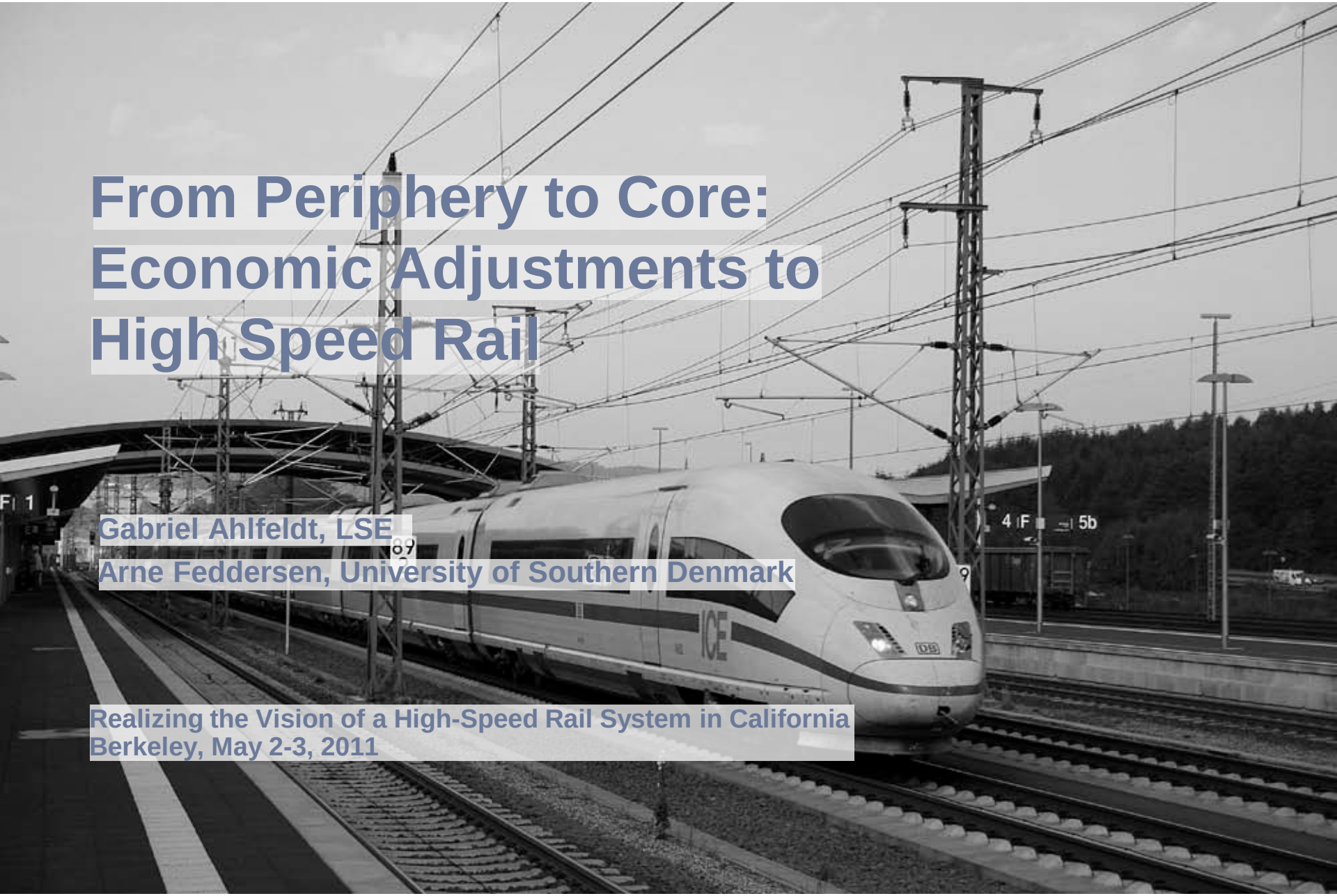

From Periphery to Core: Economic Adjustments to High Speed Rail

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Realizing the Vision of a High-Speed Rail System in California
Berkeley, May 2-3, 2011

Brief

From Periphery to Core

- HSR ***Cologne-FFM***, Germany with **intermediate** stations *Montabaur* and *Limburg*
- Limitations
  - No CBA
  - No statement “pro” / “con” HSR
  - No substitute for CBA
  - Certainly no statement pro intermediate stops
- Merits
  - Interesting case study: **large** and **exogenous** variation in accessibility
  - Establishes **causal** (and robust) **impact** of HSR on economic performance
  - **Complementary** approach to CBA
    - Focus on **agglomeration effects**
    - Foundation for the **prediction** of economic effects

A. Intro

Transport Infrastructure from the (N)EG Perspective

Centrality is Not Exogenous

- Central prediction of (**N)EG models** (e.g. Krugman, 1991)
  - Core regions benefit from centrality with respect to other region's markets due to scale economies and lower transport cost
- **Centrality** is not exogenous to **economic policy**, but depends on transport infrastructure
  - Permanent impact of temporary investment? (vs. persistency to shocks, e.g. Davis & Weinstein, 2002, AER, Brakman et. al, 2004, JEG)
  - Transport innovations offer interesting case-studies on the impact of positive **man-made** and **reproducible** variation in market access (vs. Redding & Sturm, 2008, AER)
    - *Cologne-FFM HSR* particularly interesting due to exogenous variation
- Identification procedure
  - 1) Area, 2) Period, 3) Robustness, 4) Persistency

B. The Project

The Cologne-Frankfurt High-Speed Rail Track

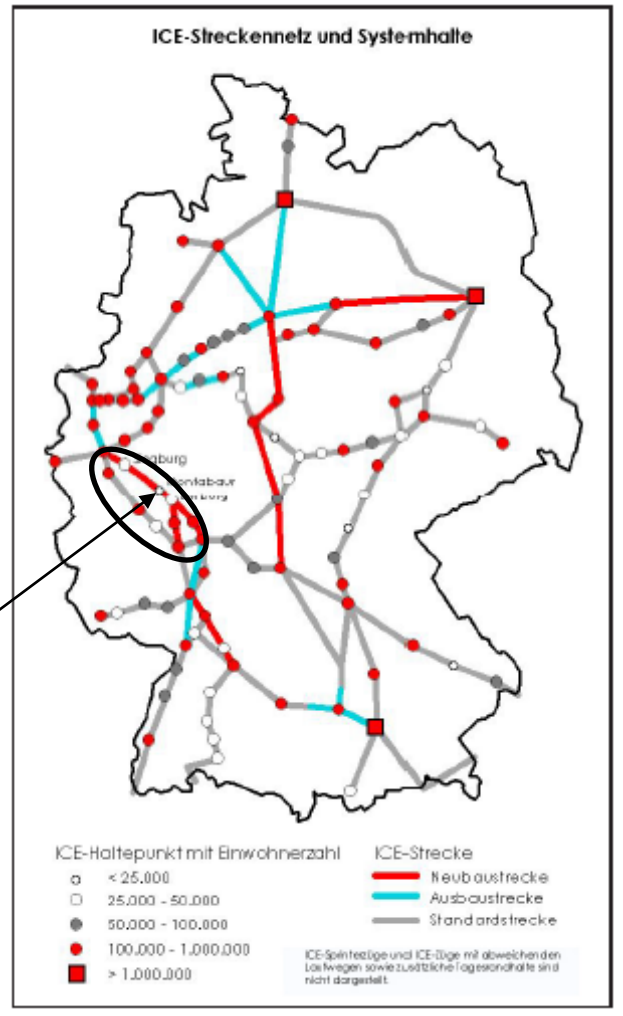
The Project

- Inauguration: 2002
- Connects two of the largest German Agglomerations
  - Rhein/Ruhr metropolitan area = 11 million habitants
  - Frankfurt/Rhein-Main metropolitan area = 5.7 million habitants
  - up to 300 km/h
  - Reduces **travel time** from **133 to 59 minutes**, corresponding to 55%
- “Intermediate” size project
  - €6 billion Investment Volume
  - Small enough to be replicable

Montabaur & Limburg

German Federalism and Economic Exogineity

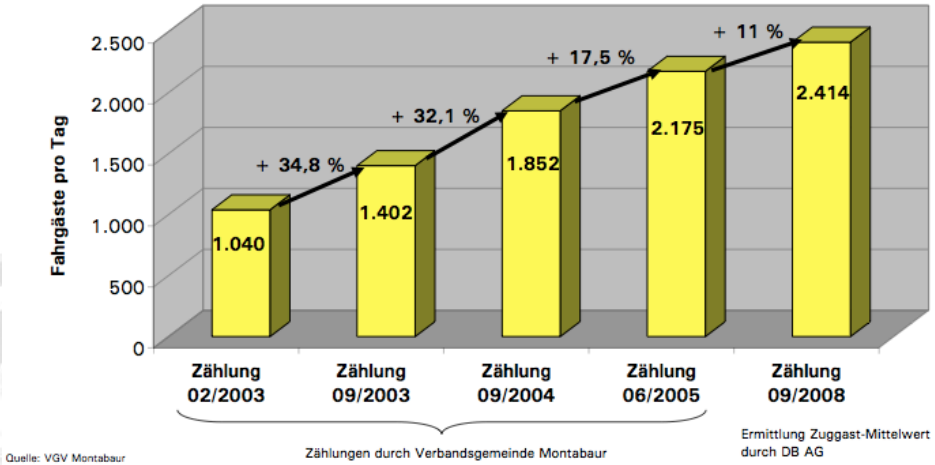
- Special feature is the connection of to *peripheral* towns to economic *cores*
  - *aprox. 40 minutes* Travel times to the cores
- Connection not based on economic, but on **(exogenous) political considerations**
  - Federalism Games
  - Provision of land for track beds conditional on stations
- Track discussed since the early 1960s
  - Decision to build in 1969!
  - **30 years of bargaining**, various obstacles, etc.
  - Exogenous timing…

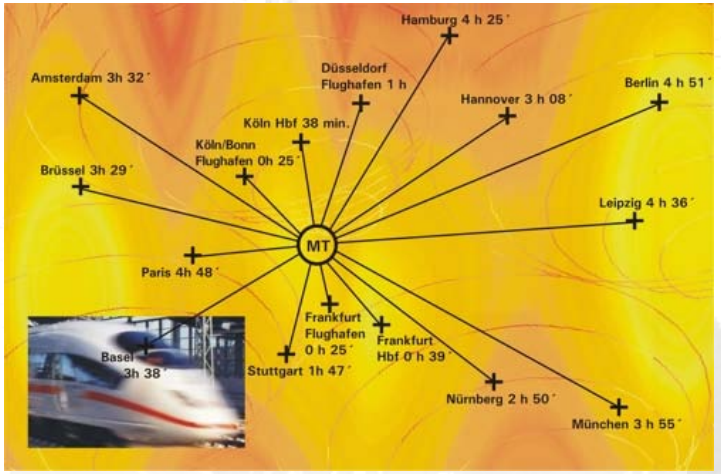


Montabaur & Limburg

Anecdotal Evidence

- Increasing passenger numbers (expected: 300)



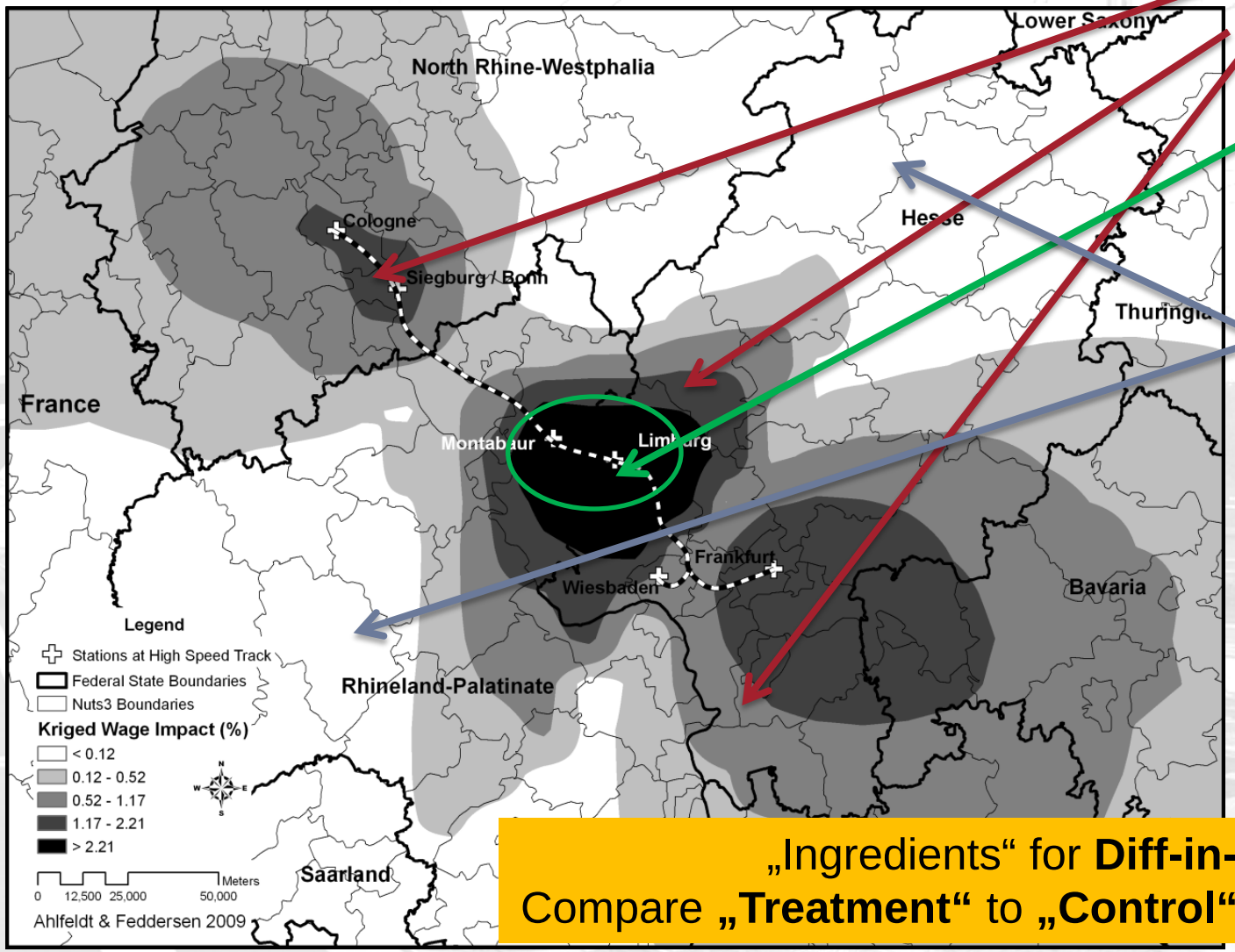


- Economic Boom
  - ICE-park “Montabaur”
  - New firms (e.g. 1&1)
  - Raising rents, employment, etc.

C. The Impact Area

The Shock

From Periphery to Core



Continuous **Treatment**

Discrete **Treatment**

Control (no effect)

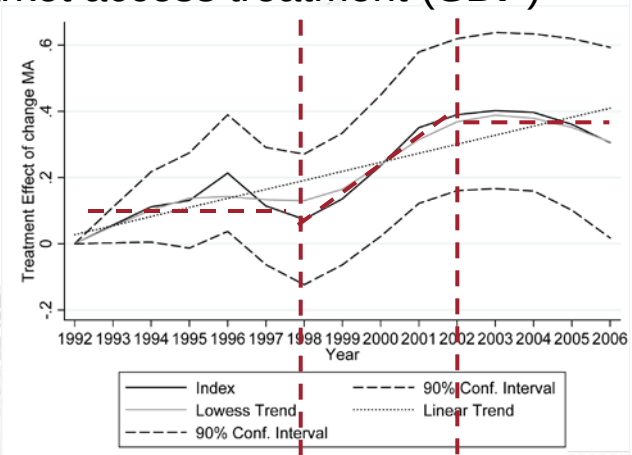
„Ingredients“ for **Diff-in-Diff**
Compare **„Treatment“** to **„Control“** areas over time

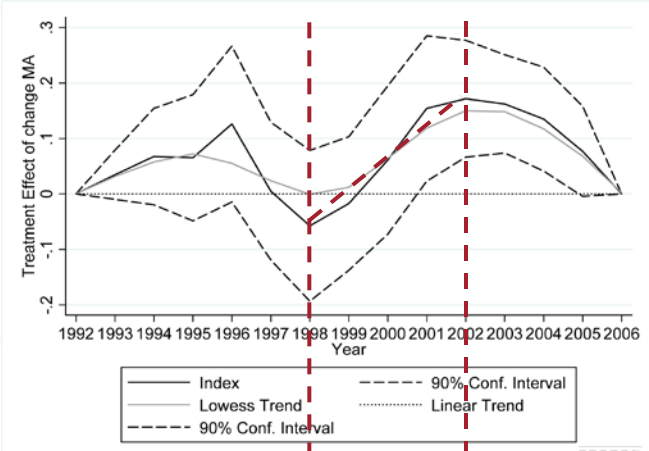
C. The Adjustment Period

Identifying the Adjustment Period

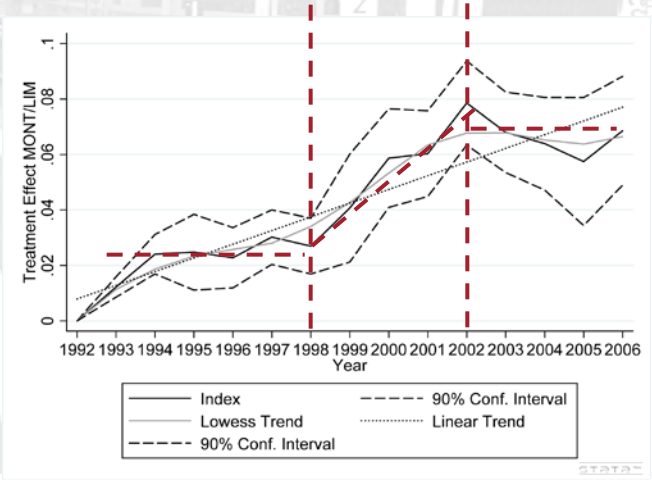
Diff-in-Diff with Time-Varying Treatments

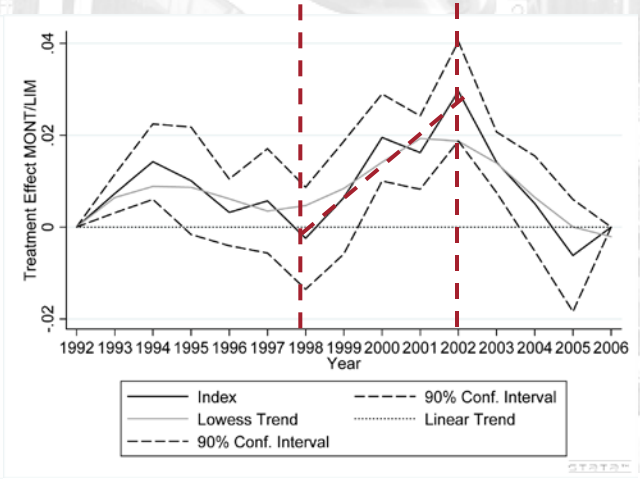
- Market access treatment (***GDP***)





- Discrete treatment for counties at intermediate stations *Montabaur/Limburg* (***GDP***)

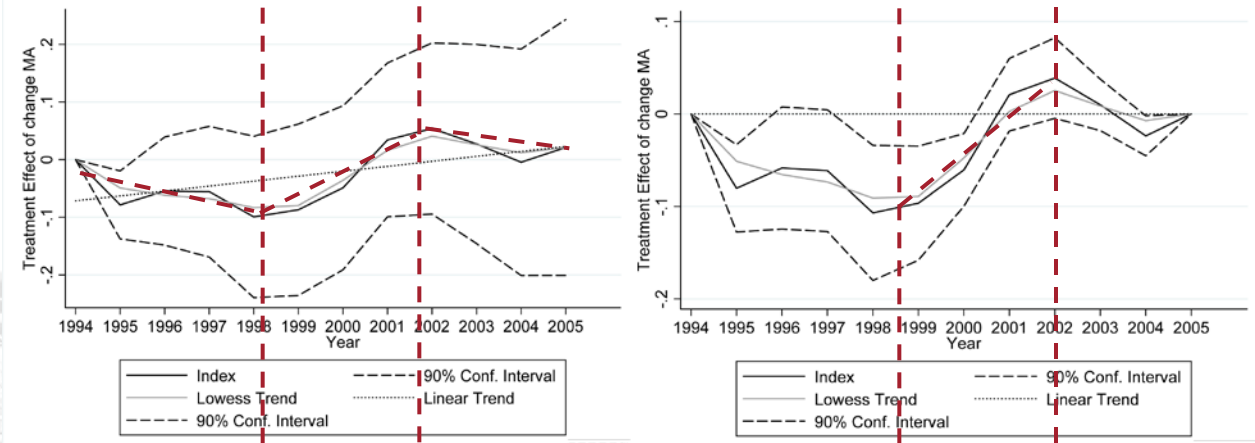




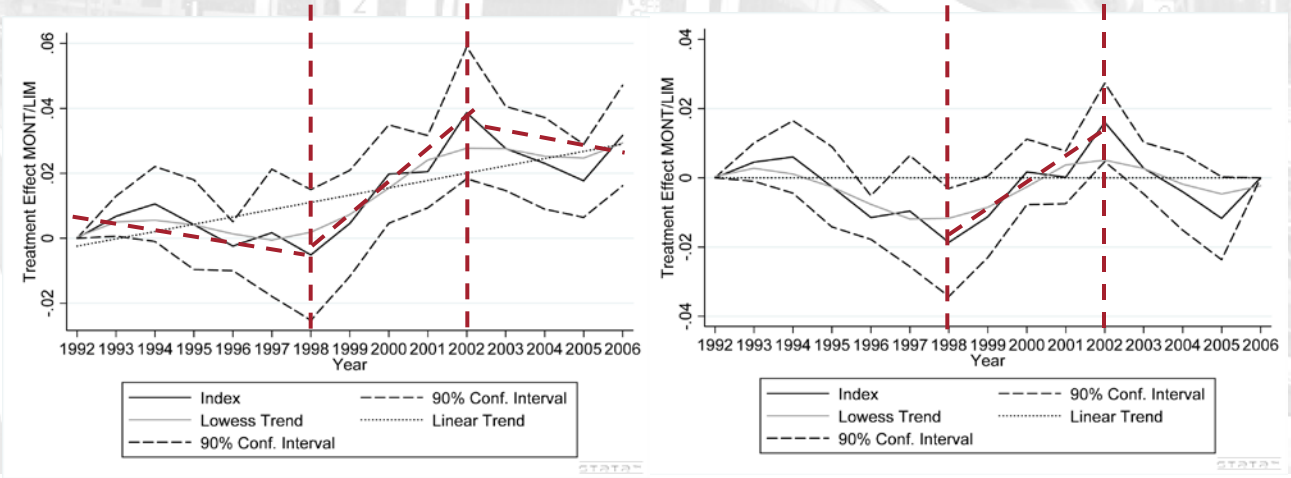
Identifying the Adjustment Period

Time-Varying Treatments

- Market access treatment (*Employment at workplace*)



- Discrete treatment for counties at intermediate stations *Montabaur/Limburg (GDP/capita)*



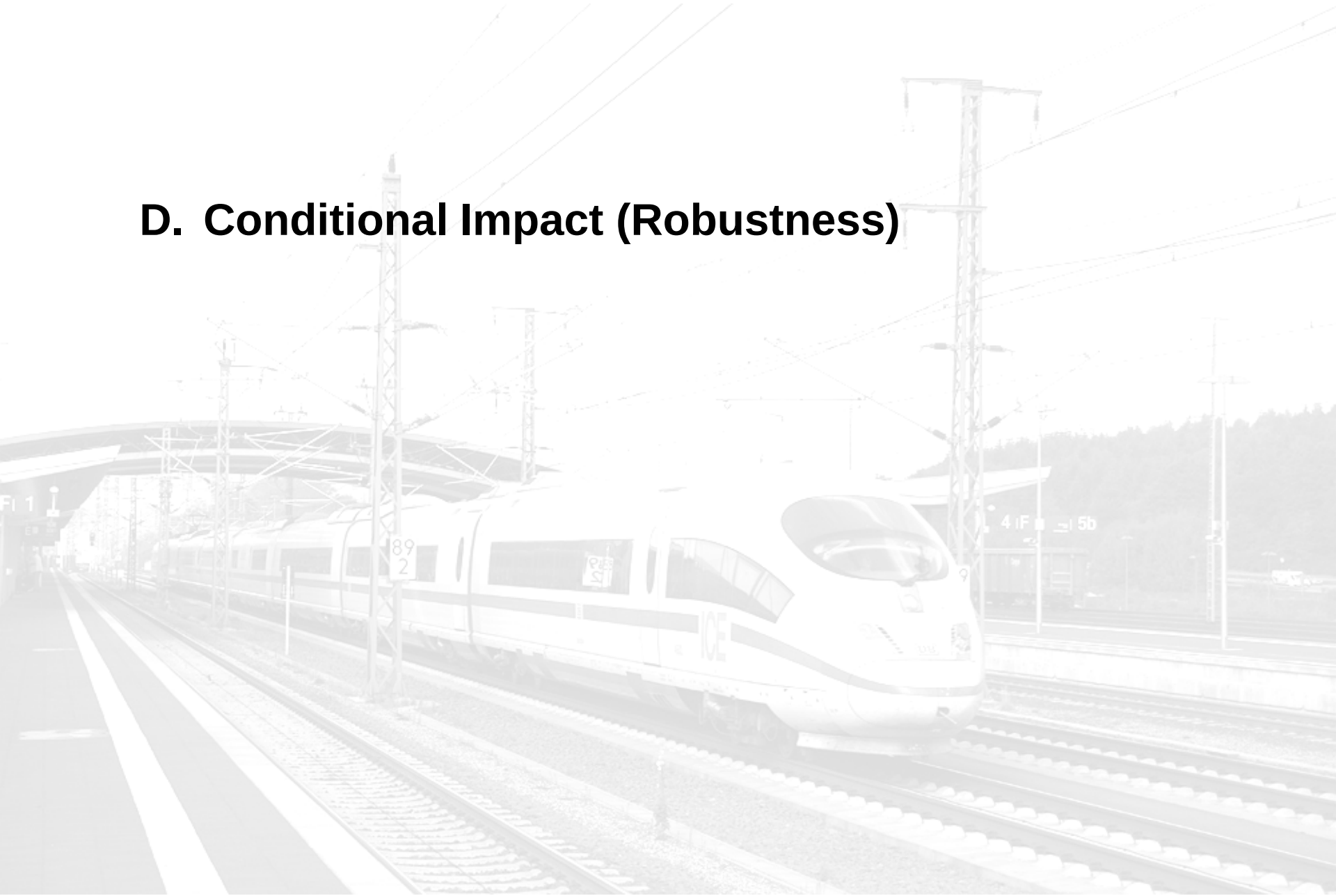
Treatment Effects

Intervention

- Market access treatment (*GDP*)
  - **Significant effect** in narrow treatment (discrete) area
  - Reduced/entirely explained by MA treatment
  - MA elasticity/treatment approx. 0.2-0.3

	(1)	(2)	(3)	(4)	(5)	(6)
MA Treatment $x_i^b \times POST$	0.271*		0.212	0.217		0.213
	(0.118)		(0.169)	(0.143)		(0.214)
Discrete Treatment $x_i^a \times POST$		0.047**	0.022		0.027**	0.001
		(0.010)	(0.023)		(0.006)	(0.028)
Year Effects	Yes	Yes	Yes	Yes	Yes	Yes
County Effects	Yes	Yes	Yes	Yes	Yes	Yes
Anticipation Effects (MA) x_i^a	Yes	-	Yes	Yes	-	Yes
Anticipation Effects (Dummy) x_i^b	-	Yes	Yes	-	Yes	Yes
Trend Effects	-	-	-	Yes	Yes	Yes
Observations	1725	1725	1725	1725	1725	1725
R-squared (within)	0.84	0.84	0.84	0.94	0.94	0.94

D. Conditional Impact (Robustness)



GDP Growth Impact (1998-2002)

Conditional Treatment

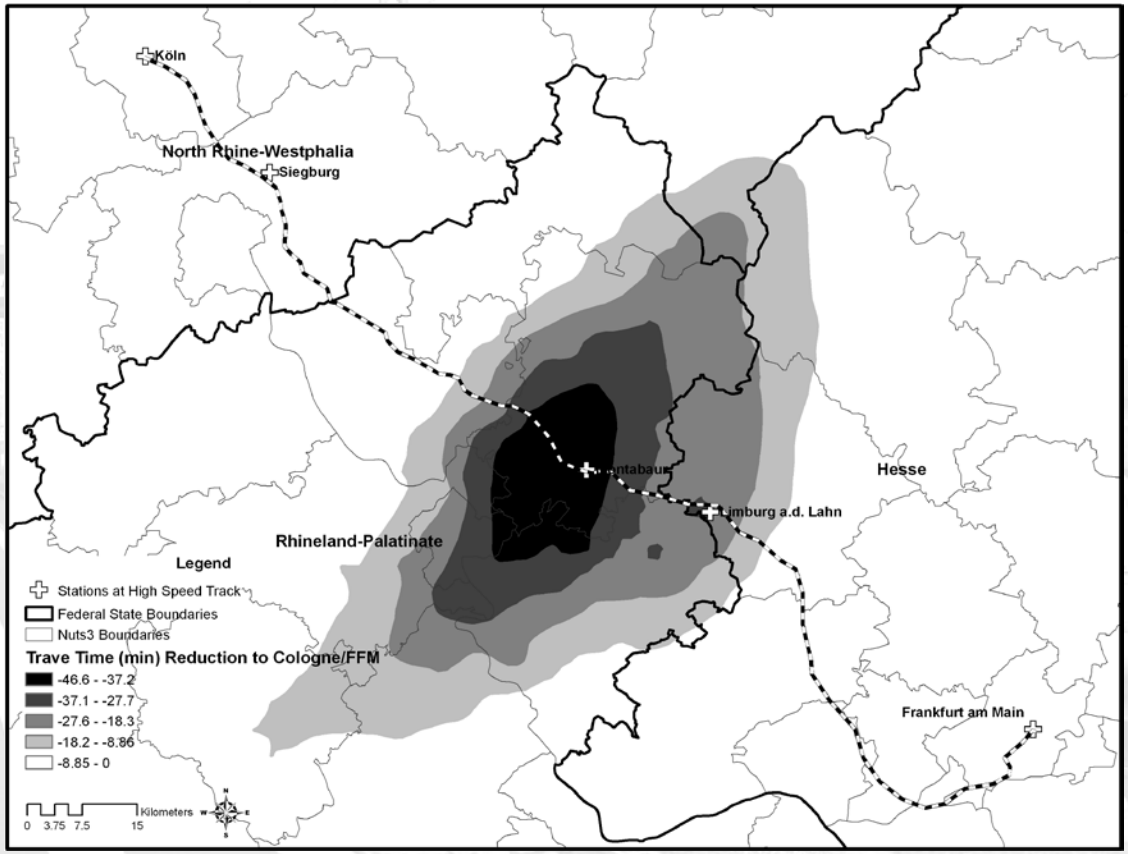
- North-Rhine Westphalia, Hesse, Rhineland-Palatinate
- log(GPD), log(GDP/Capita), log(GDP/ha) (1998)
- log(elevation), log(distance to river), log(MApre), log(dist_Cologne), log(dist_FFM)
- share of mining, services, manufacturing at GVA (1998)
- pre-trend

Log Diff GDP	(1)	(2)	(3)	(4)	(5)	(6)
Log Diff MA	0.311**	0.218**	0.296**	0.208	0.246+	0.247+
	(0.093)	(0.068)	(0.111)	(0.127)	(0.139)	(0.140)
Log Diff GDP						0.011
(1992 -1998)						(0.114)
State Effects		Yes	Yes	Yes	Yes	Yes
GDP Controls			Yes	Yes	Yes	Yes
Geo Controls				Yes	Yes	Yes
Ind Controls					Yes	Yes
Observations	114	114	114	114	114	114
R-squared	0.05	0.10	0.21	0.28	0.3	0.3

Endogineity

Conditional Treatment

- IV: Change in minimum travel time to economic cores (FFM/Cologne)



Endogineity

Conditional Treatment

- 2SLS with IVs
  - Change in travel time to closest core
  - Dummy for counties adjacent to intermediate stations
- Magnitude and significance level of treatment coefficients slightly increase
- Limited endogeneity concerns

	(1)	(1)
Log Diff MA	0.319*	0.296*
	(0.125)	(0.144)
State Effects	Yes	Yes
GDP Controls		Yes
Geo Controls		Yes
Ind Controls		Yes
Observations	114	114
R-squared	0.09	0.30

Construction and Substitution Effects

Conditional Treatment

- Construction: Dummy for counties along new track
- Substitution: Dummy for counties along old track

	(1)	(2)	(3)
Log Diff MA	0.316*	0.246+	0.323*
	(0.138)	(0.139)	(0.139)
Construction	-0.033*		-0.035*
	(0.015)		(0.018)
Substitution		0.002	-0.008
		(0.016)	(0.017)
State Effects	Yes	Yes	Yes
GDP Controls	Yes	Yes	Yes
Geo Controls	Yes	Yes	Yes
Ind Controls	Yes	Yes	Yes
Observations	114	114	114
R-squared	0.33	0.3	0.33

Industry Turnover

Conditional Treatment

- Excess Churning Rate (Duranton, 2007, AER), Findeisen & Suedekum (2008, JUE)

$$ExcChurn_i = \frac{1}{T}\left(\sum_t \sum_z \frac{|GVA(z,i,t+1) - GVA(z,i,t)|}{GVA(i,t)}\right) - \frac{1}{T}\left(\sum_t \frac{|GVA(i,t+1) - GVA(i,t)|}{GVA(i,t)}\right)$$

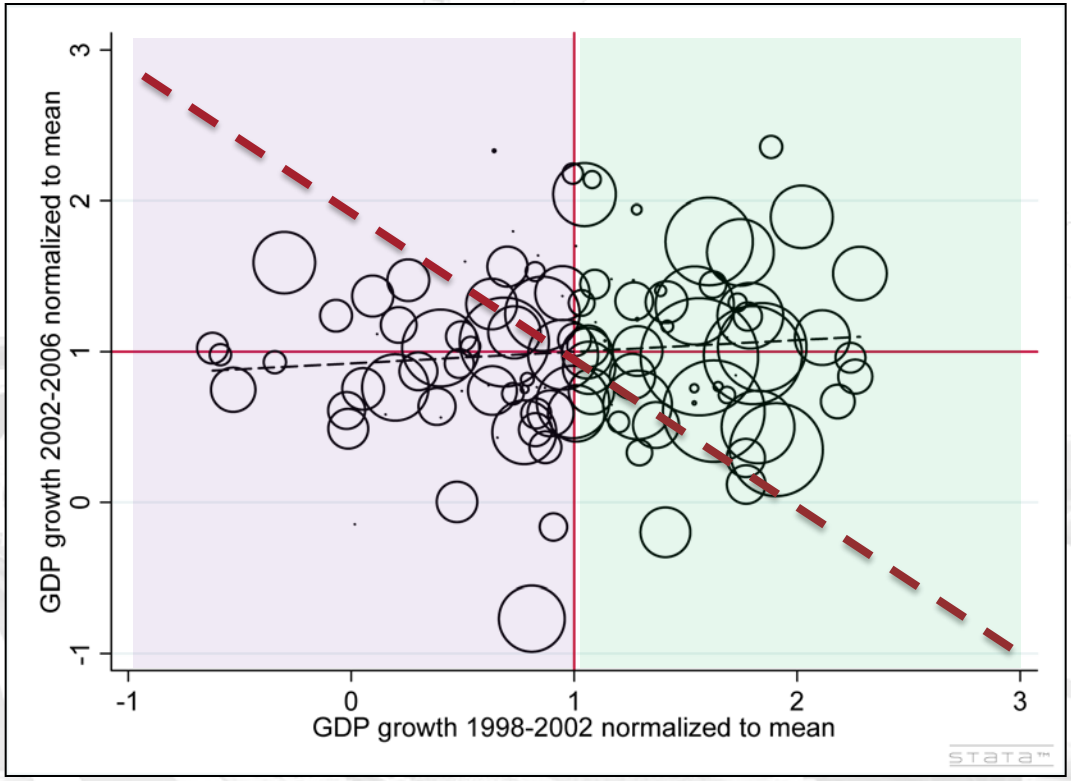
- Change in industry structure in a county relative to the study area
- Negative impact =>“structural change losers”

	(1)	(2)	(3)	(4)
Log Diff MA	0.230*	0.291+	0.289+	0.274*
	(0.094)	(0.147)	(0.152)	0.129
ExChurn	-0.015*	-0.012+	-0.017*	-0.0058
	(0.006)	(0.007)	(0.007)	(0.012)
ExChurn x NRW			0.007	
			(0.012)	
State Effects	Yes	Yes	Yes	Yes
GDP Controls		Yes	Yes	Yes
Geo Controls		Yes	Yes	Yes
Ind Controls		Yes	Yes	
Const & Subst Controls		Yes	Yes	Yes
ExChurn instrumente				Yes
Observations	114	114	114	114
R-squared	0.16	0.36	0.36	0.30

E. Persistency

Growth in Adjustment and Post-Period

Reversion of Trends?



GDP growth **pre / adjust.** 1998-2002 vs. 2002-2006

No negative correlation (reversion)

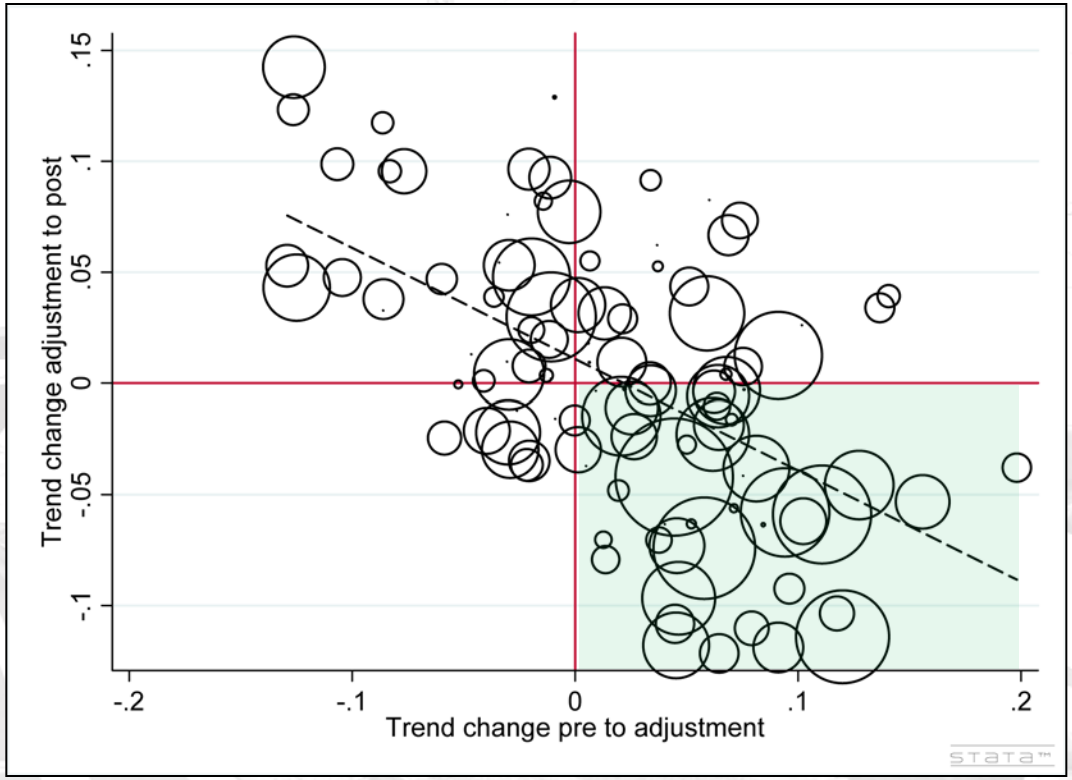
Positive correlation of treatement and pre growth

No Positive correlation of treatement and adjustment growth

No reversion of the shock/adjustment – persistency

Change in Growth into Adjustment and Post-Period

Reversion of Changes in Trends?



GDP growth **changes**: **pre-adjust.** vs. **adjist.-post** 92-98–98-02 vs. 98-02–02-06

Negative correlation (return to pre trends)

Large treatment areas in lower right quadrant (**positive** when **entering** / **negative** when **exiting** adjustment period)

Return to pre-trend at higher level – persistent effect

Persistency Tests

(Extended) Davis/Weinstein (2002) Methodology

- No Reversion
- Return to pre-trend

	(1)	(2)	(3)	(4)
	Growth (2002-2006)	Growth (2002-2006)	Growth (2002-2006)	Difference in Growth (1998-02)-(2002-06)
Log Diff GDP (1998-2002)	-0.274	-0.264	-0.273	
	(0.239)	(0.270)	(0.270)	
Difference Growth (1995-98)-(1998-02)				-1.119**
				(0.335)
State Effects		Yes	Yes	
GDP Controls		Yes	Yes	
Geo Controls		Yes	Yes	
Ind Controls		Yes	Yes	
ExChurn		Yes	Yes	
Log Diff GDP (1995-98)			Yes	
Observations	114	114	114	114
R-squared	0.01	0.26	0.26	0.05

E. Conclusion

Conclusion

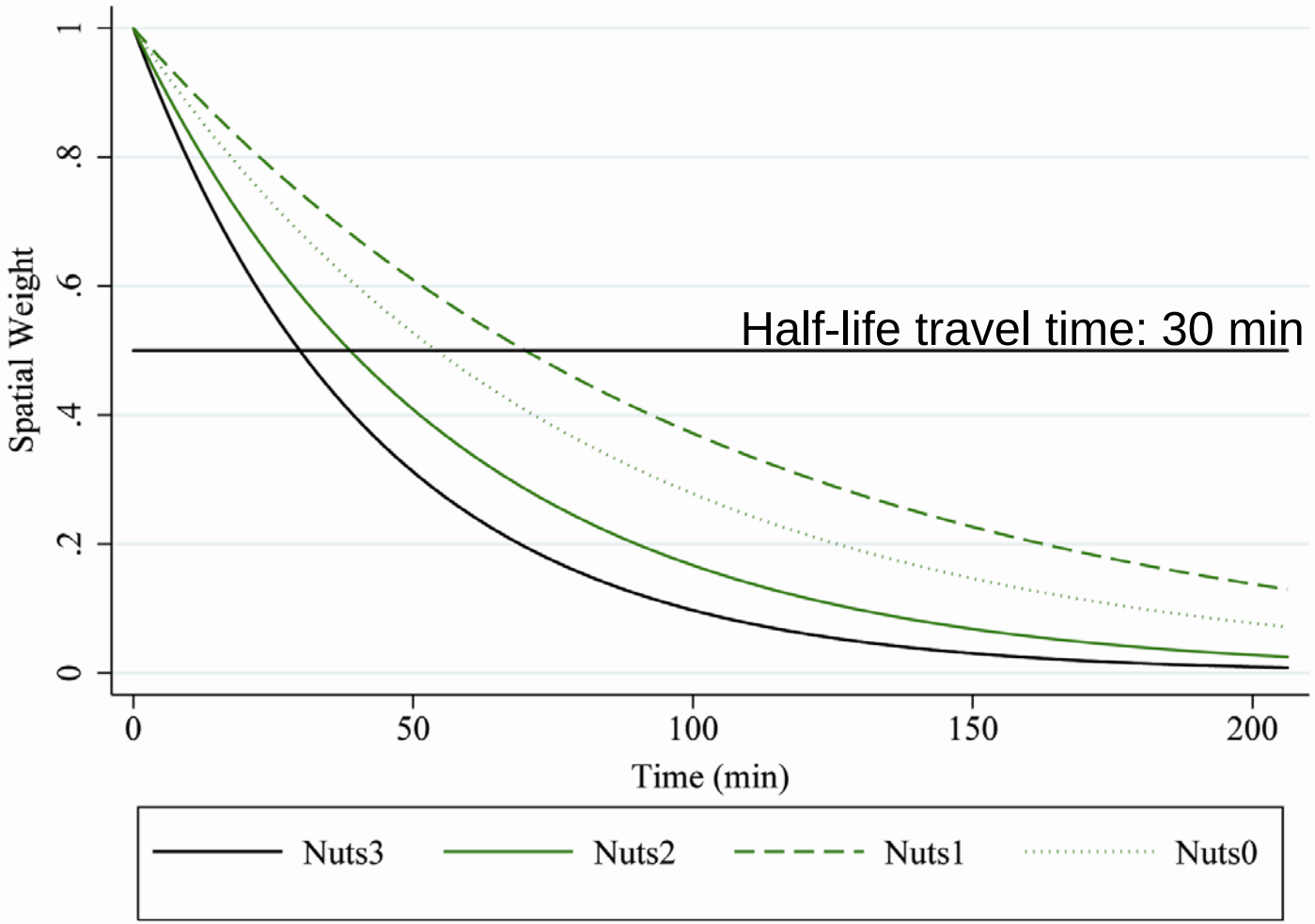
From Periphery to Core

- HSR *Cologne-FFM*, Germany with intermediate stations *Montabaur* and *Limburg* chosen due to **exogenous political considerations**
- **Significant impact**
  - Market access **elasticity** about 0.**25**
    10% increase in acces => 2.5% increase in GDP
  - Adjustment occurs in **anticipation** to HSR opening (four year period)
  - **Temporary** adjustments **growth** yields **permanent GDP shift** (in levels)
- HSR (transport infrastructure) more likely to yield **permanent shifts** in regional economic activity through temporary spending than other policies
- MA treatment can be used to **predict** regional **economic effects**
- **No CBA** – no substitute for CBA
- **No** pladoyer for **intermediate stops**

Thank you!

Spatial Weight Function

Previous Sensitivity Analysis on >200 Specifications



Pre-Test

Appendix

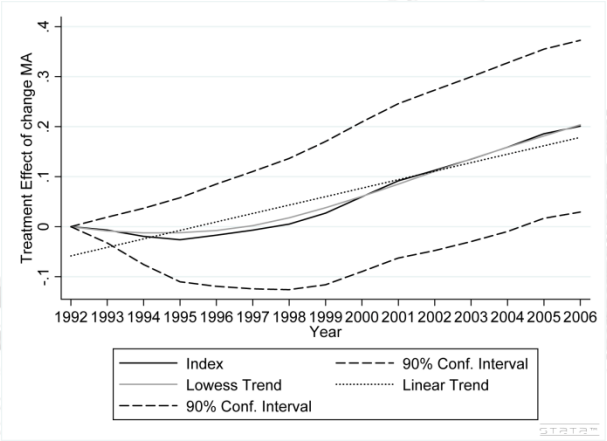
- Study area vs. rest of Germany

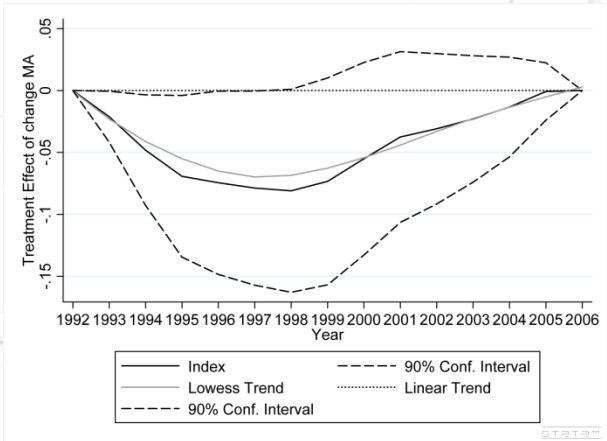
	(1)	(2)	(3)	(4)
	GDP	GDP/Capita	POP	EMP
STUDY x $YEAR_{1993}$	-0.000	-0.008	-0.008	
	(0.005)	(0.009)	(0.010)	
STUDY x $YEAR_{1994}$	-0.001	-0.014*	-0.016	
	(0.005)	(0.008)	(0.010)	
STUDY x $YEAR_{1995}$	-0.002	-0.007	-0.010	
	(0.005)	(0.008)	(0.010)	
STUDY x $YEAR_{1996}$	-0.003	-0.012	-0.015*	-0.000
	(0.004)	(0.008)	(0.009)	(0.004)
STUDY x $YEAR_{1997}$	-0.004	-0.009	-0.013	0.000
	(0.004)	(0.007)	(0.009)	(0.004)
STUDY x $YEAR_{1998}$	-0.005	-0.019***	-0.024***	-0.001
	(0.004)	(0.007)	(0.009)	(0.003)
STUDY x $YEAR_{1999}$	-0.007	-0.026***	-0.033***	-0.001
	(0.004)	(0.007)	(0.009)	(0.003)
STUDY x $YEAR_{2000}$	-0.009**	-0.032***	-0.041***	-0.002
	(0.004)	(0.008)	(0.009)	(0.003)
STUDY x $YEAR_{2001}$	-0.012***	-0.042***	-0.054***	-0.003
	(0.004)	(0.008)	(0.009)	(0.003)
STUDY x $YEAR_{2002}$	-0.015***	-0.033***	-0.048***	-0.005
	(0.005)	(0.008)	(0.009)	(0.004)
STUDY x $YEAR_{2003}$	-0.017***	-0.027***	-0.044***	-0.009**
	(0.005)	(0.008)	(0.010)	(0.004)
STUDY x $YEAR_{2004}$	-0.019***	-0.026***	-0.044***	-0.012**
	(0.005)	(0.008)	(0.010)	(0.005)
STUDY x $YEAR_{2005}$	-0.020***	-0.028***	-0.048***	-0.017***
	(0.005)	(0.009)	(0.010)	(0.005)
STUDY x $YEAR_{2006}$	-0.022***	-0.031***	-0.053***	
	(0.005)	(0.009)	(0.011)	
County effects	Yes	Yes	Yes	Yes
Year effects	Yes	Yes	Yes	Yes
Observations	4890	4890	4890	3904
R-squared	1.00	0.98	1.00	1.00

Time-Varying Treatments (MA-Treatment)

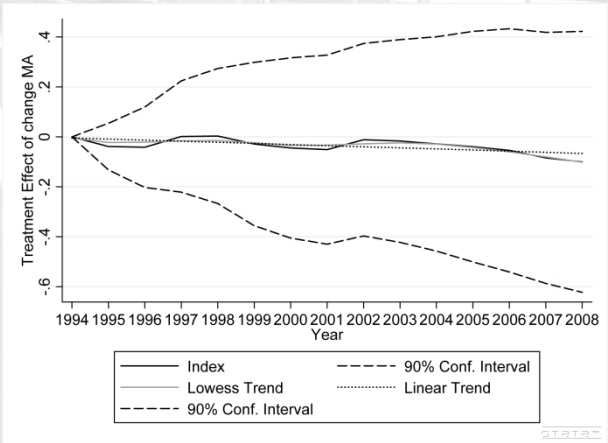
Appendix

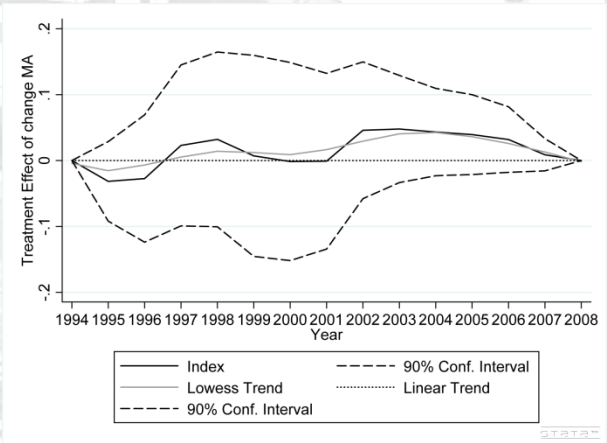
Population





Share of out commuters

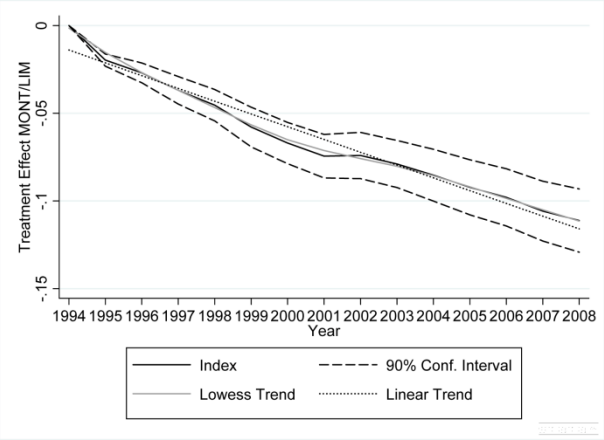


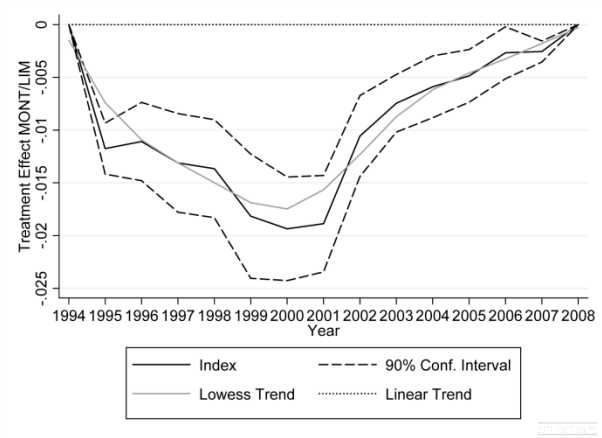


Time-Varying Treatments (Discrete)

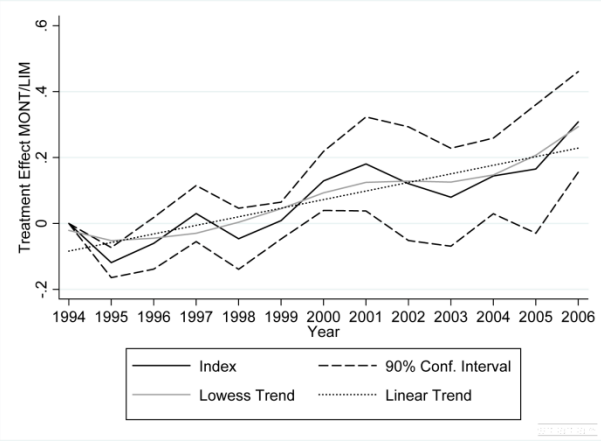
Appendix

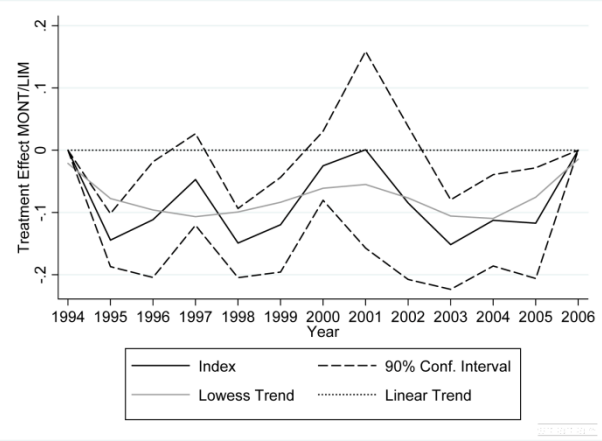
Share of out-commuters (at resident population)





Standard land values





Endogineity – 1st Stage Results

Appendix

	(1)	(1)
Discrete	0.072**	0.079**
(x_i^a)	(0.018)	(0.020)
Log Diff Travel Time	-0132**	-0.076***
(x_i^c)	(0.031)	(0.036)
State Effects	Yes	Yes
GDP Controls		Yes
Geo Controls		Yes
Ind Controls		Yes
Observations	114	114
R-squared	0.49	0.86
Kleinbergen-Paap rk LM stat (P-Val)	5.203 (0.074)	5.930 (0.0516)
F-stat (Kleinbergen-Paap rk Wald)	29.803	18.649
Hansen-Sargan stat (P-Val)	0.767 (0.381)	0.243 (0.622)

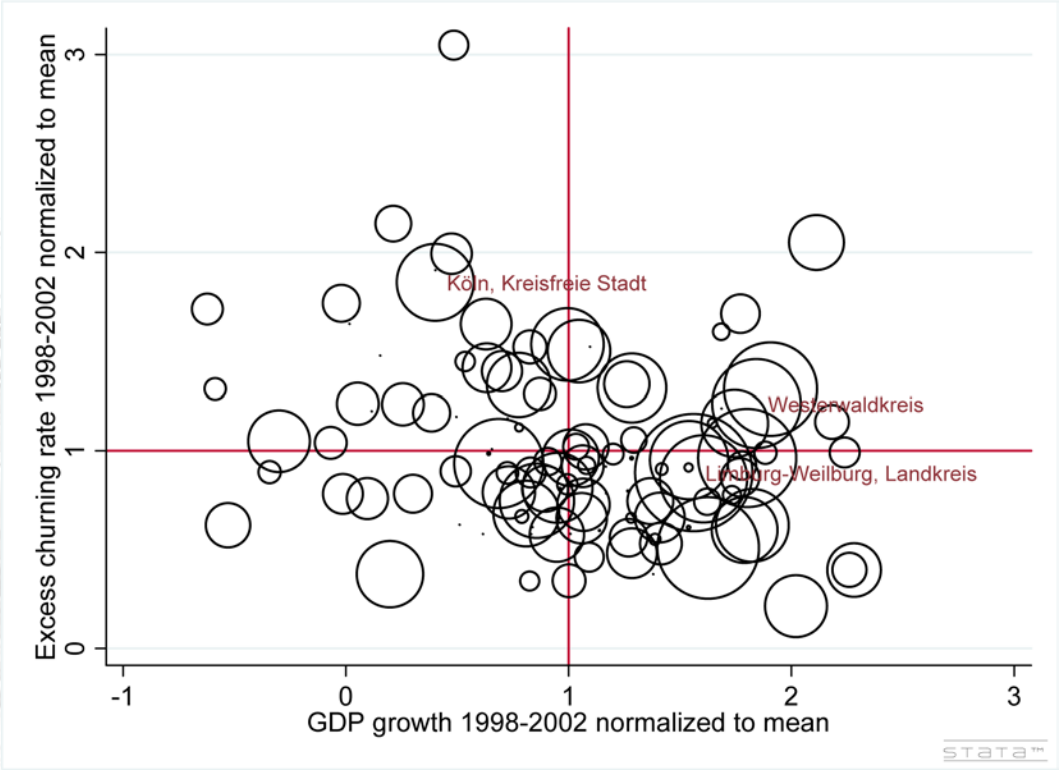
Treatment Heterogeneity

Appendix

	(1)	(2)	(3)	(4)	(5)
Log Diff MA	0.247+	0.243+	0.248+	0.250+	0.185
	(0.138)	(0.141)	(0.142)	(0.149)	(0.268)
Log Diff MA x D	0.034	0.047	-0.035	-0.023	0.076
	(0.233)	(0.232)	(0.255)	(0.268)	(0.268)
Heterogeneity	Pop	GDP/pop	Pop/area	Manufact.	Services
State Effects	Yes	Yes	Yes	Yes	Yes
GDP Controls	Yes	Yes	Yes	Yes	Yes
Geo Controls	Yes	Yes	Yes	Yes	Yes
Ind Controls	Yes	Yes	Yes	Yes	Yes
Observations	114	114	114	114	114
R-squared	0.3	0.3	0.3	0.3	0.3

Churning

Appendix



Determinants of Churning

Appendix

	(1)	(2)	(3)	(4)	(5)
Log of	-0.184+	-0.187+	-0.330**	-0.411**	-0.406**
Population	(0.105)	(0.105)	(0.111)	(0.127)	(0.119)
Log Diff MA		0.317	-0.345	-0.912	-3.15
		(1.683)	(1.561)	(2.680)	(2.716)
GDP Controls			Yes	Yes	Yes
Geo Controls				Yes	Yes
Ind Controls					Yes
Observations	114	114	114	114	114
R-squared	0.02	0.02	0.14	0.17	0.28

Persistency Test – 1st Stage Results

Appendix

	(1)	(2)
	Growth(1998-2002)	Difference in Growth
Log Diff MA	0.255+	0.342+
χ_i^a	(0.134)	(0.197)
Discrete Treatment	0.021	0.008
χ_i^b	(0.019)	(0.031)
Observations	114	114
R-squared	0.05	0.04
Kleinbergen-Paap rk LM stat (P-Val)	6.095 (0.048)	5.515 (0.064)
F-stat (Kleinbergen-Paap rk Wald)	13.068	4.808
Hansen-Sargan stat (P-Val)	0.089 (0.765)	1.915 (0.384)

The Identification Strategy

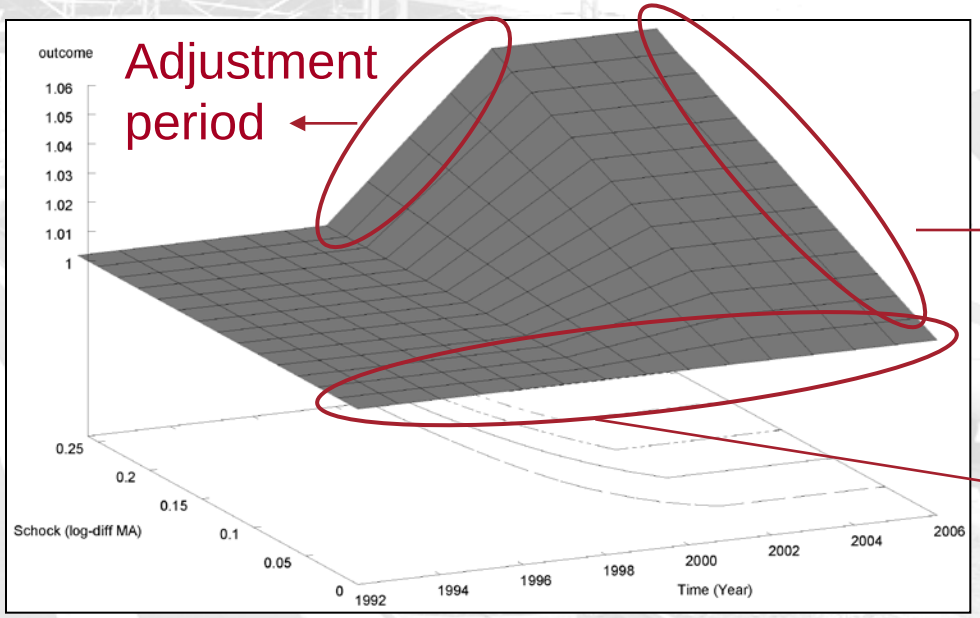
Being Flexible I

- Classical identification problem

	PRE	POST
TREAT		
CONTROL		

Intervention effect

- Reality



Treatment

Control

The Travel Time Matrices

Modeling Accessibility

- Two complete travel time matrices are generated connecting
  - 3,128 municipalities within narrow study area of 3 Bundesländer
  - 1,335 Nuts3 regions covering almost all of Europe
  - Hybrid set of 4,325 locations
- Pre-period
  - All locations are connected based on a straight-line matrix
  - 75 km/h is an approximation for average car velocity in the study area
  - Upgrade to route planner travel times in progress
  - (18,992,164/2 = 9.496.082 travel times ~ 1 year of net-computing time)
- Post-period
  - use the train if combined network path to and from any train station is faster than without the use of the train
  - otherwise use car

Transport Cost

Modeling Accessibility

- Transport cost parameter set ot **0.02**

$$x_h = \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt+1})\right) - \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt})\right)$$

- Nominal wage equation

$$\log(w_i) = \alpha_0 + \alpha_1 \log(\sum_j GDP_j \exp(-\alpha_2 tt_{ij}^{car}) + \varepsilon_i)$$

  - NLS (SAR) α_1 0.285 (0.193), α_2 0.023 R^2 0.475, N=1,335 (NUTS3)

- Rail commuting probability function (cumulative density of travel time)

$$1 - F(n) = \sum_{m>n} p(n) = \beta_1 \exp(-\beta_2 TIME_n) + \varpi_n$$

  - NLS β_1 1.632, β_2 0.0205 R^2 0.973, N=30,590
    (representative 5% sample of 2000 US census)

Transport cost

Modeling Accessibility

- Transport cost parameter set to **0.02**

$$x_h = \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt+1})\right) - \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt})\right)$$

- Nominal wage equation

$$\Delta \log(w_h) = \alpha_1 \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt+1})\right) - \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt})\right)$$

0.2

The Identification Strategy

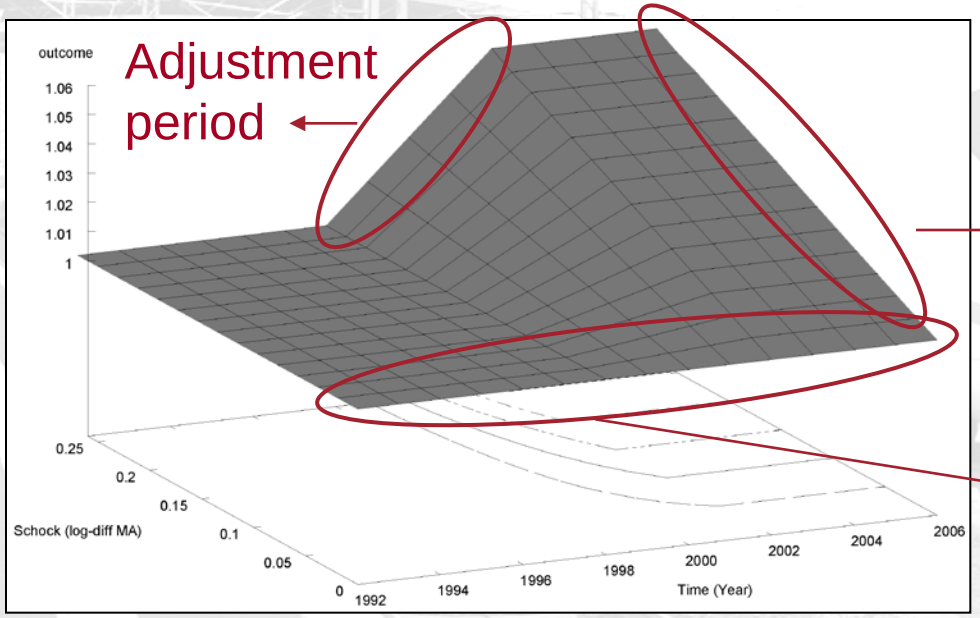
Being Flexible II

- Classical identification problem

	PRE	POST
TREAT		
CONTROL		

Intervention effect

- Reality



Treatment

Control

Identifying the Adjustment Period

Time-Varying Treatments

- Identification specification with time varying treatment effects
  - Tests for significant treatment effects relative to the base year
  - Conditional on time-invariant location characteristics and common macro-shocks

$$\log(y_{it}) = \vartheta_i + \varphi_t + \sum_{1993}^{2006} \gamma_u \, x_i \times YEAR_u + \varepsilon_{it}$$

- Alternative specification tests for a significant deviation from linear trend

$$\log(y_{it}) = \vartheta_i + \varphi_t + \theta \, x_i \times TREND_t + \sum_{1993}^{2005} \gamma_u \, x_i \times YEAR_u + \varepsilon_{it}$$

Identifying the Adjustment Period

Time-Varying Treatments

- Market access treatment
  - Calculate for municipalities (*h*) and aggregate to counties (*i*) weighted by population

$$x_i^a = \log\left(\sum_h \frac{P_h}{P_i} \sum_g [\![Y_g \exp(-\alpha_2 [\![tt_{hgt+1}]\!]) \right) - \log\left(\sum_h \frac{P_h}{P_i} \sum_g [\![Y_g \exp(-\alpha_2 [\![tt_{hgt}]\!]) \right)$$

- Discrete treatment for counties at intermediate stations *Montabaur/Limburg*

$$x_i^b = \begin{cases} 1 \text{ for "Rhein Lahn Kreis", "Rhein Sieg Kreis", "Westerwaldkreis"} \\ 0 \text{ otherwise} \end{cases}$$

- Reduce study are to the federal states of North-Rhine Westphalia, Hesse& Rhineland-Palatinate to increase homogeneity
  - Pre-tests show that study area as a whole receives no positive treatment compared to the rest of West-Germany

Treatment Effects

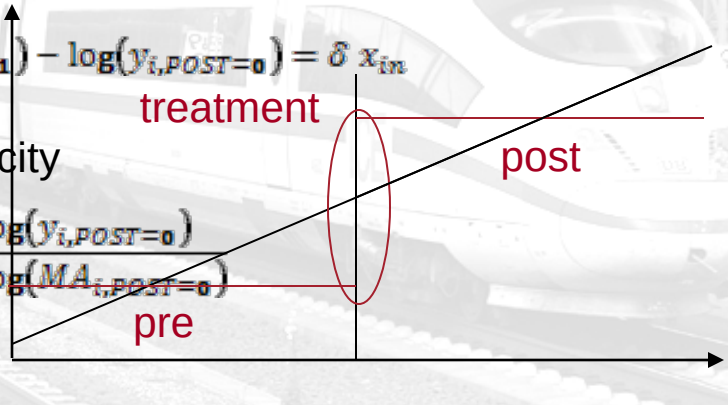
The Specification

- Test for significant treatment effect (level-shift)
  - controlling for anticipation (1998-2001), time and year effects as well as location specific trends
  - Featuring continuous (MA) and discrete treatment

$$\log(y_{it}) = \vartheta_i + \varphi_t + \sum_i \Omega_i TREND_{it} + \sum_n \sum_{1999}^{2001} \gamma_{un}\, x_i \times YEAR_{un} + \sum_n \delta_n x_{in} \times POST_t + \varepsilon_{it}$$

- Interpretation: $\log(y_{i,POST=1}) - \log(y_{i,POST=0}) = \delta\, x_{in}$

relative trend



  - Market access elasticity

$$\delta_a = \frac{\log(y_{i,POST=1}) - \log(y_{i,POST=0})}{\log(MA_{i,POST=1}) - \log(MA_{i,POST=0})}$$

  - Standard diff-in-diff

$$\delta_b = \left(\log(y_{i,POST=1}) - \log(y_{i,POST=0})\right)^{x_i^b=1} - \left(\log(y_{i,POST=1}) - \log(y_{i,POST=0})\right)^{x_i^b=0}$$

Endogineity

Conditional Treatment

- Is the market access shock really exogenous?
  - Intermediate stations provide exogenous source of variation
  - Timing of the track exogenous
    - Discussed, opposed, negotiated since the 1960s
    - Approval independent from performance during “adjustment period”
  - Treatment only significant during the adjustment period (more evidence later)
- Use instruments
  - Correlated with MA treatment
  - Only impact via changing access to markets (identifying assumption)
  - Only use exogenous variation related to the intermediate stations

Intermediate Summary

Significant Impact

- Significant positive adjustment between 1998-2002
  - Within areas that benefited from increase in access to markets (MA treatment)
  - Limited endogineity concerns
- Robust to
  - Local economic conditions
  - Geography
  - Construction & substitution
  - Industry turnover
- Open questions
  - Persistency

Treatment Effect in Pre/Post-Periods

Conditional Treatment

- Treatment effects before and after the adjustment period
- MA treatment negative and not significant before and after adjustment period
- Weak negative trends

	(1)	(2)	(3)	(4)
Log Diff MA	-0.053	-0.139	-0.092	-0.141
	(0.086)	(0.126)	(0.091)	(0.102)
Period	1995-1998	1995-1998	2002-2006	2002-2006
State Effects		Yes		Yes
GDP Controls		Yes		Yes
Geo Controls		Yes		Yes
Ind Controls		Yes		Yes
ExChurn		Yes		Yes
Observations	114	114	114	114
R-squared	0	0.31	0.01	0.28

Growth Impact

Conditional Treatment

- Long-difference over adjustment period (1998-2002)

$$\log(y_{it+1}) - \log(y_{it}) = \phi(\log(MA_{it+1}) - \log(MA_{it})) + Z_i\Psi + \xi_j + \varepsilon_i$$

  - Impact of market access, conditional on controls
  - Market access elasticity parameter
  - Unaffected areas serve as a control group

$$\phi(log\ (MA_{it+1} - log\ (MA_{it})) = (\log(y_{it+1}) - \log(y_{it}))^T - (\log(y_{it+1}) - \log(y_{it}))^C$$

Persistency

Reversion in Levels and Trends

- Davis & Weinstein (2002) test for persistency of temporary shock

$$\log(y_{it+2}) - \log(y_{it+1}) = (\rho - 1)(\log(y_{it+1}) - \log(y_{it})) + \mu$$

post — adjustment

Instrument with shock measure
discrete & MA treatment

  - Permanent impact if $\rho = 1$, $(\rho - 1) = 0$
  - Fully dissipated if $\rho = 0$, $(\rho - 1) = -1$

- For changes in growth rates

$$[\log(y_{it+2}) - \log(y_{it+1})] - [\log(y_{it+1}) - \log(y_{it})] = (\lambda - 1)([\log(y_{it+1}) - \log(y_{it})] - [\log(y_{it}) - \log(y_{it-1})]) + \mu$$

discrete & MA treatment

post — adjustment — adjustment — pre

  - Permanent impact if $\lambda = 0$, $(\lambda - 1) = -1$
  - Sustainable trend if $\lambda > 0$, $(\lambda - 1) > -1$
  - Reversion if $\lambda < 0$, $(\lambda - 1) < -1$

Economics Viability

Tax Revenues

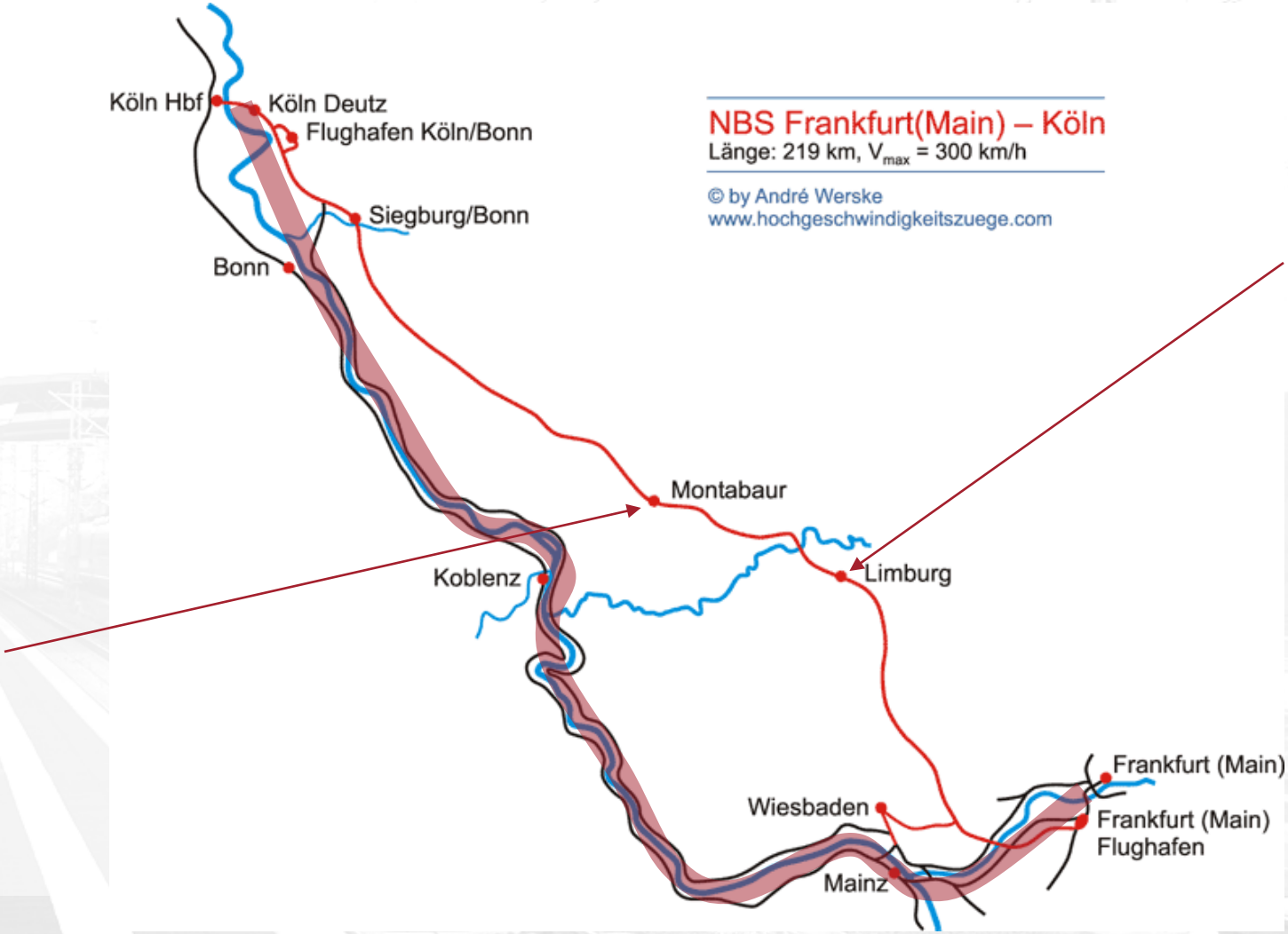
- Permanent shift in economic activity (levels not trends)
- Calculate aggregate tax revenues as PV of future tax streams
  - Based on tax ratio of 22% (BMF, 2008)
  - Discount rate 5%-10% (capital, maintancence cost, etc.)

$$PVT = \sum \hat{\phi} \times (\log(MA_{it+1}) - \log(MA_{it})) \times GDP_{i1998} \left(\times \frac{TR}{DR}\right)$$

- PVT about €13.3-€26.6 billion
  - Large compared to €6 billion construction cost
  - Upper bound estimate since it does not account for substitution effects

The Cologne-Frankfurt High-Speed Rail Track

The Project



Market Access

Modeling Accessibility

- Travel time weighted sum of GDP (Harris, 1954)

$$MA_{ht} = \sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt})$$

- Accessibility shock is change in market access only due to change in travel time

$$x_h = \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt+1})\right) - \log\left(\sum_g GDP_{gt} \exp(-\alpha \times tt_{hgt})\right)$$

- Change in travel time matrix

$$tt_{hgt} = tt^{car}_{hgt}$$

Cars only

$$tt_{hgt+1} = \min(tt^{car}_{hgt}, tt^{car}_{hrt} + tt^{HSR}_{rst+1} + tt^{car}_{hst})$$

Fastest combinednetworkpath
(Ahlfeldt, 2010, JRS)