How Card Acquisition Fee Affects New Transit Card Purchase Patterns: Evidence from New York City and Washington, D.C.

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Introduction

- Transit authorities in many cities have introduced automated fare media
  - electronic, magnetic-stripe contact cards
  - more recently to smart cards
- Most reloadable transit card come with a refundable or non-refundable one-time acquisition fee

Introduction

- A one-time $3.00 acquisition fee for a Clipper card
  - A reloadable contactless card used for automated public transit fare collection in the San Francisco Bay Area.

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- Transit authorities in many cities have introduced automated fare media
  - electronic, magnetic-stripe contact cards
  - more recently to smart cards
- Most reloadable transit card come with a refundable or non-refundable one-time acquisition fee
- The effect of the ubiquitous new transit card fee is not clear, largely due to the scarcity of reliable disaggregate card data

Introduction

- I address this gap in the literature by adopting a causal inference approach, a difference-in-difference (DID) model, to examine the effects of a new card acquisition fee on new transit card purchases with novel data sets from
  - The Washington Metropolitan Area Transit Authority (WMATA) and
  - The New York City Metropolitan Transportation Authority (MTA)

Introduction

- Transportation Authority (MTA) system has used MetroCards to collect subway and bus fares since 1998
  - A MetroCard itself used to be cost-free
  - A $1 non-refundable acquisition fee went into effect on March 3, 2013
  - Riders do not pay this fee when they refill MetroCards or purchase single-ride tickets

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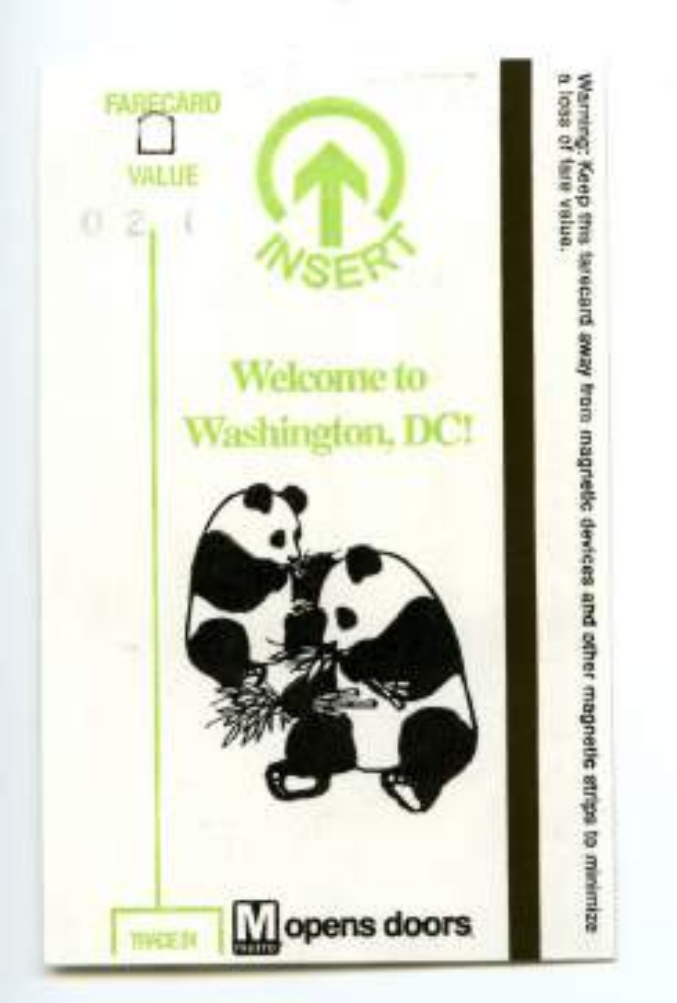
  - From October 2013 on, the rebate program was discontinued and the price of the card was reduced to $2
  - In September 2015, Washington Metro begun upgrading existing fare vending machines to dispense SmarTrip cards rather than paper farecards, and discontinued all sales of paper farecards when the last machine on the system was upgraded by January 2016

Introduction



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- The estimates derived from a simple before-after comparison may not reflect the true policy effects
- We address these potential estimation biases by adopting a causal inference approach, a difference-in-differences (DID) model
  - For new transit card sales, we use the average daily transit rides as the control group: new card sales are likely to be proportional to transit ridership and the volume of people riding the subways and buses, unless these are systematic changes in rides patterns.

Introduction

- We first estimate the impacts of different policy changes at the network (aggregate) level
- The granularity of station-level data also enables us to analyze the spatial variations in new MetroCard and SmarTrip card sales at each subway station (disaggregate level)
  - We allow the treatment effect to vary with observed baseline census tract characteristics (e.g., median household income and unemployment rate)

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- In Washington D.C., the sales of new SmarTrip cards stayed constant when the rebate program was introduced in September 2012
- Similarly, the reduction of new card fee from $5 to $2 only slightly increased the purchase of new SmarTrip cards
- In contrast, the elimination of paper farecards prompted riders to go paperless and caused a significant increase in the overall demand for new SmarTrip cards

Contribution

- This study contributes to a large literature on optimal pricing policies for public transit system.
  - Most empirical studies on optimal fare structures focus on the demand elasticity of rides in response to fare increases (Vickrey, 1955, 1963; Palma and Lindsey, 2007; Small and Verhoef, 2007; Tirachinia and Henshera, 2012; Jong and Gunn, 2001; Chen et al., 2011; Davis, 2021)

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  - This paper examines the causal effect of a surcharge fee (card activation fee) on transit card purchase and use patterns.

Contribution

- This study also contributes to an emerging literature on public transport payment preference.
  - Despite the availability of, and benefits associated with, prepaid reloadable fare cards, many transit riders continue to select traditional single ride or round trip tickets for payment of their fares (Weinstein et al., 1999).
  - A lot of public transit riders do not reuse their prepaid reloadable transit cards. For example, in New SouthWales (NSW), state of southeastern Australia, many public transit riders simply ditch free transit cards (Opal cards) with a zero or negative balance and then start afresh with a new card (Coyne, 2017).

Contribution

- Third, this work connects with a growing strand of the literature that has used smart card data for transport evaluation.
  - Data generated by cards are used widely in trip pattern analysis and planning (Wei, 2022; Shin, 2021;Wang et al., 2021).
  - A large volume of research has used large-scale smart card data to explore the responsiveness of public transit riders to different pricing policies (Hussain et al., 2021; Liu et al., 2019; Zhao and Zhang, 2019).

Background-SmarTrip

- SmarTrip was the first contactless smart card for transit in the United States

Background-SmarTrip

- A SmarTrip card is a rechargeable plastic farecard that can hold up to $300 in value to pay for
  - WMATA transit services (Metrorail, Metrobus, and DC Circulator)
  - Bus systems in Virginia (ART (Arlington Transit)
  - CUE (Fairfax City)
  - DASH (Alexandria Transit Company)
  - Fairfax Connector
  - Loudoun Commuter Bus Service
  - Bus systems in Maryland (Maryland Transit Administration, Ride On (Montgomery County Transit Services Division), TheBus in Prince George's County, and PRTC (Prince William County, Manassas and Manassas Park)).

Background-SmarTrip

- Initially, there was a one-time non-refundable $5.00 acquisition fee for a new SmarTrip card
- Starting September 1, 2012, Metro began offering $3 rebates to riders who registered their new SmarTrip cards online after purchase
  - The cards still cost $5, but a $3 credit was refunded to the card five days after first use.

Background-SmarTrip

- Effective October 1, 2013, the acquisition fee of new SmarTrip card was reduced to $2 and the rebate program was discontinued.
- In September 2015, Metro begun upgrading existing fare vending machines to dispense SmarTrip cards rather than paper farecards
  - Discontinued all sales and uses of paper farecards when the last machine on the system was upgraded by January 2016

Background-MetroCard

- The MetroCard is a stored ride fare card for
  - New York City Subway rapid transit system
  - New York City Transit buses, including routes operated by Atlantic Express under contract to the Metropolitan Transportation Authority (MTA)
  - MTA Bus and AirTrain JFK
  - Nassau Inter-County Express systems
  - The PATH subway system
  - The Roosevelt Island Tram and Westchester County's Bee-Line Bus System

Background-MetroCard

- A new Metrocard itself used to be cost-free
- A $1 surcharge fee on new metrocards went into effect on March 3rd, 2013
- The new $1 charge did not apply to single journey tickets or to MetroCards bought by reduced fare riders (seniors and riders with disabilities)

Data

- Monthly-level new SmarTrip Purchase Data
  - The number of new SmarTrip card purchases made by riders in each month
  - Before September 2015, SmarTrip cards can only be purchased at Metro sales offices, retail outlets, and commuter stores
  - Starting September 2015, the new card sales data are broken out for each metro station as Metro updated fare vending machines to dispense SmarTrip cards rather than paper farecards.

Data

- WMATA Metrorail Rides Data
  - The average number of daily Metrorail rides made each month from August 2010 to December 2019 as riders entered each station of the Metrorail, broken out for each metro station

Data

Table 1: Summary Statistics of Daily Ridership and Monthly SmarTrip Card Sales in Washington Metropolitan Areas

	(1) Aug 2010-Aug 2012	(2) Sep 2012-Sep 2013	(3) Oct 2013-Aug 2015	(4) Sep 2015-Dec 2019
New SmarTrip Sales	270.90 (67.86)	314.56 (118.95)	319.59 (109.54)	658.55 (256.98)
Daily Average Ridership	24.06 (1.41)	23.38 (1.61)	22.58 (1.54)	20.33 (1.53)

All numbers are in thousands. Standard deviation in parentheses.

Data

- Monthly-level new MetroCard Purchase Data
  - The number of new MetroCard purchases made by riders in each month, broken out for each subway station
- MTA Subway Rides Data
  - The average number of daily subway rides made each month from January 2011 to June 2015 as riders entered each station of the New York City subway system, broken out for each subway station

Data

Table 2: Summary Statistics of Daily Ridership and Monthly MetroCard Sales in New York City

	(1) Jan 2011-Feb 2013	(2) Mar 2013-Jun 2015
New MetroCard Sales (Total in-system)	7.65 (0.58)	2.3 (0.36)
Daily Average Ridership	4.51 (0.21)	4.77 (0.21)

All numbers are in million. Standard deviation in parentheses.

Data

- The 5-year-average (2011–2015) data from the American Community Survey (ACS) for each census tract in the Washington metropolitan area (all of Washington, D.C. and parts of the states of Maryland, Virginia) and each census tract throughout the five boroughs of New York City
  - Median household income
  - Population
  - Number of households
  - Unemployment rate
- Census tract data are then matched to each geocoded metro station record for heterogeneity analysis

Methodology

- Monthly new SmarTrip card sales from August 2010 to September 2013 for the rebate program analysis
  - Both the pre-treatment and post-treatment periods
  - The average weekday rail entries as the control group
- Monthly new SmarTrip card sales from September 2012 to August 2015 for the new card fee reduction analysis
  - Both the pre-treatment and post-treatment periods
  - The average weekday rail entries as the control group

Methodology

- Monthly new SmarTrip card sales from October 2013 to December 2019 for the elimination of paper farecards analysis
  - Both the pre-treatment and post treatment periods
  - The average weekday rail entries as the control group
- Monthly new MetroCard sales from January 2011 to June 2015 for the introduction of the $1 new card fee on MetroCard analysis
  - Both the pre-treatment and post treatment periods
  - The average weekday subway entries as the control group

Methodology

- The key assumption in DID estimation is a common-trends assumption
  - Treated groups would have followed the same time trend as untreated groups had they not been treated
  - Compare the time trend before any treatments occur (that is, the “pre-trend”) for groups that are treated with the pre-trend of control groups that are never treated.

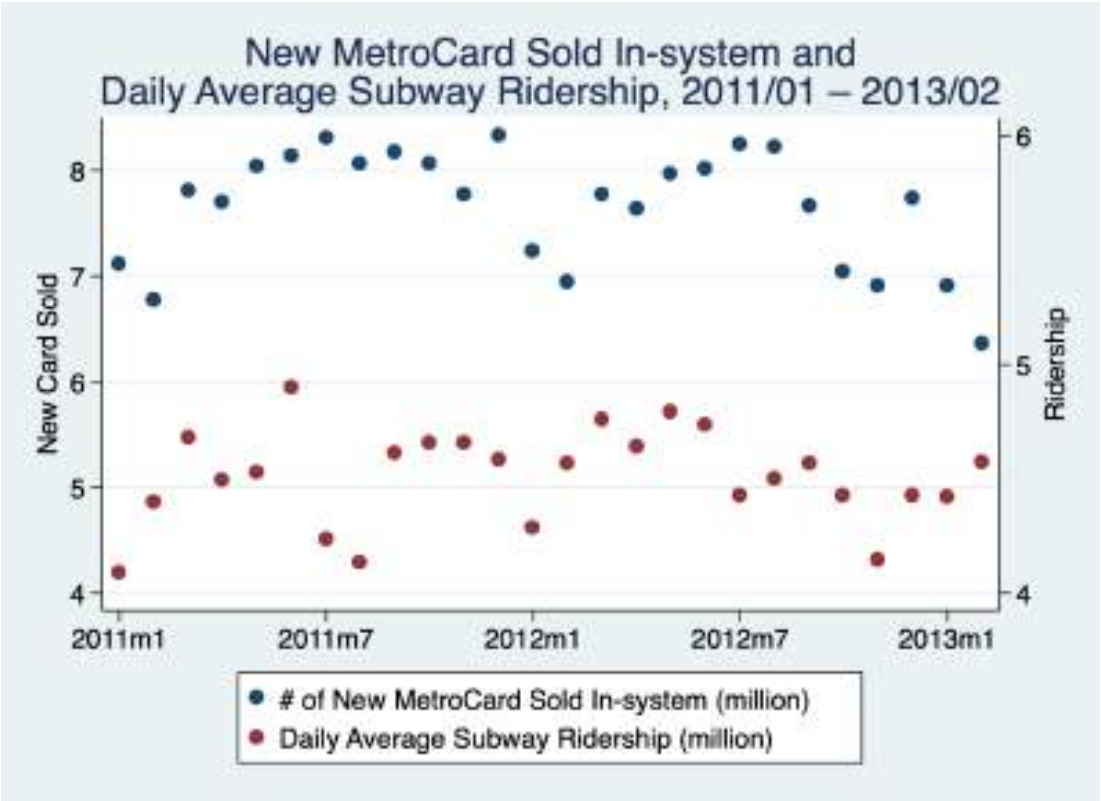
Results

Figure 1:

Note: Figure 1 plots the number of new SmarTrips sold monthly and the average weekday subway entries from August 2010 to August 2012.

Results

Figure 2:



Note: Figure 2 plots the number of new MetroCard sold monthly and the average weekday subway entries from January 2011 to February 2013.

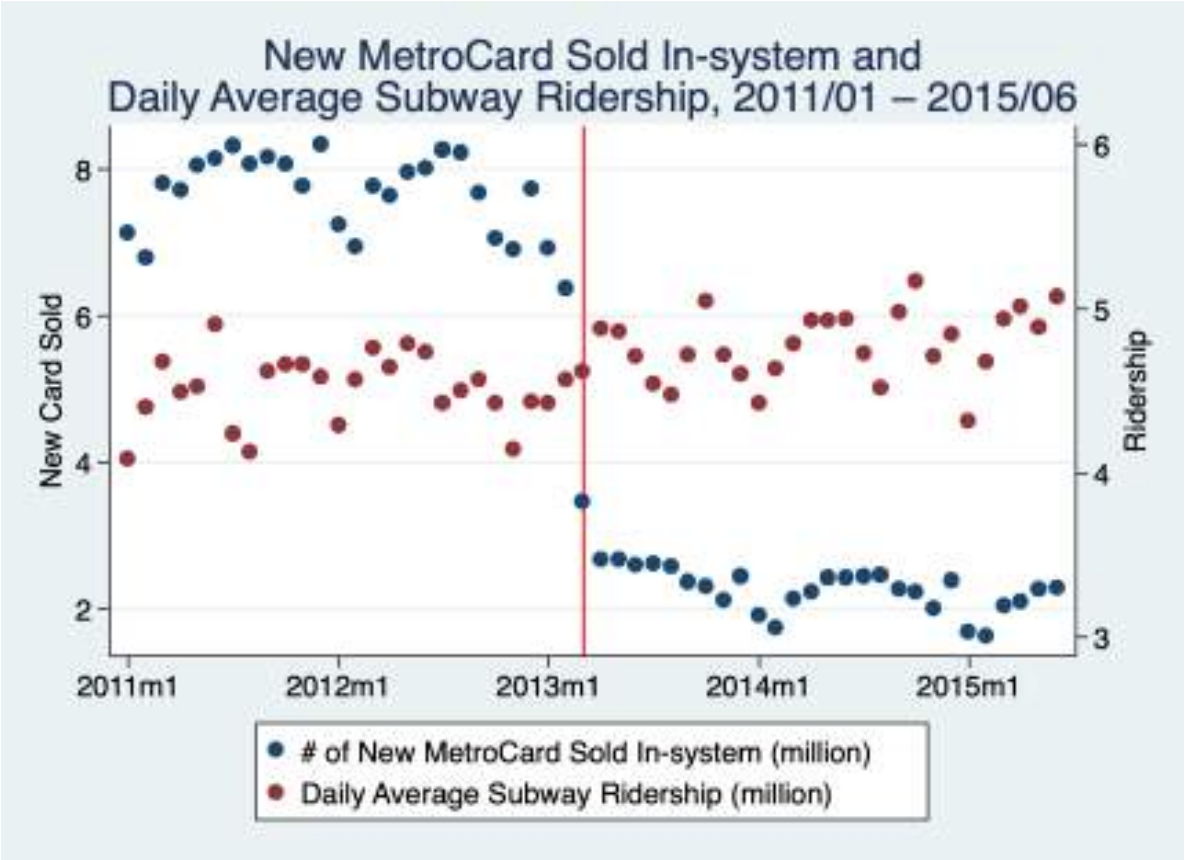
Results

Figure 3:

Note: The first vertical line marks the month when the rebate program was implemented. The second vertical line marks the month when the price of new SmarTrip card decreased from $5 to $2. The third vertical line marks the month when the paper farecards were eliminated.

Results

Figure 4:



Results

Table 3: The Impact of Rebate Program on New SmarTrip Card Sales

	(1)	(2)	(3)
Pass	-23.31	-21.97	-17.83
	(13.15)	(11.02)	(35.47)
Treat	-461.9***	-461.9***	-461.9***
	(15.57)	(13.89)	(14.06)
Pass*Treat	66.96	66.96	66.96
	(37.68)	(37.59)	(38.30)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	76	76	76
R^2	0.917	0.935	0.936

Outcome variable: SmarTrips sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. ** p < 0.05, ** p < 0.01, *** p < 0.001*

Results

Table 4: The Impact of Price Reduction on New SmarTrip Card Sales

	(1)	(2)	(3)
Pass	-34.15*	-32.16**	-101.7
	(14.05)	(11.91)	(60.17)
Treat	-394.9***	-394.9***	-394.9***
	(34.22)	(36.43)	(38.82)
Pass*Treat	68.82	68.82	68.82
	(42.75)	(44.67)	(46.46)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	84	84	84
R^2	0.782	0.803	0.810

Outcome variable: SmarTrips sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. ** $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Results

Table 5: The Impact of Paper Farecards Elimination on New SmarTrip Card Sales

	(1)	(2)	(3)
Pass	-58.78***	-69.55***	-89.09
	(10.85)	(12.95)	(91.04)
Treat	-326.1***	-326.1***	-326.1***
	(25.35)	(26.46)	(26.52)
Pass*Treat	393.6***	393.6***	393.6***
	(46.28)	(44.51)	(44.25)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	150	150	150
R^2	0.391	0.500	0.530

Outcome variable: SmarTrips sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. ** $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$*

Results

Table 6: The Impact of $1 Acquisition Fee on New MetroCard Sales

	(1)	(2)	(3)
pass	0.265***	0.209**	0.414
	(0.0569)	(0.0643)	(0.318)
treat	3.141***	3.141***	3.141***
	(0.117)	(0.0931)	(0.0936)
passXtreat	-5.615***	-5.615***	-5.615***
	(0.141)	(0.115)	(0.115)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	108	108	108
R^2	0.966	0.980	0.981

Outcome variable: MetroCard sales on monthly basis at network (aggregate) level (in millions). Robust standard errors in parentheses. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Validation Tests

- We capture the sensitivity of DID estimates relative to sample selection by analyzing two sub-samples of the original time windows:
  - Nine months before and after each policy change
  - Six months before and after each policy change

Validation Tests

Table 7: Impacts of Different Policies on New SmarTrip Sales

	(1) Rebate Program	(2) Price Reduction	(3) Paper Farecard Elimination
Pass	3.323	-34.34	-47.01
	(30.45)	(38.00)	(36.76)
Treat	-433.2***	-404.8***	-237.4***
	(32.79)	(52.68)	(52.06)
Pass*Treat	74.76	58.80	391.8***
	(58.22)	(65.72)	(64.00)
Month FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	36	36	36
R^2	0.907	0.872	0.794

Outcome variable: SmarTrips sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Validation Tests

Table 8: Impacts of Different Policies on New SmarTrip Sales

	(1) Rebate Program	(2) Price Reduction	(3) Paper Farecard Elimination
Pass	50.97	29.74	-52.23
	(175.6)	(97.14)	(81.77)
Treat	-404.4***	-476.7***	-169.3*
	(34.72)	(25.73)	(67.18)
Pass*Treat	94.98	102.2	379.0***
	(70.83)	(52.57)	(76.56)
Month FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	24	24	24
R^2	0.918	0.966	0.862

Outcome variable: SmarTrips sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. ** p < 0.05, ** p < 0.01, *** p < 0.001*

Validation Tests

Table 9: Impacts of $1 Acquisition Fee on New MetroCard Sales with Different Time Windows

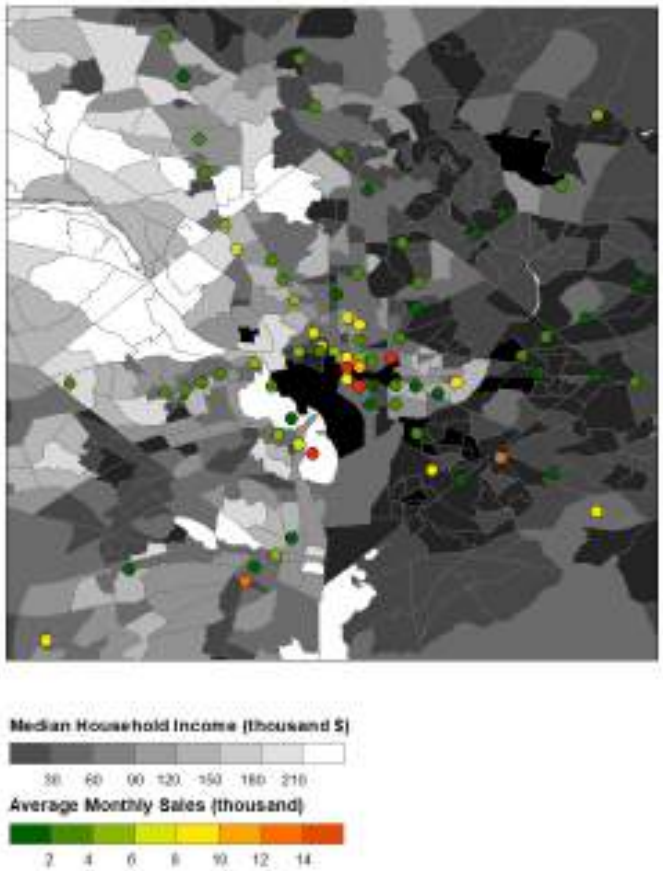
	(1) 9-month	(2) 6-month
pass	0.0513 (0.183)	0.153 (0.169)
treat	2.985*** (0.203)	2.674*** (0.216)
passXtreat	-5.119*** (0.256)	-4.592*** (0.270)
Month FE	Yes	Yes
Year FE	Yes	Yes
Observations	36	24
R^2	0.973	0.982

Outcome variable: MetroCard sales on monthly basis at network (aggregate) level (in thousands). Robust standard errors in parentheses. ** p < 0.05, ** p < 0.01, *** p < 0.001*

Spatial Variations

Note: Figure 49 plots the number of new SmarTrips sold monthly in each metro station from January 2017 to December 2018.

Spatial Variations



Note: Figure 50 plots the number of new SmarTrips sold monthly in each metro station from January 2017 to December 2018.

Spatial Variations

Table 10: New York City

	(lnSales)	(lnSales)	(lnSales)
lnIncome	-0.261**	-0.261**	-0.261**
	(0.0830)	(0.0830)	(0.0830)
lnPop	-0.155	-0.155	-0.155
	(0.188)	(0.188)	(0.188)
lnHHS	0.660***	0.660***	0.660***
	(0.155)	(0.155)	(0.155)
UnemployedRate	-1.345	-1.349	-1.349
	(0.870)	(0.870)	(0.870)
LineNumber	0.247***	0.247***	0.247***
	(0.0206)	(0.0206)	(0.0206)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	2467	2467	2467
R^2	0.115	0.117	0.117

Outcome variable: SmarTrips sales on monthly basis at station (aggregate) level. Robust standard errors in parentheses. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Spatial Variations

Table 11: Washington DC

	(lnSales)	(lnSales)	(lnSales)
lnIncome	0.517***	0.517***	0.517***
	(0.127)	(0.124)	(0.124)
lnPop	-0.361**	-0.361**	-0.361**
	(0.130)	(0.124)	(0.124)
lnHHS	0.319***	0.319***	0.319***
	(0.0668)	(0.0599)	(0.0598)
UnemployedRate	-5.578***	-5.578***	-5.578***
	(1.048)	(1.025)	(1.025)
LineNumber	0.0671**	0.0671**	0.0671**
	(0.0234)	(0.0223)	(0.0223)
Month FE	No	Yes	Yes
Year FE	No	No	Yes
Observations	1729	1729	1729
R^2	0.195	0.261	0.263

Outcome variable: SmarTrips sales on monthly basis at station (aggregate) level. Robust standard errors in parentheses. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Conclusions

- A large portion of public transit riders treat prepaid reloadable transit cards as single ride or round trip tickets when it costs nothing to get new transit cards. In contrast, a surcharge fee on new transit card prompts riders to substitute to refill existing cards.
- Rebate programs does not work well
  - No significant change in new transit card (SmarTrip card) sales
  - Only 10% riders participate in the rebate program
- Discontinuity of paper farecards pushed many riders to switch to reloadable prepaid transit cards
- Substantial variation in new card sales across different neighborhoods