

A Micro Study of the Role of Energy for Economic Development in Denmark

Sofia Henriques, Lund University

Paul Sharp, HEDG, University of Southern Denmark, CEPR,
CAGE

+ a PhD student!

But first...

- This is part of a large project financed by the Danish Research Council
- This builds on previous work by Sofia Henriques and me:
- Published in the *Economic History Review* (2016), 69:3, pp. 844-869

The Danish Agricultural Revolution in an Energy Perspective: A Case of Development with Few Domestic Energy Sources

Sofia Henriques, Lund University

Paul Sharp, HEDG, University of Southern Denmark, CEPR,
CAGE

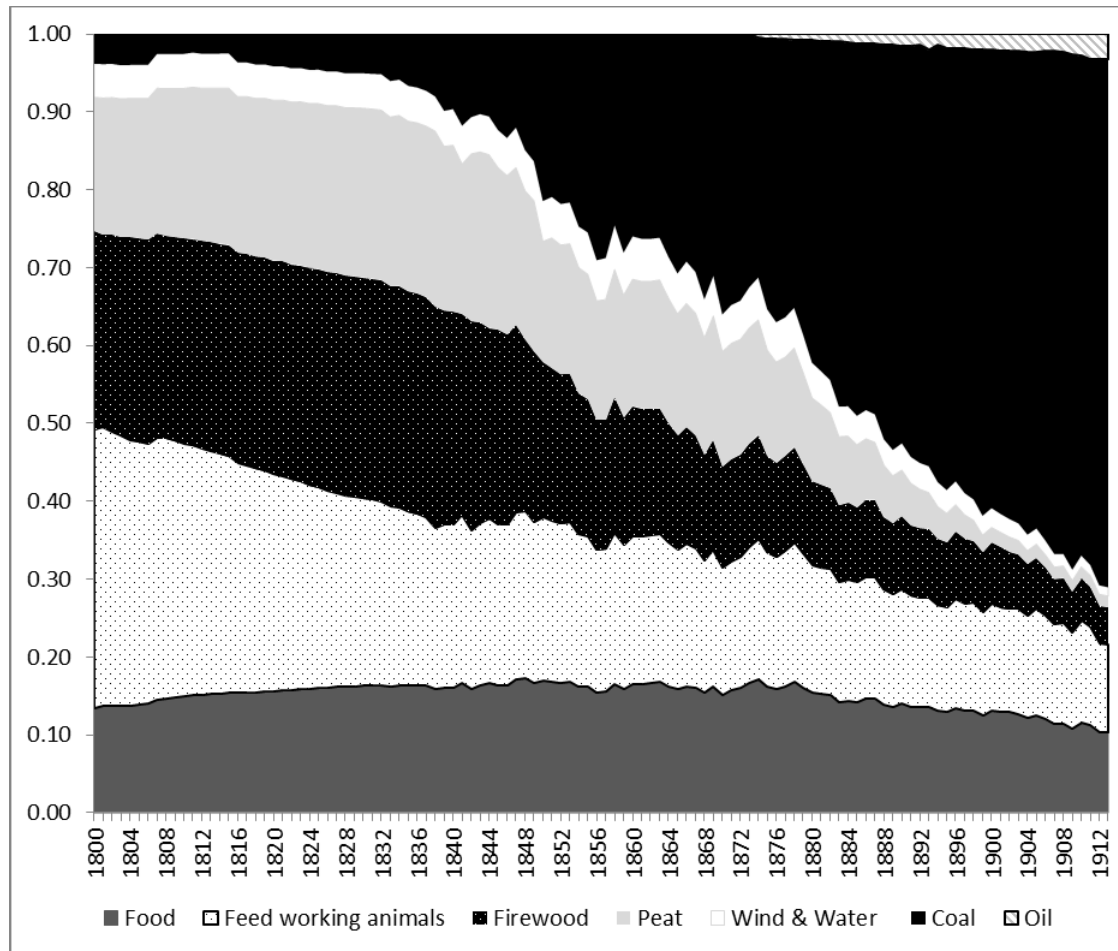
The Question!

- **Is a lack of domestic energy resources necessarily a limiting factor to growth?**
- We answer this looking at Denmark – a country which has few domestic resources
- Present new energy accounts from 1800
- Show that Denmark's take off (through dairying) was relatively dependent on coal and imported feed (concentrates)
- Demonstrate that **domestic energy resources are not necessary** if cheap imports are available
- Energy also important for **agricultural development path**

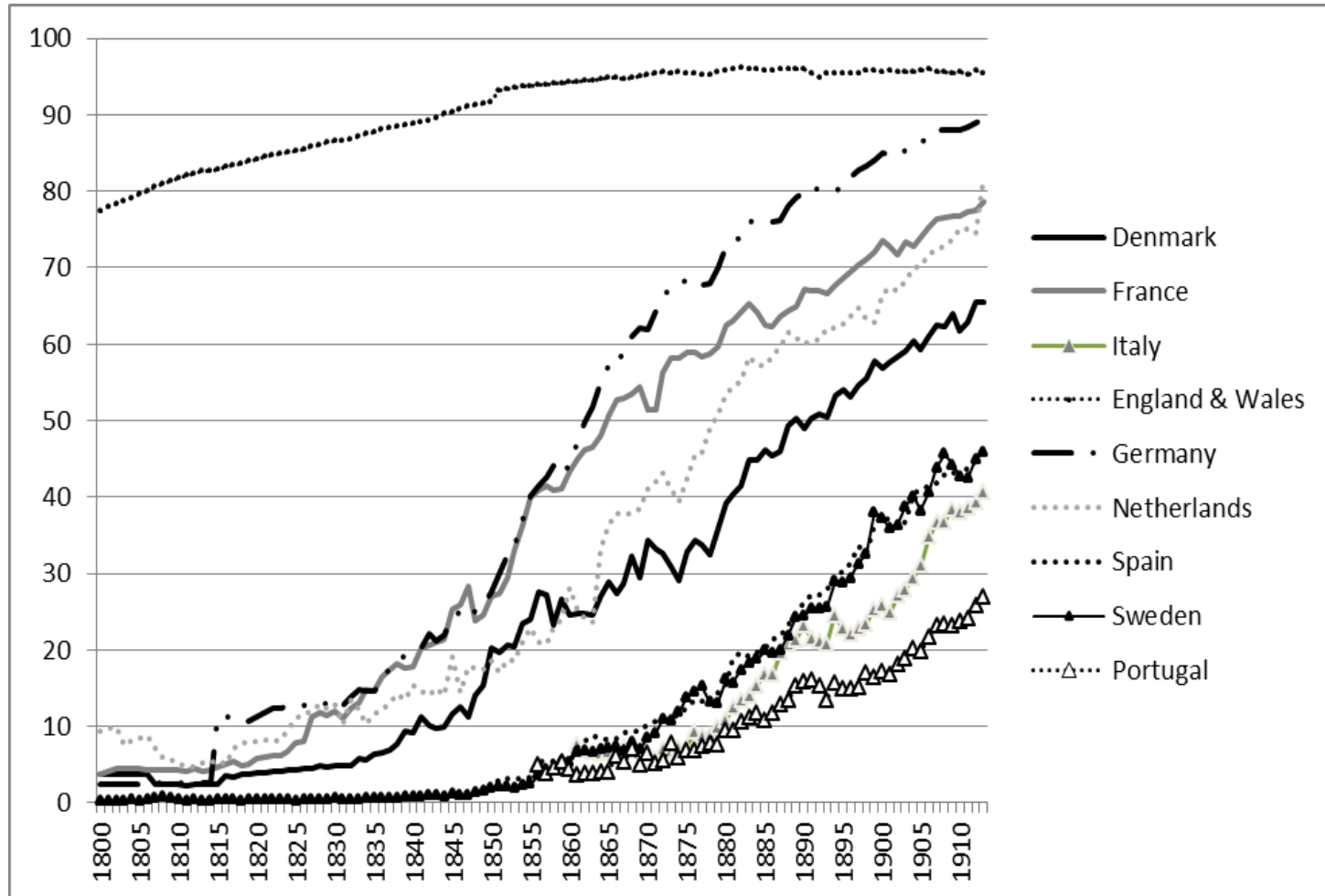
Hypotheses on the role of energy in the 19th century

- **Growth hypothesis** – Transition to fossil fuel is *necessary* for industrialization (Wrigley)
- **Location hypothesis** – Location of industry determined by location of coalfields (Allen)
- Others argue
 - the use of coal is more a symptom of modernization
 - alternative fuels were available
 - coal can anyway be transported
- Denmark might suggest low energy activities such as agriculture might be an alternative development path
- New energy accounts shows this **not** to be the case

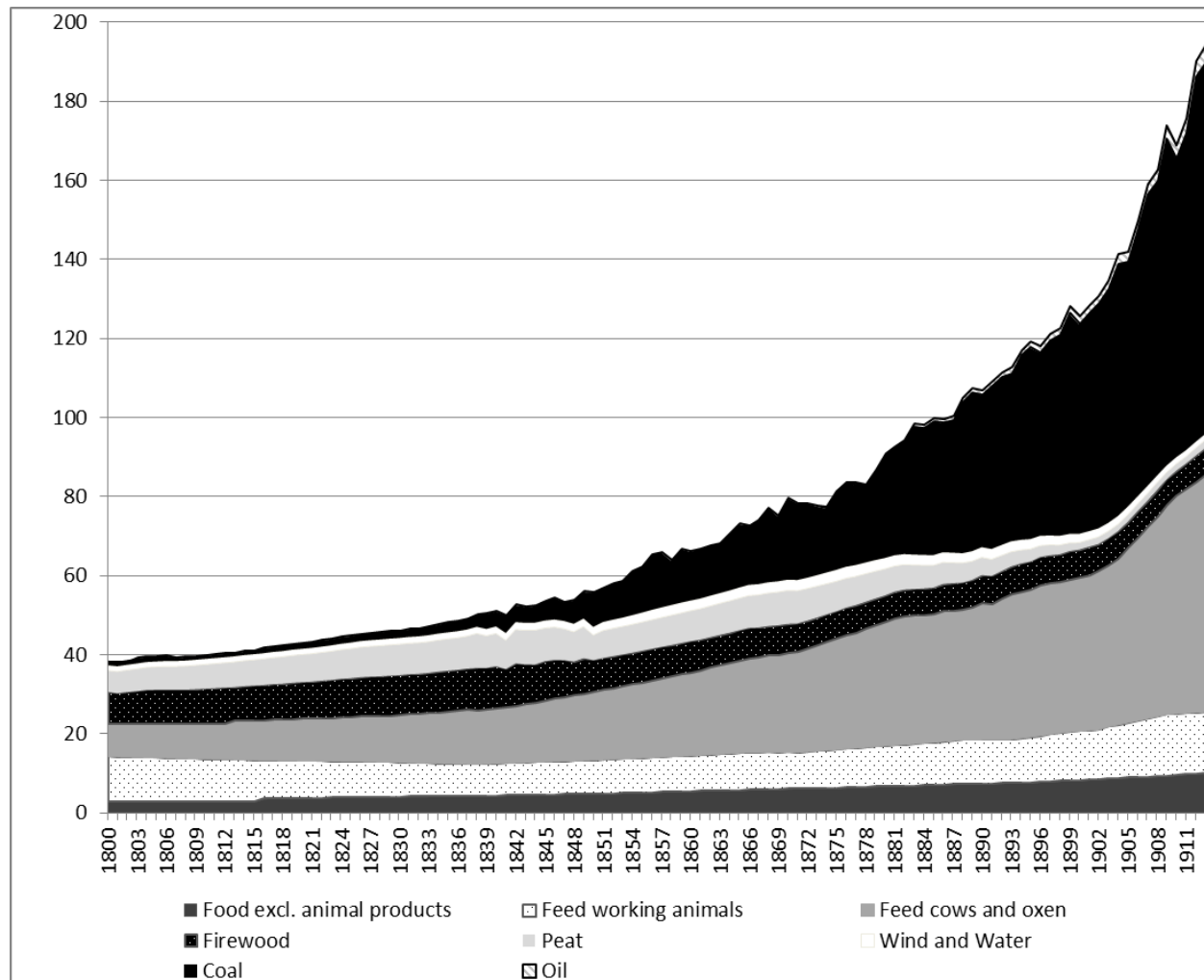
Danish Energy Consumption by source (%)



Percentage of Energy Consumption from Coal for Selected Countries, 1800-1913



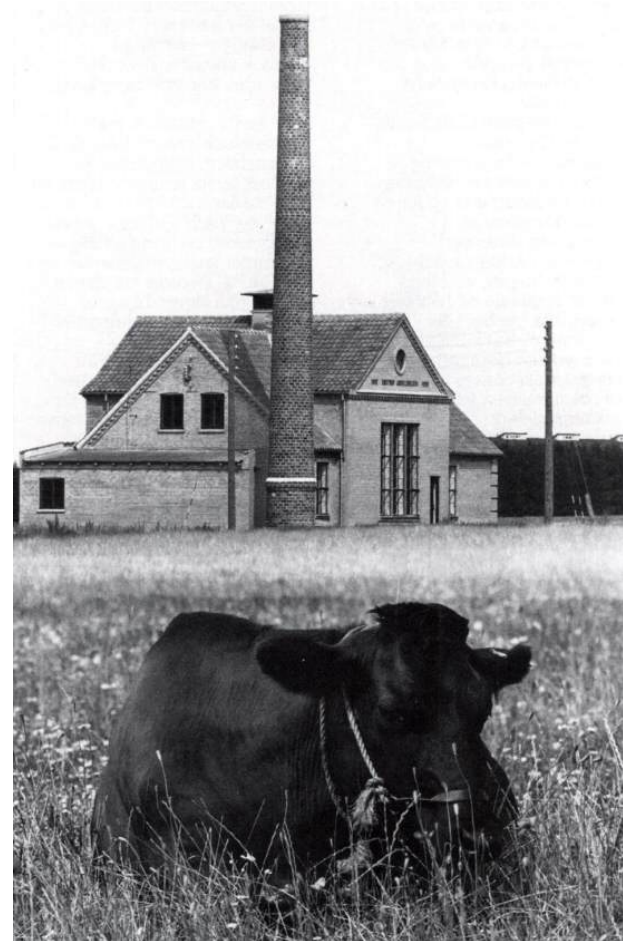
Including feed in the energy accounts, 1800-1913, PJ



The Danish development story

- Enjoyed a rapid ‘take off’ from around 1880 based on agriculture, especially **dairying**
- Based largely on exports of butter then bacon to UK
- Converges rapidly with leading countries in terms of GDP/head
- Usual story
 - Technology: Automatic cream separator
 - Institution: Cooperatives

Centrifuges and cooperative creameries



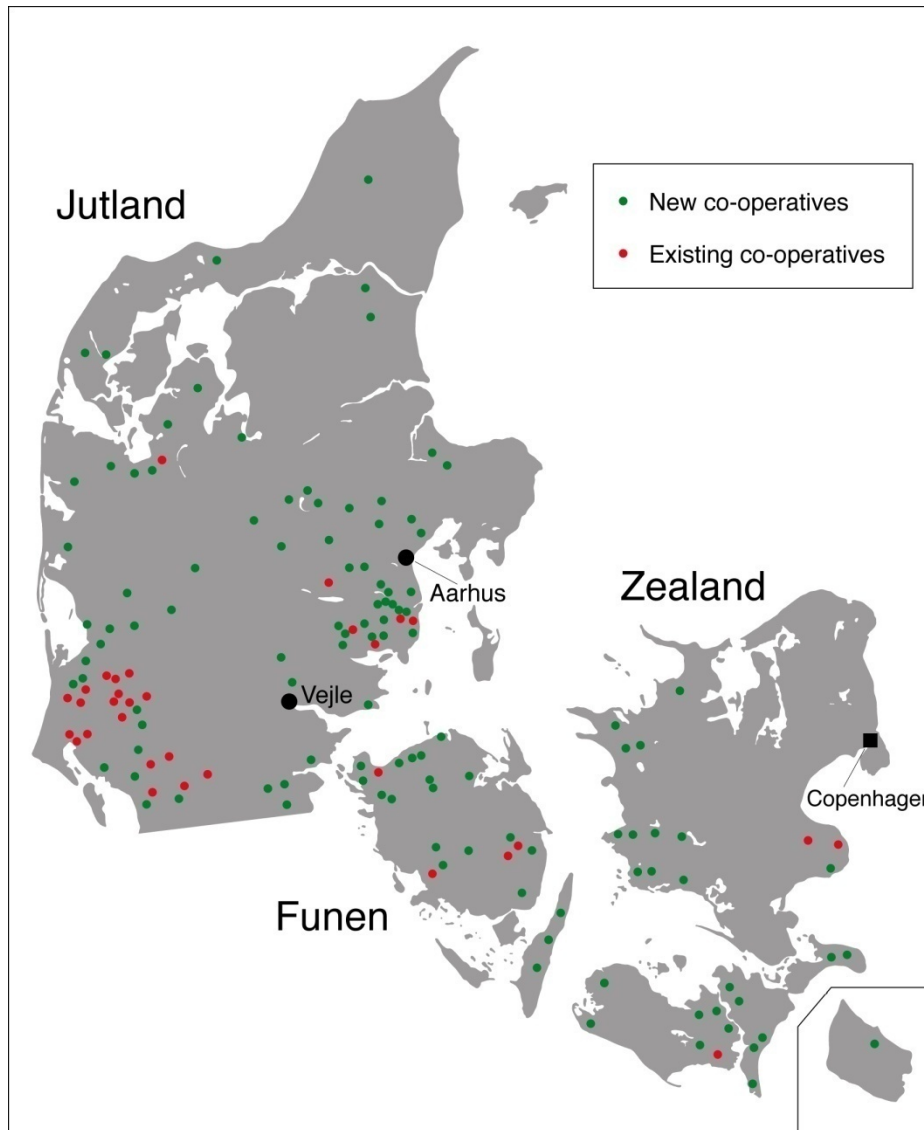
1883



1884



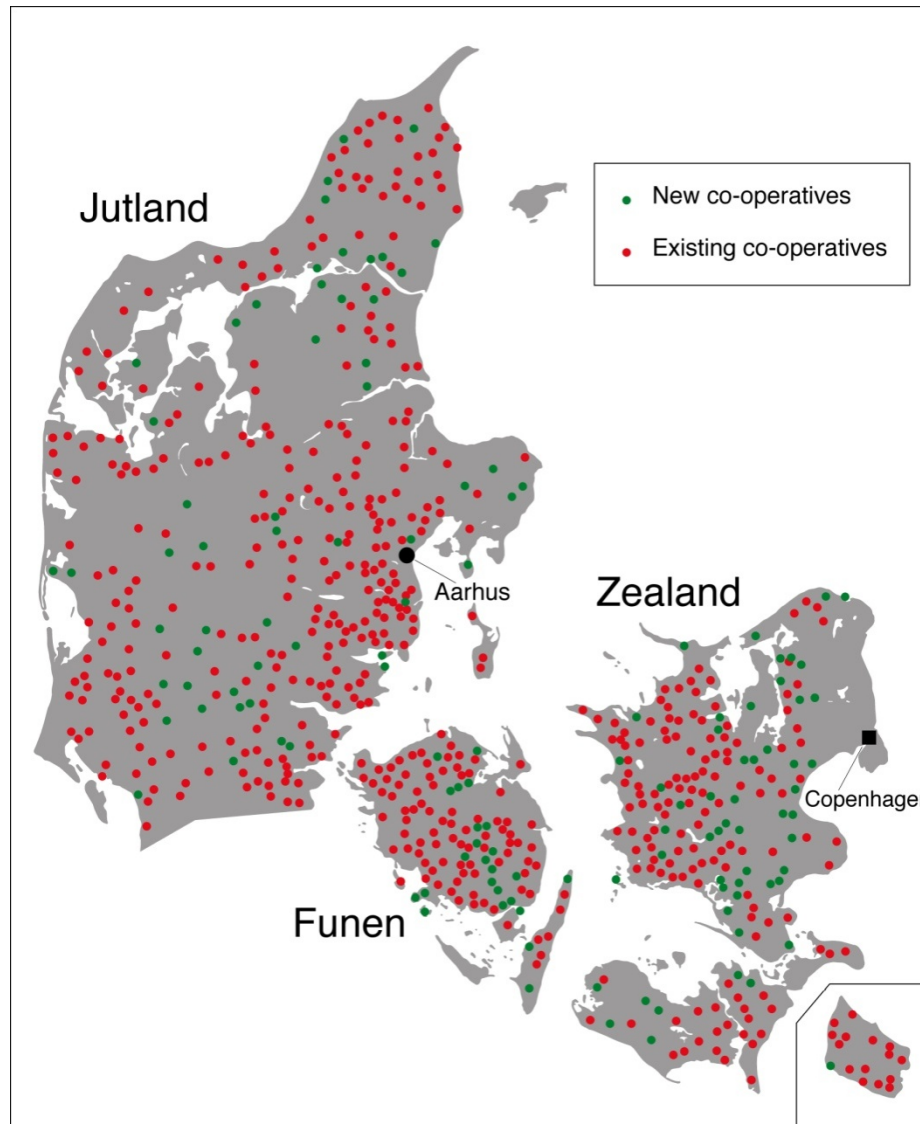
1886



1888



1890



Total energy per capita in GJ

Excluding non-working cattle

	Denmark	France	England & Wales	Germany	Italy	Netherlands	Portugal	Spain	Sweden
1880	30	35	142	43	18	40	19	19	39
1900	35	49	146	74	19	45	21	22	51
1913	46	60	162	97	24	63	23	25	64

Including non-working cattle

	Denmark	France	England & Wales	Germany	Italy	Netherlands	Portugal	Spain	Sweden
1880	44	41	145	48	18	47	19	20	47
1900	49	55	150	80	19	51	21	23	59
1913	65	67	165	102	24	70	23	28	75

HP per worker for the main branches of Danish industry, 1897

	All Factories		Mechanized factories		Total HP	HP/worker	HP/worker (mechanized)
	number	workers	% of total	workers			
Food,bv & t.	11301	30517	41	19660	19151	0.6	1
<i>Creameries</i>	1233	4391	96	4283	6173	1.4	1.4
<i>Slaughterhouses</i>	3180	3351	2	1086	1173	0.4	1.1
Textiles	4358	12533	6	8762	4962	0.4	0.6
<i>Spinning mills</i>	111	636	98	635	807	1.3	1.3
<i>Weaving mills</i>	3061	6613	3	6131	3580	0.5	0.6
Clothing	23557	28291	0.2	2369	293	0	0.1
Construction, furniture	19781	42389	1	4957	3294	0.1	0.7
Wood	4896	8119	12	4659	3722	0.5	0.8
Leather	227	1227	31	857	310	0.3	0.4
Nonmetallic minerals	1757	13700	17	9872	5833	0.4	0.6
Metals	9383	27302	5	16402	4665	0.2	0.3
Chemicals	602	4061	29	2992	1497	0.4	0.5
Paper	82	2057	45	1721	1690	0.8	1
Others	1248	5358	16	3290	677	0.1	0.2
All	77192	175554	9	75541	46093	0.3	0.6

Energy in dairying, 1890-1913

	1890-1894	1900-1904	1910-1913
Butter production, tons	68,000	97,000	110,000
kg of coal per kg of butter	1.8	1.1	1.1
Total Coal for butter production (PJ)	3.6	3.2	3.5
kg milk per kg of butter	27	26	25
ton milk per cow	2.0	2.3	2.8
Butter cows, thousands	924	1100	1016
Feed per cow (GJ)	21	22	25
Total Feed embodied in milk delivered to the dairies (PJ)	19.6	24.3	24.9
Total Energy, Dairying	23.2	27.5	28.4
in (%) of total Energy (including cows)	21%	21%	16%

Sources: Butter production is from Bjørn (1982, p.124). Kg of coal per kg of butter: 1890-1894, own calculations (see the text). Kg of milk per kg of butter: for 1890-94, Henriksen et al (2011); for 1900-04, MDS (1900); for 1910-13, MDS (1914). Metric tons of milk per cow comes from Wade (1981), using linear interpolation. Feed per cow as in the appendix.

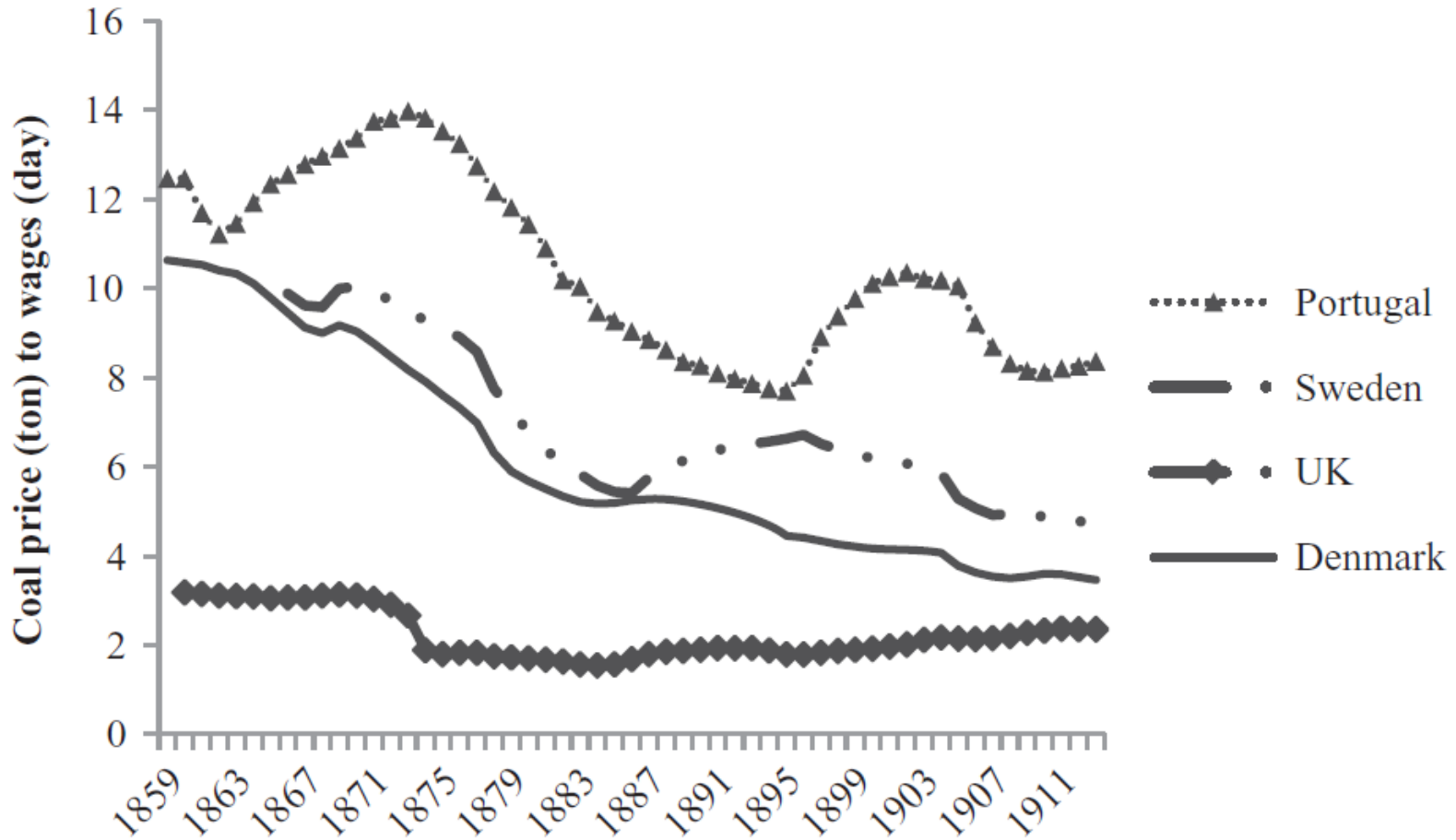
Why Denmark?

- Free trade during first era of globalization: **cheap grain**
- Geography means cheap to transport coal anywhere in the country: relatively **cheap coal**
 - Nowhere more than 52km from the coast
 - One third (135) of European ports involved in coal trade Danish in 1865
- **Labor expensive**

Coal prices at the pithead and ports in current shillings per ton, 1850-1900

	United Kingdom Pithead	Germany Pithead	France Pithead	Italy Imports	Denmark Imports	Spain Imports	Portugal Imports
1850s	5.3				15-18		18
1860s	5.6			32	16-20	31-41 ^a	19
1870-72	6.5			29	19	28	23
1879-81	5.4			24	13	21	20
1884-86	5.1	5	9	21	13	18	17
1889-91	7.5	7	10	25	15	21	16
1899-01	9.2	9	12	29	14	24	18

Bob Allen's story: Incentive to switch to capital/energy intensive production



Conclusion

- Denmark relatively heavily dependent on energy during her development
- Relatively expensive labor, inexpensive energy
- Incentive to invest in capital intensive production form
- Feed also inexpensive due to free trade stance
- Incentive to begin capital intensive dairying
- **Growth hypothesis:** YES, coal was necessary
- **Location hypothesis:** YES, but economic not geographic distance

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The idea

- To provide a counterfactual to the point made by Henriques and Sharp (2016):
 - **How would Denmark have looked without access to coal?**
- We will use the First World War as a sort of ‘natural experiment’: coal from the UK was more or less cut off
- Creameries turned to alternative sources of fuel, e.g. wood and peat
- We expect to find much of the superiority of the Danish dairy industry would have been (was) lost
 - Potentially other development routes would have been taken

The data

- From 1899 a Committee for Creamery Statistics was responsible for compiling extremely detailed information annually for a large sample of creameries in Denmark
 - **Dansk Mejeri-Drifts-Statistik** (MDS, ‘Operational Statistics for Danish Creameries’)
- Includes information on, e.g.:
 - Inputs and outputs (mostly of butter)
 - Technologies employed
 - **Energy source**

A small excerpt from 1914

Tab. I. (Fortsat)

Mejeriets Navn	Nr.	Regnskabet omfatter Tiden	Mejeriets indtægt Aar	Mejeriets udgifter Aar	Mejeriets Overskud	Mejeriets Gæld	Antal Andelskvæder			Antal Kvæder pr. Andelskvæder	kg Mælk pr. Kvæde	Antal Jerseykvæder for hvilke Mejeriet modtager Mælk	
							med over 20 Kvæder	med under 4 Kvæder	aa				
Allesø	97	25/1013—31/1014	08	—	30600	27500	65	0	29	346	5,3	31,8	0
Egerup	98	12/1013—30/1014	88	—	20000	15150	64	3	31	382	6,0	2637	0
Grindløse	99	25/1013—30/1014	92	—	14600	—	29	2	4	339	11,7	2694	18
Nybølle	100	1/1113—31/1014	89	—	14443	6000	52	0	23	261	5,0	3490	0
Alexandra	101	1/1113—1/1114	95	—	30814	9834	51	2	31	295	5,8	3090	0
Vester-Egense	102	1/1113—30/1014	88	—	11818	500	59	0	37	273	4,6	2960	0
Kogsbølle	103	0/1013—1/1014	94	—	18100	8200	43	1	16	279	6,5	2856	0
Bred	104	0/1113—2/1114	97	—	17000	7050	72	0	58	224	3,1	2989	0
Avernako	105	1/1114—22/1114	89	—	26154	13500	40	0	19	210	5,3	2972	0
Baago	106	1/1113—21/1014	91	—	10365	6700	29	0	13	165	5,7	2933	0

Afdeling B.

Mejeriets Navn	Nr.	Regnskabet omfatter Tiden	Mejeriets indtægt Aar	Mejeriets udgifter Aar	Mejeriets Overskud	Mejeriets Gæld	Antal Andelskvæder			Antal Kvæder pr. Andelskvæder	kg Mælk pr. Kvæde	Antal Jerseykvæder for hvilke Mejeriet modtager Mælk	
							med over 20 Kvæder	med under 4 Kvæder	aa				
Røjle	107	1/5 13—10/4 14	85	—	31720	8000	238	1	112	1257	5,3	2764	73
Højrup	108	1/5 13—20/4 14	86	06	61500	30000	231	4	—	1208	5,2	2737	8
Kaual-Gamborg	109	1/5 13—30/4 14	87	—	29515	13719	180	1	63	1034	5,7	3062	24
Constantia	110	25/4 13—30/4 14	88	—	34595	12000	218	4	120	1050	4,8	3006	0
Ore	111	20/4 13—1/5 14	85	12	18034	16400	181	5	80	1052	5,8	2977	0
Egedal	112	20/4 13—27/4 14	88	—	37000	—	146	4	37	1041	7,1	2950	—
Veflinge	113	1/5 13—7/5 14	86	09	36000	26500	180	4	120	950	5,3	2965	0
Gjelsted	114	1/5 13—10/4 14	86	90	36080	6000	177	1	93	895	5,1	3022	0
Sinai	115	25/4 13—4/5 14	87	12	40874	20500	73	6	23	851	11,7	3143	0
Høje	116	10/6 13—17/5 14	89	11	33700	27000	113	—	—	560	5,0	3120	0
Melby	117	1/5 13—30/4 14	89	07	18000	9000	50	4	20	330	6,6	3146	0
Erøskjøbing	118	25/4 13—22/4 14	97	—	18535	13000	66	0	27	280	4,2	3260	0
Lye	119	20/4 13—30/4 14	89	—	15301	0	56	0	28	290	5,2	3036	0
Falsled	120	10/6 13—9/5 14	88	—	14584	1400	22	1	4	180	8,2	4527	0
Lumby	121	1/5 13—1/5 14	89	—	10000	6000	26	3	4	239	9,2	2648	0

Antal kvæder	Længde km	Benyttes Iskus, da isvoren, Rorbakke, reinerer etc.	Benyttes Kølmaskiner, der hævler Fabrikat	Hvilket Brandstoft benyttes	Hvor mange Comaflugter benyttes, og hvilket Fabrikat	Hvordan hægges mælken (i de 2 første Fakker 2, 3, 4, 5 eller Fælt-Rabeder)	Er Mejeriet medlem af Mælkedelen, mælkeformering og tvilling	Undersøges Smørret for Vandindhold paa Mejeriet, og hvor ofte	Benyttes Konstabler, Kæmre, og hvilket Fabrikat	Benyttes Begerer, mælkeprøvetag, og hvilket Fabrikat	A.F.E. Mejeriet Slim til Andelskvæder og de til hvilket Tæmpert.	Sygner Mejeriet Slim i Melken til Leverandørerne	Løbeløst i Hørskol	Mejeriet-Nr.	
															4
3	3	Ja	—	»	1 A	»	»	—	»	Nej	Nej	»	»	12088	98
2	3	53	Nej	»	1 A	F.I.E.	»	1 G. mdl.	Nej	»	»	»	»	14610	99
3	3	324	»	»	1 A	F. 2	»	2 G. ug.	»	»	»	»	»	14154	100
3	3	280	»	»	1 A	—	»	Nej	»	»	»	»	»	13990	101
3	3	Nej	»	»	1 A	F.I.E.	»	forsk.	»	»	»	»	»	7272	102
3	3	—	Atlas	»	1 A	F. 2	»	Nej	Silkeb.	Buaas	»	»	»	14289	103
4	4	Ja	Nej	»	1 T	F.I.E.	»	forsk.	Nej	Nej	»	»	»	13697	104
1	2	64	»	»	1	F. 2	»	1-2 G. u.	Silkeb.	»	»	»	»	10110	105
1	4	Nej	»	»	1 G	F. 3	»	forsk.	Nej	»	»	»	»	4828	106

Afdeling B.

11	6	400	—	Kul	2 A	F.I.E.	Nej	dagl.	Hamlet	Nej	Nej	Nej	69008	107
12	6	Nej	Ja	»	3 A	»	»	1 G. ug.	Victoria	»	»	»	56871	108
9	4	700	—	»	1 A, 1 G	»	»	dagl.	Hamlet	—	—	—	59519	109
10	4	200	—	»	1 T	F. 2	»	Ja	Victoria	Nej	Nej	Nej	44746	110
9	3	294	Nej	»	1 P, 1 A	F.I.E.	»	mdl.	»	»	»	»	45729	111
8	5	160	—	»	2 A	»	—	—	Dan	»	»	»	62510	112
10	5	Nej	Sabro	»	1 P	»	Nej	Ja	Victoria	»	Nej	Nej	47794	113
7	4	Ja	Nej	»	1 A, 1 G	»	»	—	»	»	»	»	49771	114
8	2,8	125	—	»	2 A	»	»	Ja	Nej	»	»	»	14710	115
6	6	Ja	—	»	1TA40,1A	F. 2	»	1-2 G. u.	Silkeb.	»	»	»	23096	116
5	1	Ja	—	»	1 A	F.I.E.	»	Ja	Nej	»	»	»	13495	117
4	2	100	—	»	1 A	F. 2	»	forsk.	Victoria	»	»	»	12157	118
0	—	112	Nej	»	1 A	»	»	1 G. ug.	Silkeb.	»	»	»	13074	119
—	—	64	»	»	1 A	F.I.E.	—	Nej	Nej	—	—	delvis	15195	120
3	2	200	—	»	1 A	F. 2	Nej	1 G. ug.	»	Nej	Nej	Nej	8736	121

Our approach

- Stochastic frontier model with a time-varying technical efficiency term (Battese and Coelli 1995)

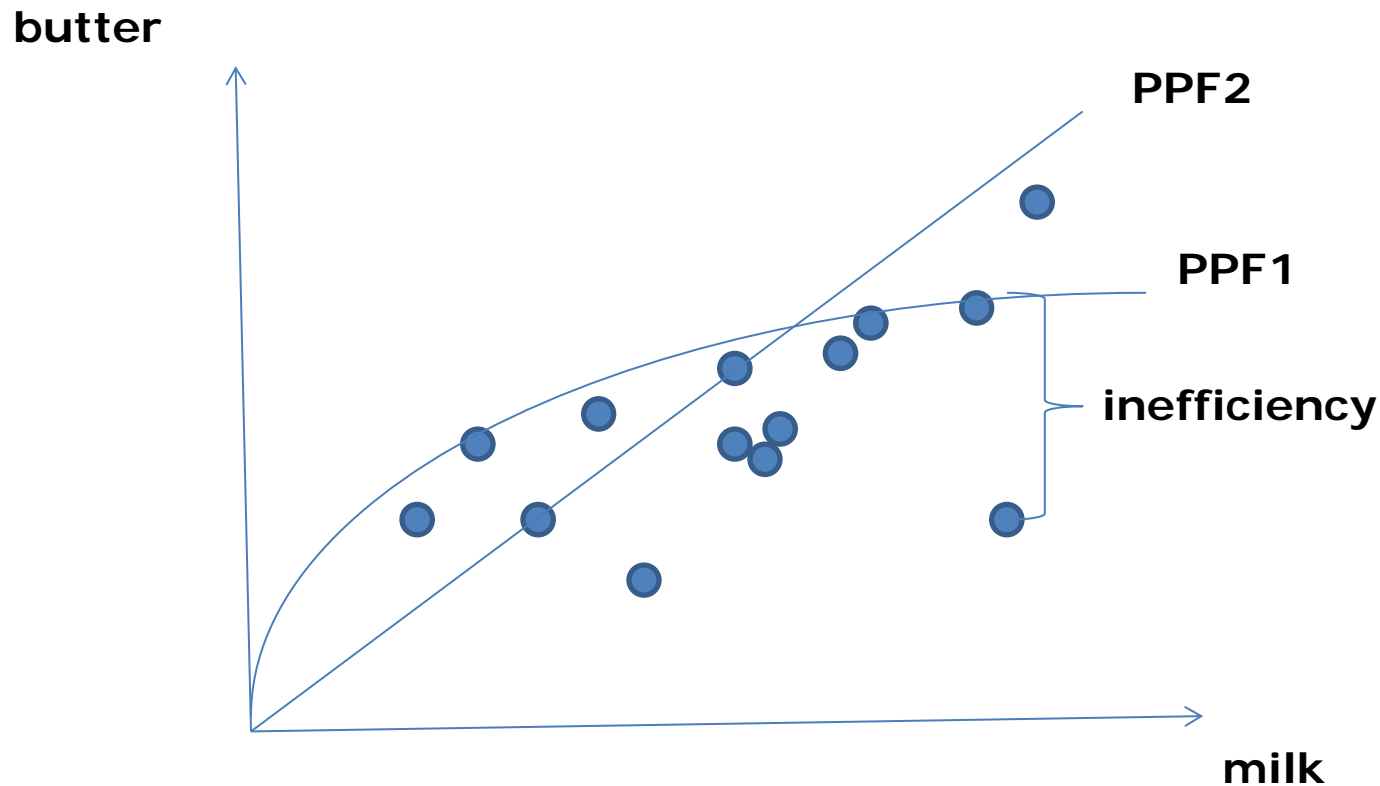
$$y_{it} = \beta' x_{it} + v_{it} - u_{it} \quad (2)$$

where $u_{it} = g(z_{it})|U_i|$ where U_i is half normal

and $g(z_{it}) = \exp(\eta' z_{it})$

The method

- Stochastic Frontier Analysis (see also Henriksen, Lampe and Sharp 2010 and Lampe and Sharp 2015)



Hypotheses

- We expect to see productivity losses when using sources other than coal
- Perhaps some areas were hit harder than others
 - E.g. Bornholm had some (poor quality) coal
- Of course the machinery was made to run on coal, so other technologies might have been used if it was not available...
- On the other hand the literature describes the difficulties for coal-poor countries when steam was the General Purpose Technology

Coal in Bornholm

