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# Freight Deliveries Directly Generated by Residential Units: An Analysis with the 2009 NHTS Data

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## Introduction

### Freight trip studies

- Freight models: vehicle touring models, O-D factor models
- Land use classification codes: NYCZR, LBCS, ITE
- Freight generation (FG) and freight trip generation (FTG) models

### Freight trips generated by residential units

- Traditionally not much studied until increase of online shopping
- Data limitation
- Previous studies are based on small sample data
- A rigorous modeling and analysis of freight trip generated by residential units is needed

## Method

- National Household Travel Survey (NHTS) 2009 data
- Use "deliver" as dependent variable (number of online purchase delivered to home)
- Assume online purchase delivery represents all freight delivery generated by residential units
- The experiment runs for **8 scenarios**, each representing a FCC case with specific organization type, location and carrier size

### Model

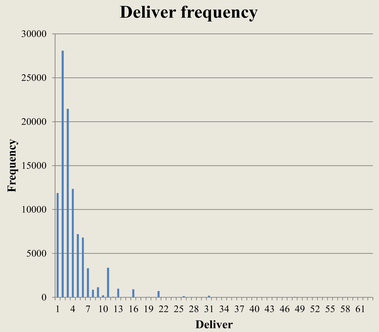
- Zero-inflated negative binomial is not used as the voung test is not significant
- Right censored negative binomial model is used
- Censored at 10

$$P(Y_i^*) = \frac{\Gamma(1/\alpha + Y_{i,i}^*)}{\Gamma(1/\alpha) Y_i^*!} \left(\frac{1/\alpha}{1/\alpha + \lambda_i}\right)^{1/\alpha} \left(\frac{\lambda_i}{1/\alpha + \lambda_i}\right)^{Y_i^*}$$

$$y_i = \min[Y_i^*, C]$$

$$\Pr[y_i = j] = \Pr[Y_i^* = j] = \text{if } y_i < C$$

$$\Pr[y_i = C] = \Pr[Y_i^* \geq C] = 1 - \Pr[Y_i^* < C] = 1 - \sum_{j=0}^{c-1} \Pr[Y_i^* = j]$$




## Data and Results

### National Household Travel Survey (NHTS) data

- Detailed household, person, social demographic and travel information based on household survey
- Carried out every 5 to 10 years
- Four data files: household file, person file, vehicle file and trip file
- 300,000+ individual records
- Final dataset after data cleaning contains 60,334 records

| Variable | Pooled model | Marginal effects | Variable | Pooled model | Marginal effects |
|---|---|---|---|---|---|
| Educ2 | 0.233***(5.930) | 0.741 | Hhvehcnt | 0.027***(7.744) | 0.070 |
| Educ3 | 0.283***(7.307) | 0.888 | Hhsize | -0.003(-0.775) | -0.009 |
| Educ4 | 0.300***(7.709) | 0.932 | Occat1 | -0.056***(-5.870) | -0.160 |
| Educ5 | 0.349***(8.971) | 1.112 | Occat2 | -0.082***(-6.594) | -0.230 |
| Webuse1 | 0.993***(20.852) | 2.003 | Selfemp0 | -0.072***(-7.597) | -0.213 |
| Webuse2 | 0.569***(11.363) | 2.182 | hhresdnsqkm | 0.0002*(1.856) | 0.0004 |
| Webuse3 | 0.272***(4.160) | 0.906 | hhpppopdnsqkm | -0.0001*(-1.816) | -0.0003 |
| Age | -0.001***(-2.542) | -0.002 | Urbansize1 | -0.044***(-3.715) | -0.125 |
| Sex | 0.099***(13.004) | 0.287 | Urbansize2 | -0.048***(-3.602) | -0.138 |
| Hhfamine2 | 0.114***(14.218) | 0.333 | Urbansize3 | -0.069***(-4.667) | -0.195 |
| Medcon | -0.179***(-8.032) | -0.566 | Urbansize4 | -0.015(-1.442) | -0.044 |
| Race2 | -0.062***(-3.488) | -0.192 | Rail | -0.054***(-5.443) | -0.158 |
| Race3 | -0.065***(-2.866) | -0.182 | Hometype2 | -0.010(-0.618) | -0.030 |
| Race4 | 0.137***(3.081) | 0.427 | Hometype3 | -0.058***(-3.220) | -0.164 |
| Race5 | -0.021(-0.297) | -0.061 | Hometype4 | -0.049*(-1.826) | -0.138 |
| Race6 | -0.086*(-1.891) | -0.240 | Hometype5 | 0.443*(1.701) | 1.618 |
| Race7 | -0.099***(-3.236) | -0.274 | Hometype6 | 0.950*(1.844) | 4.608 |
| Race8 | 0.024(0.601) | 0.071 | Hometype7 | 0.178(1.205) | 0.564 |
| Lifecycak | 0.054***(4.792) | 0.158 | Homeown | -0.007(-0.450) | -0.020 |
| Lifcyc10 | 0.036***(2.847) | 0.106 | | | |
| Alpha | | | | 0.555***(94.985) | |
| Log likelihood | | | | -123078.4 | |
| AIC | | | | 4.081 | |
| McFadden Pseudo R-squared | | | | 0.1182 | |
| Prob (Chi Sq>value) | | | | 0.0000 | |
| N | | | | 60334 | |

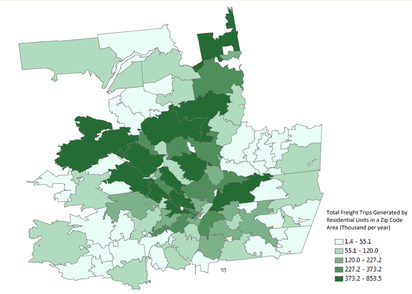
### Results implications

- Education, web use frequency, age, gender, race, etc have significantly impact on dependent variable
- Household variables such as family income, household structure and household size have significant impact on dependent variable
- Residential variables and regional variables have significant impact on dependent variable
- Results vary across different education groups

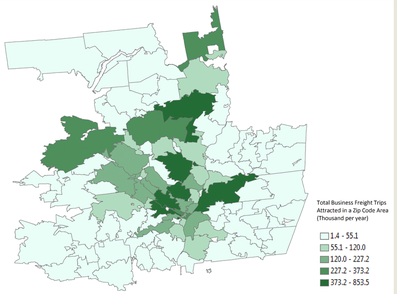
| Variable | Educ1 | Educ2 | Educ3 | Educ4 | Educ5 |
|---|---|---|---|---|---|
| Webuse1 | 0.660*(1.83) | 1.067***(13.42) | 0.984***(22.10) | 1.096***(21.52) | 1.224***(19.67) |
| Webuse2 | 0.268(0.71) | 0.714***(8.37) | 0.551***(10.63) | 0.646***(10.62) | 0.728***(9.52) |
| Webuse3 | -0.052(-0.10) | 0.392***(3.42) | -- | -- | -- |
| Age | 0.006*(1.65) | 0.001(1.20) | 0.002***(4.00) | -0.001**(-2.09) | -0.001(-1.34) |
| Sex | 0.099(1.03) | 0.082***(3.77) | 0.085***(5.80) | 0.126***(9.47) | 0.119***(8.12) |
| Hhfamine2 | -0.026(-0.24) | 0.103***(4.43) | 0.105***(6.66) | 0.140***(10.30) | 0.110***(7.02) |
| Medcon | 0.062(0.21) | -0.109**(-2.10) | -0.109***(-3.26) | -0.062(-1.50) | -0.129***(-2.97) |
| Race2 | -0.162(-0.47) | -0.110*(-2.03) | -0.035(-1.01) | 0.028(0.78) | -0.202***(-4.97) |
| Race3 | -0.306(-0.59) | -- | -- | -- | -0.100***(-2.81) |
| Race4 | 0.147(0.37) | -- | -- | -- | -- |
| Race5 | -- | -- | -- | -- | -- |
| Race6 | -0.076(-0.09) | -- | -- | -- | -- |
| Race7 | -0.193(-0.73) | -- | -- | -- | -- |
| Race8 | -0.501(-1.26) | -- | -- | -- | -- |
| Lifecycak | 0.037(0.36) | 0.041(1.41) | 0.031(1.46) | 0.065***(3.18) | 0.049**(2.03) |
| Lifcyc10 | -0.070(-0.42) | 0.007 (0.22) | 0.038*(1.65) | 0.043*(1.75) | 0.046*(1.86) |
| Hhvehcnt | 0.060**(2.11) | 0.040***(5.01) | 0.022***(3.60) | 0.034***(5.08) | 0.033***(4.16) |
| Hhsize | 0.013(0.46) | -0.008(-0.74) | 0.006(0.72) | 0.002(0.27) | 0.015(1.61) |
| Occat1 | -0.174*(-1.83) | -0.090***(-3.97) | -0.052***(-3.19) | -0.025(-1.47) | -0.023(-0.89) |
| Occat2 | -0.502**(-2.46) | -0.106***(-3.76) | -0.110***(-5.42) | -0.049**(-2.11) | 0.028(0.63) |
| Selfemp0 | -0.167*(-1.79) | -0.106***(-4.26) | -0.040**(-2.26) | -0.078***(-4.58) | -0.024(-1.33) |
| Hhresdnsqkm (in 100,000 units) | -0.0005(-0.06) | 0.0005(0.21) | 0.003**(2.15) | -0.001(-0.73) | 0.003***(2.68) |
| Hhpppopdnsqkm (in 100,000 units) | 0.001(0.24) | -0.0004(-0.33) | -0.0001(-0.13) | -0.0002(-0.33) | -0.002**(-2.73) |
| Urbansize1 | 0.187(1.53) | -0.028(-0.92) | 0.007(0.34) | -0.036*(-1.70) | -0.109***(-4.57) |
| Urbansize2 | -0.226(-1.04) | -0.079**(-2.04) | -0.023(-0.90) | -0.019(-0.80) | -0.079***(-2.93) |
| Urbansize3 | 0.210(1.31) | -0.025(-0.58) | -0.098***(-3.35) | -0.010(-0.38) | -0.137***(-4.77) |
| Urbansize4 | 0.020(0.17) | 0.029(1.05) | -0.026(-1.29) | 0.007(0.40) | -0.037*(-1.78) |
| Rail | -0.231*(-1.70) | -0.043(-1.57) | -0.006(-0.29) | -0.044**(-2.55) | -0.058***(-3.11) |
| Hometype2 | 0.003(-0.01) | 0.087**(1.98) | -0.046(-1.43) | 0.037(1.27) | -0.063*(-1.83) |
| Hometype3 | -0.302(-1.14) | -0.084*(-1.65) | -0.079**(-2.28) | -0.036(-1.14) | -- |
| Hometype4 | 0.212*(1.81) | -0.070(-1.53) | -0.026(-0.63) | -- | -- |
| homeown | -0.106(-0.72) | 0.012(0.32) | 0.011(0.42) | -0.009(-0.30) | -0.004(-0.12) |
| Alpha | 0.344***(6.55) | 0.521***(34.58) | 0.555***(49.88) | 0.552***(52.88) | 0.578***(49.49) |
| Log likelihood | -1029.0 | -17289.1 | -33921.2 | -38370.0 | -32417.7 |
| AIC/N | 3.609 | 3.912 | 4.035 | 4.119 | 4.207 |
| McFadden Pseudo R-squared | 0.0515 | 0.1037 | 0.1160 | 0.1184 | 0.1289 |
| Chi squared | 111.75 | 4001.2 | 8906.0 | 10300.2 | 9589.8 |
| Prob (ChiSqd>value) | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| N | 588 | 8853 | 16827 | 18643 | 15423 |
| Right censored at | 10 | 10 | 10 | 10 | 10 |
| Degree of freedom | 32 | 27 | 27 | 26 | 25 |
| Likelihood ratio test | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |

## Application

- Estimate residential freight trips in Capital District in New York State using zip code level data
- Zip code level data in Capital District (U.S. Census Bureau, 2014c)
- Convert freight delivery to freight trips using housing structure data (U.S. Census Bureau, 2014b)
- One freight trip may only make partial freight deliveries to house
- Use average number to provide minimum estimation of freight trips of units: 0.747
- Compare estimated residential freight trips with actual business freight trips




**Capital District residential freight trips estimation —15.4 million**




**Capital District business freight trips attraction —9.25 million**

| Housing structure | Estimate | Percent | Conversion factor to freight trip | Converted freight trips |
|---|---|---|---|---|
| 1-unit, detached | 224,295 | 57.0% | 1.000 | 224,295 |
| 1-unit, attached | 15,358 | 3.9% | 1.000 | 15,358 |
| 2 units | 50,041 | 12.7% | 0.500 | 25,021 |
| 3 or 4 units | 29,338 | 7.5% | 0.286 | 8,391 |
| 5 to 9 units | 22,427 | 5.7% | 0.143 | 3,207 |
| 10 to 19 units | 16,076 | 4.1% | 0.069 | 1,109 |
| 20 or more units | 20,555 | 5.2% | 0.050 | 1,028 |
| Mobile home | 15,319 | 3.9% | 1.000 | 15,319 |
| Boat, RV, van, etc. | 34 | 0.0% | 1.000 | 34 |
| Total | 393,443 | 100% | 0.747 | 293,762 |

- Freight trips generated by residential units are substantial
- Spatial distributions are different
  - –More residential freight trips in outskirt areas
  - –Less business freight trips in outskirt areas

## Conclusion

- Estimate freight trips generated by residential units using NHTS 2009 dataset
- Residential variables, web use frequency, education level and household characteristics contribute to residential freight generation
- Freight trips generated by residential units are substantial compared to business freight trips
- Future work
  - –Establish connection between delivery-tour-trip chain
  - –Collect more detailed residential freight data