

# Regionalized Input-Output Modeling to Assess the Impacts of Energy Transition Investments on the Local Economy: A Case Study of Schleswig-Holstein, Germany

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1<sup>st</sup> IAEE Digital Conference (Zoom), June 7-9, 2021

FCN | Future Energy Consumer Needs and Behavior



# Agenda

- Introduction and Motivation
  - Why Schleswig-Holstein?
  - ➢ Why I/O modelling?
- Related Literature
- Methodology
  - Input-Output Models
  - Regionalization Techniques
- Data
- Results
  - Further work in progress
- Discussion







# **Introduction and Motivation I**



Technology

Society

Economy

Ecology

#### Schleswig-Holstein:

#### Germany's northernmost federal state and "Modellregion" ('model region')



- well-developed wind power generation
- extensive grid infrastructure
- representative social and demographic structure





# **Introduction and Motivation II**



## **Research Question**

What effects do investments in energy assets and grid infrastructure have on the

regional economy (in the short-term)?



# **Related Literature I**

### I/O models and energy

Madlener and Schreiner (2021), *Energy Policy*: National I/O analysis of grid investments

Madlener and Koller (2007), *Energy Policy*: Regional I/O study on heating systems

DIW Berlin (2020), *DIW-Expertisen*: Regional I/O study on onshore wind energy in Schleswig-Holstein

Kronenberg et al. (2018), *report*: I/O-based scenario analysis for sustainable development in NRW, Germany

Lehr et al. (2018), *report*: I/O-based analysis of employment effects

#### I/O models and regionalization

Klijs et al. (2016), *Impact* Assessment in Tourism Economics: Comparison of commonly used regionalization methods

Flegg et al. (1995, 2000), *Regional Studies*:

Development of the FLQ-methods for regionalization

Flegg and Tohmo (2008, 2019), *Papers in Regional Science*: Empirical evaluation of the FLQ method

Többen and Kronenberg (2015), *Economic Systems Research*: Development of the CHAR-method

Pratt (2015), Annals of Tourism Research: Regionalized I/O analysis on tourism

#### Energy and (regional) economy

Chang et al. (2019), *Global Energy Interconnection*: Investment optimization model for the entire grid

De Oliveira-De Jesus and Henggeler Antunes (2018), *Sustainable Energy*: welfare optimization model for grid investments

Wolak (2015), *Energy Policy*: Competitiveness benefits to consumers from grid expansion

> Missing Piece: regional I/O studies

> > for energy

infrastructure





# Methodology I: Intput/Output Modeling I: I/O Tables

## I/O Models

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## Based on I/O-Tables, I/O models describe the structure of an economy

		Intermediate demand			Fi	nal expe	nditure	Direct	
	Symmetric industry-by-industry I-O table	Industry 1		Industry 36	Domestic demand	Cross- border exports	Direct purchases by non-residents	purchases abroad	Output (bp)
	Industry 1 (domestic, bp)								
	1.000 M								
6	Industry 36 (domestic, bp)								
7	Product 1 (imports, bp)				-				
			Α		В	С	D	E	
2	Product 36 (imports, bp)	<b></b>							
3	Taxes less subsidies in intermediate and final imported products								
4	Taxes <i>less</i> subsidies on intermediate and final products paid in the domestic territory								
5	Total intermediate / final expenditure (pu)	Sum of (1:74)							
6	Value-added (bp)								
7	Output (bp)								
	GDP (expenditure approach) GDP (output approach) pu: purchasers' prices bp: basic prices								
	A: Imports of intermediate products B: Imports of final products C: Re-imports and re-exports D: Imported products for non-residents expenditu E: Direct purchases abroad of foreign products b	ures ly resident	s						
	Imports are valued at basic prices of the country c.i.f. purchasers' prices are re-allocated to trade, subsidies received in foreign countries are exclu	of origin, i transport ded from r	.e. the d and insu ow 37 to	omestic a irance sec row 72 an	nd internati tors of fore	ional distri ign and do	bution included omestic industri n row 73	in goods imp es. Taxes pa	orts in id and

## I/O Table:

- national statistical office
- time-lag
- production by sector
  - intermediate use
  - final consumption

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#### Image:

https://www.oecd.org/sti/ind/input-outputtables.htm



# Methodology I: Intput/Output Modeling II: A brief overview

$$X_{i} = \sum_{j=1}^{N} X_{ij} + F_{i} \qquad i = 1, \dots, N$$
Total production = sum of intermediate and final use
$$X_{ij} = a_{ij}X_{j} \rightarrow a_{ij} = \frac{X_{ij}}{X_{j}} \coloneqq const$$
Assumption: constant technology in the short-run
$$X_{i} = \sum_{j=1}^{N} a_{ij}X_{j} + F_{i}, \qquad i = 1, \dots, N$$
Substitution
$$\begin{pmatrix} X_{1} \\ X_{2} \\ X_{3} \\ X_{...} \\ X_{n} \end{pmatrix} = \begin{pmatrix} a_{11} & a_{12} & a_{13} & \dots & a_{1n} \\ a_{21} & a_{22} & a_{23} & \dots & a_{2n} \\ a_{31} & a_{32} & a_{33} & \dots & a_{3n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & a_{n3} & \dots & a_{nn} \end{pmatrix} \cdot \begin{pmatrix} X_{1} \\ X_{2} \\ X_{3} \\ X_{...} \\ X_{n} \end{pmatrix} + \begin{pmatrix} F_{1} \\ F_{2} \\ F_{3} \\ F_{...} \\ F_{n} \end{pmatrix}$$
Obtaining a system of linear equations

# X = AX + F



# Methodology I: Intput/Output Modeling II: A brief overview

# X = AX + F

(I-A)X = F	Production by sector as a function of demand
$X = (I - A)^{-1} \cdot F$	Light a location inverse matrix
$L = (I - A)^{-1}$	(in honor of Wassily Leontief)
$X = \mathbf{L} \cdot F$	<ul> <li>describes output multipliers</li> </ul>

Challenge:

Estimating L (or A) for a single region without survey data

Assumption: linear relationship with national coefficients

$$a_{ij}^{ir} = t_{ij}^{ir} \cdot a_{ij}^n$$



## Methodology II: Regionalization Simple-Location Quotient

Location Quotient	а	$_{ij}^{ir} = t_{ij}^{ir} \cdot a_{ij}^n$	nation	al I/O table		
	Data:	regional production				
1	Assumptions: 1 The bigger/smaller the (relative) size of sector > The bigger/smaller the likelihood of supplying goods 2 Regional relative supply cannot exceed national supply					
$t_i^{ir} = SLQ$	$p_i = \frac{\left(\frac{x_i^r}{x^r}\right)}{\left(\frac{x_i^n}{x^n}\right)}$	$a_{ij}^r = \begin{cases} SLQ_i \cdot a_{ij}^n \\ a_{ij}^n \end{cases}$	$\forall SLQ_i^r < 1 \\ \forall SLQ_i^r \ge 1$			
	N No meas	Limitations: o Cross-Hauling ure of import-propensity	,			



## Methodology II: Regionalization Flegg Location Quotient

Location Quotient		$a_{ij}^{ir} = t_{ij}^{ir} \cdot a_{ij}^n$	nation	I I/O table			
		n					
	Assumptions:						
	The bigger/smaller the (relative) size of sector and the						
	smaller/biç	er the (relative) size of the receiving sector by region size					
	> The big	gger/smaller the likelihoo	od of supplying goods	Rule of Thumb:			
	2 Regional r	elative supply cannot ex	ceed national supply	$\delta = 0.25$			
	$[ ( r)]^{\delta}$	$\langle SIO \rangle$					
$t_i^{ir} = FLQ_{ij} =$	$\left \log_2\left(1+\frac{x}{x^n}\right)\right $	$\left(\frac{SLQ_j}{SLQ_i}\right)  \forall \ i \neq j$	$r$ (FLQ <sub>ii</sub> · $a_i$	$\forall FLQ_i^r < 1$			
		$(SLQ_j)$	$a_{ij}^r = \begin{cases} a_{ij}^n \end{cases}$	$\forall FLQ_i^r \geq 1$			
$t_i^{ir} = FLQ_{ij}$	$=\left[\log_2\left(1+\frac{x^r}{r^n}\right)\right]$	$SLQ_i  \forall \ i = j$					

#### Limitations:

#### Strong assumptions on cross-hauling



# Methodology III: Cross-Hauling Adjusted Method – CHARM

#### **Cross-Hauling**

- Simultaneous importing and exporting of goods in the same sector
- Leads to an overestimation of regional multipliers

Scaling of national I/O table with regional employment data

$$z_{ij}^r = \left(\frac{l_j^r}{l_j^n}\right) \cdot z_{ij}^n$$

$$w_{ij}^r = \left(\frac{l_j^r}{l_j^n}\right) \cdot w_{ij}^n$$

$$d_i^r = \left(\frac{BIP^r}{BIP^n}\right) \cdot d_i^n$$

Estimation of cross – hauling based on production and consumption by sector
Measure of intra-sector heterogeneity

$$v = e_i + m_i = |b_i| + h_i \cdot (x + z + d)$$

#### Assumption

National heterogeneity estimates regional heterogeneity

$$h_i = h_i^r = h_i^n = \frac{v_i^n - |b_i^n|}{x_i^n + z_i^n + d_i^n}$$

enables estimation of regional im- and exports



## Data

#### Macroeconomic Survey - Data:

#### National I/O Table:

- High resolution
- Time-lagged
  - 2017 version

Regional Economic Data:

- Much lower resolution
- Inconsistent classifications
- Incomplete w.r.t. trade, employment

Harmonization and Reclassification necessary





Statistisches Amt für Hamburg und Schleswig-Holstein

Project – specific investment data:

Collected investment data from various reports and projects

- Few available on disaggregated level
- Classification of components according to producing sector
- Discounting future expenditures (if applicable)
  - Calculatory interest rate according to NEP

Construction of F – vector for projects:

Normalization of Investment Costs to "representative" €uro

- Calculation of project share per sector
- F-vector sums to 1



# Results: Comparison of total output multiplier effects

	SLQ	FLQ _0.05	FLQ _0.25	FLQ _0.3	AFLQ _0.05	AFLQ _0.25	AFLQ _0.3	National
Grid Asset	1.44	1.41	1.24	1.21	1.58	1.15	1.11	1.82
Wind Asset	1.43	1.42	1.24	1.22	1.60	1.16	1.12	1.85
average multiplier	1.35	1.29	1.18	1.16	1.52	1.10	1.07	1.65
weighted average multiplier	1.34	1.27	1.16	1.14	1.49	1.11	1.08	1.71

- Regional Multipliers are smaller than national multipliers
  - About 25% 30% of induced effects stay local!
- Energy Assets have an above-average multiplier effect
  - Consistent across all regionalization methods and national benchmark



# Results: Comparison of total output multiplier effects – role of $\delta$

Total Output Multipliers depending on  $\delta$ 



- SLQ gives highest estimates for reasonable values of  $\delta$  (as expected)
  - Expected to overestimate
    - Can exclude  $\delta < 0.15$
- AFLQ and FLQ estimates decrease in  $\delta$  (as expected)
- AFLQ and FLQ estimates are in same ballpark
  - > very close estimates for reasonable values of  $\delta$  (i.e.  $\delta > 0.15$ )



# Results: Further Work (in progress)

#### Previous work and reference:

Schreiner, L., & Madlener, R. (2021). A pathway to green growth? Macroeconomic impacts of power grid infrastructure investments in Germany. *Energy Policy* 

#### Now: From national analysis to regional analysis

- Regionalization of employment multipliers
  - in progress
- Inclusion of operation phase
  - data on operation expenditures
  - discounting to today
    - necessary for static I/O model
  - in progress
- Regionalization of fiscal multipliers
- Estimation of optimal
  - in progress

- Expansion to partially closed IOM
  - in progress
  - difficulty: locally available wage and expenditure data
- **Displacement effects** for grid infrastructure
  - applicable to grid assets
  - not applicable to privately owned generation assets
  - need to recoup costs for infrastructure via grid-fees
    - not applicable, as expenses are recouped by grid fees on national level

## **Ongoing Research - Forthcoming FCN Working Paper**

Croé, L., Madlener R. (2021). *Regionalized Input-Output Modeling to Assess the Impacts of Energy Transition Investments on the Local Economy: A Case Study of Schleswig Holstein*, FCN Working Paper Series, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University (in prep.)

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# Discussion

#### Limitations:

- no empirical (survey-) data to corroborate regional estimates
  - limited by regionally available data
- single projects highly dependent on individual characteristics
- short-run
  - no change in technologies
  - ho operation (yet)
- changing structure of economy not considered

#### Policy Implications:

- effects on local economy small, but noticeable
- advertisement on local effects could ameliorate regional opposition to infrastructure projects
  - estimation of employment and (local) fiscal multiplier!
- energy assets create above average local economic effects
  - presumably even bigger when operation is considered

#### Further avenues of research:

- corroboration of method in regions with available survey data
- dynamic I/O modelling
  - inclusion of changing structure of economy
  - structural change analysis
- expansion to projects which require more local labor
  - e.g. solar roof installations, local microgrids
- estimation of **optimal**, **i.e. error-minimizing**,  $\delta$
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**Acknowledgements** 

## We thank the

## German Federal Ministry of Education and Research

for their generous support through the Kopernikus project ENSURE.



We thank

all our project partners in ENSURE for their kind help and advice.



