Are We Successful in Reducing Vehicle Miles Traveled in Air Quality Nonattainment Areas?

Statistical Evidence of the Impact of Air Quality Control and Nonattainment Designation on Vehicle Miles Traveled in the Past Three Decades

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AQ-VMT

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* Views herein do not necessarily represent agency views. The authors are responsible for all statements.

Background

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Federal Involvement with Air Quality Control

- 1955 APCA; 1969 NEPA; 1963~1990 CAA and CAAA; 1980 APA; 1993 Conformity Regulation; Provisions in ISTEA, TEA-21, SAFETEA-LU, Etc.

Reducing VMT is an Official Goal of the U.S. Government Policy

- Stated in the CAA, the President's 1993 CCAP, and CMAQ Program in ISTEA, TEA-21, and SAFETEA-LU

Reducing VMT in Nonattainment Areas

- Air quality conformity rule, SIP in transportation planning
- Congestion Management and Air Quality Improvement
- Other federal, state, and local efforts

AQ-VMT Research Overview

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General Research Question

- Have air quality control, the associated funding preference, and state/local planning efforts to attain conformity actually reduced VMT and VMT growth rates in air quality nonattainment areas?

Nonattainment Designation → Reduction in VMT

- Is there a statistically significant correlation?
- Is there a causal effect?
- Which policies are effective, or not so effective?
- What are the policy implications for air quality conformity regulation, CMAQ, GHG emission goals, and transportation reauthorization?

Data and Methods

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Data Sources

- National household travel surveys
- Highway performance monitoring system
- Other datasets from FHWA, EPA, EIA, Census Bureau, BTS, BLS, and BEA

Methods

- 31 case studies at the metropolitan level (Phase 1)
- Regression and discrete choice analysis at the household level (Phase 2)
- Structural equation modeling at the state level (Phase 3)

NHTS Data Processing and Integration

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National Household Travel Surveys

- Socio-economic, demographic, location, vehicle ownership, and travel information at the household level
- Arguably the most comprehensive dataset for travel analysis and monitoring at the national level

Integration with EPA Nonattainment Areas

- Identifying whether or nor an NHTS household resides in a nonattainment area for each criteria pollutant over time

Integration with Energy/Environmental Data

- Fuel price at the state and county levels
- Vehicle characteristics such as price, fuel type, pollution emission rates, etc.

HPMS Data Processing and Integration

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Highway Performance Monitoring System Raw Data

- Annual AADT and VMT measurements/estimates on all roads in the U.S. by >1.5million segments since 1978

Data Cleaning and Aggregation

- VMT totals for counties, states, and non-attainment areas

Data Geo-Coding

- Merging HPMS and NHPN into a GIS-based VMT database

VMT by Vehicle Type

- Extrapolation from truck percentages on HPMS sample sections to all universe sections
- VMT by vehicle type at segment, county, and state levels

Phase 1 Research Question

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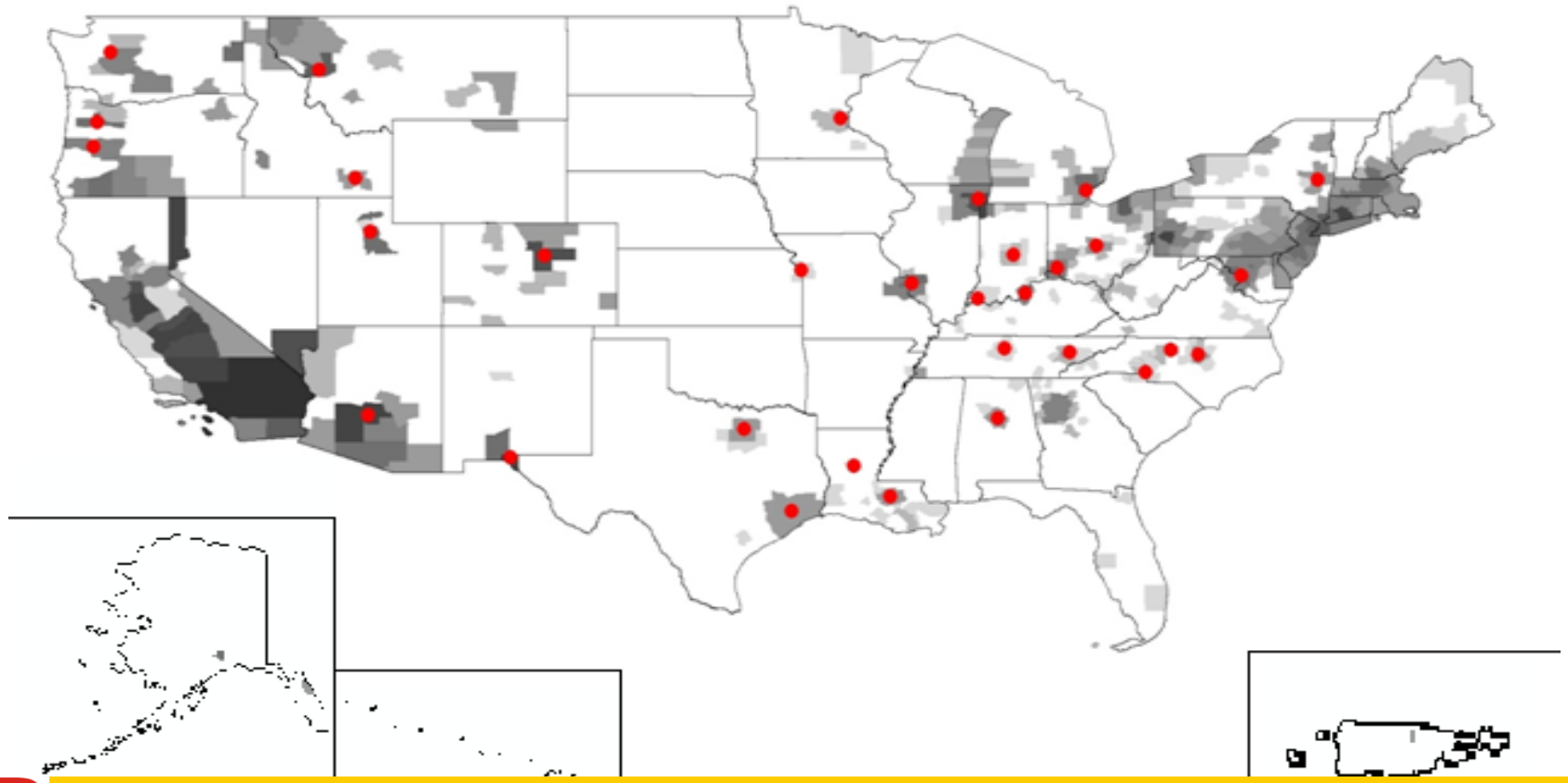
Is there a statistically significant difference between per capita VMT (VMT growth rate) in air quality nonattainment areas and that in the surrounding attainment areas?

Case Studies

31 case studies across the U.S. representing various urban and rural areas are selected based on CO, PM, and Ozone nonattainment status from 1978 to 2008.



Spatial Analysis for Case Studies

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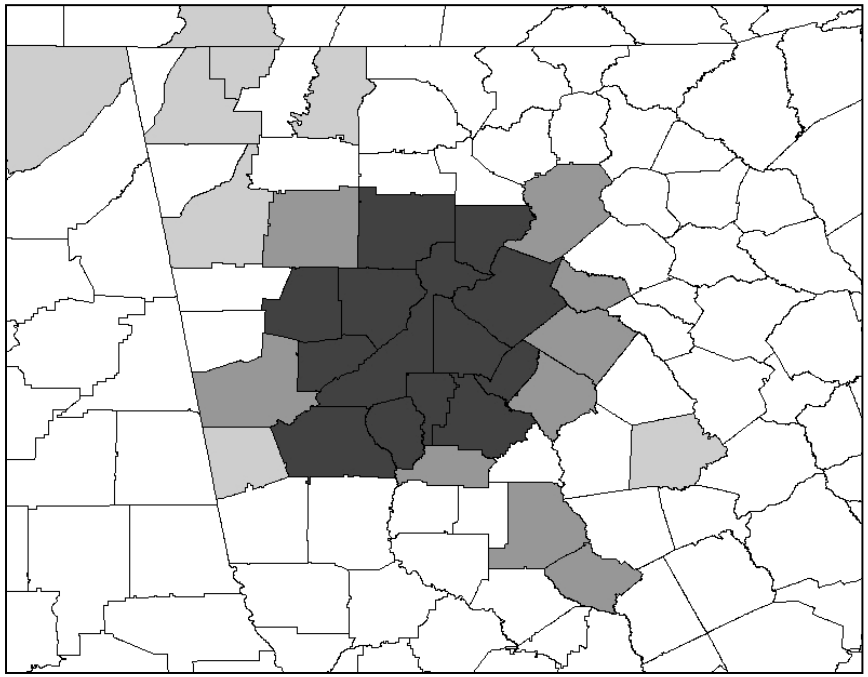
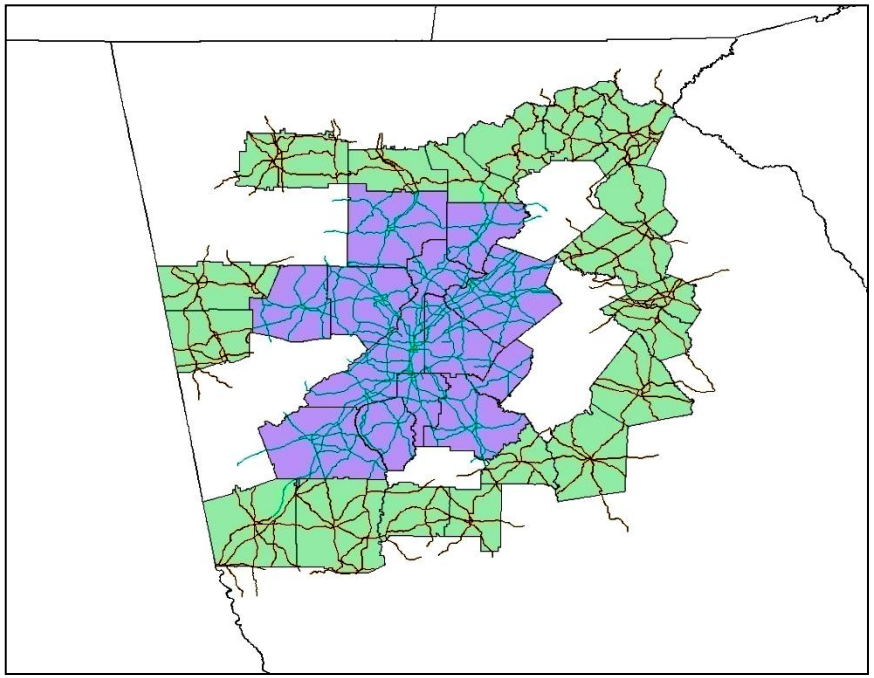
Example: Atlanta, GA



a. Nonattainment status in Atlanta



b. Nonattainment/attainment areas

Difference in Total VMT/Person/Day

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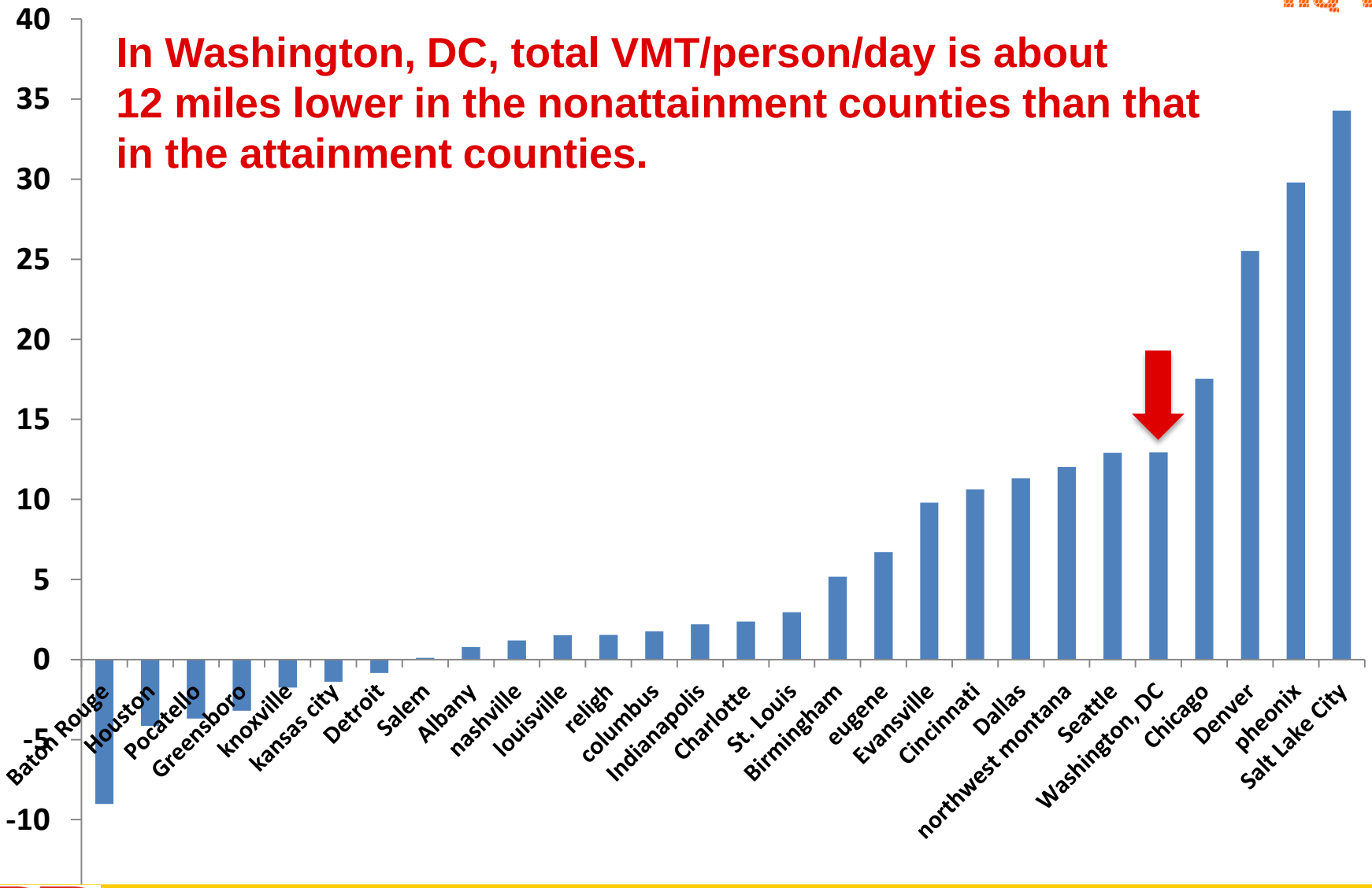

Difference in Total VMT Growth Rate

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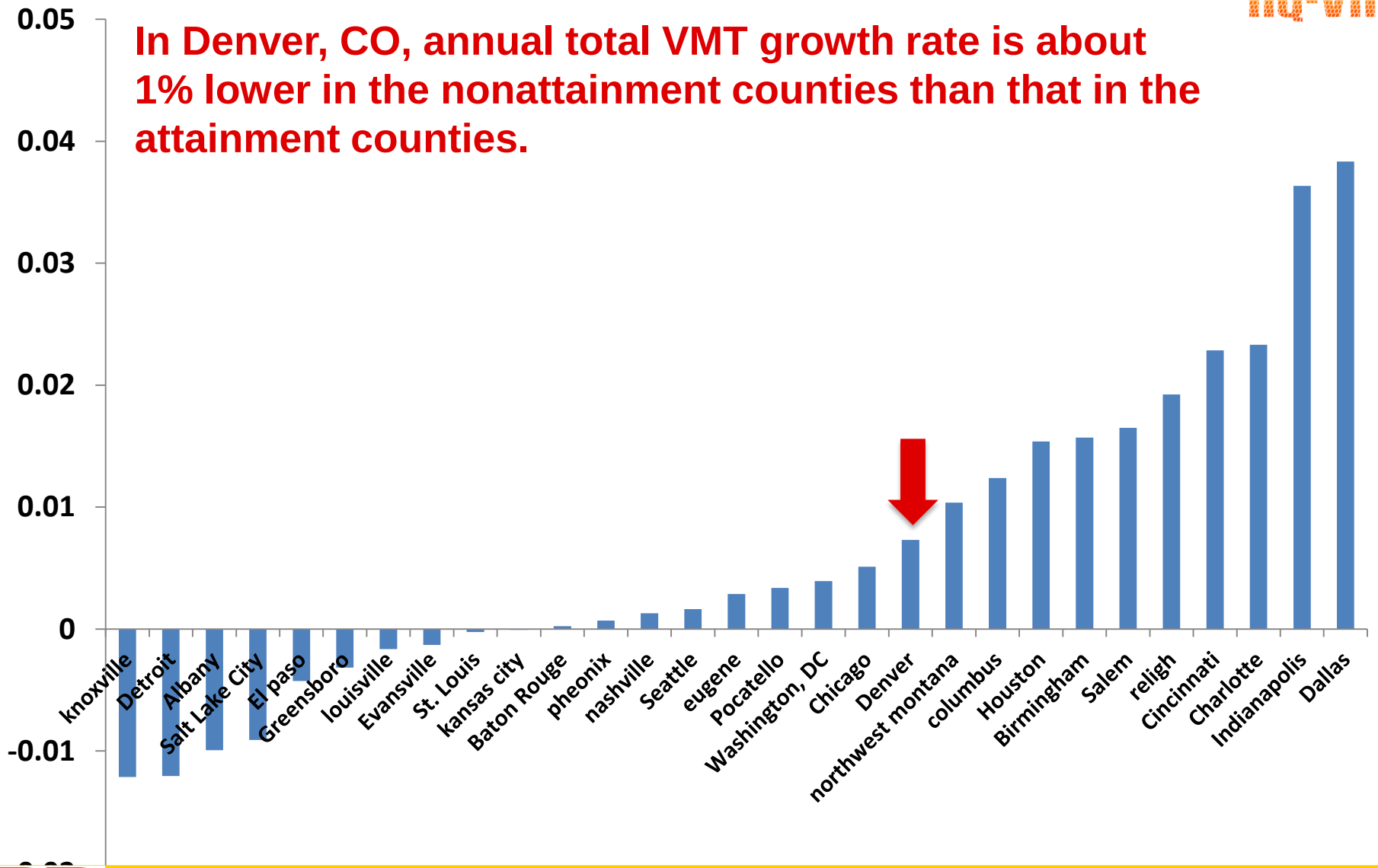

Is the Difference Statistically Significant?

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Yes…

- On average, VMT/person/day is 6.79 miles (~20%) lower in nonattainment counties than that in surrounding attainment counties (97% confidence level).
- Annual VMT growth rate is 0.52% lower (99% confidence)

But…

- The difference in VMT/person and VMT growth rate may also be explained by factors other than nonattainment designation
- Need additional analysis controlling for other confounding factors

Phase 2 Research Question

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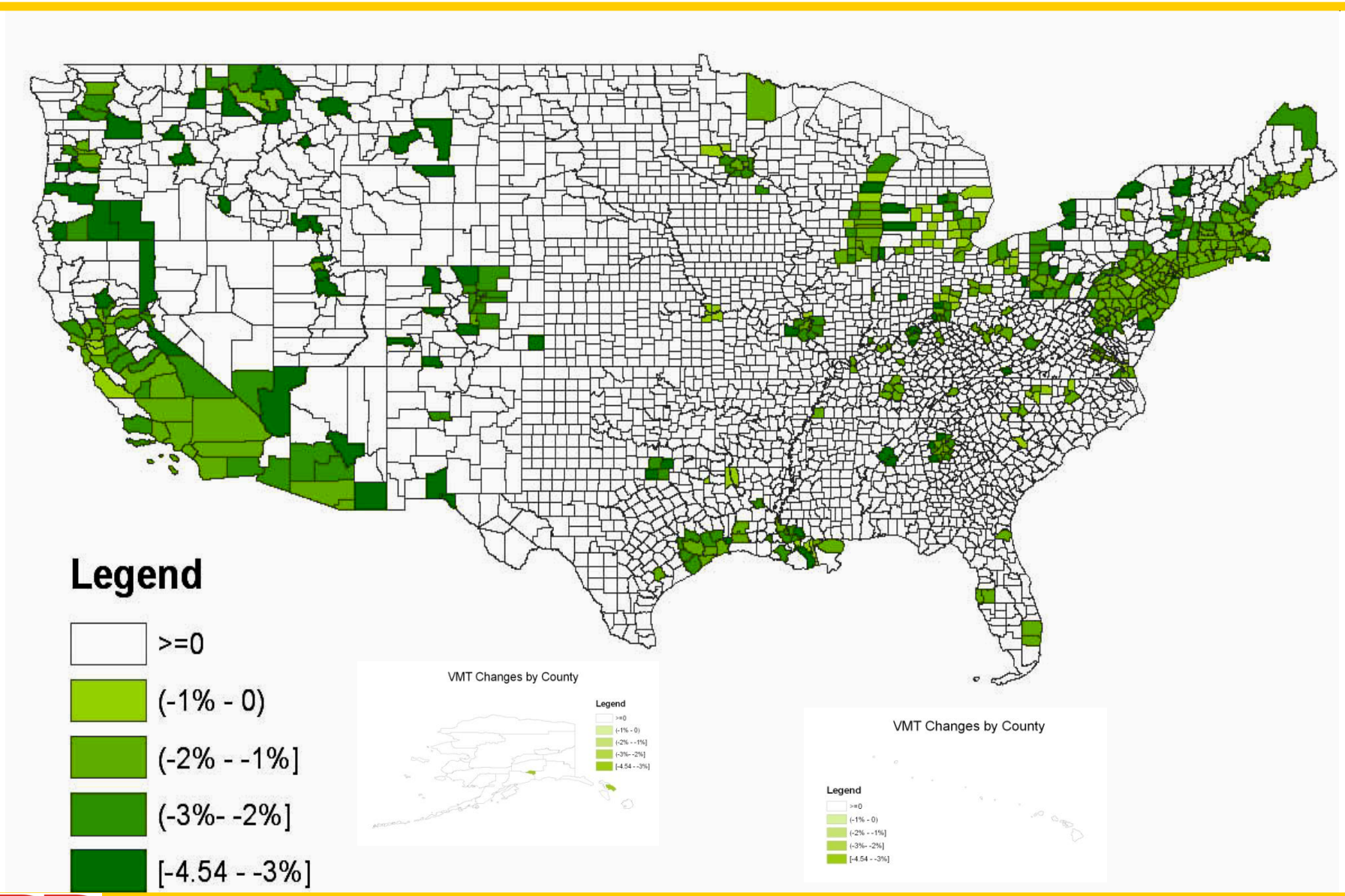
Is there a statistically significant correlation between nonattainment designation and VMT reduction after the other factors have been controlled for?

Controlling for Other Factors

Dependent Variable: VMT	Regression Model 1	Regression Model 2
Nonattainment Status: Own County	-0.0165**	-0.0465***
Nonattainment Status: Adjacent Counties		0.0349*
Large urban area	0.0206*	0.0199*
Small urban area	-0.0313***	-0.0296***
Distance to urban center	-0.0002**	-0.0002**
Population density	-0.0612***	-0.0613***
Number of transit trips taken	-0.1620***	-0.1635***
Adjusted R-Square	0.7113	0.7116
Household socio-economic and demographic variables not shown.		

Nonattainment designation is linked to 1.15%~4.54% reduction in VMT/household with control for other factors.

VMT Reduction Varies by County



Nonattainment and Vehicle Ownership

Dependent Variable: Number of Vehicles Households Choose to Own				
	One Vehicle	Two Vehicle	Three Vehicle	Four+ Vehicle
Variable	Coefficient	Coefficient	Coefficient	Coefficient
Income	0.0031**	0.0048**	0.0052**	0.0054**
Worker Count	0.4314**	1.1623**	1.6643**	2.1180**
Large Urban	-0.2068**	-0.7471**	-1.1362**	-1.5120**
Small Urban	0.1067*	-0.1961**	-0.5461**	-0.8678**
White	0.5404**	0.7970**	0.5025**	0.4121
African American	0.2604	0.0920	-0.3448	-0.9135*
Children/HHSIZE	0.3847**	1.8204**	1.6741**	1.3740**
MALE	0.3258**	0.8109**	0.7398**	0.8417**
Age <35	0.2271**	0.6236**	0.3261**	0.4975*
Age 36~54	0.1722**	0.2147**	0.4368**	0.4875**
Home ownership	1.6165**	2.8679**	3.3428**	3.9284**
Nonattainment	**-0.2426****	**-0.6977****	**-0.9351****	**-0.7516****

Households living in nonattainment areas tend to own fewer vehicles.

Nonattainment and Vehicle Type Choice

	Small Car	Large Car	Small SUV	Large SUV	Small Truck	Large Truck
Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Price*Income	.26E-06**					
Price	-0.0015**					
Fuel Cost	-3.9173**					
Price*Fuel Cost	0.0002**					
Safety	1.1609**					
Inter. Room*HHSize	0.0129**					
Engine Size	0.0227					
Male	-0.0554	-0.0262	-0.3019**	0.2280**	1.6328**	1.4092**
Income	0.0015**	.65E-04	0.0013**	-0.0018**	.21D-04	-0.0024**
Large Urban	0.3133**	0.2202**	0.1869	-0.1175	-0.6555**	-0.6272**
Small Urban	0.0430	0.0571	0.0084	-0.2272*	-0.5907**	-0.3861**
Nonattainment	0.6600**	-0.0352	0.1768	-0.1872	0.1352	0.3136

Households living in nonattainment areas favor small cars more.

Phase 2 Findings

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There is a statistically significant correlation between nonattainment designation and VMT reduction after other factors have been controlled for.

- 1.15%~4.52% (average 1.64%) reduction in VMT
- Annual VMT growth rate is 0.52% lower (99% confidence)

How about causality?

- Can we claim that nonattainment designation and the associated planning efforts and policies are the causes of the VMT reduction?
- Need additional analysis testing causal effects

Phase 3 Research Question

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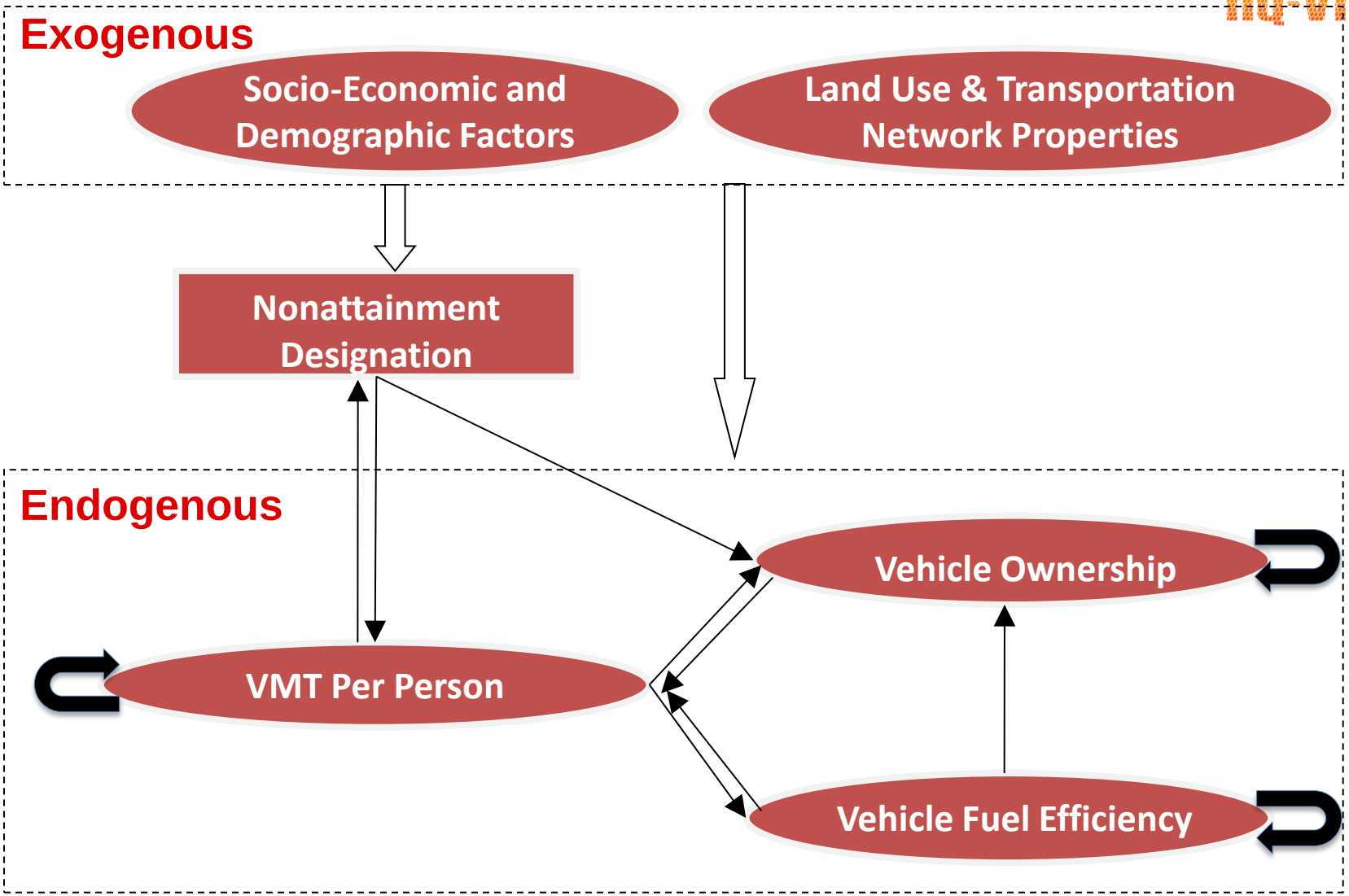
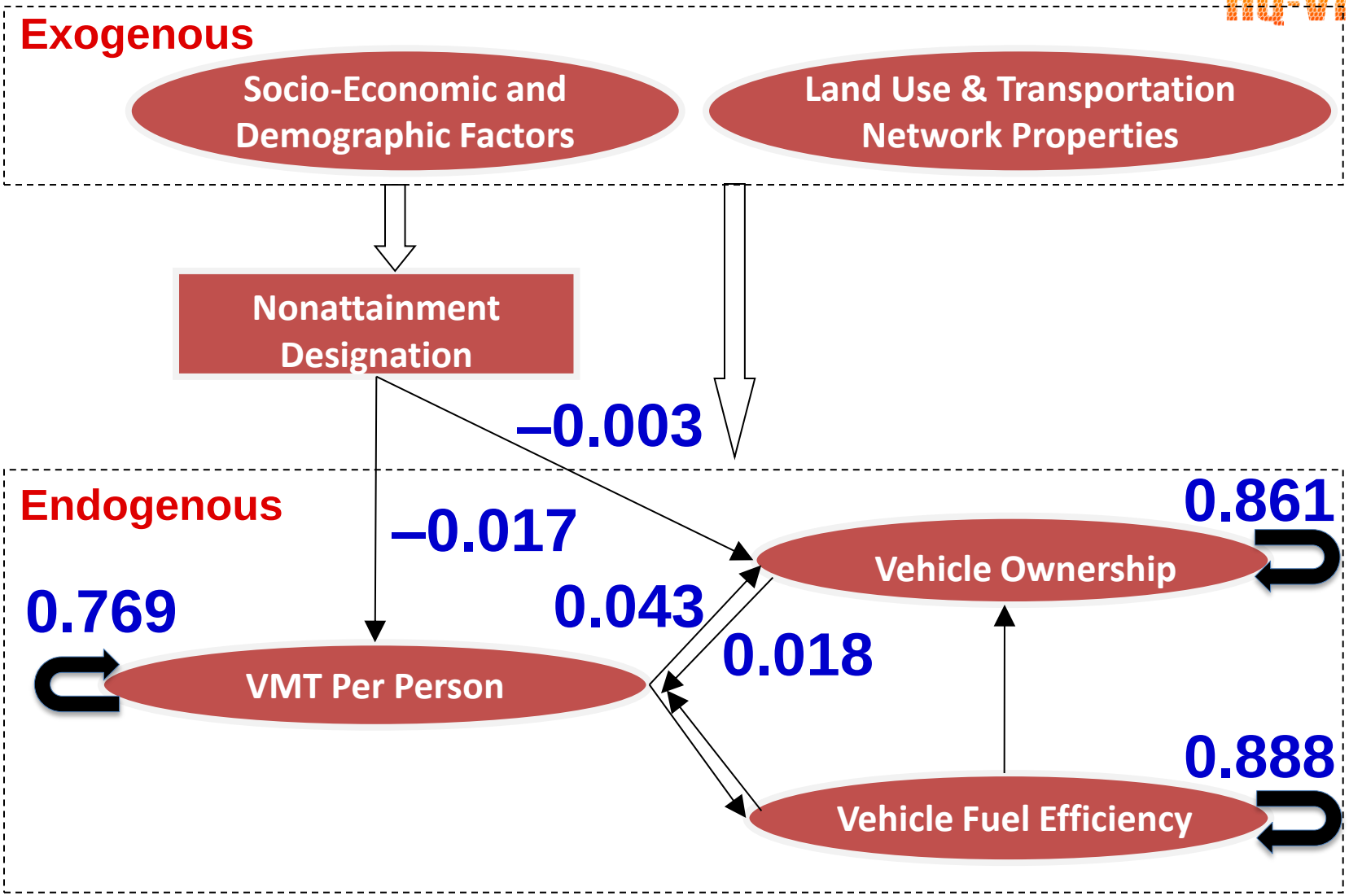
Is VMT reduction in nonattainment areas caused by air quality control policies and programs?

Hypothesized Causal Relationships



Structural Equation Model Results



SEM Model Results

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Short-Run Impact of Nonattainment Designation

- 1.67% reduction in VMT
- 0.32% reduction in vehicle ownership

Long-Run Impact of Nonattainment Designation

- 7.27% reduction in VMT
- 4.05% reduction in vehicle ownership
- Actual long-run impact will be smaller because an area may not be designated as nonattainment forever

Conclusions

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In Air Quality Nonattainment Areas, We Found…

- 0.5~2.8% lower annual total VMT growth rate
- 1.2~4.5% lower short-run total VMT/person
- Up to 7.3% lower long-run total VMT/person
- Larger reduction in passenger VMT than truck VMT

VMT Reduction Caused by Air Quality Control?

- Results are obtained after we control for various confounding factors
- Hypothesized causal structure cannot be rejected
- While causality has not been proven, it is probable

Practical Significance of the Findings

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Nonattainment Designation is Linked to:

- 5.6~15.8 billion miles reduced total VMT annually
- 250~721 million gallons of reduced fuel consumption and the associated reduction in pollution and GHG emissions
- Annual non-emission cost savings at $2.8~7.4 billion

The estimated VMT reduction in nonattainment areas is about equivalent to the VMT reduction caused by a 25% increase in fuel price.

Policy Implications

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Strong Statistical Evidence that Air Quality Control and VMT Reduction/Slower VMT Growth Are Correlated.

Still Premature to Make Concrete Policy Recommendations based on These Findings Alone.

Need Further Analyses that…

- **Either establish stronger causality evidence or reject causality altogether**
- **Attribute VMT reduction in nonattainment areas to specific policy instruments, e.g. air quality conformity rule, CMAQ, and other federal/state/local planning efforts**

Future Research

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- In-depth case studies in selected nonattainment areas
- More sophisticated statistical models that can separate the effects of individual policy instruments in nonattainment areas
- Decision support tool for air quality control policy design and evaluation

Thank You!

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Questions, Comments, and Suggestions are Welcome.

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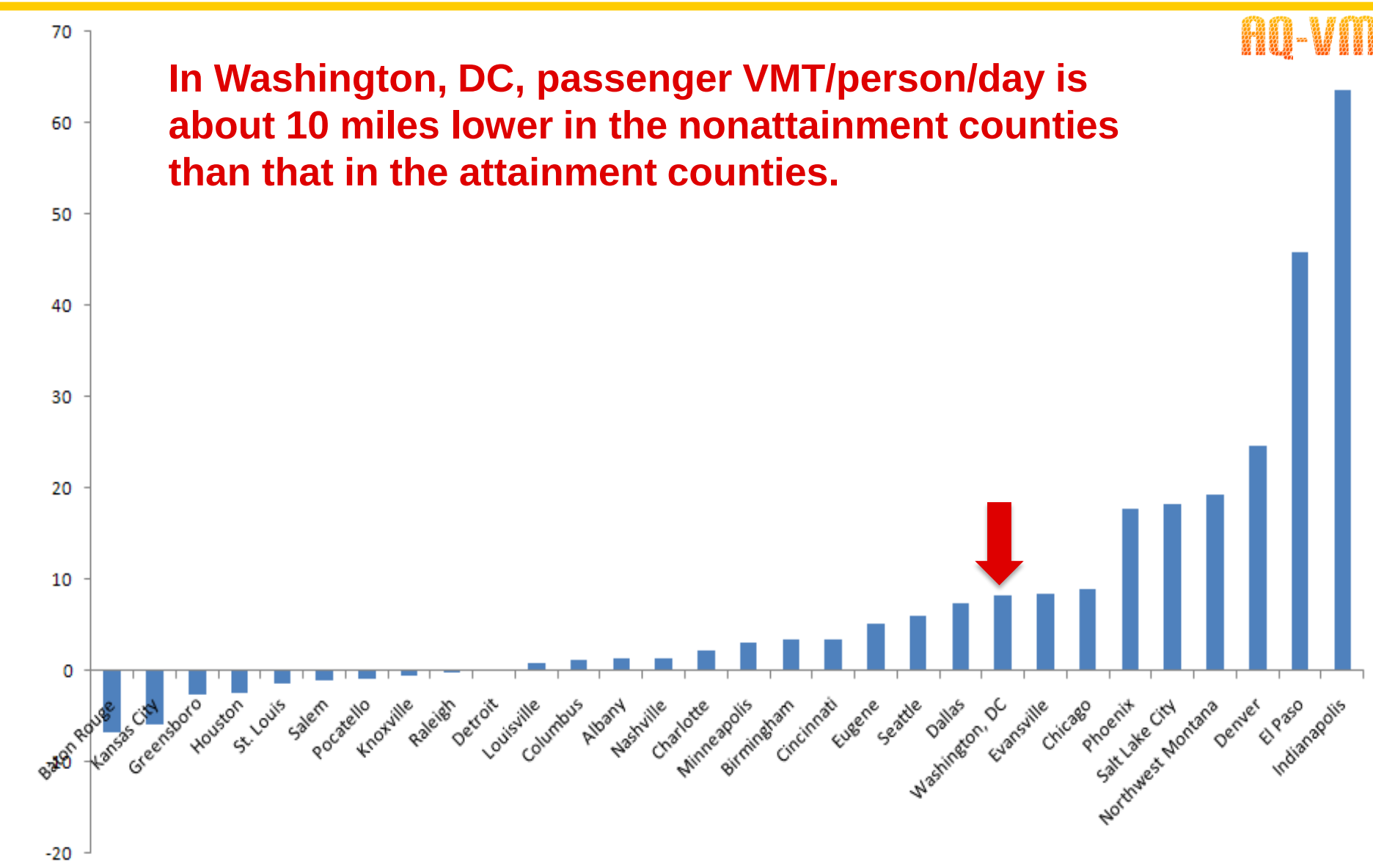
Additional Slides for Q&A

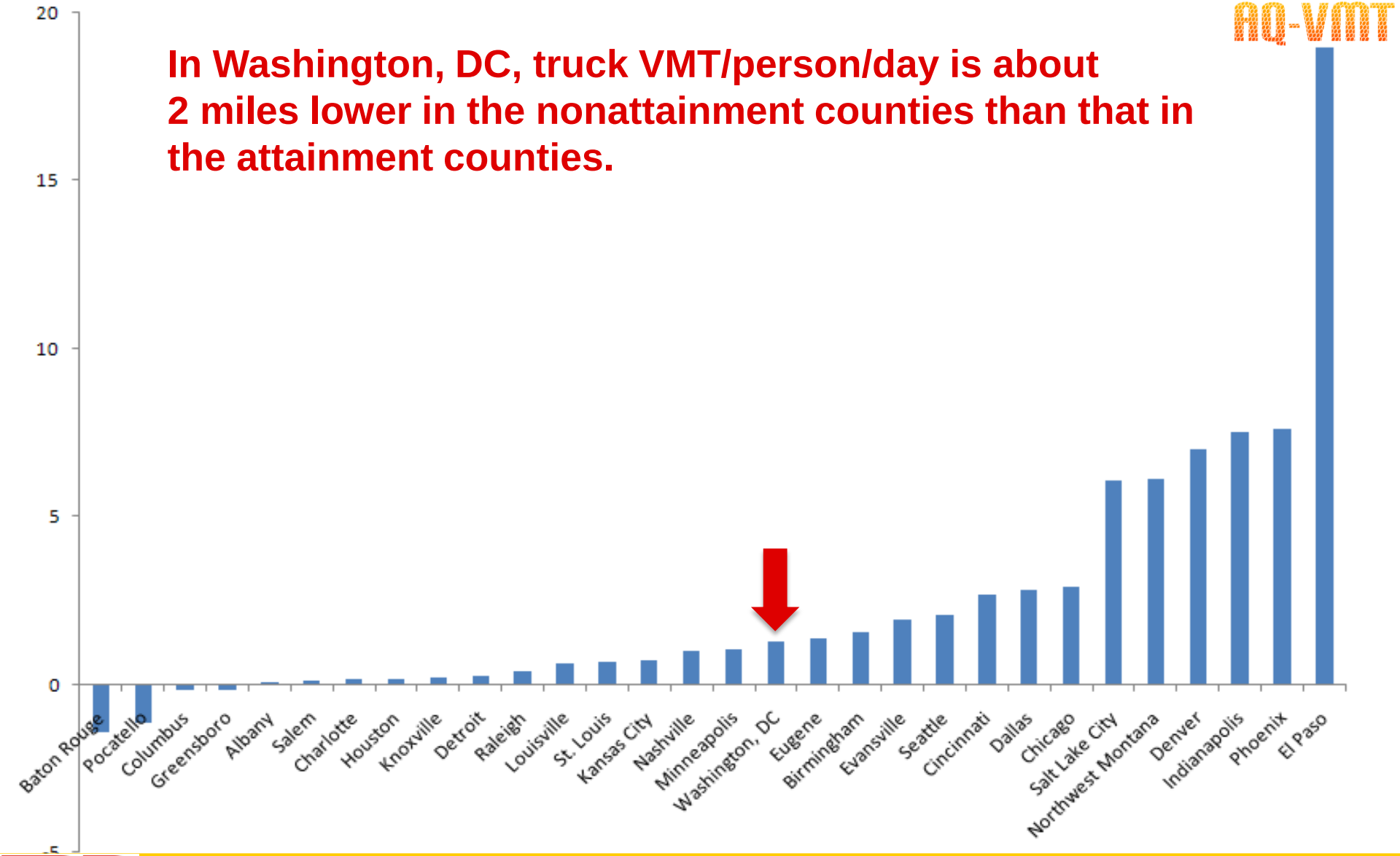
AQ-VMT

- Difference in Passenger VMT/Person/Day
- Difference in Truck VMT/Person/Day
- T-Test Results based on 1993-2007 Data
- Sensitivity Analysis: Time Period Effect
- Structural Equation Model Details
- SEM Model Result: VMT
- SEM Model Result: Vehicle Ownership
- SEM Model Result: Fuel Efficiency

Difference in Passenger VMT/Person/Day



Difference in Truck VMT/Person/Day



T-Test Results based on 1993-2007 Data

T-Test Type	Passenger VMT/Person	Truck VMT/Person	Total VMT/Person
Spatial T-test	0.01 (7.62)	0.00 (2.41)	0.00 (10.03)
	Passenger VMT/person Growth Rate	Truck VMT/person Growth Rate	Total VMT/person Growth Rate
Spatial T-test	0.12 (0.01)	0.02 (0.03)	0.12 (0.01)

Table Note: Smaller values suggest the differences in VMT measurements are statistically more significant between nonattainment and attainment areas. Values in parentheses show how much lower the VMT measurements are in nonattainment areas.

Sensitivity Analysis: Time Period Effect

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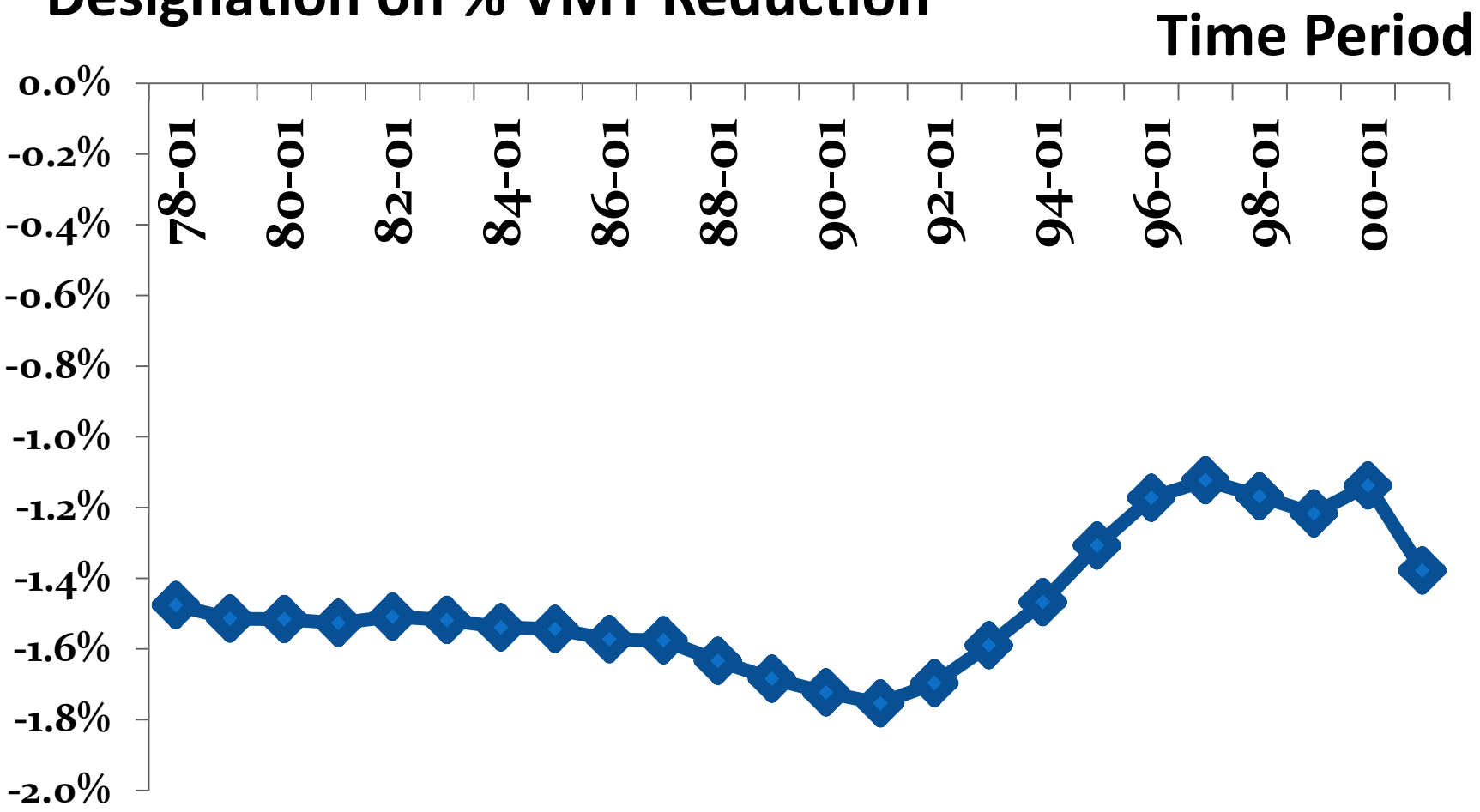
Estimated Impact of Nonattainment Designation on % VMT Reduction



Structural Equation Model Details

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Specification

$$vma = \alpha^{v} * vma(t-1) + \alpha^{sv} * vehstock + \alpha^{fv} * (fuelcost/mile) + \beta^{v} * X^{v} + u_t^{v}$$

$$vehstock = \alpha^{s} * vehstock(t-1) + \alpha^{vs} * vmt + \alpha^{fs} * (fuelcost/mile) + \beta^{s} * X^{s} + u_t^{s}$$

$$fint = \alpha^{f} * fint(t-1) + \alpha^{fv} * vma + \alpha^{fp} * (fuelprice) + \beta^{f} * X^{f} + u_t^{f}$$

With autoregressive errors:

$$u_t^k = \rho^k u_{t-1}^k + \varepsilon^k, \quad k = v, s, f$$

Estimation

- **3-stage least square**
- **Longitudinal panel dataset based on HPMS and other national data sources between 1966 and 2004**

SEM Model Result: VMT

Dependent Variable: vmt	Coefficient	t	P>|t|	Description
vmt(t-1)	0.7691**	57.19	0	Vehicle miles traveled per adult
vehstock	0.0180*	1.91	0.057	Vehicle ownership per adult
fuelcost/mile	-0.0630**	-14.74	0	Fuel cost per mile at 1987 prices
(fuelcost/mile)^2	-0.0240**	-3.37	0.001	
*(fuelcost/mile)*income*	0.0694**	5.07	0	
income	0.0913**	7.34	0	Personal income per capita at 1987 prices
adults/road-mile	-0.0215**	-4.28	0	
urban	-0.1818**	-3.53	0	Fraction of population living in urban areas
%race_black	0.1838**	2.63	0.009	
%pop_19	0.2246**	2.22	0.026	
%pop_2034	0.3626**	2.75	0.006	
%pop_3564	0.4573**	3.14	0.002	
Nonattainment	-0.0167**	-4.03	0	Combined variable representing the nonattainment status of 1 hour ozone, CO and PM-10 (Fraction of population living in nonattainment areas)
constant	1.9171**	11.18	0	
rho	0.0084	0.33	0.741	Coefficient of error autocorrelation
No. of Observations	1887			
R-squared	0.9815			
Adjusted R-squared	0.9809			

SEM Model Result: Vehicle Ownership

Dependent Variable: vehstock	Coefficient	t	P>|t|	Description
vehstock(t-1)	0.8611**	58.44	0	Vehicle miles traveled per adult
vmt	0.0429**	3.10	0.002	Vehicle miles traveled per adult
pv	-0.0421	-1.33	0.182	Price of new vehicles (index)
fuel price	-0.0151**	-2.03	0.043	Fuel price at 1987 dollars
urban	-0.0954	-1.47	0.141	Fraction of population living in urban areas
adults/road-mile	-0.0229**	-3.30	0.001	
licenses/adult	0.05371**	3.26	0.001	
Trend	-0.0018**	-2.67	0.008	Used to capture changes in technology and consumer preferences
employment/capita	0.0732**	2.72	0.007	
%race_black	0.1727*	1.85	0.064	
%race_hispanic	0.2617**	2.54	0.011	
Nonattainment	**-0.0025**	**-0.55**	**0.584**	Combined variable representing the nonattainment status of 1 hour ozone, CO and PM-10 (Fraction of population living in nonattainment counties)
constant	-0.2854**	-2.05	0.041	
rho	-0.1169**	-4.43	0	Coefficient of error autocorrelation
No. of Observations	1887			
R-squared	0.9590			
Adjusted R-squared	0.9576			

SEM Model Result: Fuel Efficiency

Dependent Variable: fint	Coefficient	t	P>|t|	Description
fint(t-1)	0.8881**	69.29	0	Fuel intensity (Reciprocal of Fuel Efficiency)
vmt+fuel price	-0.0209**	-3.57	0	Vehicle miles traveled per adult; fuel cost per gallon at 1987 prices
cafe	-0.0738**	-6.71	0	Variable measuring strength of CAFÉ regulation
employment/capita	-0.0767**	-3.53	0	
D7479	-0.0350**	-8.52	0	Dummy variable for the years 1974 and 1979
Trend66-73	0.0009	0.94	0.349	Trend before the OPEC embargo in 1973
Trend74-79	-0.0021**	-2.56	0.011	Trend between the embargo and the Iranian revolution in 1979
Trend80+	-0.0013**	-4.15	0	Trend after the Iranian revolution
constant	-0.1610**	-2.41	0.016	
rho	-0.1318**	-5.40	0	Coefficient of error autocorrelation
No. of Observations	1887			
R-squared	0.9606			
Adjusted R-squared	0.9593			