A Longitudinal Study of Bike Infrastructure Impact of Bike-share System Performance

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Motivation
A need for effective system-wide decision support tools for public agencies to determine amount and timing of bike infrastructure investments.

Research Problem
Longitudinal data
• Bike-share ridership (Citi Bike)
• Weather factors (i.e. temperature)
• Build environment factors (i.e. bike lane length)

Time Series Model - Autoregressive Conditional Heteroscedasticity (ARCH)
Measuring the marginal cost of building bike lanes/paths on bike share ridership

How to evaluate at a network-wide level (for NYC Citi Bike)?

Proposed Methodology
• Basic ARCH(1) model from Engle (1982,2001)
  - Mean Equation: \( y_t = x_t \beta + e_t \)
  - Variance Equation: \( h_t = \gamma + \alpha e_{t-1}^2 \)

where \( x_t \beta \): mean value of the time series with parameters \( \beta; e_t \): error of the regression (normally distributed and heteroskedastic); \( h_t \): variance of \( e_t \) (depends on the squared error in the preceding time period); \( \alpha, \gamma \): variance parameters

• We added AR disturbance following an ARCH process:
  - \( y_t = x_t \beta + AR(y_t, p) + e_t \)
  - \( AR(y_t, p) = c + e_t + \sum_{i=1}^{p} \varphi_i Y_{t-i} \)
  - \( h_t = \gamma + \alpha_1 e_{t-1}^2 + \alpha_2 e_{t-2}^2 \)

where \( y_t \): dependent variable, in this case it is Average Daily Trip Counts per Week; \( x_t \): vector of independent variables; \( \beta \): matrix of parameter coefficients; \( AR(p) \): autoregressive disturbance with \( p = 6 \); \( e_t \): error in the model; \( c \): constant term; \( \varepsilon_t \): error in AR; \( \varphi_i \): coefficients in AR

Model Estimation

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<tbody>
<tr>
<td>( \epsilon_t )</td>
<td>-0.112</td>
<td>-0.129</td>
<td>-0.112</td>
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<tr>
<td>( \varphi_1 )</td>
<td>0.166</td>
<td>0.177</td>
<td>0.166</td>
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<td>( \varphi_6 )</td>
<td>0.01</td>
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Model Accuracy

Model 1
- only average over the seven days
  - NRMSE: 7.323 %
- each week's observation is based on average over the seven days
  - NRMSE: 7.323 %

Model 2
- only average weekdays are included in each observation
  - NRMSE: 7.475 %
- each week's observation is based on average over the seven days
  - NRMSE: 7.475 %

Model 3
- only average over Saturday and Sunday are included in each observation
  - NRMSE: 8.515 %
- each week's observation is based on average over the seven days
  - NRMSE: 8.515 %

Scenario Analysis

Starting from week 141, there is one greater shock every week for scenario 1, and smaller shock every week for scenario 2. At the end of the projection, the values are same in both scenarios 1 and 2. The same conclusion can be obtained from figure at right. Scenario 1 with no infrastructure investment is considered as baseline. One-time investment (Scenario 2) at the beginning is always the best without considering equipment or labor cost.

Conclusion and Future Work
• The time series regression analysis - ARCH with AR disturbance was applied to investigate the relationship between the Citi Bike daily trip counts and the total length of bike lane in NYC.
• There are about 100 Citi Bike daily average trips (per week) will be conducted with one additional mile of bike lane installed.
• New bike lanes have a positive impact on weekend (Saturday & Sunday) cyclist activity, and no significant impact on weekday.
• The series has annual seasonal cycles, and we only have limited three cycles. In future studies, we will update the model framework by adding more observed attributes.
• Another interesting research direction is to investigate the effect of bike lane coverage for Citi Bike members’ route choice, which would require additional work.