

# **Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles certified to Tier-2 Standards**

## **Analysis of Data from EPA Phase 3**

**(EPAct/V2/E-89)**

### **Appendix I.3d**

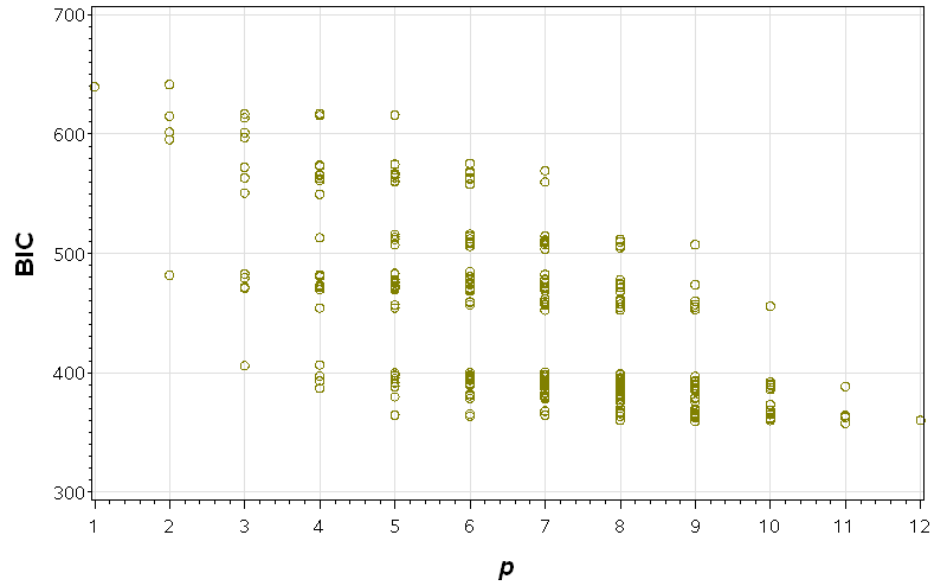
#### **Final Model Fitting**

#### **Non-Methane Hydrocarbons (NMHC) (Bag 1)**

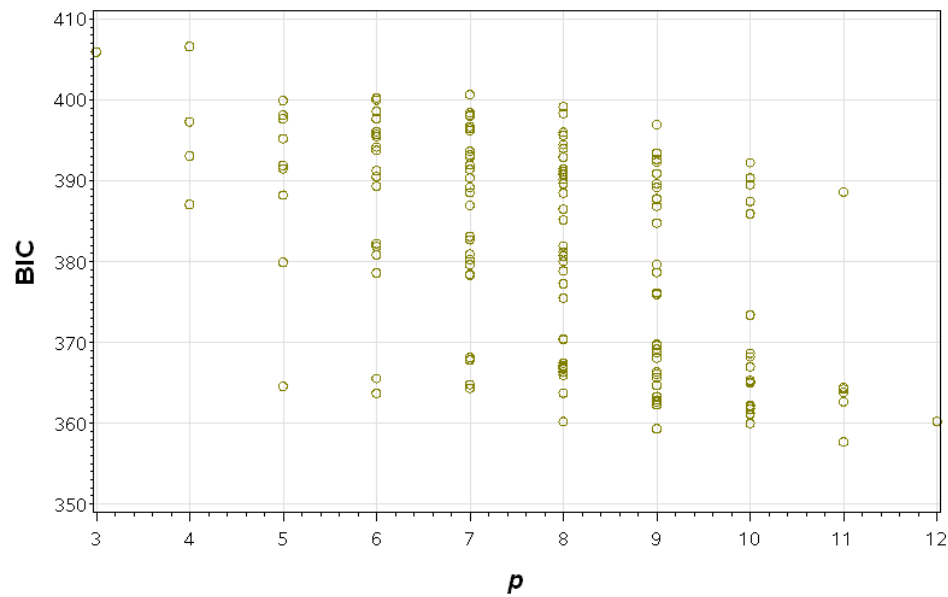
No. Observations:	956
No. Vehicles:	15
No. censored measurements:	0
No. missing measurements:	0
No. measurements removed:	0
Model Type:	Mixed model

### I.3d.1 Model fitting with respect to the 11-term design model.

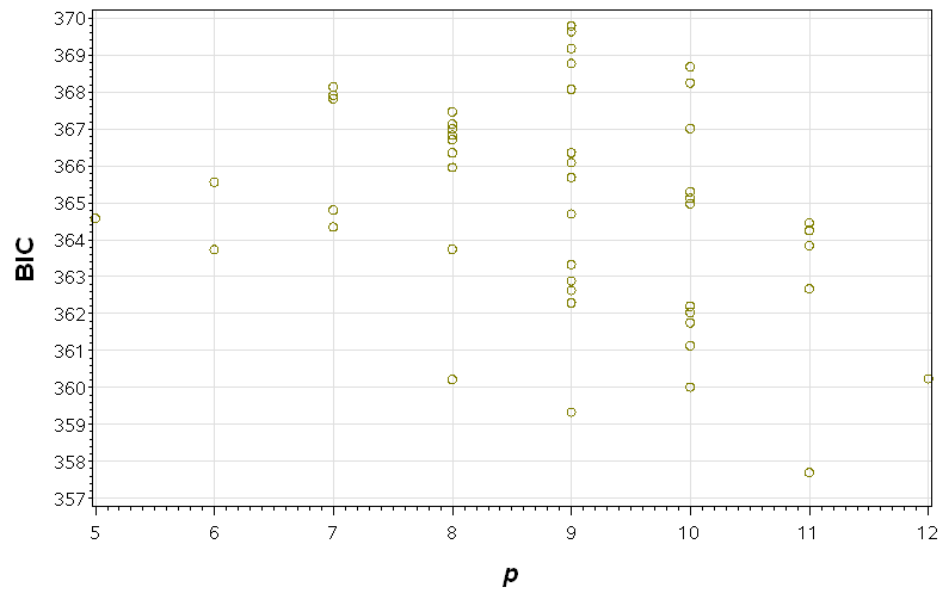
**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**Design Model (11-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy (CLOSEUP of previous figure).**



**NMHC (Bag 1):** Number of terms (*p*), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 294 possible models with hierarchy). (Terms included in models ranked 1-5 comprise the “superset” for final model-fitting).

Rank	<i>p</i>	BIC	Design Terms										
			etOH	Arom	RVP	T50	T90	etOH x etOH	T50 x T50	etOH x Arom	etOH x RVP	etOH x T50	etOH x T90
1	11	357.702	•	•	•	•	•	•	•		•	•	
2	9	359.339	•	•	•	•	•		•	•			
3	10	360.017	•	•	•	•	•	•			•	•	
4	8	360.223	•	•	•	•	•		•			•	
5	12	360.243	•	•	•	•	•	•	•	•	•	•	
6	10	361.141	•	•	•	•	•	•	•				
7		361.761	•	•	•	•	•		•	•		•	
8	10	362.04	•	•	•	•	•		•	•	•		
9	10	362.209	•	•	•	•	•	•	•		•		
10	9	362.298	•	•	•	•	•	•				•	
11	9	362.635	•	•	•	•	•		•		•	•	
12	11	362.678	•	•	•	•	•	•		•	•	•	
13	9	362.892	•	•	•	•	•		•			•	
14	9	363.339	•	•	•	•		•	•	•		•	
15	6	363.737		•	•	•	•		•				
16	8	363.753	•	•	•	•	•		•	•			
17	11	363.849	•	•	•	•	•	•	•	•		•	
18	11	364.257	•	•	•	•	•	•	•	•	•		
19	7	364.352	•	•	•	•			•	•			
20	11	364.464	•	•	•	•	•		•	•	•	•	
21	5	364.584		•	•	•			•				
22	9	364.705	•	•	•	•	•	•			•		
23	7	364.811	•	•	•	•	•		•				
24	10	364.985	•	•	•	•	•	•		•		•	
25	10	365.131	•	•	•	•		•	•	•	•		
26	10	365.31	•	•	•	•	•		•		•	•	
27	6	365.57	•	•	•	•			•				
28	9	365.696	•	•	•	•	•	•	•				
29	8	365.966	•	•	•	•		•	•		•		
30	9	366.096	•	•	•	•	•		•	•		•	
31	8	366.36	•	•	•	•		•	•	•			
32	9	366.361	•	•	•	•	•		•	•	•		
33	8	366.716	•	•	•	•			•	•		•	
34	8	366.841	•	•	•	•			•	•	•		
35	8	367.009	•	•	•	•	•	•	•				

**Models fit for NMHC (Bag 1): (all models include an intercept term).**

Model Term	Notation	Model	
		Superset	SM1 <sup>1</sup>
etOH	$Z_e$	•	•
Arom	$Z_a$	•	•
RVP	$Z_r$	•	•
T50	$Z_5$	•	•
T90	$Z_9$	•	•
etOH $\times$ etOH	$ZZ_{ee}$	•	•
T50 $\times$ T50	$ZZ_{55}$	•	•
etOH $\times$ Arom	$ZZ_{ea}$	•	•
etOH $\times$ RVP	$ZZ_{er}$	•	$\times$
etOH $\times$ T50	$ZZ_{e5}$	•	•
etOH $\times$ T90	$ZZ_{e9}$	•	•
<sup>1</sup> denotes “Superset minus 1.”			

**NMHC (Bag 1): Model fitting history, starting with the 10-term superset model.**

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	$p$	$-2\ln L$	BIC <sup>1</sup>	Dev.	$d$	$\Pr > \chi^2$
Superset	12	322.331	360.243			
SM2 <sup>2</sup>	11	322.497	357.702	0.167	1	0.683
<sup>1</sup> A lower value indicates a better fit.						
<sup>2</sup> Best fit with respect to the 11-term design model.						

**NMHC (Bag 1): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 11-term design model.**

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
Intercept	-1.0314	0.09233	15	-11.2	0.00000
$Z_e$	0.03153	0.01341	941	2.35	0.019
$Z_a$	0.09476	0.00935	941	10.1	0.00000
$Z_r$	-0.04514	0.01068	941	-4.23	0.000026
$Z_5$	0.1376	0.01347	941	10.22	0.00000
$Z_9$	0.02123	0.00935	941	2.27	0.023
$ZZ_{ee}$	0.04746	0.01800	941	2.64	0.0085
$ZZ_{55}$	0.07579	0.01348	941	5.62	0.00000
$ZZ_{ea}$	0.02076	0.00914	941	2.27	0.023
$ZZ_{er}$	0.00381	0.00933	941	0.408	0.68
$ZZ_{e5}$	0.04862	0.01932	941	2.52	0.012
$ZZ_{e9}$	0.02384	0.00918	941	2.60	0.0095

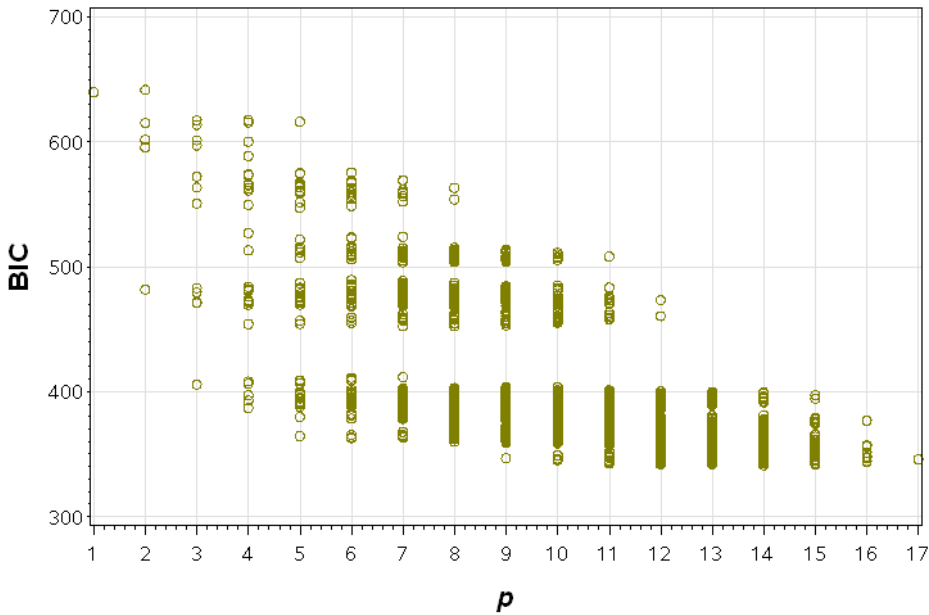
$\sigma_{veh}^2$	0.1267
$\sigma_{\varepsilon}^2$	0.07623

<i>Reduced Model (SM1)</i>				
Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
-1.0315	0.09231	15	-11.2	0.00000
0.03094	0.01333	941	2.32	0.02054
0.09461	0.00934	941	10.1	0.00000
-0.04568	0.01059	941	-4.31	0.000018
0.13689	0.01336	941	10.25	0.00000
0.02160	0.00931	941	2.32	0.021
0.04612	0.01770	941	2.61	0.0093
0.07534	0.01343	941	5.61	0.00000
0.02045	0.00911	941	2.24	0.025
0.04729	0.01904	941	2.48	0.013
0.02441	0.00907	941	2.69	0.0072

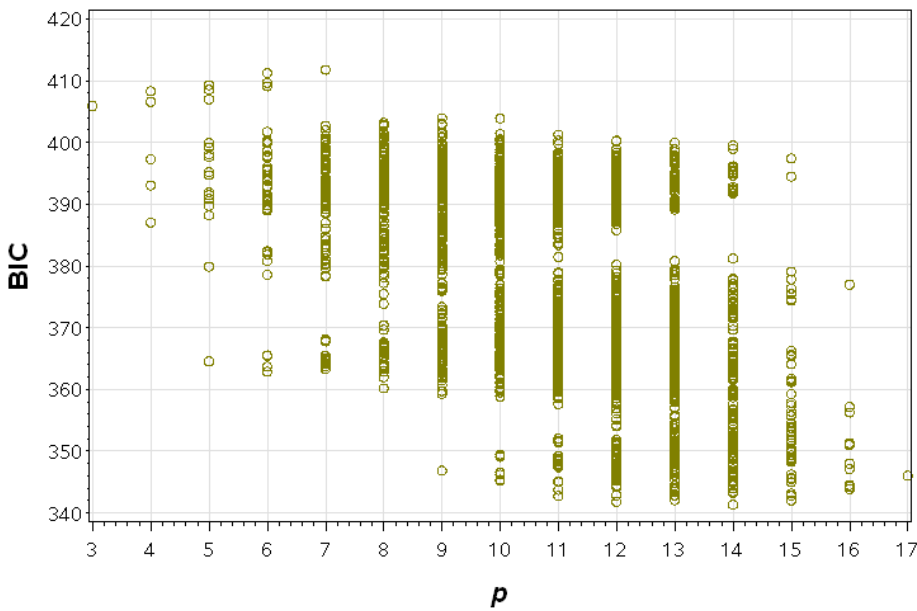
$\sigma_{veh}^2$	0.1266
$\sigma_{\varepsilon}^2$	0.07624

### I.3d.2 Model Fitting with respect to the 16-term extended Model.

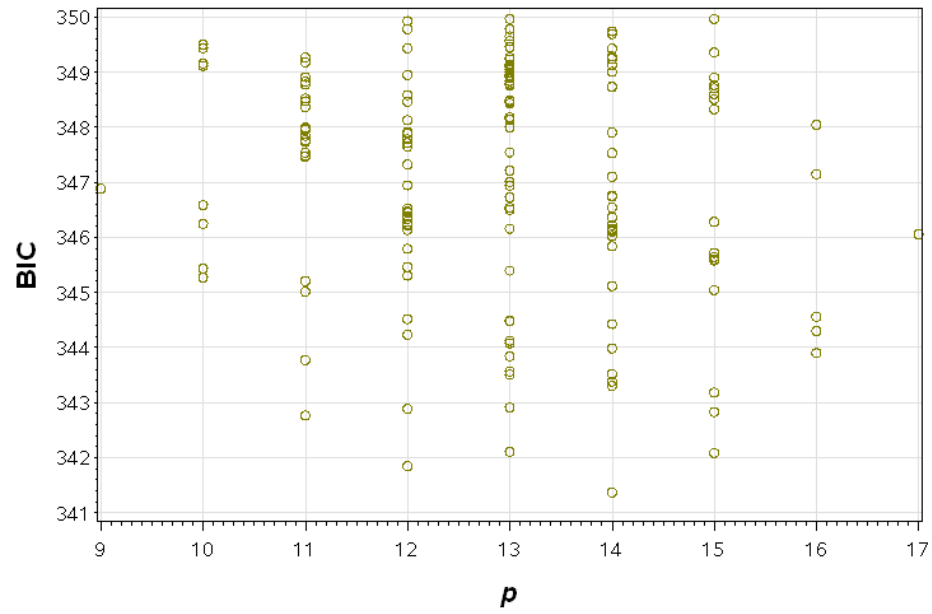
Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for all possible models respecting hierarchy.



Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).



**Extended Model (16-terms): Bayesian Information Criterion (BIC) vs. number of terms in model ( $p$ ) for subset of models respecting hierarchy (CLOSEUP of previous figure).**



**NMHC (Bag 1):** Number of terms (*p*), Goodness-of-fit (BIC) and terms included in the 35 best-fitting candidate models (out of a total of 2,964 possible models with hierarchy). (Terms included in models ranked 1-8 comprise the “superset” for final model-fitting).

Rank	<i>p</i>	BIC	Design Terms										Extended Terms				
			etOH	Arom	RVP	T50	T90	etOH x etOH	T50 x T50	etOH x Arom	etOH x RVP	etOH x T50	etOH x T90	Arom x RVP	Arom x T50	Arom x T90	T50 x T90
1	14	341.37	•	•	•	•	•	•	•		•	•	•		•	•	
2	12	341.85	•	•	•	•	•		•	•		•	•	•		•	
3	15	342.09	•	•	•	•	•	•	•		•	•	•	•	•	•	
4	13	342.11	•	•	•	•	•	•	•				•	•		•	
5	11	342.77	•	•	•	•	•		•	•					•	•	
6	15	342.83	•	•	•	•	•	•	•	•	•	•	•		•	•	
7	12	342.89	•	•	•	•	•	•	•						•	•	
8	13	342.92	•	•	•	•	•	•	•		•	•	•		•	•	
9	15	343.19	•	•	•	•	•	•	•			•	•			•	•
10	14	343.31	•	•	•	•	•	•	•				•	•	•	•	
11	14	343.39	•	•	•	•	•	•	•		•	•	•	•	•	•	
12	13	343.51	•	•	•	•	•		•	•				•	•	•	
13	14	343.52	•	•	•	•	•	•	•	•	•	•	•		•	•	
14	13	343.57	•	•	•	•	•	•	•		•	•	•			•	•
15	11	343.78	•	•	•	•	•		•	•				•	•	•	
16	13	343.85	•	•	•	•	•	•	•	•				•	•	•	
17	16	343.90	•	•	•	•	•	•	•			•	•	•	•	•	•
18	14	343.99	•	•	•	•	•	•	•	•	•				•	•	
19	13	344.08	•	•	•	•	•	•	•	•					•	•	
20	13	344.13	•	•	•	•	•		•	•	•			•	•	•	
21	12	344.24	•	•	•	•	•		•	•				•	•	•	
22	16	344.30	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
23	14	344.43	•	•	•	•	•	•	•	•				•	•	•	•
24	13	344.48	•	•	•	•	•		•	•				•	•	•	•
25	13	344.49	•	•	•	•	•		•	•		•	•	•	•	•	
26	12	344.52	•	•	•	•	•		•	•	•			•	•	•	
27	16	344.57	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
28	11	345.02	•	•	•	•	•		•					•	•	•	
29	15	345.05	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
30	14	345.12	•	•	•	•	•	•	•	•		•	•		•	•	•
31	11	345.21	•	•	•	•	•		•					•	•	•	
32	10	345.28	•	•	•	•	•		•						•	•	
33	12	345.31	•	•	•	•	•		•	•		•	•		•	•	
34	13	345.40	•	•	•	•	•	•	•					•	•	•	•
35	10	345.44	•	•	•	•	•		•	•					•	•	

**Models fit for NMHC (Bag 1): (all models include an intercept term).**

Model Term	Notation	Model	
		Superset	SM2 <sup>1</sup>
etOH	$Z_e$	•	•
Arom	$Z_a$	•	•
RVP	$Z_r$	•	•
T50	$Z_5$	•	•
T90	$Z_9$	•	•
etOH $\times$ etOH	$ZZ_{ee}$	•	•
T50 $\times$ T50	$ZZ_{55}$	•	•
etOH $\times$ Arom	$ZZ_{ea}$	•	•
etOH $\times$ RVP	$ZZ_{er}$	•	$\times$
etOH $\times$ T50	$ZZ_{e5}$	•	•
etOH $\times$ T90	$ZZ_{e9}$	•	•

Arom $\times$ RVP	$ZZ_{ar}$	•	•
Arom $\times$ T50	$ZZ_{a5}$	•	$\times$
Arom $\times$ T90	$ZZ_{a9}$	•	•
T50 $\times$ T90	$ZZ_{59}$	•	•
RVP $\times$ T90	$ZZ_{r9}$	---	---

<sup>1</sup> Represents “Superset minus 2,” etc.

**NMHC (Bag 1): Model fitting history, starting with the 9-term superset model.**

Fit Parameters				<i>Test with respect to Previous Model</i>		
Model	$p$	$-2\ln L$	BIC <sup>1</sup>	Dev.	$d$	$\text{Pr}>\chi^2$
Superset	16	295.558	344.303			
SM2 <sup>2</sup>	14	298.043	341.372	2.485	2	0.289

<sup>1</sup> A lower value indicates a better fit.

<sup>2</sup> Best fit with respect to the 16-term extended model.

**NMHC (Bag 1): Coefficients and Tests of Effect for the Superset and Reduced Models, with respect to the 16-term extended model.**

Effect	<i>Full Model (superset)</i>				
	Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
Intercept	-1.0304	0.09200	15	-11.2	0.00000
$Z_e$	0.05238	0.01514	941	3.46	0.00057
$Z_a$	0.1125	0.00998	941	11.3	0.00000
$Z_r$	-0.03708	0.01333	941	-2.78	0.0055
$Z_5$	0.1683	0.01710	941	9.84	0.00000
$Z_9$	0.01811	0.01032	941	1.76	0.079
$ZZ_{ee}$	0.04814	0.01801	941	2.67	0.0076
$ZZ_{55}$	0.08384	0.01428	941	5.87	0.00000
$ZZ_{ea}$	0.04042	0.01492	941	2.71	0.0069
$ZZ_{er}$	0.00718	0.01020	941	0.703	0.48
$ZZ_{e5}$	0.03943	0.01938	941	2.03	0.042
$ZZ_{e9}$	0.04967	0.01110	941	4.47	0.00001
$ZZ_{ar}$	0.04215	0.01599	941	2.64	0.00854
$ZZ_{a5}$	0.02025	0.01818	941	1.11	0.26569
$ZZ_{a9}$	0.01889	0.01016	941	1.86	0.06315
$ZZ_{59}$	0.05480	0.01223	941	4.48	0.00001
$ZZ_{r9}$	---	---	---	---	---
$\sigma_{veh}^2$	0.1258				
$\sigma_{\varepsilon}^2$	0.07410				

<i>Reduced Model (SM2)</i>				
Estimate	Std. Err.	d.f.	<i>t</i> -value	Pr> <i>t</i>
-1.0308	0.09197	15	-11.2	0.00000
0.04439	0.01415	941	3.14	0.0018
0.11119	0.00994	941	11.2	0.00000
-0.04765	0.01070	941	-4.45	0.000010
0.15733	0.01524	941	10.3	0.00000
0.01682	0.00967	941	1.74	0.082
0.04274	0.01768	941	2.42	0.016
0.07769	0.01369	941	5.68	0.00000
0.02594	0.00924	941	2.81	0.0051
0.03579	0.01926	941	1.86	0.063
0.05125	0.01105	941	4.64	0.00000
0.02820	0.01272	941	2.22	0.027
0.02068	0.01002	941	2.06	0.039
0.05225	0.01209	941	4.32	0.00002
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$\sigma_{veh}^2$	0.1257			
$\sigma_{\varepsilon}^2$	0.07430			