Measuring And Explaining Productivity Growth Of Renewable Energy Producers: The case of Austrian Biogas plants

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Background: Renewable Energy in Austria

- European Union climate policy
  - 20% increase in energy efficiency
  - 20% reduction in EU greenhouse gas emissions from 1990 levels
  - **20% of gross final energy consumption from renewable energy**
- Production of renewable energy promoted by the EC, as well as national and local governments in the EU (e.g. Austria: green electricity act 2002)
- Target for Austria (directive 2009/28/EG) 2020: **34 %**

	2002	2010	2014
Share of Renewable Energy	21 %	27 %	31 %
Share of Biomass (solid, liquid & gas)	5 %	12 %	13 %
Share of Hydro power	11 %	9.5 %	11 %

Table 1: Share of renewable energies in gross energy consumption in Austria
Source: Statistics Austria

Background: Biogas in Austria

- **Share of biogas** in total **renewable** gross energy consumption: 1.8 % (2013)
- Development of biogas plants in Austria:

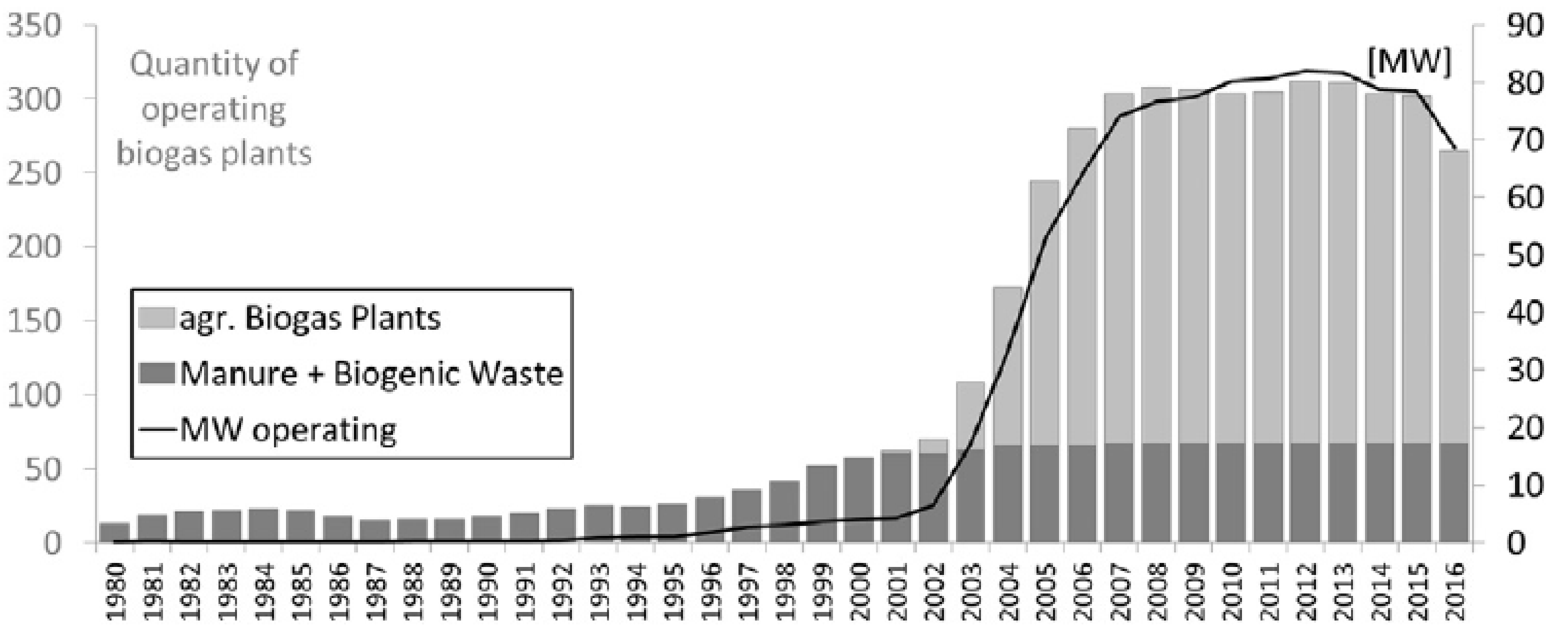


Fig. 1. Number and capacity of biogas plants operating in Austria from 1980 to 2016.

Source: Stürmer (2017)

Background and motivation: Biogas in Austria

- **Green electricity act / Feed-in-tariffs are effective** in raising renewable electricity generation

  Guaranteed feed-in-tariff for electricity **expires** after 13 years

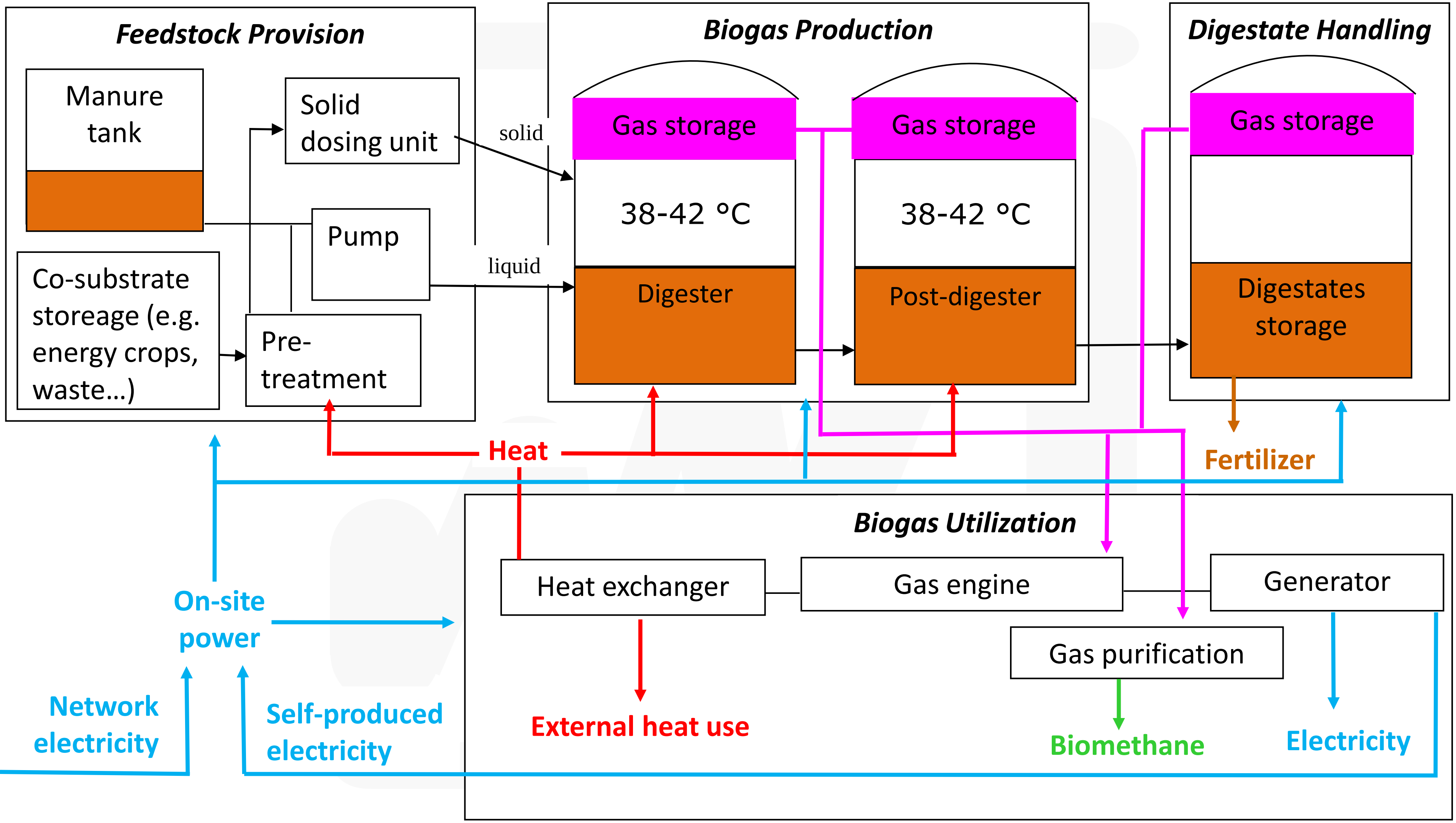
  - Average feed-in-tariff 2016: 17.31 cent / kWh_{el}
  - Average market price 2016: ~ 2.70 cent / kWh_{el}

- **Green electricity act** also aims at making **renewable energy** technologies **ready for the market**
- **Productivity** is an essential **determinant of** unit costs, profit and **competitiveness**
- Measuring and **understanding productivity growth** of biogas plants seems to be a **necessary condition to increase** their **productivity**
- **Fill gap in the literature**

Aim of the study

- Investigating **productivity development** in the Austria biogas sector from 2006 to 2014
- Finding the **drivers** of productivity change (i.e. efficiency change, technical change, etc.)
- Identifying further **influences** on productivity change (i.e. meaningful correlates or determinants of productivity change)

Biogas plants: material and energy flows



Input and output measures

Variable	Description
Inputs	
Feedstock (Nm³ CH_4)	Aggregated methane content of the substrates, excluding waste. Reflects the energy content of the feedstock.
Capital (Euros)	Total investments until end of year including e.g. CHP, digesters, ...
Labour (h)	Working hours for operating and managing the plant
Electricity consumption (kWh_{el})	Electricity consumption for operating the plant
Other costs (Euros)	Include e.g. insurance and maintenance costs
Outputs	
Electricity sold (kWh_{el})	Amount of Electricity generated by the CHP, fed into grid
Heat sold (kWh_{th})	Amount of Heat generated by the CHP, externally used
Waste disposed (t FM)	Amount of industrial bio waste processed

note: heat consumption, harvesting and transportation of feedstock as well as digestate handling are not covered (due to data unavailability).

Change of average input and output volumes from 2006 to 2014

	2006	2014	% change
Inputs:			
Feedstock (Nm^3 CH_4)	508,530	589,903	**16%**
Capital (Euros)	1,259,744	1,413,318	**12 %**
Labour (h)	1,382	1,869	**35 %**
Electricity Consumption (kWh_{el})	209,304	241,816	**16 %**
Other costs (Euros)	94,229	135,019	**43 %**
Outputs:			
Electricity sold (kWh_{el})	1,906,822	2,324,796	**22 %**
Heat sold (kWh_{th})	370,375	1,307,123	**253 %**
Waste disposed (t FM)	374	628	**68 %**

note: number of observation is 65.

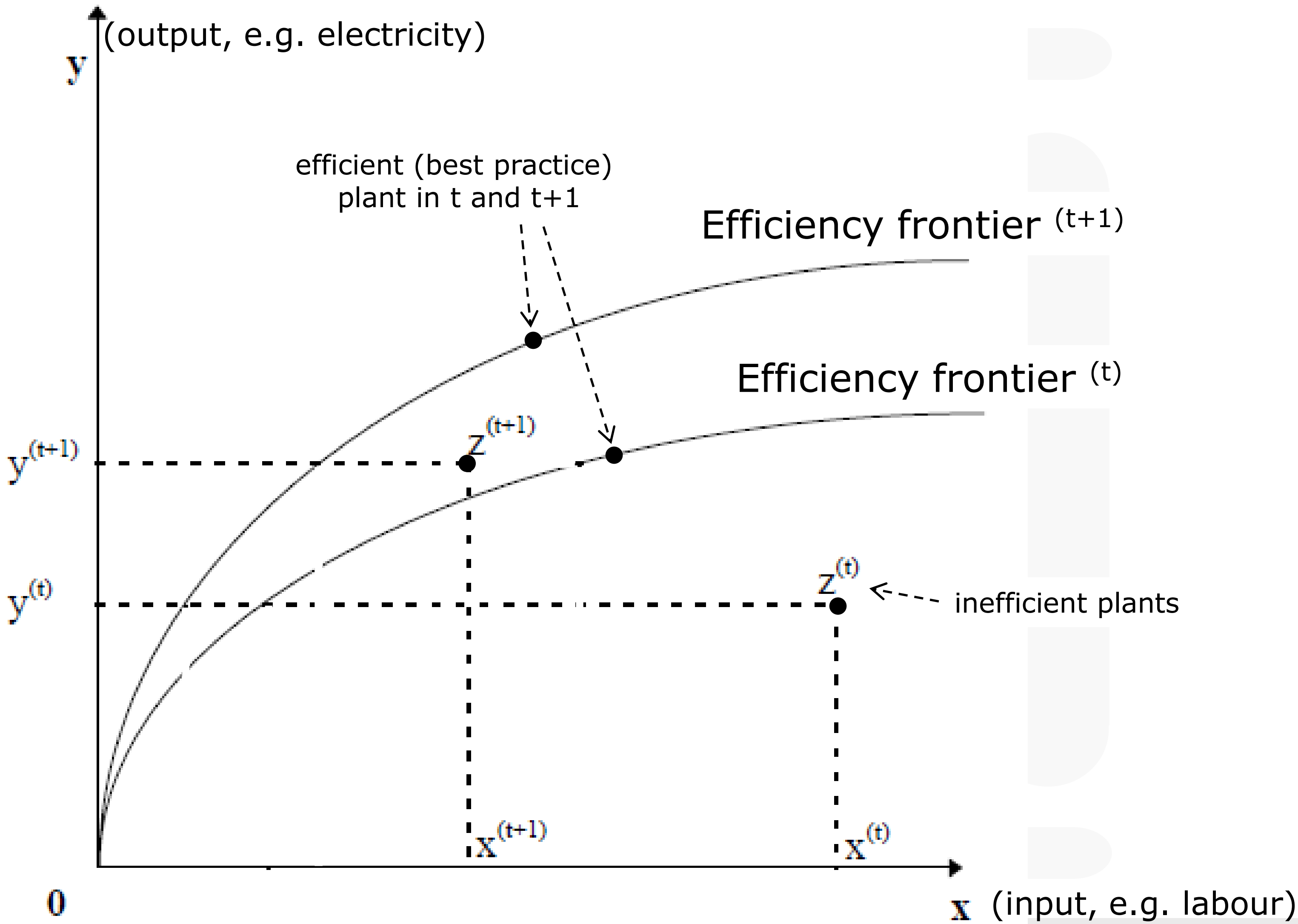
Methodology

The following methods are applied:

- Efficiency computed using basic radial **Data Envelopment Analysis-** models
- Hypothesis test CRS vs. VRS, NIRS vs. VRS (Simar & Wilson 2002)
- Productivity change computed using **Malmquist productivity index**
- **Productivity change decomposed** according to Ray and Desli (1997) in
    - pure technical efficiency change
    - pure technology change
    - scale change factor
- **Sources** of productivity change **identified** based on regression analysis

note: CRS … constant returns to scale, VRS … variable returns to scale, NIRS … non-increasing returns to scale

Methodology



Results: Productivity estimates and decomposition

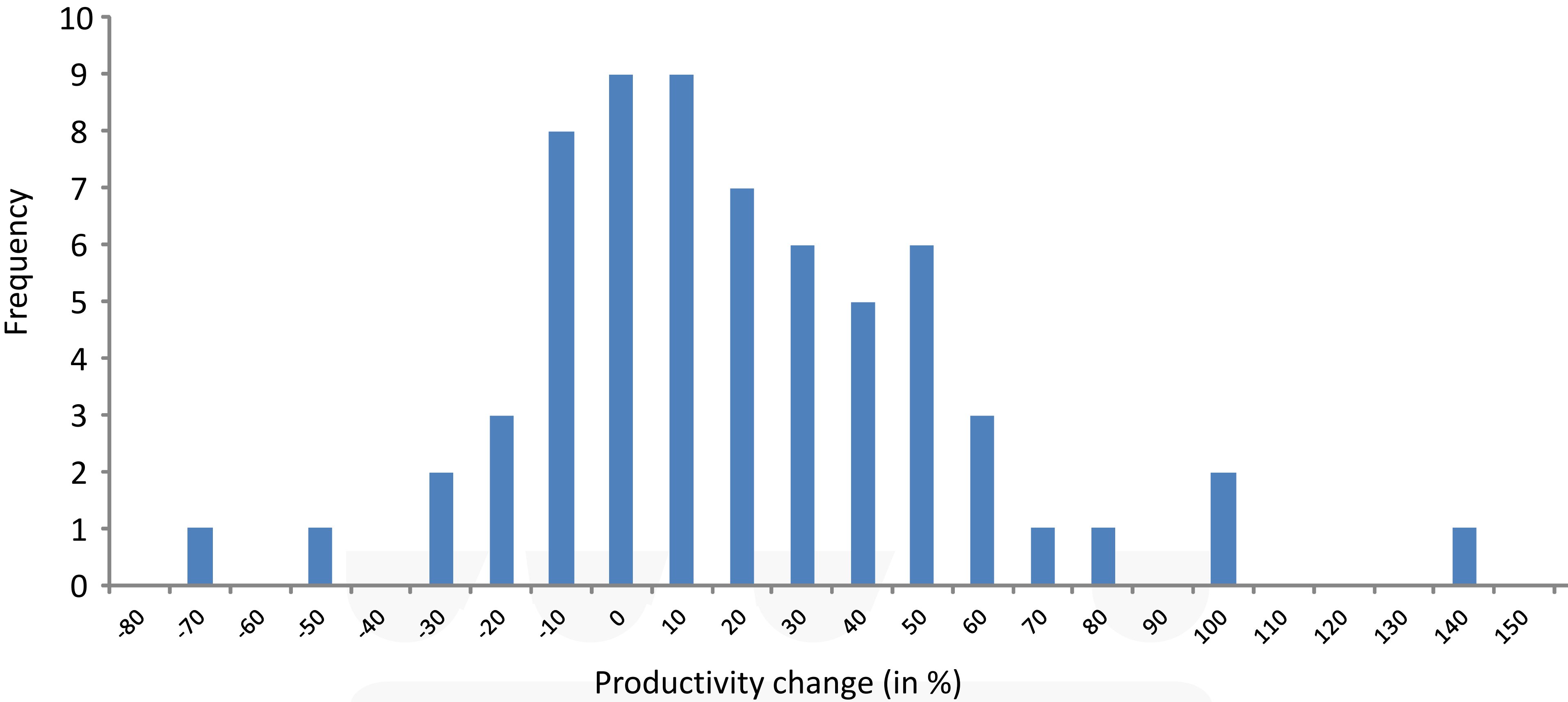
	Productivity change
Mean	**9.4%**
Coefficient of variation	30.8%
Minimum	-72.6%
Maximum	138.9%

Drivers:

	Efficiency change	Technical change	Scale change
Durchschnitt	**2.3%**	**2.2%**	**4.7%**
Coefficient of variation	15.2%	20.9%	12.1%
Minimum	-37.0%	-69.7%	-13.3%
Maximum	53.8%	67.3%	61.5%

note: number of observation is 65.

Results: Distribution of productivity change scores



note: number of observation is 65

Regression model (pooled OLS)

$$PRODCH_{i,t} = \alpha + \beta X_{i,t} + \gamma time + \varepsilon_{i,t}$$

i = 1, ..., 65 t = 2006-12, 2012-13, 2013-14

Explanatory Variables $X_{i,t}$:

- Initial efficiency (in 2006, 2012, 2013)
- Dummies for: i) waste plant, ii) capital subsidy, iii) Austrian federal states
- Age of the plant and age squared (years)
- Size and Δ size (capacity in kW_{el}); investment dummy
- Δ Capacity utilization
- Δ Output concentration (Change in Herfindahl index)
- Δ Capital intensity (Change in capital-labour ratio)
- Δ Feedstock price (feedstock t oTS / feedstock costs)

Regression results

Independent Variables	Dependent Variable
	PRODCH
Initial efficiency level	-0.376*** (0.124)
Δ Size	0.002** (0.001)
Δ Capacity utilization	0.354** (0.165)
Δ Output concentration	-0.437*** (0.154)
Δ Capital intensity/100	0.016*** (0.003)
Δ Feedstock price	0.001** (0.000)
R-squared	0.41
Adj. R-squared	0.35
Number of obs.	195

Note: Estimated coefficients of the pooled-OLS model are reported. Standard errors clustered on the plant identifier are shown in parenthesis. p<0.01, ** p<0.05, * p<0.1.

Summary and conclusions

Average **productivity gains of 9.4% (annual growth rate 1.1 %)** of Austrian biogas plants between 2006 and 2014:

- Due to **exploration of returns of scale.** The estimated average scale change factor is 4.7%. Smaller plants have higher scale change factors (catching-up in size).
- Due to **Catching-up** of less efficient plants: Average pure technical efficiency increased by 2.3%.
- **Small technical change (2.2 %):** In the long-run productivity growth will be exhausted if there is no technical change (frontier shifts)

- **Increasing the size** (i.e., increasing the nominal installed capacity), **labour productivity**/automation (i.e., increasing the capital-labour ratio), **increasing capacity utilization** (i.e. more full load hours or shorter operational interruption), and **output-diversification** (e.g. increased heat utilization) contribute to productivity growth.

Policy and regulatory implications

Policy makers and regulators should be aware that:

- **Biogas plants** exhibit **increasing returns** to scale at small-scale operation (<160 kW_{el}).
- **Biogas plants** using **co-generation units** are characterized by **positive synergies among power and heat generation,** primarily based on fuel savings.

Policies that incentivise

i) biogas plant operators to diversify and

ii) scaling up small-sized plants can generate substantial productivity gains

<u>The current FIT-scheme provides no or only weak incentives</u>

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Appendix: Previous literature

The only published **study** on productivity change is **Rácz and Vestergaard** (2016):

- Country: Denmark
- Sample size: 7 to 19 per year (unbalanced panel)
- Observation period: January 1992 to December 2005 (14 years)
- Inputs:
  - Animal Manure
  - Other organic waste
- Outputs:
  - Biogas product
- Main results:
  - Since the expiring of support scheme productivity growth is mainly due to catching-up effects with improvements in both pure technical efficiency and scale efficiency.
  - The biogas plants have optimized their production with very few investments and hence technical progress is absent.

Appendix: Open questions

Investments and technical change are low:

- Implementing Innovations that push the production frontier outwards are highly needed to realise productivity gains in the future. How?

Causality between Investments and Productivity change:

- Are investments low because of low productivity growth. Is productivity growth low because of low investments? (or bidirectional relationship?)

Appendix: Conversion tables for feedstock

The energy content and the content of volatile dry matter per tonne of fresh matter for the various substrates is delivered by the ARGE Biogas and Kompost as follows:

	Ø Nm^3 CH_4/t FM	Solids (dry matter)	Volatile solids (% of solids)
Waste	145	24%	85%
Grass	110	33%	93%
Cascading use	85	65%	90%
Maize	115	35%	98%
Other renewables	105	33%	95%
Manure	20	10%	85%

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