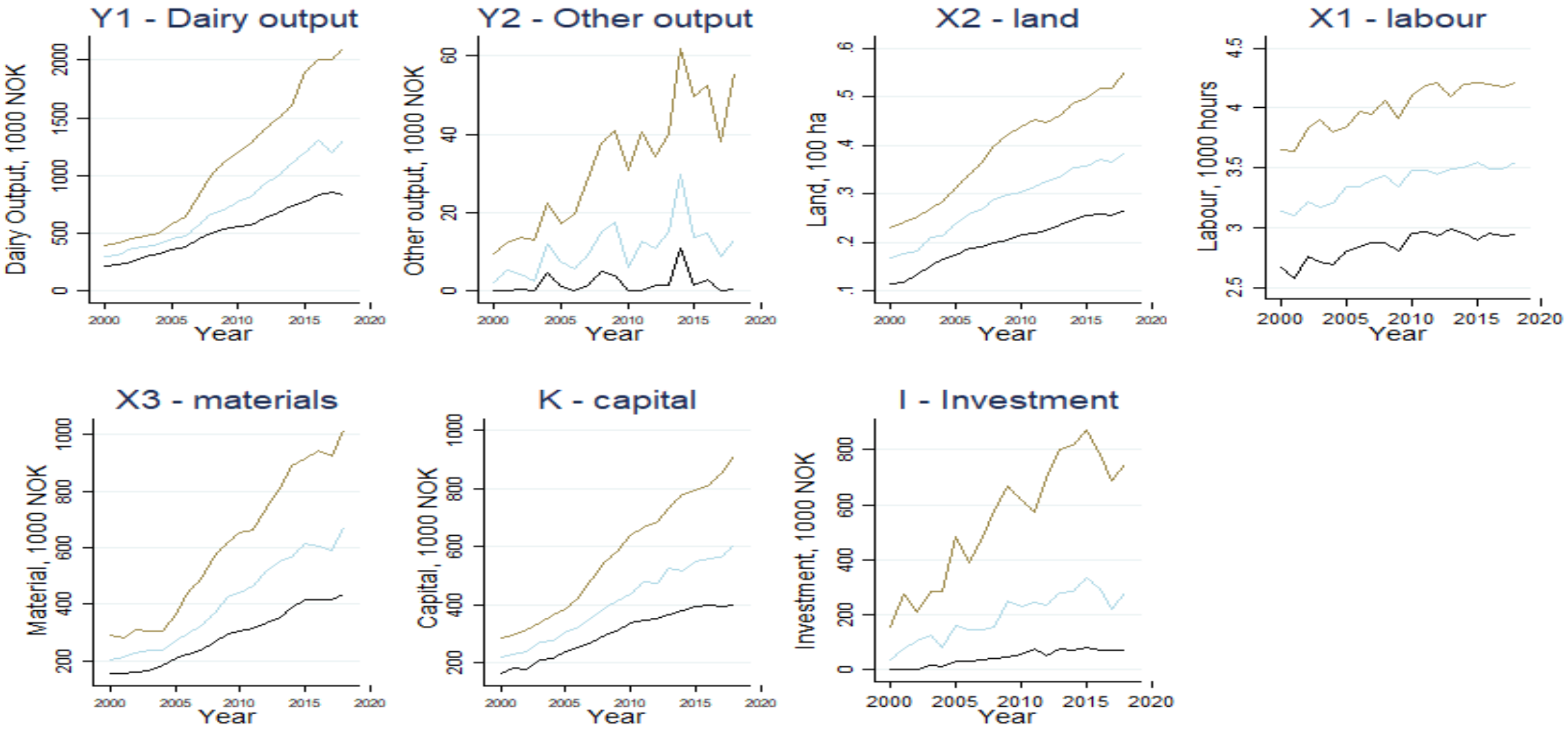
  iv) off-farm income measured in NOK.

Table 1 Descriptive statistics for the main variables used for the year 2000-2018.

	Mean	Std. Deviations
Output and input variables		
Dairy revenue in 1000 NOK* (y1)	969.031	696.191
Other output in 1000 NOK (y2)	32.497	60651
Land in hectare (x1)	34.404	20.438
Labour 1000 in hours (x2)	3.534	0.940
Materials in 1000 NOK (x3)	535.469	402.353
Capital in 1000 NOK (K)	503.570	312.117
Investment in 1000 NOK (I)	449.655	605.403
Exogenous variables		
Debt Asset Ratio (Z1)	0.400	0.181
Government support in 1000 NOK (Z2)	533.134	228.512
Farm experience in year (Z3)	27	10
Off-farm income in 1000 NOK (Z4)	0.671	0.331
Observation	5327	

* NOK = Norwegian kroner in 2015 values. 1 NOK = 11 EUR

Fig 1. The median, first and third quantile values (middle, bottom, and top lines) of outputs and inputs



	Dynamic Model		Static Model	
	Estimated value	*Robust Std. error*	Estimated value	*Robust Std. error*
Elasticities				
x_2 (Land)	**0.242*** **	**0.008**	**0.147*** **	**0.007**
x_3 (material)	**0.359*** **	**0.009**	**0.416*** **	**0.009**
K (Capital)	**0.184*** **	**0.007**	**0.209*** **	**0.008**
I (Investment)	**0.005*** **	**0.000**		
y_1 (Dairy output)	-0.453***	0.012	-0.535***	0.009
y_2 (Other output)	-0.007***	0.001	-0.009***	0.001
D (year)	**0.005*** **	0.001	0.001	0.001
Constant	0.112***	0.006	0.160***	0.004
Marginal effects of determinates on technical efficiency [b]				
Debt-asset ratio	0.469***	0.111	0.892***	0.160
Subsidy	0.002***	0.000	0.002**	0.000
Farm experience	-0.001***	0.002	-0.004***	0.002
Off-farm activity	0.000	0.000	0.001	0.000
Different tests of the technology				
Welch test comparing mean TE	22.836***	0.000		
LR test of random effect	3480***	0.000	2562**	0.000
Cobb-Douglas technology	1285***	0.000	985***	0.000
Log. Likelihood	5291***	0.000	3984***	0.000
Technical Efficiency	0.902	0.115	0.876	0.124
Number observation	5327		5327	

** p<0.10, ** p<0.05, and *** p<0.01*

The second-order parameters in the TL are dropped

Monotonicity fulfilled

The estimated partial elasticity of **all inputs and outputs** are statistically significant dynamic and Static models.

The highest partial elasticity is found in both models for **material input (x_3)** i.e. 0.359 (dynamic) and 0.416 (Static)

The partial elasticity of **investment (I)** was positive and statically significant a value of 0.005 (dynamic)

The coefficients for the time trend is statically significant at 1 % level with values of 0.005 (dynamic) and 0.001(static)

These positive values for I and D suggest Investment based **technical progress during the study period**

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Table 2: Estimated parameters for the dynamic model and its Static counterpart

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Off-farm activity	0.000	0.000	0.001	0.000

The negative of the inverse of the **sum of the partial output elasticities** provides a measure of

- the **economies of scale** (EOS) (Panzer and Willig, 1977) and
- it is referred to as **ray scale economies** (Ray, 1982)

$$\mathbf{EOS} = -\left[\sum_{m=1}^{2} \frac{\partial lnD_I}{\partial \ln y_{mit}}\right]^{-1}$$

The technology exhibits

Constant RS If the EOS= 1
Decreasing RS EOS< 1
Increasing RS EOS> 1

EOS is **2.14 - 1.83 >1** ….the dairy technology exhibit **increasing returns to scale** for the average farm for the year 2000-2018.

Similar results reported in **Alem et al,** (2019). Economies of Scale and scope paper

c. Technical efficiency

Table 3 Distribution of technical efficiency scores

Percentile	*Dynamic model*	*Static model*	*Difference*
1%	0.384	0.366	0.018
5%	0.696	0.634	0.062
10%	0.774	0.726	0.048
25%	0.869	0.842	0.027
Mean	0.902	0.876	0.026
75%	0.974	0.954	0.020
90%	0.999	0.968	0.031
95%	0.999	0.972	0.027
99%	0.999	0.982	0.017
Std.devation	0.115	0.124	
Observations	5327	5327	
Welch test comparing mean TE		22.836***	

The Welch test, reported indicates the dynamic and the static efficiency scores are significantly different

As the dynamic efficiency scores are higher, this suggests that, in our sample,

the static model **underestimate the performance** of the dairy farms.

The dynamic efficiency score implies that

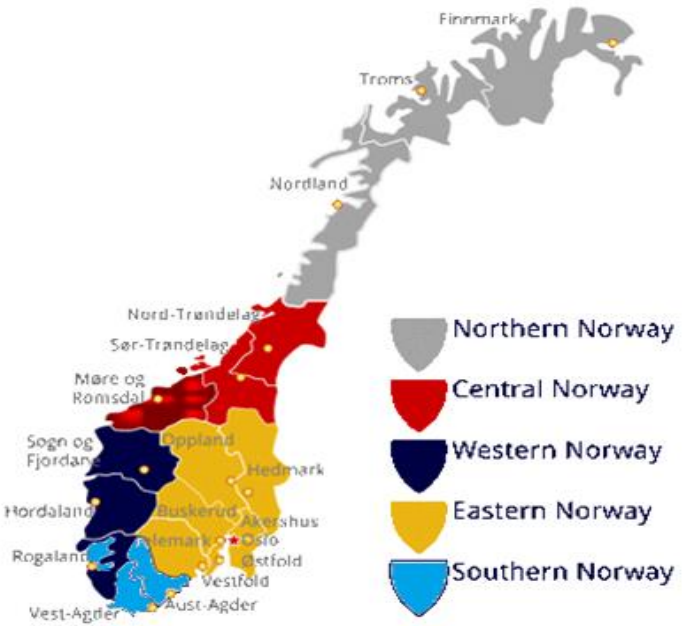
…the Norwegian dairy farms **can reduce the input** requirement of producing the average output by 10 % if the operation becomes technical efficient.

Regional performance difference

Table 4 Technical efficiency scores by region

Regions	Dynamic model	Static model	Number of Observations
Eastern Norway Lowlands	0.880	0.844	442
	(0.117)	(0.138)	
Eastern Norway other parts	0.916	0.888	865
	(0.094)	(0.105)	
Agder and Rogaland -Jæren	0.901	0.914	304
	(0.113)	(0.112)	
Agder and Rogaland -other parts	0.906	0.889	539
	(0.122)	(0.134)	
Western Norway	0.910	0.883	1132
	(0.127)	(0.113)	
Trøndeland -Lowlands	0.892	0.898	388
	(0.104)	(0.101)	
Trøndeland -other parts	0.909	0.882	676
	(0.102)	(0.108)	
Northern Norway	0.885	0.842	981
	(0.122)	(0.118)	
All regions	0.902	0.876	5327
	(0.115)	(0.124)	

Standard errors in parentheses



The results show that there is no statically difference between regions

Similar results reported in **Alem et al, 2018** (regional performance in Norwegian Dairy farms)

Farm size and performance

Table 5 technical efficiency scores by Farm size

Regions	Dynamic model	Static model	Number of Observations
< 10 hectar of land	0.941	0.932	125
	(0.051)	(0.041)	
10- 20 hectar of land	0.959	0.950	1091
	(0.039)	(0.023)	
20- 30 hectar of land	0.942	0.927	1514
	(0.048)	(0.045)	
30- 50 hectar of land	0.894	0.870	1725
	(0.087)	(0.088)	
> 50 hectar of land	0.770	0.701	872
	(0.186)	(0.178)	
All farm size	0.902	0.876	5327
	(0.115)	(0.124)	

Standard errors in parentheses

The performance of small and medium farms better than the big farms.

This might be due to determinants of inefficiency which is discussed below

Table 2: Estimated parameters for the dynamic model and its Static counterpart

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Subsidy	0.002***	0.000	0.002**	0.000
Farm experience	-0.001***	0.002	-0.004***	0.002
Off-farm activity	0.000	0.000	0.001	0.000

- High debt/asset ratio negatively correlated to the Norwegian dairy farm performance

Conflicting results from the literature

- Sipiläinen et al. (2013) support our finding (Norway and Finland)
- Minviel and Sipiläinen (2018) reported a **positive correlation** between technical efficiency and debt/asset ratio (France)

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- **Subsidy** negatively correlated to performance

Still conflicting results from the literature

Similar results have been reported

- subsidies could **slow down the rate** at which resources are reallocated to more productive use in response to new technologies or investment (Matthews , 2013)
- public **subsidies could distort** the timing of adjustment decision (Minviel and Sipiläinen, 2018)
- Subsidy **reduce producer incentives** to generate the highest possible income from farming (Giannakas et al., 2001)

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D (year)	0.005***	0.001	0.001	0.001
Constant	0.112***	0.006	0.160***	0.004
Marginal effects of determinates on technical efficiency [b]				
Debt-asset ratio	0.469***	0.111	0.892***	0.160
Subsidy	0.002***	0.000	0.002**	0.000
Farm experience	-0.001***	0.002	-0.004***	0.002
Off-farm activity	0.000	0.000	0.001	0.000

- experience of farmers positive correlated to farm performance
  - farm managers with **more experience** are likely to be more efficient than those with fewer years of experience.
- Similar results have been reported in the literature (Wilson et al., 2001; Bozoğlu & Ceyhan, 2007; Kumbhakar et al., 2014).
- Off-farm activity is not significant
  - Conflicting results from the literature

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Conclusion

- The SF analysis advances in methods based on different assumption on the model specification and input use

- The static modelling ignores the inter-temporal nature of production decisions thus **under estimate the performance** of the farmers

- The dynamic production model provides a more realistic approach to measure the performance of the Norwegian dairy farm,

Conclusion

- The marginal **effects experience** positively correlated with dairy farm performance

While

  – **subsidy** and **debt-asset ratio** negatively correlated

Further study

- Dairy farmers are receiving different types of government support **based on various criteria**

  - Different subsidies might have a **different effect** on dairy farm-performance.

  - it would be necessary **to repeat the analysis with less aggregated data**

Thank you!!

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