ENERDAY 2014
11 April 2014

Is there still a Case for Merchant Interconnectors?

Insights from an Analysis of Welfare and Distributional Aspects of Options for Network Expansion in the Baltic Sea Region

Clemens Gerbaulet, Alexander Weber

Technische Universität Berlin, Fachgebiet Wirtschafts- und Infrastrukturpolitik (WIP)

Agenda

1. Introduction
2. Model
3. Application
4. Results
5. Conclusion

Motivation (1/2): Empirics

- Current European electricity policy sets a strong impetus for transmission expansion, TYNDP (2012) projects total to ~ €100 bn
- In general, network infrastructure in Europe is delivered by regulated network companies
- However, “merchant” (cross-border, HVDC) lines are possible, when approved by NRAs and EC: Those must earn all of their income by arbitrage between price zones
- Some projects have been realized, but recently, the EC has become more and more reluctant to approve merchant projects (Cuomo and Glachant, 2012)
- Still, (financial) investors still have an ongoing appetite for merchant lines (Mann, 2013)
- This is not unimportant: Merchant lines are designed with the objective of profit- instead of welfare maximiziation, the financing aspect is more of a side aspect

Austria	1.1	Ireland	3.9
Belgium	1.9	Latvia	0.4
Bosnia & Herzegovina	0.0	Lithuania	0.7
Bulgaria	0.2	Luxembourg	0.3
Croatia	0.2	Montenegro	0.4
Czech Republic	1.7	Netherlands	3.3
Cyprus	0.0	Norway	6.5
Denmark	1.4	Poland	2.9
Estonia	0.3	Portugal	1.5
Finland	0.8	Romania	0.7
France	8.8	Serbia	0.2
FYROM	0.1	Slovakia	0.3
Germany	30.1	Slovenia	0.3
Greece	0.3	Spain	4.8
Hungary	0.1	Sweden	2.0
Iceland	0.0	Switzerland	1.7
Italy	7.1[3)]	United Kingdom	19.0
		Total ENTSO-E perimeter	104.0

Table 7.1:
Investment costs breakdown in billion €

Source: ENTSO-E (2012, p. 70)

Motivation (2/2): Theory

- **In what cases may merchant investments be justified?**
  - Risky technology: Regulator inable to credibly commit to not expropriate the upside (Gans and King 2004)
  - Co-ordination problems between jurisdictions or problems due to vertical integration (Brunekreeft 2004, Kristiansen and Rosellón 2010, Teusch et al. 2012)

- **What problems may arise?**
  - Underinvestment (Joskow and Tirole 2005, Kuijlaars and Zwart 2003, Knops and De Jong 2005)
  - Internal grid issues, external effects (Joskow 2005, Turvey 2006)

- **Question**
  - What role is left for merchant lines in Europe, given the huge investment foreseen? What are the implications with respect to welfare and distribution?

Agenda

1. Introduction
2. **Model**
3. Application
4. Results
5. Conclusion

The Approach

- **To approach the question, we model a two-stage game (MPEC):**
  - A merchant strategically exploits its possibilities of a full exemption (i.e. free line capacity choice)
  - A “regulator” coordinates across certain borders (not those on which the merchant is active) and does cost-minimizing unit dispatch and network expansion.

STEP 1: Merchant decides on investment, anticipating the reaction of the regulator

STEP 2: Regulator conducts least cost transmission expansion and unit dispatch

- **These outcomes (in terms of welfare, costs, and rents) are eventually compared against a situation where (i) none of the (potentially) merchant connectors are allowed at all and (ii) a situation where a regulator can fully- co-ordinate across the whole modeling region**

- **Later, we relax the Stackelberg assumption to understand the range and structure of possible outcomes of merchant investment**

The Merchant‘s Objective

The merchant tries to optimize its profit which consists of the congestion rent on a line minus the cost needed to build the corresponding lines.

Prices are a result from the market clearing by the regulator.

$$\max_{exp_{lm}} \left(\sum_{lm} exp_{lm} \left[\frac{\sum_t flow_{lm,t} \times pD_{lm,t}}{Exp0_{lm} + exp_{lm}} - I_{lm} \right] \right)$$

s.t.

$$pD_{lm,t} = \sum_{\substack{\forall n,nn: \\ Inc_{lm,n}=1, \\ Inc_{lm,nn}=-1}} (p_{n,t} - p_{nn,t}) \qquad \forall lm, t$$

$$exp_{lm} \geq 0 \qquad \forall lm$$

The Regulator's Objective (1/3)

A single fully coordinated regulator determines the investments in grid infrastructure while dispatching the power plants in a cost-minimizing way.

$$\min \sum_{s,bz,t} C_s \times q_{s,bz,t} + \sum_{l} I_{lr} \times exp_{lr}$$

[generation; $\forall\, s, bz, t$]

$$0 \geq q_{s,bz,t} - \sum_{bz:(n \in bz)} Q^{\max}_{s,n}$$

[nodal balance; $\forall\, n, t$]

$$\begin{aligned} 0 = &+ D_{n,t} - \sum_{s,bz:(n \in bz)} \left[Q^{\max}_{s,n} \times \frac{q_{s,bz,t}}{\sum_{nn \in bz} Q^{\max}_{s,nn}} \right] \\ &- \sum_{lm} \left[Inc_{lm,n} \times \zeta_{lm,t} \right] \\ &- \sum_{lr} \left[Inc_{lr,n} \times \left(\zeta_{lr,t} + B_{lr} \times Exp0_{lr} \times \sum_{nn} \delta_{nn,t} \times Inc_{lr,nn} \right) \right] \end{aligned}$$

[DCLF, slack bus; $\forall\, n, t$]

$$0 = \delta_{n,t} \times Slack_n$$

The Regulator's Objective (2/3)

Separate flow limits for controllable (DC) and AC flows

$$[\text{HVDC-Limits}; \forall\, lm, t]$$

$$0 \geq \zeta_{lm,t} - exp_{lm} - Exp0_{lm}$$
$$0 \geq -\zeta_{lm,t} - exp_{lm} - Exp0_{lm}$$

$$[\text{DCLF-Limits}; \forall\, lr, t]$$

$$0 \geq B_{lr} \times \sum_{n} \delta_{n,t} \times Inc_{lr,n} - \min\{M_{lr}^{\zeta}, F_{lr}^{\max}\}$$
$$0 \geq -B_{lr} \times \sum_{n} \delta_{n,t} \times Inc_{lr,n} - \min\{M_{lr}^{\zeta}, F_{lr}^{\max}\}$$

The Regulator‘s Objective (3/3)

M_{ζ}(l) are flow limits due to parallel lines, identified with a Dijkstra pre-processing
Lower limits on absolute flows are possible due to upper limits on expansion

[DCLF expansion flow upper limits on abs flow; $\forall\, lr, t$]

$$0 \geq -\zeta_{lr,t} - \min\{M^{\zeta}_{lr}, F^{\max}_{lr}\} \times exp_{lr}$$

$$0 \geq \zeta_{lr,t} - \min\{M^{\zeta}_{lr}, F^{\max}_{lr}\} \times exp_{lr}$$

[DCLF expansion flow lower limits on abs flow; $\forall\, lr, t$]

$$0 \geq B_{lr} \times \sum_{n} Inc_{lr,n} \times \delta_{n,t} \times \overline{Exp}_{lr} - \zeta_{lr,t}$$

$$- \min\{M^{\zeta}_{lr}, F^{\max}_{lr}\} \times [\overline{Exp}_{lr} - exp_{lr}]$$

$$0 \geq -B_{lr} \times \sum_{n} Inc_{lr,n} \times \delta_{n,t} \times \overline{Exp}_{lr} + \zeta_{lr,t}$$

$$- \min\{M^{\zeta}_{lr}, F^{\max}_{lr}\} \times [\overline{Exp}_{lr} - exp_{lr}]$$

Agenda

1. Introduction
2. Model
3. **Application**
4. Results
5. Conclusion

(Before the Application)

Regulator's Problem:

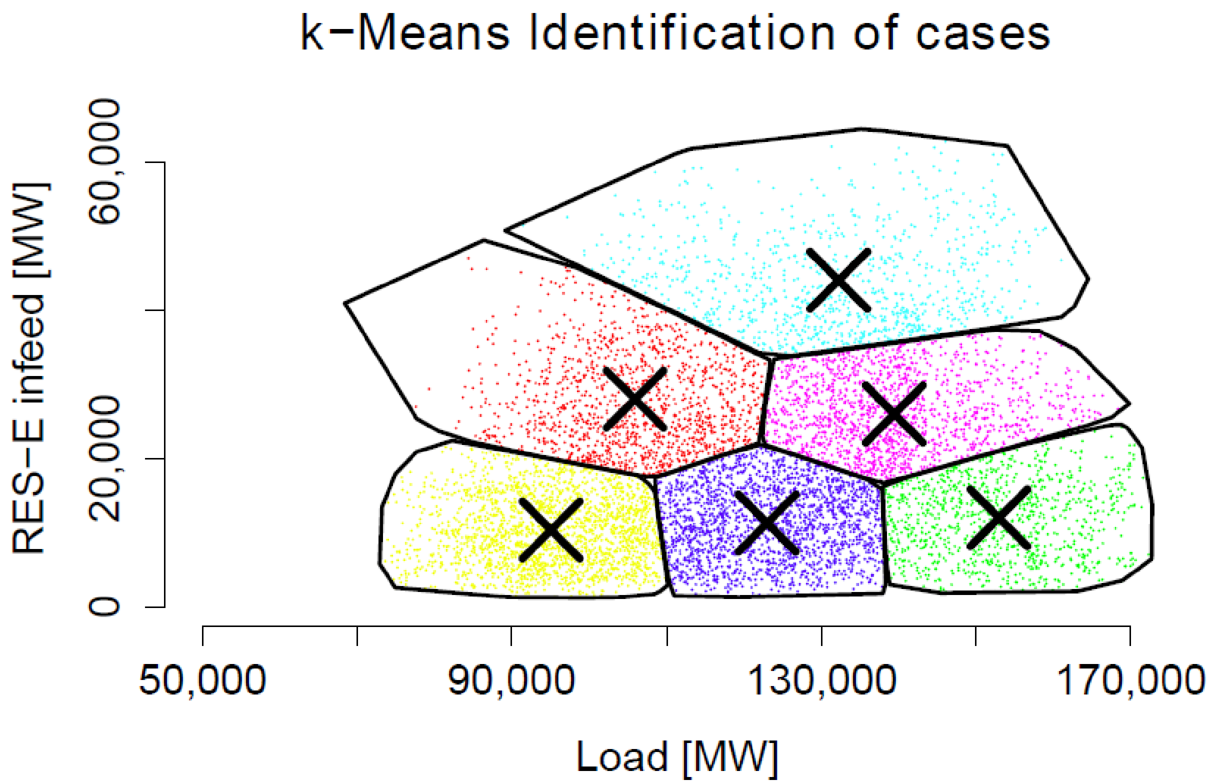
- **LP with DCLF continuous network expansion approximation (Taylor, Hover 2011)**
- **Pre-processing of network topology to identify lines constrained by parallel lines (Dijkstra-Algorithm)**

Merchant's Problem:

- **Discretization of merchant capacity choices; "fully planned" case + "step overs"**
- **Results in 35,280 expansion choices for which the LP is solved (~ 200 seconds per LP)**

Further Optimization:

- **Clustering of Load+RES-infeed**



Model Application

The model is applied to the Baltic Sea neighboring states, applying SOAF (2013) assumption for 2020, "Best Estimate" Scenario.

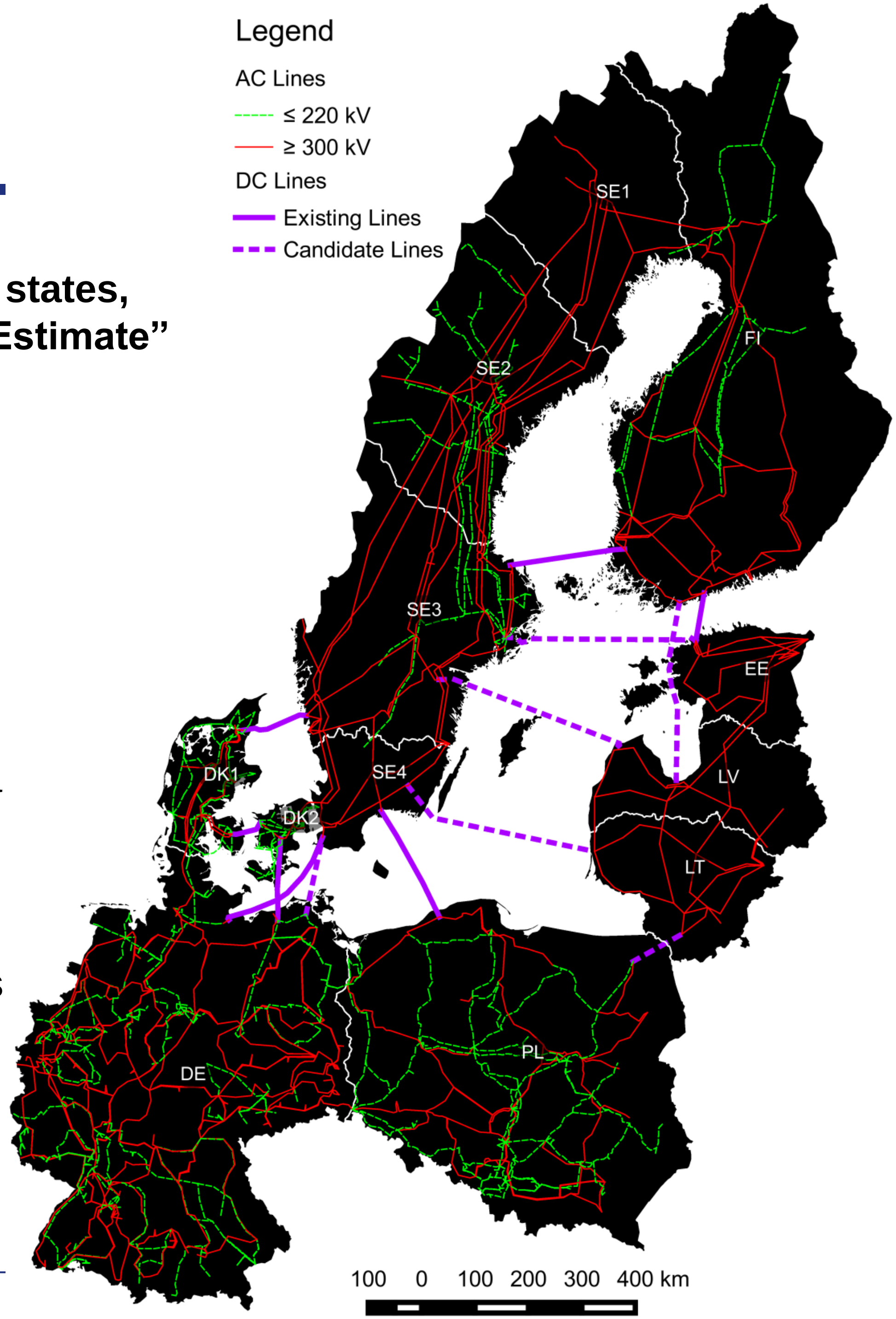
Full EHV network:

13 DC lines, 7 of which already exist

1,273 AC lines, 835 power plants

We compare three cases to show the effect of different grid expansion approaches:

- ***AC Only:*** No submarine cables are allowed; only a fully coordinated regulator may expand AC-landlines between adjacent countries,
- ***Game:*** The Stackelberg-game is modeled; Merchant is first-mover for HVDC lines; regulator is follower for AC connections and dispatch,
- ***Fully Planned:*** All lines are expanded on a cost-minimizing basis by the regulator.

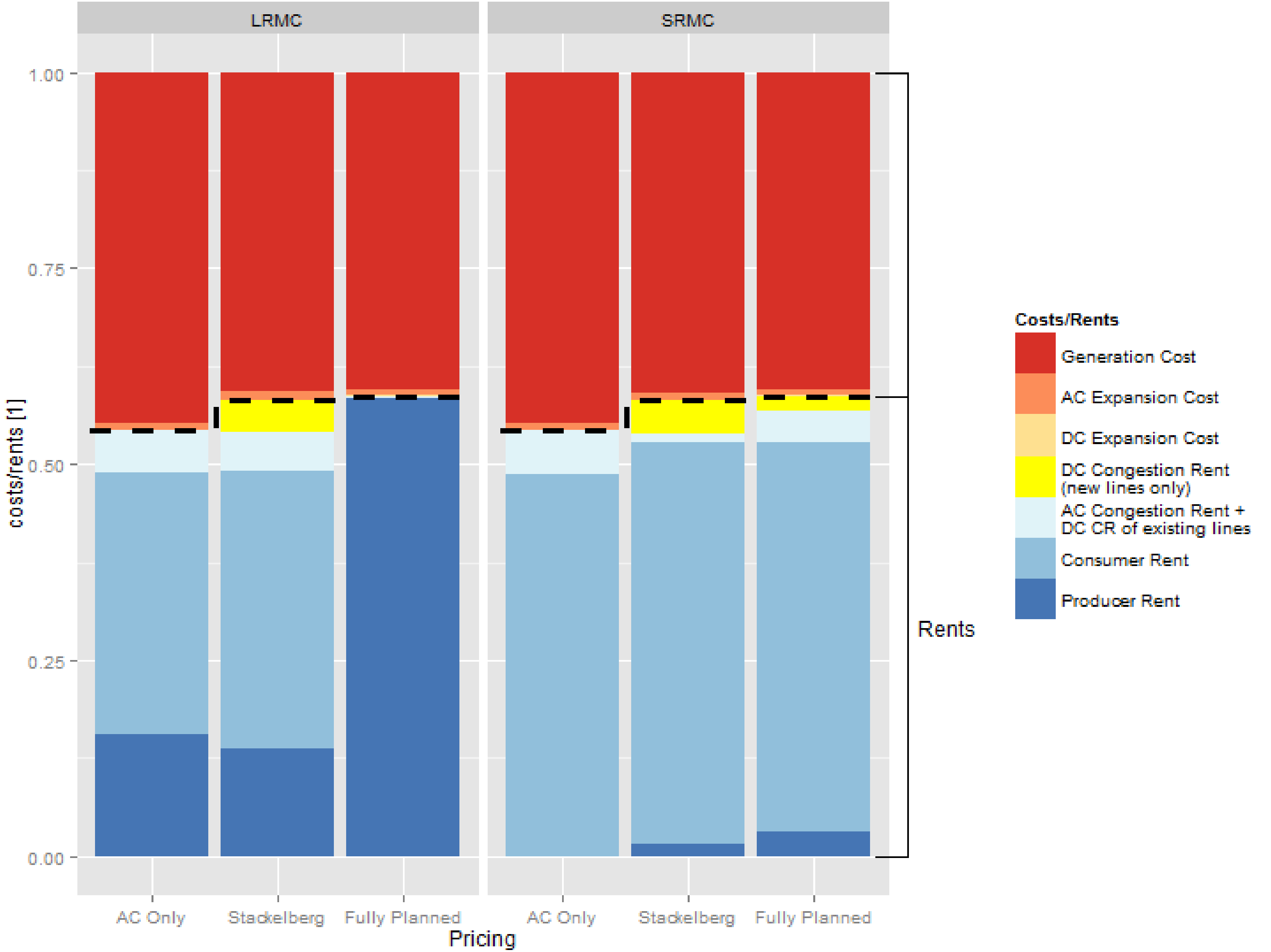


Agenda

1. Introduction
2. Model
3. Application
4. **Results**
5. Conclusion

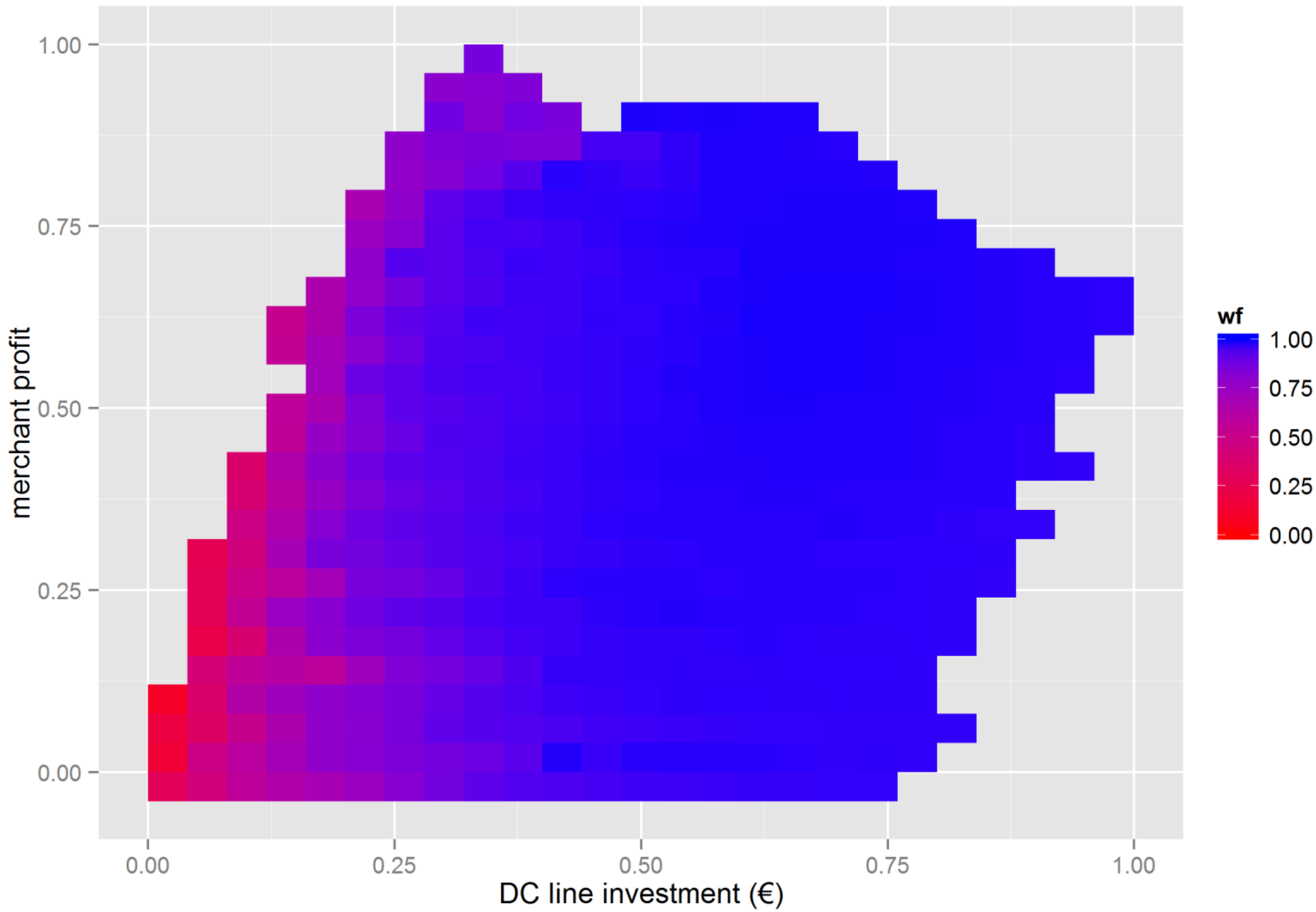
Results: Expansion of Transmission

	Line	Line Expansion [MW]		
		Stackelberg-LRMC	*Stackelberg-SRMC*	*Fully Planned*
existing DC Lines	DE-DK2 (Kontek)	-	-	-
	DE-SE4 (Baltic Cable)	-	-	-
	DK1-DK2 (Storebælt)	-	-	-
	DK1-SE3 (Konti-Skan)	-	-	-
	FI-EE (Estlink)	-	-	1609
	FI-SE3 (Fenno-Skan)	-	-	-
	PL-SE4 (SwePol)	-	-	1435
candidate DC Lines	DE-SE4 (Hansa PowerBridge)	600	1800	989
	EE-SE3	-	-	-
	FI-LV	-	-	-
	LT-PL (LitPol)	-	-	759
	LT-SE4 (NordBalt)	-	-	-
	LV-SE3 (Ambergate)	1200	600	639
Total DC Line Investment costs [mn €]		382.31	425.61	660.87

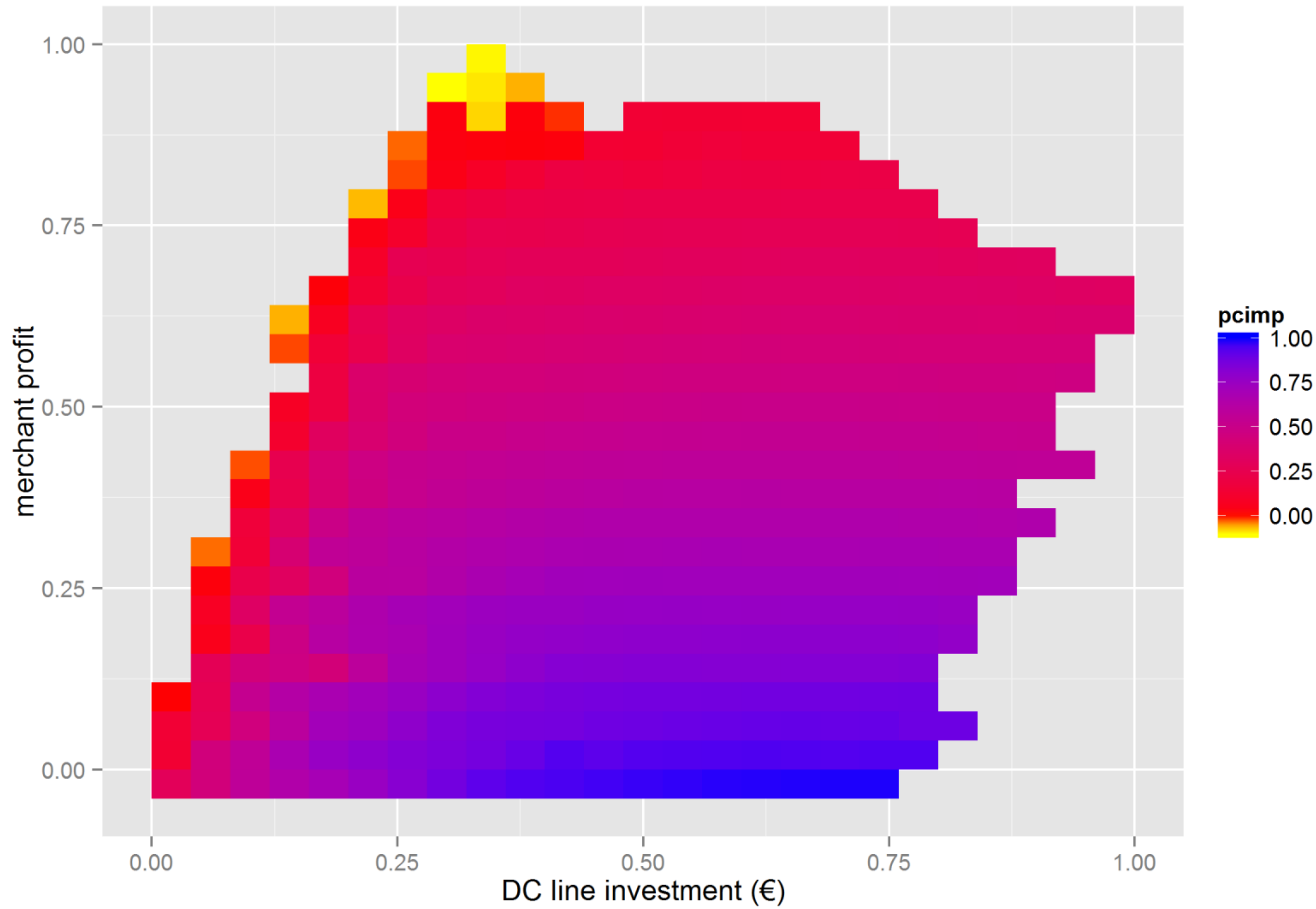


LRMC
SRMC
1.00
0.75
0.50
0.25
0.00
costs/rents [1]
AC Only
Stackelberg
Fully Planned
AC Only
Stackelberg
Fully Planned
Pricing
Rents
Costs/Rents
Generation Cost
AC Expansion Cost
DC Expansion Cost
DC Congestion Rent (new lines only)
AC Congestion Rent + DC CR of existing lines
Consumer Rent
Producer Rent

Relaxing the Stackelberg Assumption (1/2): Welfare (prices based on short-run marginal costs)



Relaxing the Stackelberg Assumption (2/2): Distribution (prices based on short-run marginal costs)



Agenda

1. Introduction
2. Model
3. Application
4. Results
5. **Conclusion**

Conclusion

"The merchant takes it all"

- Even under a Stackelberg assumption, welfare gains are fair, about 80-90% of the optimum, but at the same time are nearly fully reaped by the merchant
- When the Stackelberg assumption is relaxed, still, in many cases, contributions of the merchants expansion choices are not giving much benefit to consumers, generators and regulated transmissions.

Therefore:

- Our results indicate that allowing merchant interconnectors may lead to a mere redistribution of efficiency gains to (financial) investors, the rest of the actors possibly benefit very little from these efficiency gains.
- If policy is not indifferent as to whom welfare gains should benefit, it makes sense to bring forward regulated transmission investment, even for HVDC lines, especially as:
  - Technology has matured over the last 20 years and
  - Regulators have shown to be able to cope with both the technology and possible coordination problems.

Literature

Brunekreeft, G. (2004): Market-based investment in electricity transmission networks: controllable flow. Utilities Policy 12, 269–281.

Cuomo, M., Glachant, J.-M. (2012): EU Electricity Interconnector Policy: Shedding Some Light on the European Commission's Approach to Exemptions.

ENTSO-E (2012): 10-Year Network Development Plan 2012. ENTSO-E, Brüssel.

Gans, J.S., King, S.P. (2004): Access Holidays and the Timing of Infrastructure Investment. Economic Record 80, 89–100.

Joskow, P.L. (2005): Patterns of Transmission Investment (No. 0527), Cambridge Working Papers in Economics. Faculty of Economics, University of Cambridge.

Joskow, P., Tirole, J. (2005): Merchant Transmission Investment. Journal of Industrial Economics 53, 233–264.

Knops, H., De Jong, H. (2005): Merchant interconnectors in the European electricity system. Journal of Network Industries 6, 261–292.

Kristiansen, T., Rosellón, J. (2010): Merchant electricity transmission expansion: A European case study. Energy 35, 4107–4115.

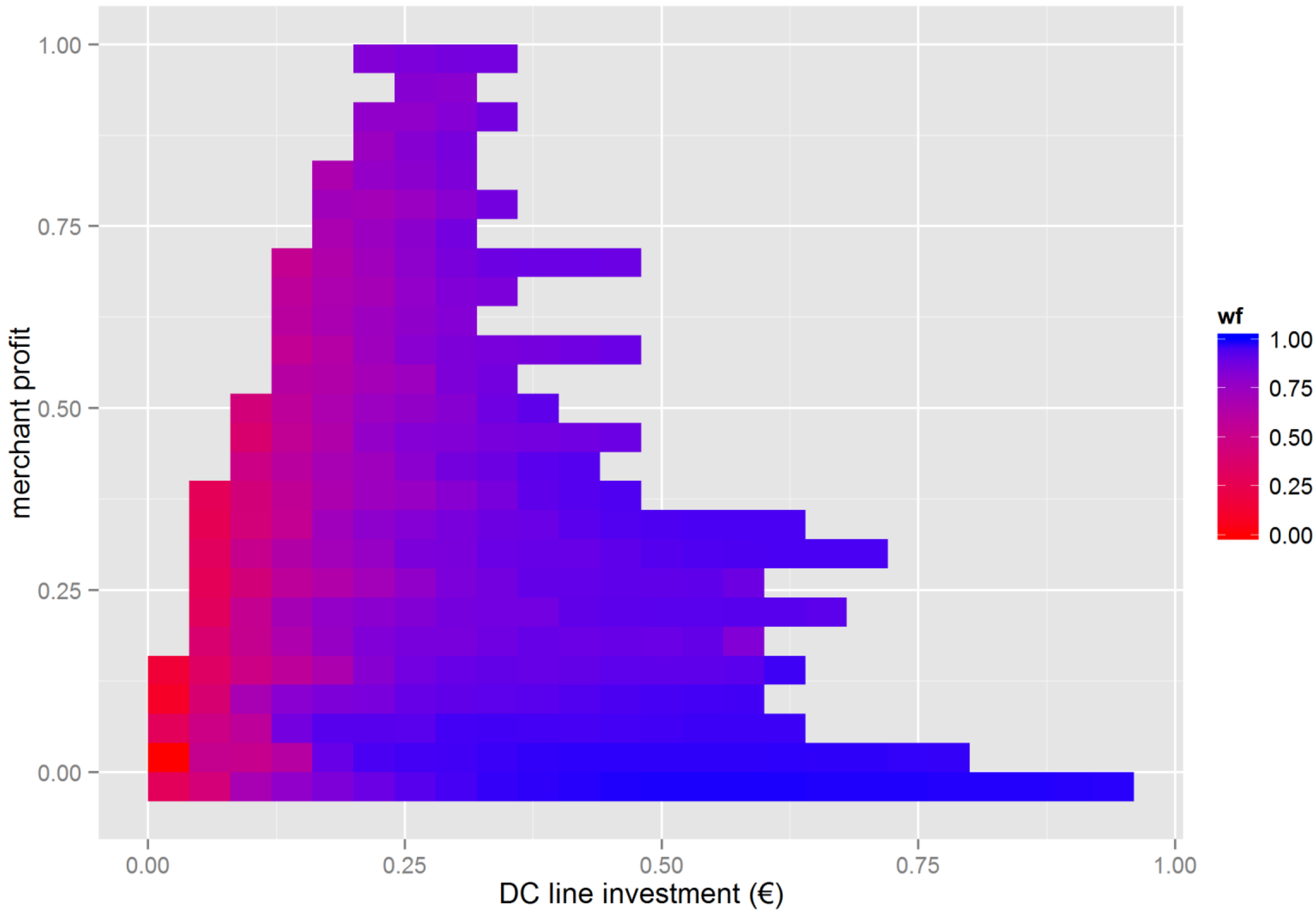
Kuijlaars, K.-J., Zwart, G. (2003): Regulatory Issues Surrounding Merchant Interconnection. Presented at the Conference on Methods to Regulate Unbundled Transmission and Distribution Business on Electricity Markets, Stockholm.

Mann, J. (2013): Financing transmission – a third way?

Teusch, J., Behrens, A., Egenhofer, C. (2012): The Benefits of Investing in Electricity Transmission: Lessons from Northern Europe (No. 59). CEPS - The Centre for European Policy Studies.

Turvey, R. (2006): Interconnector economics. Energy Policy 34, 1457–1472.

Relaxing the Stackelberg Assumption (1/2): Welfare (prices based on long-run marginal costs)



Relaxing the Stackelberg Assumption (2/2): Distribution (prices based on long-run marginal costs)