# Money for MetroCards: How a New Card Fee Made Transit Riders Invest More and Lose More

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**Abstract**

In 2013, the New York City Metropolitan Transportation Authority (MTA) imposed a $1 card fee (surcharge) on new purchases of prepaid transit cards (MetroCards). Using a novel dataset with transaction-level card information, I show that the fee caused riders to put more money on new MetroCard purchases, particularly those in low-income neighborhoods and those who used cash or debit (rather than credit) cards. As a result, the net monthly outstanding balance of card deposits increased dramatically, with riders lending an extra $150 million, on an annual basis, to the MTA. Moreover, over $20 million of the annual increased balances were never redeemed and escheated to the MTA when these cards expired. The leading explanation highlights card carrying costs. I pose a structural model to calibrate the effect of a new card fee. The importance of card carrying costs may explain the prevalence of required minimum deposit amounts in the online or mobile prepaid services such as E-ZPass and Skype. These findings have implications for public policy designs and fee structures of prepaid services. (*JEL* D12, H41, R41, R42, R48)

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# 1 Introduction

Prepaid cards have become an increasingly prominent form of payment for many industries and public services providers. For instance, currently over 23 million US adults, mostly "unbanked" consumers from low-income households, use general purpose reloadable cards such as Green-Dot Card every month (Urahn et al. 2014). Meanwhile, many developing countries promote the use of prepaid cards for public services as they face large numbers of tiny and dispersed consumers. Some controversy has emerged because merchants are critical of the card fees, challenging both structure and level, and heated debates among researchers, practitioners, and policymakers have ensued. While the academic literature has so far focused on fees that are proportional to the transaction values or fixed per-transaction fees, the effect of a new card fee is not clear, especially in monopolistic markets.

In this paper, I show how a new card fee for prepaid transit cards induced riders to put more money on cards and lose more when these cards expired. I present a novel transaction-level data set from the public transit system in New York City that allows me to analyze changes in deposit amounts and forgone balance on expired cards. The data set contains detailed information on all the deposits and card uses from January 2013 to May 2015, with more than 100 million observations.

In March 2013, the New York City Metropolitan Transportation Authority (MTA) imposed a \$1 "green" card fee on new MetroCard purchases to motivate riders to refill and keep using their existing cards rather than purchasing new ones, thereby reducing litter. The Authority's stated goal behind the card fee was achieved as the number of new MetroCards sold dropped immediately and stayed low after the card fee was imposed. Before 2013, the Authority, on average, sold about 7 million cards per month. After the card fee, this number dropped to about 2 million per month. Meanwhile, there was only a minor decrease in ridership since the imposition of the card fee.

Surprisingly, riders started to make much larger deposits on new MetroCard purchases after the \$1 new card fee (surcharge); this translates into riders lending the transit authority \$150 million more annually. The monthly outstanding balance that riders carry on their MetroCards (defined as the difference between the total amount loaded on the cards in that month and the reductions caused by swipes at turnstiles in the same month[1]) jumped from less than \$35 million to more than \$45 million. Currently, the MTA is paying 0.37% interest on funds raised from short-term notes. This additional free lending potentially saved the MTA hundreds of thousands of dollars in interest payments.

Moreover, over \$20 million of the increased balances were never redeemed and escheated to the MTA when these cards expired. Each MetroCard is valid for about 18 months after the initial

[1]Mathematically, the net outstanding balance for a specific month is calculated as $Balance = \sum deposits * (1 + bonus(\%)) - \sum rides * basefare$

purchase; inactive balances on cards become assets of MTA under the category "expired fare revenue" after the expiration date. The aggregate forgone balance (i.e., expired fare revenue) in 2015, from cards initially purchased in late 2013 and 2014, the first year after the MTA implemented the card fee, increased to \$75 million from \$52 million, the aggregate forgone balance in 2014. The increase in forgone balances persisted as \$80 million and \$76 million stashed on MetroCards that expired in 2016 and 2017, respectively.

There are five main empirical findings regarding changes in deposit amounts and forgone balances on expired cards. First, the changes largely came from new cards that would not have subsequent refill activities, not from cards that showed subsequent refill activities. Second, the changes mainly came from cash or debit card payments rather than from credit card payments. Third, among cash payments, the changes were mostly from payments made at vending machines rather than from payments made at manned booths (tellers). Fourth, the response to the new card fee was larger in low-income neighborhoods than in high-income neighborhoods. Fifth, the response to the new card fee was not primarily from tourists. Although part of the changes could have come from tourists and short-term visitors, deposits and forgone balances increased dramatically in neighborhoods with few tourists such as South Bronx and Sunset Park in Brooklyn.

The increase in deposit amounts and leftover balances on expired cards was unanticipated: the MTA never said that the goal of this card fee was to attract more deposits; also, the card fee on a new MetroCard purchase is a one-time fee, which should have no impact on deposit amounts. Now the question is: why did riders make larger deposits to their MetroCards and lose more money after the new card fee was introduced? I explore potential explanations, including avoidance of coins, persuasion by vending machine messages, and commitment device.

In my view, these findings are consistent with a rational model that highlights the cost to carry the same MetroCard for future rides, the cost to add money on Metrocard, and rider uncertainty about future rides. When MetroCards were free, riders with a low cost of making deposits to MetroCards deposited only a small amount of money on cards and purchased a new MetroCard each period if needed. They chose not to incur the cost of effort to carry the same card for future days. After the new card fee was imposed, many riders switched to refilling existing cards since their card carrying costs were smaller than the new card fee. They started making larger deposits to save on the cost of making deposits to cards. Because riders are uncertain about future rides, these riders on average had higher leftover balances after the card expiration dates.

To calibrate the effect of a new card fee, I develop and estimate a dynamic model of MetroCard deposits and uses by utilizing detailed MetroCard data in the years 2013-2015. Given my parameter estimates, counterfactual simulations predict the effect of a \$1 new card fee had it been implemented with all the default choices of deposit amounts giving exact numbers of rides. Holding base fare for subway and bus rides fixed, my simulations predict an increase in expired fare revenue of $21.76 million (41.84%) after the $1 card fee is imposed on new MetroCard purchases, as opposed to $25 million. I then simulate the amount of new card fee that maximizes the MTA's profit while holding the payment prompts on Touchscreen and base fare for subway rides fixed. The model predicts that a new card fee of $4.35 maximizes the MTA's profit.

The importance of card carrying costs and costs to make deposits may explain the prevalence of required minimum deposit amounts in the online or mobile prepaid services such as E-ZPass and Skype. When authorities or firms adopt online or mobile payments with an automatic deduction from bank accounts or credit cards, consumers' costs to make deposits converge to zero. As a result, cash flow from prepaid services will drop significantly as consumers switch from prepaying for future consumption to paying only for consumption this period (pay-as-you-go). To maintain the benefits from unused account balances, most online or mobile prepaid services providers have required minimum deposit amounts and use suggested deposit amounts to attract even more deposits.

The results of this study are likely to generalize to 8.3 million Americans who use public transit to go to work. In 2019, Americans took 9.9 billion trips on public transportation (American Public Transportation Association 2020). Therefore, both in terms of monetary magnitude and in terms of population involved, the new card fee on transit card has a significant economic impact. Empirical analysis on optimal pricing for public transit system has been limited, with most studies focusing on the demand elasticity of rides in response to fare increases (Vickrey (1955); Vickrey 1963; Palma and Lindsey 2007; Small and Verhoef 2007; Tirachinia and Henshera 2012; Jong and Gunn 2001; jia Wang et al. 2015; Chen et al. 2011; Graham et al. 2020; Davis 2021). This paper is the first to examine in detail the effects of a new transit card fee. I show that a new card fee induced riders, especially low-income riders, to put more money on cards and lose more when these cards expire.

These findings also have implications for the fee structure of payment cards, especially reloadable prepaid debit cards. The academic literature has so far focused on fees that are proportional to the transaction values or fixed per-transaction fees (Shy and Wang 2011; Schwartz and Vincent 2006; Schmalensee 2002). Shy and Wang (2011) showed that, when card networks and merchants both have market power, card networks earn higher profits by charging proportional fees. Schwartz and Vincent (2006) showed that, when a card company faces local monopolist merchants, the No Surcharge Rule which prohibits merchants from charging higher prices to consumers who pay by card instead of other means ('cash') raises card company profit and harms cash users and merchants. Complementing prior studies, I show that, when a prepaid card issuer has market power, a new card fee (or card activation fee) could nudge consumers to prepay more for future consumption.

Furthermore, these findings have implications about regressive ways to raise money. Mainly due to data limitations, studies on regressive fees focus on the portion of fee revenue collected from low-income people (Dorfman 1977; Gertler et al. 1987; Grainger and Kolstad 2010; Leape 2006; McMillen and Singh 2020; and Oates and Fischel 2016). Here I provide evidence that whether or not the card fee itself is regressive, it may push low-income consumers to behave in ways that cost them money, especially in monopolistic market. The authorities should take into consideration the possible additional responses from low-income people when imposing a fee.

The remainder of the paper is organized as follows. Section 2 gives a brief introduction to MetroCards and the new card fee. Section 3 describes main features of MetroCard data sets used in the empirical analysis. Section 4 presents the main findings about MetroCard sales, deposit patterns, and leftover balances on expired cards. Section 5 describes my model and identification in a simplified setting. Section 6 discusses estimation and counterfactual analysis. Section 7 considers other potential mechanisms that might explain the results. Section 8 performs robustness tests. Section 9 concludes the paper.

# 2 Background

## 2.1 MetroCard

The MetroCard is a stored ride fare card for the New York City public transit system. It is a thin plastic card on which a rider electronically loads fares. Various types of MetroCards are available for purchase. There are two types of value-based cards: pay-per-ride MetroCards and single-ride tickets. Also, there are two types of time-based cards: 7-day-unlimited MetroCards and 30-day-unlimited MetroCards. The minimum purchase on a new pay-per-ride MetroCard is the fare of a round trip (currently \$5.50). No minimum purchase is required for refill transactions. Riders can put as much money on the card as they want.

A rider can purchase new or refill existing MetroCards at a subway station MetroCard vending machine (MVM) (Figure 1a) or at a station's manned booth (teller) (Figure 1b) [2]. Upon the imposition of the card fee in March 2013, there was no major change in the user interface of vending machine screens, except for the added message about the card fee (Figure 2). More information is available on MTA's website: www.mta.info.

[2]MetroCards can also be purchased out-of-system through the MTA extended sales network (including merchants and tax-benefit providers), which now accounts for the majority of MetroCards sold. Approximately 2.8 million MetroCards are sold out-of-system each month, and this level has not changed noticeably since the introduction of the \$1 new card fee (out-of-system sales are not subject to the \$1 fee).

**Bonus Free Ride for Pay-per-ride Purchases**

Since January 1, 1998, the MTA has given a "bonus" for pay-per-ride purchases that are at or above a certain threshold amount. For instance, from June 28, 2009, to December 29, 2010, the bonus value for pay-per-ride purchases was 15% of the purchase amount for purchases of $8 or more. For example, when a rider made a deposit of $10 to a pay-per-ride MetroCard, the card balance increased by $11.50 ($10 + $1.50).

This is not a typical bonus since it is always a certain percent of the purchase amount (i.e., linear) while a usual bonus is an increasing percent of the purchase amount (i.e., non-linear). The bonus value for pay-per-ride MetroCards was 11% of the purchase amount for purchases of $5.50 or more (Table 1 row 6) from March 22, 2015 to March 18, 2017.

## 2.2 Policy Changes

Table 1 shows the recent history of MTA policy changes. Column 1 presents the fare hike in 2009. On June 28, 2009, the base subway and bus fare rose from $2 to $2.25. The monthly MetroCard rose from $81 to $89. The weekly MetroCard rose from $25 to $27. The pay-per-ride MetroCard bonus remained at 15%, but the threshold for the bonus increased from $7 to $8.

Column 2 lists the fare hike at the end of 2010. On December 30, 2010, the 30-day-unlimited card increased to $104 and the 7-day-unlimited card increased to $29. The bonus value for pay-per-ride cards decreased to 7% for every $10. There was no change in base subway and bus fares, but the cost of a single-ride ticket went from $2.25 to $2.50.

Column 3 shows the fare hike in 2013. On March 3, 2013, the base subway and bus fare increased from $2.25 to $2.50. The cost of a 30-day-unlimited card increased to $112. The cost of a 7-day-unlimited card increased to $30. The bonus for the pay-per-ride MetroCard decreased from 7% to 5%, but the threshold for the bonus decreased from $10 to $5. The price of a single-ride ticket increased from $2.50 to $2.75. The MTA also imposed a $1 fee on new card purchases, the impact of which forms the basis of this study.

Column 4 depicts the fare hike in 2015. On March 22, 2015, the base fare of subway and bus rides rose from $2.50 to $2.75. The cost of a 7-day-unlimited card rose from $30 to $31 and the cost of a 30-day-unlimited card increased from $112 to $116.50. Pay-per-ride bonuses increased from 5% to 11% for purchases greater than or equal to $5.50.

### 2.2.1 Card Fee on New Purchases

The main policy change that concerns this paper is the imposition of a card fee on new MetroCard purchases. A new MetroCard itself used to be cost-free. A $1 new card fee, tacked on when someone buys a new MetroCard, went into effect with the fare hikes on March 3, 2013. The fee applies to each new MetroCard purchased at a MetroCard Vending Machine, station booth, or commuter rail station. Riders can avoid this fee by refilling their MetroCards. The MTA will issue a new MetroCard at no charge if a card is expired or damaged. The new $1 charge did not apply to single-ride tickets or to MetroCards bought by reduced fare riders (seniors and riders with disabilities)[3].

### 2.3 Environmental Impact

The transportation authority justified the $1 card fee on new MetroCards purchases in environmental terms, arguing that the policy would lead to cleaner subway stations by discouraging people from littering subway stations with their discarded, empty MetroCards. MTA officials mentioned this fee as an environmentally friendly initiative in numerous news reports [4]. On average, it costs the agency $20 million a year to print and clean up discarded cards from subway stations. According to the MTA, after the imposition of the new card fee, printing fewer MetoCards and trimming cleanup costs was expected to save about $2 million a year [5].

## 3 Data

In this section, I present the main features of the data sets used in this study. This paper documents changes in deposit amounts on MetroCard purchases and increases in forgone balances on expired MetroCards using three data sets: MetroCard deposit data, swipe data, and trade-in and trade-out data.

[3] Also, the card fee does not apply to MetroCards purchased out-of-system through MTA extended sales merchants, users of EasyPayXpress cards, transit benefit organization riders who get their MetroCards directly from employers or their benefit providers, or riders who purchase a combination railroad/MetroCard ticket. Out-of-system MetroCard sales now account for the majority of MetroCards sold. Approximately 2.8 million MetroCards are sold out-of-system each month, and this level has not changed noticeably when comparing MetroCard numbers sold before and after the card fee went into effect.

[4] Some news reports where MTA talked about the $1 new card fee: NY Times, NY Daily News, NBC News

[5] Some news reports where MTA mentioned the potential savings from the imposition of the new care fee: NY Daily News-1, NY Daily News-2, NBC New York

## 3.1 MetroCard Deposit Data

### Monthly-Aggregate Deposit Data

The MetroCard monthly revenue data from January 2009 to June 2015 include information on the number of deposit transactions (new sales versus refills) as well as total in-system MetroCard purchase amounts, broken out for various types of MetroCards [6].

### Transaction-level Deposit Data

The transaction-level MetroCard deposit data[7] cover all deposit transactions for the following periods: 1) May 1, 2009 - September 30, 2009; and 2) January 1, 2013 - May 31, 2015. Each observation corresponds to a MetroCard deposit transaction and includes information on the amount of money added to the card, the station at which the card was purchased, the date and time of purchase, the type of deposit, the method of payment, and the balance of the card before the transaction. This data also include information on whether the transaction took place at a booth station or at a vending machine.

## 3.2 MetroCard Swipe Data

### Transaction-level Swipe Data

The transaction-level swipe data[8] cover all MetroCard swipe transactions from January 1, 2013 to May 31, 2015. Each observation corresponds to a MetroCard swipe transaction and includes information on the amount of money deducted from the card, the station or bus route at which the card was swiped, the date and time of card swipe, and the balance of the card before the transaction.

[6] Pay-per-ride, 7-day-unlimited, 30-day-unlimited, 7-day-unlimited Express, single-ride, reduced-fare seniors and disabled, etc.

[7] This dataset includes deposit transactions from the 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 Nassau Inter-County Express systems; the PATH subway system; the Roosevelt Island Tram; AirTrain JFK; and Westchester County's Bee-Line Bus System

[8] This dataset includes MetroCard swipe transactions from the 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 Nassau Inter-County Express systems; the PATH subway system; the Roosevelt Island Tram; AirTrain JFK; and Westchester County's Bee-Line Bus System

**Weekly-Aggregate Swipe Data**

This data set includes the total number of MetroCard swipes riders made each week as they entered each station of the New York City Subway, PATH, AirTrain JFK and Roosevelt Island Tram from January 2011 to December 27, 2019, broken out for various types of MetroCards.

### 3.3 MetroCard Trade-in and Trade-out Data

Riders can transfer money in (trade-in) and out (trade-out) across different MetroCards they own. Also, riders can trade in their old cards that expired within the past two years and transfer any remaining money to a new card. This data set includes all trade-in and trade-out transactions from January 1, 2013 to May 31, 2015, which allows me to link multiple cards to the same rider. I can then compare changes in deposit amounts and foregone balances on cards initially purchased before and after the implementation of the new card fee by the same rider.

## 4 Main Findings

The main empirical findings are summarized in Table 2. In particular, riders purchase MetroCards with much larger deposit amounts after the imposition of the new card fee. Consequently, the monthly outstanding balance of deposits and forgone balances on expired cards jump up significantly.

### 4.1 New MetroCard Sales Dropped After the New Card Fee was Introduced

Table 3 shows the monthly new MetroCard sales from January 2009 to June 2015. After the implementation of the new card fee, the monthly new MetroCard sales dropped from over 7 million to about 2 million and stayed low. This drop in sales is very robust across different subgroups: the monthly sales of new pay-per-ride cards decreased from 5.8 million to 1.8 million; the monthly sales of new 30-day-unlimited cards decreased by about 75% to 0.15 million; and the monthly sales of new 7-day-unlimited cards decreased by over 1.2 million to 0.34 million.

Figure 3 plots the monthly new MetroCard sales from January 2009 to June 2015. This figure shows that new MetroCard sales dropped immediately and stayed low after the imposition of the new card fee, confirming the summary statistics in Table 3. I replicate this analysis using transaction-level deposit data in Figure 4. This figure plots the daily new MetroCard sales from January 1, 2013 to April 30, 2013. The MTA sold about 200 thousand new MetroCards each day before the new card fee was introduced. This estimate dropped immediately to about 130 thousand on the first day the new card fee was implemented and further decreased gradually over the next two months. Similar results are observed for all three MetroCard subgroups (Figure 5-7).

**Regression-Discontinuity Approach**

Since there was no significant sorting of MetroCard sales around the date when the MTA implemented the new card fee, I estimate the effect of the new card fee with a regression discontinuity (RD) design. Under some mild regularity conditions, the average causal effect of the new card fee on MetroCard sales just before and just after the new card fee could be identified. There was no discontinuity in ridership or other covariates around the implementation date of the new card fee.

Assuming a homogeneous effect of the new card fee on MetroCard sales with one cutoff date:

$$Y_t = \beta + \gamma \mathbb{1}\{t \geq t_0\} + a(t) + X_t + u_t, \tag{1}$$

where $t$ is the indexed date, $Y_t$ denotes the new MetroCard sales on day $t$, $t_0$ was the distinct cutoff point (i.e., March 3, 2013), $a(.)$ is a flexible function of date, *X* is a set of controls including day-of-week and month-of-year fixed effects. The coefficient of interest is $\gamma$ which measures the effect of the new card fee on daily new MetroCard sales.

I present estimates using the analog of the Calonico et al. (2014) bandwidth selectors for sharp RD. Similar estimates are observed under alternative bandwidth selectors based on the Imbens and Kalyanaraman (2012). In the baseline specifications, I use local quadratic regression (a local polynomial of order two) for $a(.)$. Across specifications, the estimated effect of the new card fee from both local linear and local quadratic regressions corroborate the visual evidence.

Table 4 presents the results for the effect of the new card fee on daily new MetroCard sales, using different control variables in each specification. The model in column 2 controls for day-of-week fixed effects. The results show that the implementation of the new card fee caused a decrease of 125,000 (70%) in daily new MetroCard sales. To account for the possibility of variations in MetroCard sales across different months, my preferred specification in column 3 includes month-of-year fixed effects. As with the other controls, the addition of month-of-year fixed effects has little impact on the estimated effect of the new card fee.

Using this preferred specification, Table 5 includes measures of daily new card sales for 7-day-unlimited cards, 30-day-unlimited cards, and pay-per-ride cards in response to the implementation of the new card fee. The imposition of the new card fee led to a decrease of 120,000 (65%) in daily new pay-per-ride MetroCard sales, a decrease of 23,000 (73%) in daily new 7-day-unlimited MetroCard sales, and a decrease of 24,000 (75%) in daily new 30-day-unlimited MetroCard sales.

## 4.2 Deposits to MetroCards Increased Significantly

After the MTA imposed the new card fee, riders who purchased new MetroCards, on average, made larger deposits. The imposition of the new card fee led to a decrease in the percentage of riders who made deposits of approximately \$5 by about 40% and an increase in the percentage of riders who made deposits of approximately \$10 and \$20 by about 35% (Figure 12a and Figure 13a). I check the robustness of the findings by limiting my focus to deposit transactions within one week before and after the imposition of the new card fee. The same changes in deposit amounts are observable (Figure 12b and 13b). As a result, monthly revenue jumped up by 9.4%, from around \$160 million to \$175 million after the implementation of the new card fee (Figure 11a). This increase in monthly revenue becomes more noticeable when looking at year-on-year monthly revenue (Figure 11b).

I then use equation (1) to evaluate the effect of the new card fee on deposits. Table 6 presents the results for the effect of the new card fee on deposit amounts on new pay-per-ride purchases from January 1, 2013, to April 30, 2013, using different control variables in each specification. The model in column 3 controls for day-of-week fixed effects. The results show that the implementation of the new card fee caused a increase of \$1.64 in deposit amounts on new pay-per-ride purchases. Riders, on average, make larger deposits during morning and evening rush hours. To account for the possibility of variations in deposit amounts across different neighborhoods, my preferred specification in column 4 includes station fixed effects. The addition of station fixed effects causes the estimated effect of the new card fee to be smaller, which indicates that there is heterogeneity in deposit amounts across different neighborhoods.

## 4.3 Changes in the Outstanding Balance of Deposits

Because of the significant increases in deposit amounts, the monthly outstanding balance of deposits made to pay-per-ride MetroCards unexpectedly jumped by about one-third, from around \$35 million to over \$45 million, after the imposition of the new card fee (Figure 8). The aggregate monthly outstanding balance that riders carry on their MetroCards is defined as the difference between the total amount loaded on the cards and the reductions caused by swipes at turnstiles[9].

[9]Mathematically, the monthly outstanding balance of deposits is calculated as:

$$Balance_{mi} = \sum deposits * (1 + bonus(\%)) - \sum rides * basefare \tag{2}$$

where $mi$ is month $i$. base fare is \$2.0 for months before February 2008, \$2.25 for months from March 2008 to February 2013, and \$2.5 for months from March 2013 to February 2015.

Theoretically, the monthly outstanding balance of deposits should be calculated as:

$$Balance_{mi} = \sum deposits + \sum bonus - \sum rides * basefare \tag{3}$$

This additional outstanding balance translates to riders lending, on an annual basis, an extra $150 million to the MTA. The outstanding balance showed no significant increase after the fare hikes in 2009 or 2010, nor after the fare hike in 2015. Hence, the observed changes in deposit patterns after the new card fee is not likely driven primarily by the $0.25 base fare increase.

## 4.4 Increases in Forgone Balances on Expired MetroCards

Over $20 million of the increased balances on MetroCards were never redeemed and escheated to the MTA when these cards expired. Each MetroCard is valid for about 18 months after the initial purchase date; inactive balances on cards become assets of the MTA under the category "expired fare revenue" after the expiration date. The aggregate forgone balance (i.e., expired fare revenue) in 2015, from cards initially purchased in late 2013 and 2014, the first year after the new card fee was introduced, increased to $75 million from $52 million, the aggregate forgone balance in 2014.

Figure 9 plots the forgone balances on MetroCards initially purchased between January 1, 2013 and April 30, 2013. This figure shows that the leftover balances on expired MetroCards jumped by about 50%, from around $150,000 to over $250,000 after the imposition of the new card fee, confirming the observed increase in aggregate forgone balances on expired MetroCards.

## 4.5 Heterogeneity in Deposits to New Pay-per-ride Cards: Cards Held for Different Lengths of Time

To explore the heterogeneity in deposit amounts, I examine the deposit patterns on MetroCards held for different lengths of time. Deposits on new pay-per-ride purchases increased tremendously on MetroCards that had no subsequent refill activities. Before the new card fee, about 60% of deposits were $5 or less on pay-per-ride cards that had no subsequent refill activities. After the new card fee, this percentage dropped by half to about 30%, while the percentage of $10 or $20 deposits almost doubled. In contrast, there was only a minor change in deposit amounts on pay-per-ride cards that had subsequent refill activities (Figure 14b).

However, I only have aggregate monthly deposit data and cannot observe bonus amount for each deposit transaction. Hence, the outstanding balance calculated using equation (1) is the upper bound of the outstanding balance for each month. Since the threshold for bonus free rides was much higher ($10) before the new card fee was imposed, the jump in the outstanding balance after the imposition of the new card fee should be even larger.

## 4.6 Heterogeneity in Deposits to New Pay-per-ride Cards and Forgone Balances on Expired Cards: By Payment Methods

With transaction-level MetroCard information, I then examine the heterogeneity in deposit amounts and forgone balances on cards purchased using different payment methods (cash, debit card, versus credit card). The main changes come from cash or debit card payments rather than from credit card payments. Consistent with changes in deposit patterns, forgone balances increased significantly on MetroCards initially purchased by cash or debit cards rather than by credit cards (Figure 16b, 16d, and 16f). For credit card payments, there was only a slight increase in deposit amounts and forgone balances after riders are charged a fee for purchasing a new MetroCard (Figure 16e and 17c). In contrast, the percentage of riders who made cash deposits of approximately \$10 or \$20 increased significantly, from 33% to 63%. The percentage of riders who made cash deposits of approximately \$5 dropped by about one-third (Figure 16a and 17a). For debit card payments, the percentage of riders who made deposits of approximately \$10 or \$20 increased significantly from 46% to 63%. The percentage of riders who made deposits of approximately \$5 dropped by about half (Figure 16c and 17b).

### 4.6.1 Changes in Deposit Amounts Across Different Neighborhoods

The Survey of Consumer Finances (SCF) indicates that it is primarily the poor who use cash in the US (Bricker et al. (2014); Kennickell and Kwast (1997)). To test whether this is true in the case of MetroCards, I link deposit data in different subway stations to local census tract income data. As shown in Figure 18, low-income neighborhoods have a much higher percentage of cash payments compared to high-income neighborhoods. This finding is in line with other studies on cash usage across different socioeconomic groups (Klee (2006); Feudner (2011)).

Since the increase in deposit amounts and forgone balances mainly came from cash or debit-card payments, the new card fee may nudge low-income riders to load more money onto their cards. Controlling for station-level covariates, I use a regression framework to evaluate the effect of new card fee on deposit amounts across different neighborhoods. The empirical model takes the following forms:

$$Y = \theta_0 + \theta_1 \textit{Surcharge} + \theta_2 \textit{Income} + \theta_3 \textit{Surcharge*Income} + \lambda X + \epsilon$$

where *Y* is the deposit amount for pay-per-ride cards, and *Surcharge* is an indicator for observations after the implementation of the new card fee. *Income* represents log-income at the census-tract level. *X* is a set of controls such as day-of-week fixed effects. The coefficient of interest is $\theta_3$, the coefficient on the interaction of *Surcharge* and *Income*, which measures the effect of local income level on changes in deposit amounts after the new card fee relative to changes in deposit amounts before the new card fee.

Table 7 presents the results for the effect of the new card fee on deposit amounts using MetroCard transactions from January 1, 2013 to April 30, 2013. After the implementation of the new card fee, change in deposit amounts is larger in poorer neighborhoods. Meanwhile, there are no significant changes in ridership across different neighborhoods before and after the new card fee (Table 8). These results indicate that the new card fee induces poor riders to make larger deposits on new MetroCard purchases and lose more balances on expired cards. This is not surprising because riders from richer neighborhoods already made large deposit amounts on their MetroCards before the new card fee was imposed.

# 5 Model

I present a simple rational model that highlights card carrying costs and estimate this model using my observational data. A rider is assumed to take two rides (a round-trip) or no rides each day. The base fare for a ride is $p$. Each rider is assumed to live in New York City for the next n-day time period ($n \in (0, \inf)$). The card fee for purchasing a new MetroCard is $T$. The discount factor is ignored since the time horizon is small.

For rider $i$, the average cost of each deposit (e.g., the opportunity cost of waiting in line to add money to the card, the expected opportunity cost of missing a train in station, etc) is $c_i$. I assume that $c_i$ is independent of time. This is a reasonable approximation since the main policy change that concerns this paper is the imposition of a card fee on new MetroCard purchases and riders can add money to their cards during non-rush hours to avoid mammoth lines at MetroCard vending machines.

Among riders, latent $c_i$ is normally distributed censored at zero: $N_c \sim (\mu_c, \sigma_c)$. Rider $i$ incurs a utility cost $e_i$ to remember to carry the same MetroCard to the next day (Homonoff 2018). Latent $e_i$ is normally distributed censored at zero among riders: $N_e \sim (\mu_e, \sigma_e)$. (Throughout the paper, I use the parameters of the pre-censoring distributions to describe the censored distributions.) The correlation, $\rho_{c,e}$, between $e_i$ and $c_i$ is assumed to be zero since $c_i$ largely depends on rider $i$'s opportunity cost of time while $e_i$ depends on rider $i$'s mental cost to be well-organized (Anderson et al. 2017; Cohen and Gollwitzer 2008; Piauilino et al. 2010; Smith 2003).

We start observing riders on day 1 when they are about to take a round-trip. On each day but the first, $q_i$ is the probability of taking a round-trip for rider $i$. Among riders, latent $q_i$ is normally distributed censored at zero and one: $N_q \sim (\mu_q, \sigma_q)$. Given that realization of $q_i$, demand for trips is inelastic. I assume that $q_i$ is independent of the price of a subway ride. This is a reasonable approximation for the changes I study because the main policy change that concerns this paper is the imposition of a card fee on new MetroCard purchases. $N_i$ denotes the number of rides that rider $i$ actually takes. Hence, $N_i$ is distributed binomially with parameters $2n$ and $q_i \sim B(2n, q_i)$.

On day $t$, rider $i$ decides whether or not to incur cost $C_{it}$ to make a deposit amount $D_{it} \in [0, 2np]$ to her MetroCard. Let $C_{it} = 1$ if she decides to do so (i.e., if $D_{it} > 0$) and $C_{it} = 0$ otherwise (i.e., if $D_{it} = 0$). The delivery of fares is immediate. Also, rider $i$ decides whether or not to exert effort $E_{it} \in \{0, 1\}$ to remember to carry the same card to the next day. Rider $i$ incurs utility cost $e_i$ if she exerts effort (i.e., $E_{it} = 1$).

The marginal utility of a subway or bus ride for rider $i$ on day $t$ is $r_{it}$. Assume riders are risk neutral and they have quasilinear utility. The marginal value of a dollar is normalized to one. Rider $i$'s money-metric utility from riding subways and buses on day $t \geq 2$ is:

$$U_{it} = q_i(r_{it} - D_{it} - E_{it}e_i - C_{it}c_i - T(1 - E_{i,t-1})) \tag{4}$$

When purchasing a new MetroCard with card fee $T$ and taking two rides in day 1, rider $i$'s objective is to choose a fare deposit policy $\{D_{it}, E_{it}, C_{it}\}$ that minimizes the expected total cost:

$$E[\min_{\{D_{it},E_{it},C_{it}\}}(D_{i,1} + E_{i,1}e_i + C_{i,1}c_i + T + \sum_{t=2}^{n} q_i(D_{it} + E_{it}e_i + C_{it}c_i + T(1 - E_{i,t-1})))] \tag{5}$$

## 5.1 Modeling Response of New MetroCard Purchases to the New Card Fee

When will riders choose to carry the same MetroCard to the next day when the card balance is zero (i.e., when will riders choose to refill the same card)? Table 9 below outlines the conditions under which a rider would choose to keep the MetroCard when card balance is zero. Without a new card fee, a rider discards her MetroCard when card balance is zero if $e_i > 0$ (i.e., if a rider has to incur a utility cost to remember to carry the same card to the next day). With a new card fee, a rider keeps the same card when card balance is zero if the loss in utility from paying the new card fee is larger than the cost to remember to carry the same card to the next day.

## 5.2 Optimal Strategy: Prepay versus No Prepay

To begin the analysis, I look at the case of $n = 2$. When $n = 2$, a rider makes the decision whether to prepay for rides in the second day or not. Table 10 outlines the conditions under which a rider would prepay for rides in the second day. Without a new card fee, a rider would prepay for future rides if the cost to make deposits is larger than the cost to remember to carry the same card to the second day and the risk of losing prepaid rides fare. With a new card fee, a rider would prepay for future rides only if the cost to make deposits and the cost of the new card fee are larger than the cost to remember to carry the same card to the second day and the risk of losing prepaid rides fare.

Figure 19 shows the threshold of prepaying for rides in the second day when no card fee is imposed (Figure 19a) and when a card fee is imposed (Figure 19b), respectively. With no card fee, riders in region $C$ only deposit the fare of the first day rides since the cost to make deposits in the second day is smaller than the cost to remember to carry the same card to the second day and the risk of losing prepaid rides fare. After the new card fee is imposed, these riders switch to prepaying for the second day rides as the cost to make deposits and the cost of the new card fee are larger than the cost to carry the same card to the second day and the risk of losing prepaid rides fare. As a result, they lose $2p$ on expired MetroCards if they do not actually take rides in the second day (Table 11).

### 5.2.1 Tourists versus Local Residents

The model developed above supports the observation that major changes in deposit amounts and forgone balances came from MetroCards purchased by local residents rather than from MetroCards purchased by tourists. Visitors are likely to have low probability of taking rides in the second day (i.e., small $q_i$). Also, visitors may have low costs to make deposits to their MetroCards (i.e., small $c_i$) since they may not realize they are missing a train or they are on vacation so their time is not very valuable. To these visitors, the cost to make deposits and the cost of the new card fee are smaller than the cost to carry the same card to the next day and the risk of losing prepaid rides fare if they do not actually take rides in the second day. Therefore, visitors are not likely to increase their deposits after the new card fee is imposed.

Local residents, in contrast, have high probability of taking rides in the second day (i.e., large $q_i$). Also, their costs to make deposits to their MetroCards are likely to be high (i.e., high $c_i$) since their opportunity cost of missing a train and being late for work is high. To local residents, the cost to make deposits and the cost of the new card fee are larger than the cost to carry the same card to the next day and the risk of losing prepaid rides fare if they do not actually take rides in the second day. As a result, local residents are more likely to increase their deposits after the new card fee is imposed.

### 5.2.2 n=3 Case

In line with the $n = 2$ case, when $n = 3$, riders in region $D$ switch from only depositing the fare of the first day rides to prepaying for rides in the second day after the new card fee $T$ is introduced. Riders in region $E$ switch from prepaying for rides in the second day to prepaying for rides in the second and third day after the new card fee is imposed (Figure 20b). Forgone balances on expired cards will increase accordingly.

## 5.3 n=30 Case

Since frequent riders would purchase 30-day passes instead of pay-per-ride cards, I focus on the $n = 30$ case in the following analysis. When $n = 30$, according to the model, there should be thirty regions ranging from no prepay for future rides to prepay for rides in the next 29 days (Figure 21). In reality, riders either choose the "other amount" option and manually enter \$4.5 (or \$5) as the desired deposit amount, or choose one of the payment prompts (i.e., suggested deposit amounts) on Touchscreen (Figure 22a and 22c). Therefore, there should be four regions as in Figure 23a and Figure 23b, corresponding to the "other amount" choice, "the first default choice", "the second default choice", and "the third default choice", respectively.

Therefore, instead of $D_{it} \in [0, 2np]$, rider $i$ makes choice of deposit amount $D_{it} \in \{5, 10, 20, 40\}$ to her new MetroCard. When purchasing a new MetroCard with card fee $T$ and taking two rides in day 1, rider $i$'s objective is to choose a fare deposit policy $\{D_{it}, E_{it}, C_{it}\}$ that minimizes the expected total cost:

$$E[\underset{D_{it}\in\{5,10,20,40\},E_{it},C_{it}}{min}(D_{i,1}+E_{i,1}e_i+C_{i,1}c_i+T+\sum_{t=2}^{n}q_i(D_{it}+E_{it}e_i+C_{it}c_i+T(1-E_{i,t-1})))] \quad (6)$$

When riders are charged a fee for purchasing a new MetroCard, riders in region $A'$ switch from choosing "other amount" choice to the first suggested deposit amount (\$10); riders in region $B'$ switch from the first suggested deposit amount to the second suggested deposit amount (\$20); riders in region $C'$ switch from the second suggested deposit amount (\$20) to the third suggested deposit amount (\$40) (Figure 23c). Consistent with the predictions of the model, the number of deposits in suggested amounts jump up significantly after the new card fee is imposed (Figure 24)

## 5.4 Parameter Estimates

I use equation (6) to calculate the thresholds of the four regions in Figure 23a and Figure 23b, corresponding to the "other amount" choice, "the first default choice", "the second default choice", and "the third default choice", respectively. I then use changes of deposits in suggested amounts (table 12) to calibrate the values of three groups of unobservables that must be integrated out: individual specific unobserved heterogeneity, including $e_i$, $c_i$, and $q_i$. Computational difficulties in estimation mainly come from the model's high dimensional unobserved heterogeneity which requires many evaluations of the likelihood function.

As shown in Table 12, our model does a good job of fitting shares of deposit choices before and after the card fee went into effect. Before the new card fee was imposed, for the share of the first suggested deposit amount ($10) on cards with no subsequent refill activities, we predict to be 21.63 percent and is observed to be 22.91 percent. For the share of the second suggested deposit amount ($20) on cards with no subsequent refill activities, we predict to be 13.07 percent and is observed to be 9.46 percent. After the new card fee was imposed, for the share of the first suggested deposit amount ($10) on cards with no subsequent refill activities, we predict to be 39.64 percent and is observed to be 37.71 percent.

The estimates for the six parameters discussed in the main text are shown in Table 13. Recall that the parameters of the pre-censoring distributions are used to describe the censored distributions. The six parameters characterize the normal distribution of riders' riding probability $q_i$, cost to make deposits to MetroCards $c_i$, and card carrying cost $e_i$. The average riders' riding probability $q_i$ is estimated to be 0.62. The average riders' cost $c_i$ is estimated to be \$1.45, while the average riders' card carrying cost $e_i$ is \$0.83. The population standard deviations of $q_i$, $c_i$, and $e_i$ ($\sigma_q$, $\sigma_c$, and $\sigma_e$) are 0.34, \$0.56, and \$0.53, respectively.

## 5.5 Counterfactual Analysis

### 5.5.1 Fixed Price Counterfactual: Impact of Default Choices

The MTA has been criticized for the payment prompts (i.e., default choices of deposit amounts) on TouchScreen of MetroCard vending machines. The payment prompts do not give exact number of rides: If a rider chooses one of the payment prompts on Touchscreen, she will end up with a card that has leftover amount because none of the suggested amounts (a $9.00 MetroCard with a $.45 bonus, a $19.00 card with a $.95 bonus, or a $39.00 card with a $1.95 bonus) are divisible by $2.50, the base fare for subway rides.

Some people have proposed a software change as shown in Figure 27. Now all the payment prompts on Touchscreen give exact number of rides: a $9.55 MetroCard with a $.48 bonus gives exactly 4 rides, a $19.05 card with a $.95 bonus gives 8 rides, while a $38.10 card with a $1.91 bonus gives 16 rides.

I simulate the change in expired fare revenue that results from the introduction of the $1 new card fee with these new payment prompts while holding base fare constant. I construct this counterfactual simulation in the sense that I hold fixed the number of riders and their riding patterns. The model predicts that, even with all the payment prompts giving exact number of rides, expired fare revenue would still increase by 41.84% ($21.76 million)

### 5.5.2 Optimal New Card Fee

I simulate the optimal amount of new card fee that maximizes the MTA's profit while holding the payment prompts on Touchscreen and base fare for subway and bus rides constant. I construct this counterfactual simulation in the sense that I hold fixed the number of riders and their riding patterns. The model predicts that the optimal amount of new card fee is $4.35.

# 6 Alternative Mechanisms

This paper provides evidence of the impacts of the new card fee that is consistent with a rational model highlighting the cost of effort to carry the same MetroCard for future rides, the cost to add money to MetroCards, and rider uncertainty about future rides. However, cost of carry is not the only possible explanation for the observed increases in deposit amounts and forgone balances on expired cards. This section investigates other potential theories or mechanisms that might explain the results described above.

## 6.1 Persuasion

The screens of vending machines show three suggested deposit amounts ($10, $20, $40), along with bonuses. This could potentially nudge riders to make higher deposit amounts. However, the screen displays the same $10 and $20 suggested amounts before and after the card fee went into effect; only the third suggested amount changed from $50 to $40 (Figure 22a and 22c). Since the main changes in deposit amounts were from $5 to $10 and $20, persuasion, solely, is not likely to account for the observed changes in new purchases.

## 6.2 Avoidance of Coins

When riders add money to MetroCards using cash at vending machines, they may receive as many as 20 quarters (i.e., $4) as change if they purchase new cards with a $10 bill and only make a deposit of round-trip fare to the card (i.e. $10 - $5 fare cost - $1 new card fee). If some riders prefer not to have a lot of coins as change, they may start adding $10 or $20 cash deposits to new pay-per-ride cards at vending machines.

However, this explanation, solely, cannot explain the changes observed in debit card payments. Before the new card fee, more than 30% of riders made only $5 deposits (round-trip fare) when they purchased new pay-per-ride MetroCards (Figure 16c). Since $5 has never been one of the suggested deposit amounts on the screen, this means that many riders used to hit the "other amount" option and manually enter $5 as the desired deposit amount. These riders can still choose the "other amount" option and manually enter $6 ($5 fare + $1 new card fee) after the new card fee. But the percentage of $5 deposits dropped to below 20% after the new card fee (Figure 16c).

### 6.3 Quick Fix

Some riders may want to make larger deposits when purchasing new cards because larger deposits could minimize (or alleviate) the perceived cost of the new card fee. For instance, riders may want to compensate for the absolute monetary cost of the new card fee by bonuses on pay-per-ride deposits. The existence of a quick fix can largely explain why larger increases on new card purchases were mainly on cards that had no subsequent refill activities: Before the new card fee, more than 60% of the deposits on new cards that had no subsequent refill activities were $4.50 (the fare of a round-trip) while more than 70% of the deposits on new cards with subsequent refill activities were already at least $10 or $20.

However, this mechanism is not likely to explain the persistent increase in deposit amounts on new cards and forgone balances on expired cards. If riders only increased their deposit amounts to alleviate the perceived cost of the new card fee but did not incur utility cost to keep the same card, their forgone balances on lost or expired cards would increase. Over time, they shall decrease their deposit amounts back to the pre-fee level. However, I did not observe significant decrease in deposit amounts or forgone balances in the several years after the introduction of the new card fee.

### 6.4 Commitment Device

Many riders may use larger deposits as a means to push themselves to remember to carry the same card and avoid paying the new card fee. As the forgone balances on expired cards increased by 50%, the larger deposits is clearly a failed commitment device. Literature shows that people stop using a commitment device that does not work (Brocas and Carrillo 2001; Carrillo and Mariotti 2000; Vigna and Malmendier 2006). If this explanation is the primary one, we should see deposits bounce back to lower level. However, no significant decrease in deposit amounts or forgone balances was observed in the several years after the introduction of the new card fee.

## 7 Robustness tests

In this section, I perform several robustness tests to further validate the explanations for the findings.

## Sample

The same results remain no matter I use the whole sample or sub-samples (e.g., one week before and after the implementation of the new card fee, or randomly picked stations).

## Minor Decrease in Ridership

There was only a minor decrease in ridership after the introduction of the new card fee (Figure 10).

## Cross-type switches in MetroCard purchases

One concern with interpreting changes in deposit patterns as a response to the new card fee is that there may be cross-type switches from pay-per-ride cards to unlimited-ride cards or single-ride tickets due to the variations in fare hikes across different types of MetroCards.

Table 16 lists monthly revenue before and after the new card fee. There was no significant change in the percentage of revenue from pay-per-ride cards versus that from time-based cards. Table 14 and Table 15 show that the threshold of switching from pay-per-ride cards to unlimited-ride cards barely changed after the fare hikes in March 2013. This suggests that differences in fare hikes across different types of MetroCards are unlikely to be driving these results. These findings confirm that there is minimal cross-type switching.

### Cross-type Switch from Pay-per-ride cards to Single-ride Tickets

A seemingly reasonable implication from the imposition of the new card fee is that the sales of single-ride tickets are likely to rise since some riders may switch from pay-per-ride cards to single-ride tickets, especially when they forget their regular MetroCards but need to take a round trip. However, monthly sales of single-ride tickets actually decreased after the new card fee went into effect (Figure 28).

### Cross-type Switch from Pay-per-ride Cards to Time-based Cards

Table 14 compares costs of trips using pay-per-ride cards versus 7-day-unlimited cards. The red oval circles mark the threshold number of trips needed to switch from pay-per-ride to 7-day-unlimited before versus after the new card fee implementation. Before the new card fee, a rider would only save more money buying a 7-day-unlimited card than buying a pay-per-ride card if she takes more than 14 trips within one week. After the new card fee, this threshold became 13, only decreasing by one trip.

Table 15 compares costs of trips using pay-per-ride versus 30-day-unlimited cards. The red oval circles mark the threshold number of trips needed to switch from pay-per-ride to 30-day-unlimited before versus after the new card fee implementation. Again, the threshold of switching from pay-per-ride to 30-day-unlimited cards only slightly changed after the fare hikes in March 2013.

### No Significant Increases in Deposit Amounts Before versus After the Fare Hikes in 2009 or 2015

There may be some concern that changes in deposit patterns are solely due to the fare hike in 2013. Figure 31 and 32 plots the histogram for deposits on pay-per-ride cards before and after the fare hike in 2009 and 2015, respectively. For both new and refill purchases, there were barely any changes in deposit amounts. Hence, the observed changes in deposit patterns after the new card fee was not likely driven primarily by the $0.25 base fare increase.

# 8 Implications of the Findings

In this section, I discuss implications of the findings developed above. My evaluation of new card fee on MetroCard purchases could be insightful in other contexts, such as mobile and online prepaid services as well as general purpose reloadable prepaid cards.

## 8.1 Mobile and Online Prepaid Services

The cost of effort to carry the same card ($e_i$) and the cost to add money to cards ($c_i$) highlighted in this model may explain the prevalence of required minimum deposit amounts in the online or mobile prepaid services such as E-ZPass and Skype. When authorities or firms adopt online or mobile payments with an automatic deduction from bank accounts or credit cards, riders' cost to add money $c_i$ and cost of carry $c_i$ converge to zero. As a result, consumers switch from prepaying for future consumption to paying only for consumption in current period (pay-as-you-go). To maintain the benefit from unused account balances, most online or mobile prepaid services providers have required minimum deposit amounts and use suggested deposit amounts to attract even more funds. For skype credit, the minimum purchase amount is $10 (Figure 33a) and consumers can only select from $10 or $25 to buy.

### 8.2 General Purpose Reloadable Cards

Findings in this model are consistent with findings in the prepaid card industry. Currently, over 23 million U.S. adults use general purpose reloadable cards such as green dot cards each month. Consumers loaded $672 billion on these cards in 2013. Since most general purpose reloadable card users are low-income and excluded from the financial mainstream, they do not have other banking options (Urahn et al. 2014). Most card companies charge a new card fee (or card activation fee) as high as $9.95. When a prepaid card issuer has market power, a new card fee (or card activation fee) could push consumers to prepay more for future consumption.

## 9 Discussions and Conclusions

How do consumers respond to the imposition of a new card fee? In this paper, I show how a new card fee for prepaid transit cards induced riders to put more money on cards and lose more when these cards expired. I present a novel transaction-level data set from the public transit system in New York City that allows me to analyze changes in deposit amounts and forgone balances on expired cards. After the introduction of a $1 new card fee, the net monthly outstanding balance of transit card deposits increased dramatically, with riders lending an extra $150 million, on an annual basis, to the MTA. Moreover, over $20 million of the increased balances were never redeemed and escheated to the MTA when these cards expired.

There are five main empirical findings regarding changes in deposit amounts and forgone balances on expired cards. First, the changes largely came from new card purchases, not from refills. Second, the changes were mainly from new cards with no subsequent refill activities, not from cards that showed subsequent refill activities. Third, the changes mainly came from cash or debit card payments rather than from credit card payments. Fourth, among cash payments, the changes were mostly from payments made at vending machines rather than from payments made at manned booths (tellers). Fifth, the response to the new card fee was larger in low-income neighborhoods than in high-income neighborhoods.

One leading explanation highlights the cost of effort to carry the same MetroCard for future rides, the cost to add money to MetroCards, and rider uncertainty about future rides. When MetroCards were free, riders with a low cost of making deposits to MetroCards deposited only a small amount of money on cards and purchased a new MetroCard each period if needed. They chose not to incur the cost of effort to carry the same card for future days. After the new card fee was imposed, many riders switched to refilling existing cards since their card carrying costs were smaller than the new card fee. They started making larger deposits to save on the cost of making deposits to cards. Because riders are uncertain about future rides, these riders on average had higher forgone balances after the card expiration dates.

The results of this study are likely to generalize to 8.3 million Americans who use public transit to go to work. 10.65 billion passenger trips were taken on transit systems in 2013 (American Public Transportation Association 2014). Therefore, both in terms of monetary magnitude and in terms of population involved, the new card fee on transit card has a significant economic impact. These findings are also consistent with findings in the prepaid card industry. Since most general purpose reloadable card users are low-income and excluded from the financial mainstream, they do not have other banking options (Urahn et al. 2014).

These findings also have implication about regressive ways to raise money. Mainly due to data limitations, studies on regressive fees focus on the portion of fee revenue collected from low-income people. Here I provide evidence that whether or not the card fee itself is regressive, it may push low-income consumers to behave in ways that cost them money, especially in monopolistic market. The authorities should take into consideration the possible additional responses from low-income people when imposing a fee.

Findings in this paper predict that riders' cost to add money to cards and cost of carry converge to zero with mobile payments and automatic deductions from bank accounts or credit cards. As a result, riders will switch from prepaying for future rides to paying only for rides in this period (pay-as-you-go). A natural follow-up works is to track changes in expired fare revenue after the New York MTA completes contactless payments rollout in 2021 and phase Out MetroCard in 2023.

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_ , "Pricing in Urban and Suburban Transport," *American Economic Review*, 1963, *53*, 452–465.

**Vigna, Stefano Della and Ulrike Malmendier**, "Paying not to go to the gym," *The American Economic Review*, 2006, *96* (3), 694–719.

Table 1: Recent History of MTA Policy Changes

| Date | Jun 28, 2009 - Dec 29, 2010 | Dec 30, 2010 - Mar 2, 2013 | Mar 3, 2013 - Mar 21, 2015 | Mar 22, 2015 - Mar 18, 2017 |
|---|---|---|---|---|
| Base fare ($) | 2.25 | 2.25 | 2.50 | 2.75 |
| 7-day-unlimited ($) | 27 | 29 | 30 | 31 |
| 30-day-unlimited ($) | 89 | 104 | 112 | 116.50 |
| Single-ride tickets ($) | 2.25 | 2.50 | 2.75 | 3.00 |
| $1 Card Fee on new MetroCard purchase | No | No | Yes* | Yes |
| Bonus for Pay-Per-Ride, %(threshold) | 15%($8) | 7%($10) | 5%($5) | 11%($5.50) |

* The main policy change that concerns this paper is the imposition of $1 card fee on new MetroCard purchases.

Table 2: Empirical Findings And Possible Explanations

| After the new card fee | Persuasion of Machine Screen Info | Avoidance of Coins | Quick Fix | Commitment Device | Cost of Carry |
|---|---|---|---|---|---|
| Finding 1<br>A large drop in the number of new MetroCard sold | Yes | Yes | Yes | Yes | Yes |
| Finding 2<br>Monthly outstanding balance of pay-per-ride deposits jumped by 1/3 | No | Yes | Yes | Yes | Yes |
| Finding 3<br>Increases in expired fare revenue | No | Yes | Yes | Yes | Yes |
| Finding 4<br>No decrease in deposit amounts or forgone balances over time | Yes | No | No | No | Yes |
| Finding 5<br>Increase in deposit amounts on new purchases | No | Yes | Yes | Yes | Yes |
| Finding 6<br>Larger increase in deposits on cash or debit card payments | No | No | Yes | Yes | Yes |
| Finding 7<br>Larger increase in deposits on cards with no subsequent refill activities | No | Yes | Yes | Yes | Yes |
| Trivial change in deposit amounts on cards with refill activities | No | No | Yes | Yes | Yes |

Table 3: Monthly New Card Sales Before And After the New Card Fee (In millions)

| | **Before (Jan 2009 to Feb 2013)** | | **After (Mar 2013 to Jun 2015)** | | |
|---|---|---|---|---|---|
| | **Number (1)** | **Percent (2)** | **Number (3)** | **Percent (4)** | ***p-value* (5)** |
| Total | 7.70 | 1 | 2.32 | 1 | |
| | (0.55) | | (0.39) | | |
| Pay-per-ride | 5.84 | 0.758 | 1.826 | 0.791 | <0.0001* |
| | (0.47) | (0.011) | (0.28) | (0.01) | |
| 30-day-unlimited | 0.58 | 0.076 | 0.15 | 0.063 | <0.0001* |
| | (0.055) | (0.01) | (0.042) | (0.01) | |
| 7-day-unlimited | 1.26 | 0.163 | 0.339 | 0.144 | <0.0001* |
| | (0.079) | (0.005) | (0.076) | (0.01) | |
| *N* | 104 | 104 | 112 | 112 | |

Standard deviations in parentheses
Table reports mean values of each variable
∗ p-value of mean difference in percent sales before and after the new card fee was implemented.

Table 4: Effect of New Card Fee on Daily Total New MetroCard Sales

| | (1) Sales | (2) Sales | (3) Sales |
|---|---|---|---|
| Card Fee | -125286*** | -124822*** | -163102*** |
| | (6634) | (4975) | (19695) |
| Day of Week FE | No | Yes | Yes |
| Month Fixed Effects (FE) | No | No | Yes |
| Observations | 120 | 120 | 120 |
| $R^2$ | 0.751 | 0.868 | 0.879 |

Outcome variable: total new card sales on daily basis from January 1, 2013 to April 30, 2013

*Note:* Robust standard errors in parentheses.
*+ p < 0.1 * p < 0.05, ** p < 0.01, *** p < 0.001*

Table 5: Effect of New Card Fee on Daily New MetroCard Sales By Different Types of Cards

| | (1)<br>Pay-per-ride | (2)<br>7-day-unlimited | (3)<br>30-day-unlimited |
|---|---|---|---|
| Card Fee | -120825*** | -22733*** | -24305*** |
| | (13076) | (4325) | (4886) |
| Day of Week FE | Yes | Yes | Yes |
| Month Fixed Effects (FE) | Yes | Yes | Yes |
| Observations | 120 | 120 | 120 |
| $R^2$ | 0.906 | 0.854 | 0.554 |

Outcome variable: new card sales on daily basis from January 1, 2013 to April 30, 2013

*Note:* Robust standard errors in parentheses.

*+ p < 0.1 * p < 0.05, ** p < 0.01, *** p < 0.001*

Table 6: Effect of New Card Fee on Deposit Amounts: RD Regressions ($)

| | (1) | (2) | (3) |
|---|---|---|---|
| Card Fee | 1.614*** | 1.644*** | 0.933*** |
| | (0.062 ) | (0.058 ) | (0.011 ) |
| AM Early Hrs | –0.697*** | –0.755*** | –0.235*** |
| (0:01-6:29am) | (0.120 ) | (0.118 ) | (0.014 ) |
| AM Rush Hrs | 0.736*** | 0.574*** | 1.078*** |
| (6:30-10:00am) | (0.102 ) | (0.095 ) | (0.008 ) |
| AM Late Hrs | –0.147*** | –0.170*** | –0.051*** |
| (10:00-1:00pm) | (0.031 ) | (0.031 ) | (0.009 ) |
| PM Rush Hrs | 1.174*** | 1.149*** | 0.741*** |
| (4:30-8:00pm) | (0.060 ) | (0.057 ) | (0.009 ) |
| PM Late Hrs | –0.293*** | –0.246*** | –0.486*** |
| (8:00-11:59pm) | (0.055 ) | (0.054 ) | (0.011 ) |
| Card Fee * AM Early Hrs | 0.494*** | 0.491*** | 0.661*** |
| | (0.067 ) | (0.068 ) | (0.029 ) |
| Card Fee * AM Rush Hrs | 0.379*** | 0.318*** | 0.347*** |
| | (0.034 ) | (0.033 ) | (0.015 ) |
| Card Fee * AM Late Hrs | 0.240*** | 0.232*** | 0.117*** |
| | (0.024 ) | (0.025 ) | (0.016 ) |
| Card Fee * PM Rush Hrs | –0.310*** | –0.333*** | –0.265*** |
| | (0.048 ) | (0.049 ) | (0.016 ) |
| Card Fee * PM Late Hrs | –0.058 | –0.072* | 0.107*** |
| | (0.035 ) | (0.035 ) | (0.021 ) |
| Day of Week FE | No | Yes | Yes |
| Station Fixed Effects (FE) | No | No | Yes |
| Observations | 13260141 | 13260141 | 13260141 |
| $R^2$ | 0.011 | 0.015 | 0.011 |

Dependent variable: deposit amounts at new pay-per-ride purchases. Standard Deviation in parentheses and clustered at station level. The sample is limited to all deposit transactions made to new pay-per-ride MetroCards from January 1, 2013 to Aril 30, 2013. The coefficients reported here are based on default bandwidth with local quadratic described in Calonico et. al(2014).

*+ p < 0.1 * p < 0.05, ** p < 0.01, *** p < 0.001*

Table 7: Median Neighborhood Income and Pay-per-ride Deposit Amounts ($)

| | Total | | New | |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Income(log) | 0.221*** | 0.220*** | 0.245*** | 0.242*** |
| | (0.001 ) | (0.001 ) | (0.001 ) | (0.001 ) |
| Card Fee | 0.129*** | 0.123*** | 0.411*** | 0.404*** |
| | (0.012 ) | (0.011 ) | (0.014 ) | (0.014 ) |
| Card Fee*Income(log) | –0.6*** | –0.5*** | –0.30*** | –0.30*** |
| | (0.001 ) | (0.001 ) | (0.001 ) | (0.001 ) |
| Day of Week FE | No | Yes | No | Yes |
| Observations | 68632976 | 68632976 | 13659758 | 13659758 |
| $R^2$ | 0.015 | 0.020 | 0.015 | 0.020 |

Dependent variable: transaction-level deposit amounts to pay-per-ride MetroCards. The sample is limited to all deposit transactions to pay-per-ride MetroCards from January 1, 2013 to Aril 30, 2013. Standard Deviation in parentheses and clustered at station level.

** p < 0.05, ** p < 0.01, *** p < 0.001*

Table 8: Median Neighborhood Income and Ridership At Station-level

| | Pay-per-ride | | 7-day | | 30-day | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Income(log) | 0.293* | 0.293* | –0.155 | –0.155 | 0.663*** | 0.663*** |
| | (0.115 ) | (0.115 ) | (0.125 ) | (0.125 ) | (0.124 ) | (0.124 ) |
| Card Fee | –0.184 | –0.186 | 0.347 | 0.340 | 0.113 | 0.102 |
| | (0.240 ) | (0.239 ) | (0.279 ) | (0.279 ) | (0.210 ) | (0.210 ) |
| Card Fee*Income(log) | 0.014 | 0.014 | –0.003 | –0.003 | –0.013 | –0.013 |
| | (0.024 ) | (0.024 ) | (0.029 ) | (0.029 ) | (0.021 ) | (0.021 ) |
| Month of year FE | No | Yes | No | Yes | No | Yes |
| Observations | 34132 | 34132 | 34087 | 34087 | 34078 | 34078 |
| $R^2$ | 0.040 | 0.041 | 0.051 | 0.054 | 0.144 | 0.150 |

Dependent variable: weekly rides from different types of MetroCards. The sample is limited to weekly MetroCard swipes from January 2010 to May 2015. Standard Deviation in parentheses and clustered at station level

** p < 0.05, ** p < 0.01, *** p < 0.001*

Table 9: Conditions to Keep a Pay-per-ride MetroCard When Card Balance is Zero

| | Keep the same card for next day | | Condition to Carry the Same Card When Card Balance is Zero |
|---|---|---|---|
| | Save on card fee | Loss on Carrying cost | |
| No Card Fee | 0 | $e_i$ | $e_i = 0$ |
| With Card Fee | $q_iT$ | $e_i$ | $e_i < q_iT$ |

Table 10: Conditions to Prepay for Rides in the Second Day

| | Cost Function | Decision Variables | Condition to Prepay for Rides in the Second Day |
|---|---|---|---|
| With Card Fee | $4p + e_i + c_i$ | $E_{i,1} = C_{i,1} = 1$ *and* $C_{i,2} = 1$<br>$D_{i,1} = 4p$ *and* $D_{i,2} = 0$ | $e_i + (1 - q_i)2p$<br>$< q_ic_i$ |
| | $(1 + q_i)2p + e_i + (1 + q_i)c_i$ | $E_{i,1} = C_{i,1} = C_{i,2} = 1$<br>$D_{i,1} = D_{i,2} = 2p$ | |
| | $(1 + q_i)2p + (1 + q_i)c_i$ | $E_{i,1} = 0$ *and* $C_{i,1} = C_{i,2} = 1$<br>$D_{i,1} = D_{i,2} = 2p$ | |
| With Card Fee | $4p + e_i + c_i + T$ | $E_{i,1} = C_{i,1} = 1$ *and* $C_{i,2} = 1$<br>$D_{i,1} = 4p$ *and* $D_{i,2} = 0$ | If $e_i < q_iT$<br>$(1 - q_i)2p < q_ic_i$<br><br>If $e_i \geq q_iT$<br>$e_i + (1 - q_i)2p$<br>$< q_i(c_i + T)$ |
| | $(1 + q_i)2p + e_i + (1 + q_i)c_i + T$ | $E_{i,1} = C_{i,1} = C_{i,2} = 1$<br>$D_{i,1} = D_{i,2} = 2p$ | |
| | $(1 + q_i)2p + (1 + q_i)c_i + (1 + q_i)T$ | $E_{i,1} = 0$ *and* $C_{i,1} = C_{i,2} = 1$<br>$D_{i,1} = D_{i,2} = 2p$ | |

Table 11: Welfare Analysis: Cost of Rides for $n = 2$ Case

| | No Card Fee | With Card Fee | Changes in Utility |
|---|---|---|---|
| A | $-(c_i + 2p) - q_i(c_i + 2p)$ | $-(c_i + 2p) - e_i - q_i(c_i + 2p)$ | $-e_i$ |
| B | $-(c_i + 2p) - q_i(c_i + 2p)$ | $-(c_i + 2p) - q_i(c_i + 2p + T)$ | $-q_iT$ |
| C | $-(c_i + 2p) - q_i(c_i + 2p)$ | $-(c_i + 4p) - e_i$ | $-e_i - (1 - q_i)2p + q_ic_i$ |
| D | $-(c_i + 4p) - e_i$ | $-(c_i + 4p) - e_i$ | No change |

Table 12: Shares of Deposit Choices (percent)

| | Deposit Amount | No Card Fee | | With Card Fee | |
|---|---|---|---|---|---|
| | | Observed | Predicted | Observed | Predicted |
| Cards With No Refills | Other Amount (˜ \$5) | 66.19 | 64.87 | 39.14 | 31.49 |
| | 1st Default Choice (˜ \$10) | 22.91 | 21.63 | 37.71 | 39.64 |
| | 2nd Default Choice (˜ \$20) | 9.46 | 13.07 | 20.15 | 27.88 |
| | 3rd Default Choice | 1.44 | 0.43 | 3.00 | 0.98 |
| Cards With Refills | Other Amount (˜ \$5) | 37.87 | 40.10 | 32.79 | 36.24 |
| | 1st Default Choice (˜ \$10) | 38.75 | 41.85 | 43.33 | 46.65 |
| | 2nd Default Choice (˜ \$20) | 18.83 | 13.05 | 20.51 | 17.02 |
| | 3rd Default Choice | 4.55 | 5.00 | 3.37 | 0.09 |

Table 13: Parameter Estimates

| Parameter | | Estimate |
|---|---|---|
| $E[q_i]$ | Mean of Probability | 0.62 |
| $\sigma[q_i]$ | Standard Error of Probability | 0.34 |
| $E[c_i]$ | Mean of Cost | 1.45 |
| $\sigma[c_i]$ | Standard Error of Cost | 0.56 |
| $E[e_i]$ | Mean of Carrying Cost | 0.83 |
| $\sigma[e_i]$ | Standard Error of Carrying Cost | 0.53 |

Table 14: Comparison of Rides Costs Pay-per-ride versus 7-day-unlimited

| Rides | Dec 30, 2010 to Mar 2, 2013 7% bonus for every $10 | | Mar 3, 2013 to Mar 21, 2015 5% bonus for every $5 | |
|---|---|---|---|---|
| | Pay-per-ride | 7-day-unlimited | Pay-per-ride | 7-day-Unlimited |
| 1 | 2.25 | 29 | 2.5 | 30 |
| 2 | 4.5 | 29 | 5.0 | 30 |
| ... | ... | ... | ... | ... |
| 12 | 25.23 | 29 | 28.57 | 30 |
| 13 | 27.34 | 29 | 30.95 | 30 |
| 14 | 29.44 | 29 | 33.33 | 30 |

Table 14 compares costs of trips using pay-per-ride versus 7-day-unlimited cards. The red oval circles mark the threshold number of trips needed to switch from pay-per-ride to 7-day-unlimited before versus after the new card fee was implemented.

Table 15: Comparison of Rides Costs Pay-per-ride versus 30-day-unlimited

| Rides | Dec 30, 2010 to Mar 2, 2013 7% bonus for every $10 | | Mar 3, 2013 to Mar 21, 2015 5% bonus for every $5 | |
|---|---|---|---|---|
| | Pay-per-ride | 30-day-unlimited | Pay-per-ride | 30-day-Unlimited |
| 1 | 2.25 | 104 | 2.5 | 112 |
| 2 | 4.5 | 104 | 5.0 | 112 |
| ... | ... | ... | ... | ... |
| 47 | 98.83 | 104 | 111.90 | 112 |
| 48 | 100.93 | 104 | 114.29 | 112 |
| 49 | 103.04 | 104 | 116.67 | 112 |
| 50 | 105.14 | 104 | 119.05 | 112 |

Table 15 compares costs of trips using pay-per-ride versus 30-day-unlimited cards. The red oval circles mark the threshold number of trips needed to switch from pay-per-ride to 30-day-unlimited before versus after the new card fee was implemented.

Table 16: Monthly Revenue Before and After the New Card Fee (In Millions $)

| | **Before (Jan 2011 to Feb 2013)** | | **After (Mar 2013 to Jun 2015)** | |
|---|---|---|---|---|
| | **Value (1)** | **Percent (2)** | **Value (3)** | **Percent (4)** |
| Total | 269.47 | 1 | 310.00 | 1 |
| | (8.82) | | (1.36) | |
| Pay-per-ride | 159.02 | 0.59 | 179.97 | 0.58 |
| | (6.92) | (0.012) | (9.39) | (0.013) |
| New | 53.98 | | 20.68 | |
| | (4.04) | | (2.94) | |
| Refill | 105.04 | | 159.28 | |
| | (4.39) | | (7.63) | |
| 30-day-unlimited | 64.81 | 0.241 | 69.56 | 0.225 |
| | (3.78) | (0.015) | (4.40) | (0.014) |
| New | 60.56 | | 16.68 | |
| | (5.67) | | (4.64) | |
| Refill | 4.25 | | 52.88 | |
| | (3.94) | | (5.90) | |
| 7-day-unlimited | 38.61 | 0.143 | 51.96 | 0.168 |
| | (2.18) | (0.005) | (4.15) | (0.009) |
| New | 36.46 | | 10.17 | |
| | (2.28) | | (2.26) | |
| Refill | 2.15 | | 41.79 | |
| | (2.01) | | (4.71) | |
| Reduced fares | 5.63 | 0.022 | 6.91 | 0.021 |
| | (0.25) | (0.001) | (0.40) | (0.001) |
| *N* | 104 | 104 | 112 | 112 |

Standard deviations in parentheses
Table reports mean values of each variable
Table 16 shows monthly revenue from sales of different types of MetroCards before and after the new card fee. There was no significant change in the percent of revenue from pay-per-ride cards versus that from time-based cards.

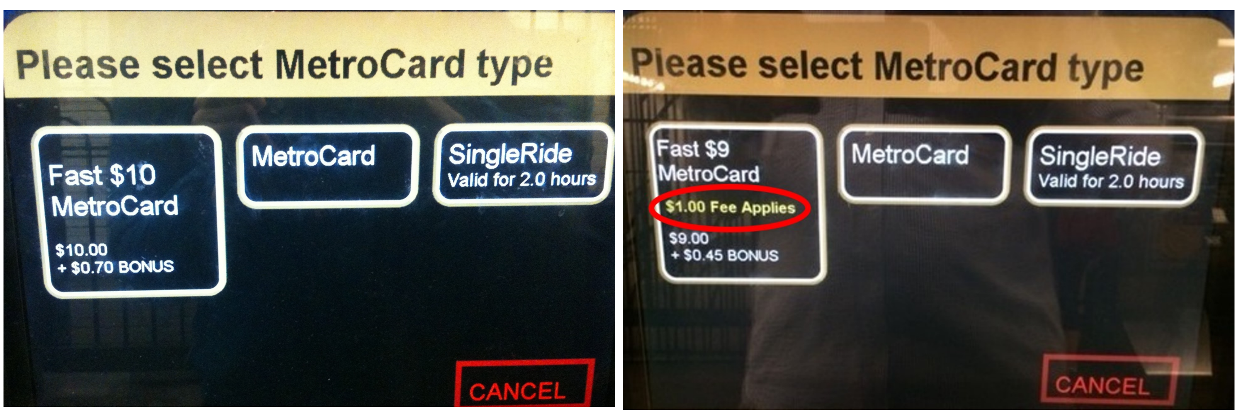
Figure 1: MetroCard Purchase Venues

(a) Vending Machine (b) Manned Booth

*Source*: Figure 1a www.fastcompany.com; Figure 1b Benjamin Kabak on Flickr

Figure 2: First Screen Snapshot on Vending Machine Purchases Before and After the New Card Fee

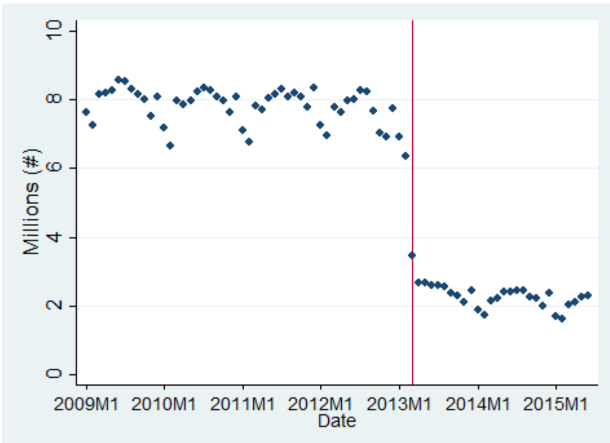
(a) Before (b) After



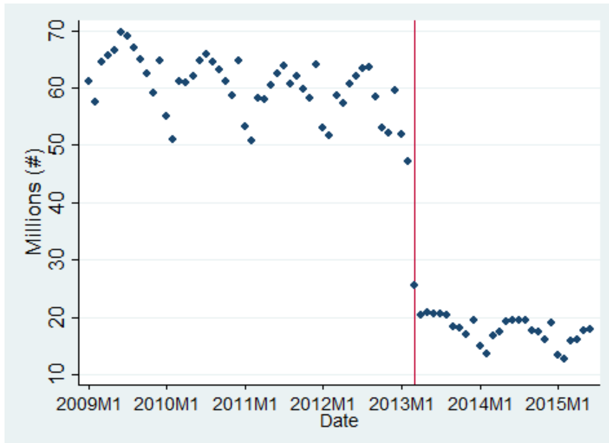

*Note*: Figure 2 shows the first screen snapshot of the vending machines before (2a) and after (2b) the new card fee went into effect, respectively.

Figure 3: Monthly New MetroCard Sales From January 2009 to June 2015

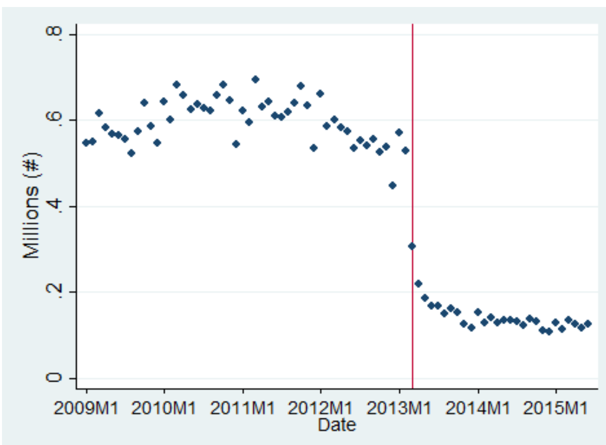
(a) Total



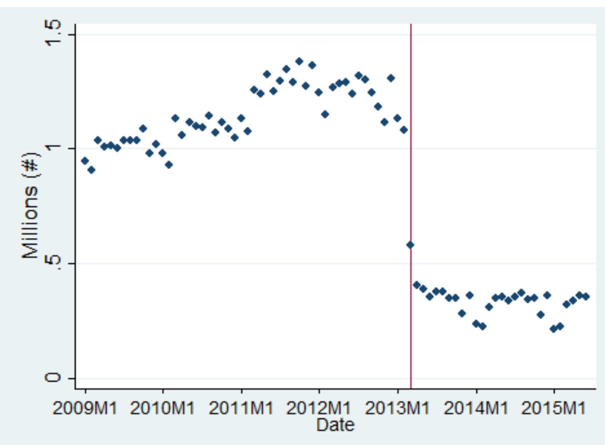

(b) Pay-per-ride




(c) 30-day-unlimited




(d) 7-day-unlimited




*Note*: Figure 3 plots monthly new MetroCard sales from January 2009 to June 2015, broken out for different types of MetroCards. The vertical line marks the month when the new card fee was implemented.

Figure 4: Daily New MetroCards Sales (All Types) from January 1, 2013 to April 30, 2013

(a) Raw (b) Adjusted

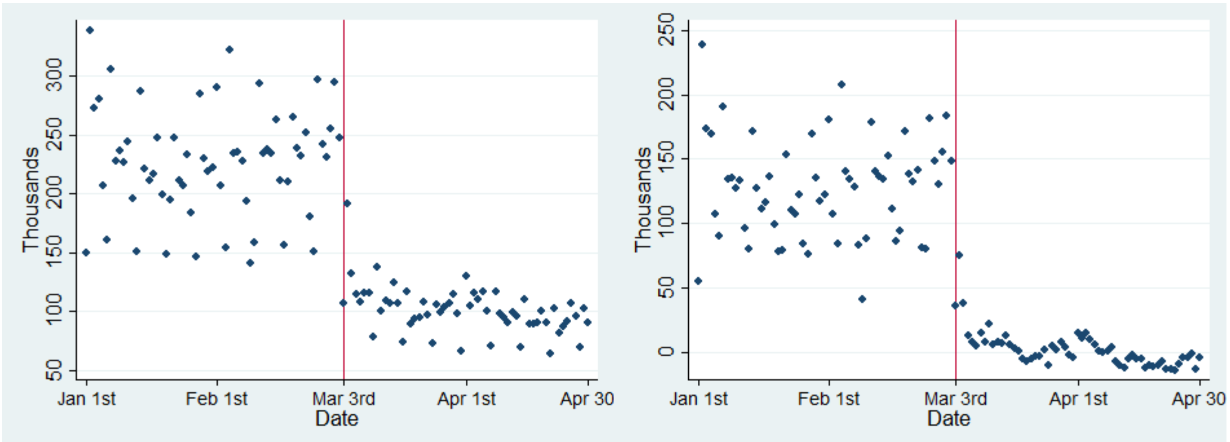
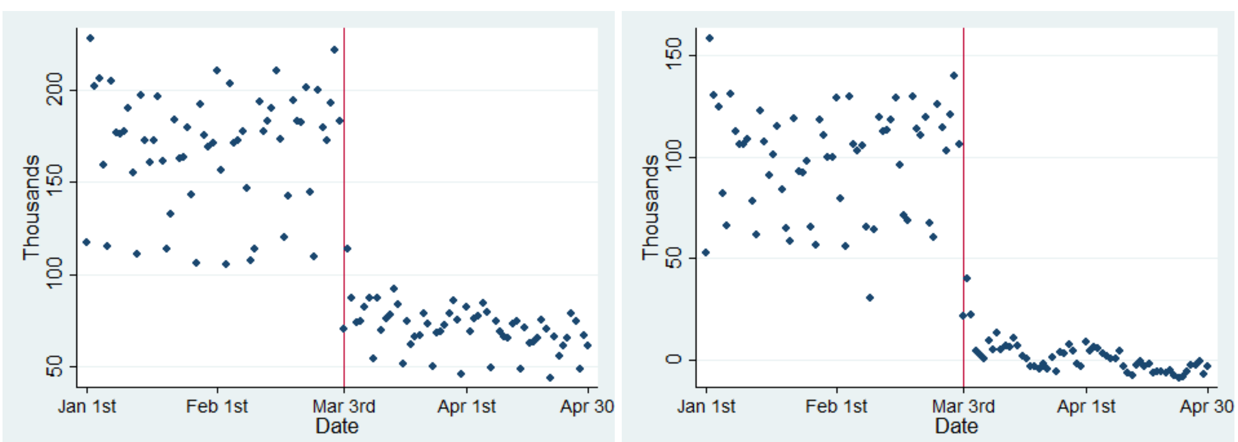



Figure 4a plots daily new MetroCard sales (all types) from January 1, 2013 to April 30, 2013. Figure 4b plots residual of daily sales from day of week fixed effects. The vertical line marks the day when the new card fee was implemented.

Figure 5: Daily Sales of New Pay-per-ride MetroCards from January 1, 2013 to April 30, 2013

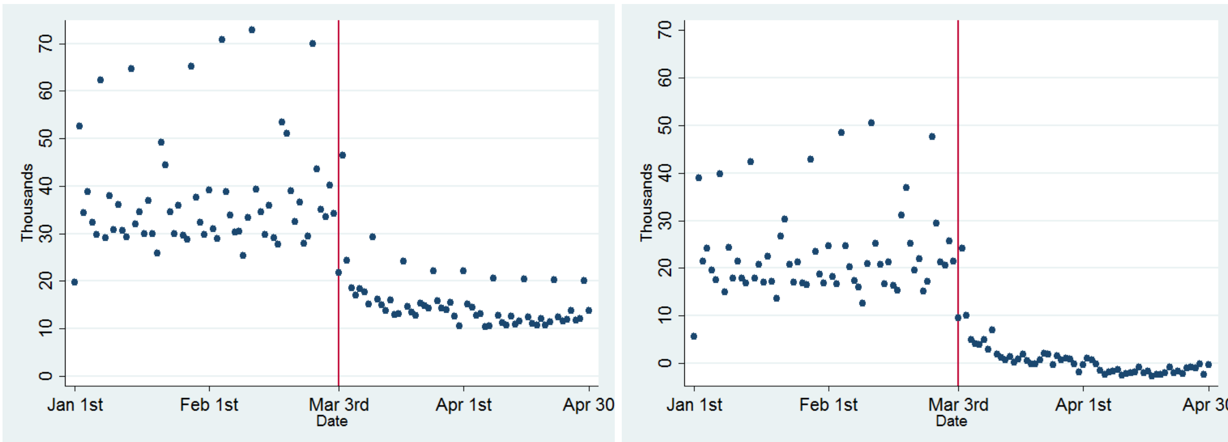
(a) Raw (b) Adjusted




*Note*: Figure 5a plots daily sales of new pay-per-ride MetroCards from January 1, 2013 to April 30, 2013. Figure 5b plots residual of daily sales from day of week fixed effect. The vertical line marks the day when the new card fee was first imposed

Figure 6: Daily Sales of New 7-day-unlimited MetroCards from January 1, 2013 to April 30, 2013

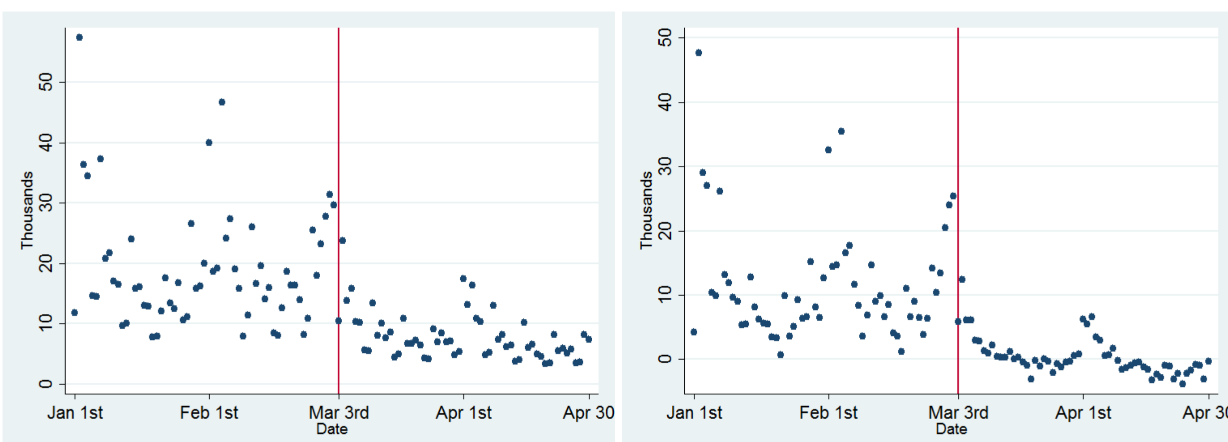
(a) Raw (b) Adjusted




*Note*: Figure 6a plots daily sales of new 7-day-unlimited MetroCards from January 1, 2013 to April 30, 2013. Figure 6b plots residual of daily sales from day of week fixed effects. The vertical line marks the day when the new card fee was first imposed

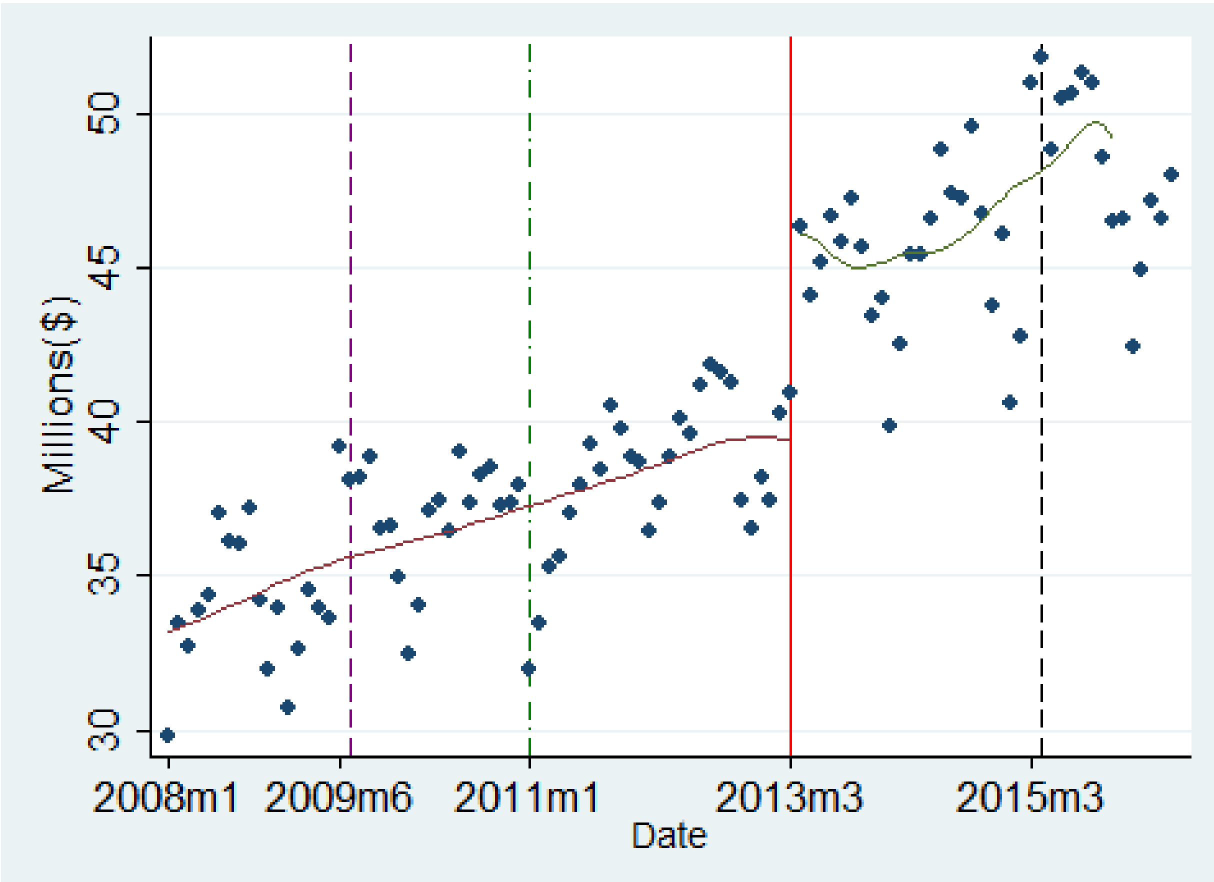
Figure 7: Daily Sales of New 30-day-unlimited MetroCards from January 1, 2013 to April 30, 2013

(a) Raw (b) Adjusted



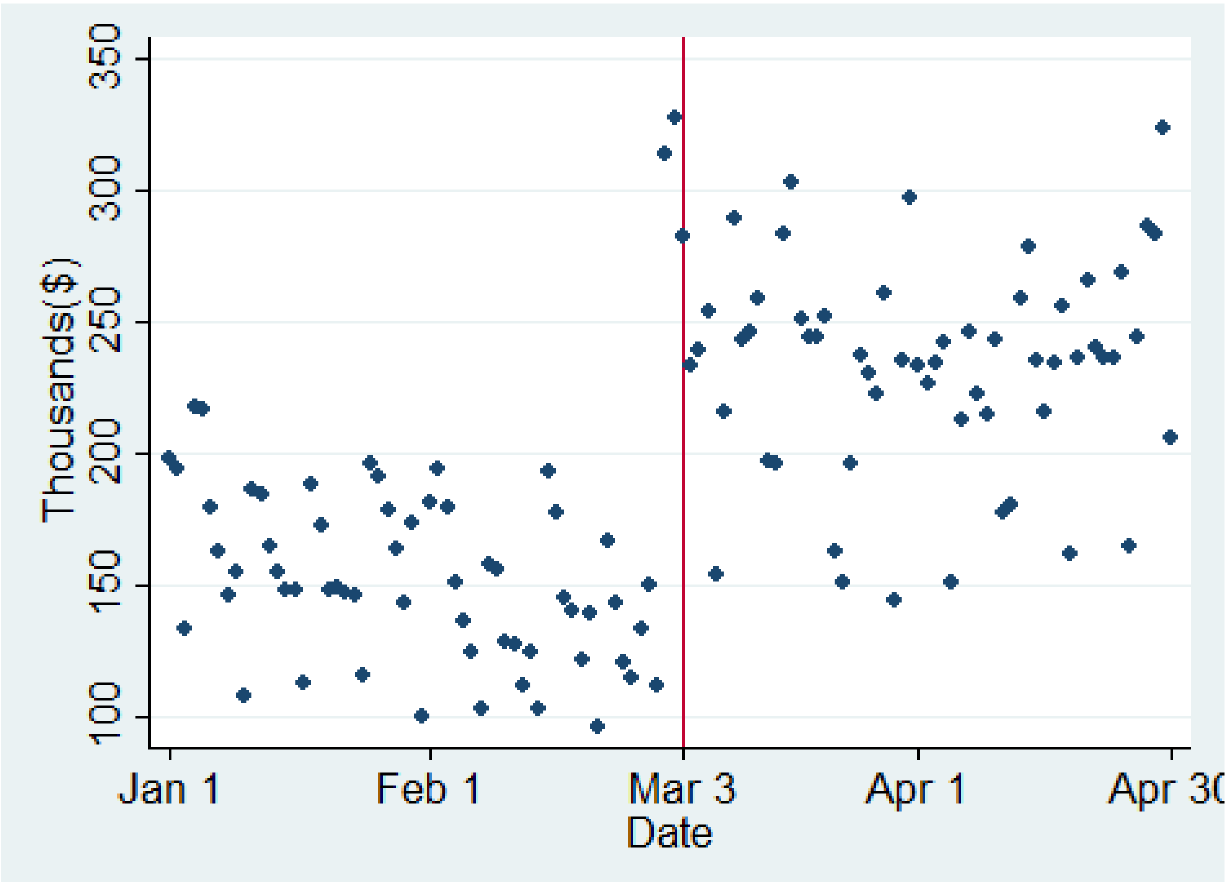

*Note*: Figure 7a plots daily sales of new 30-day-unlimited MetroCards from January 1, 2013 to April 30, 2013. Figure 7b plots residual of daily sales from day of week fixed effects. The vertical line marks the day when the new card fee was first imposed

Figure 8: Monthly Outstanding Balance of Pay-per-ride Deposits from January 2008 to April 2015



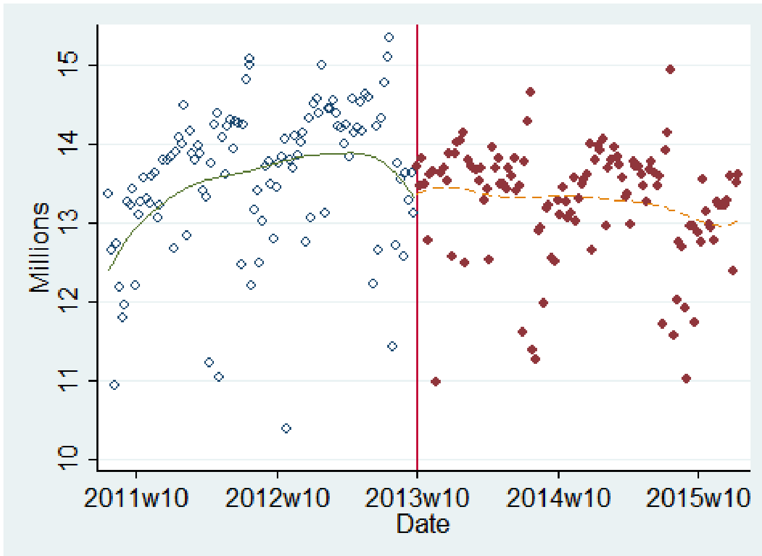

*Note*: Figure 8 plots monthly outstanding balance of pay-per-ride deposits from January 2008 to April 2015. The aggregate monthly outstanding balance that riders carry on their MetroCards is defined as the difference between the total amount they loaded on the cards and reductions caused by swipes at turnstiles. The first vertical line (purple) marks the month when the 2009 fare hike went into effect, the second vertical line (green) marks the month when the 2010 fare hike went into effect, and the third vertical line (red) marks the month when the new card fee was introduced (also the month when the 2013 fare hike went into effect). The fourth vertical line (purple) marks the month when the 2015 fare hike went into effect. The lines plot fitted values of locally weighted regressions (using Stata's lowess command) of outstanding balance on time.

Figure 9: Aggregate Forgone Balances on Pay-per-ride MetroCards Initially Purchased Between January 1, 2013 and April 30, 2013




*Note*: Figure 9 plots the aggregate forgone balances on pay-per-ride MetroCards initially purchased between January 1, 2013 and April 30, 2013. The forgone balances on pay-per-ride MetroCards is defined as the unspent balances on expired MetroCards. The vertical line marks the day when the new card fee was first imposed.

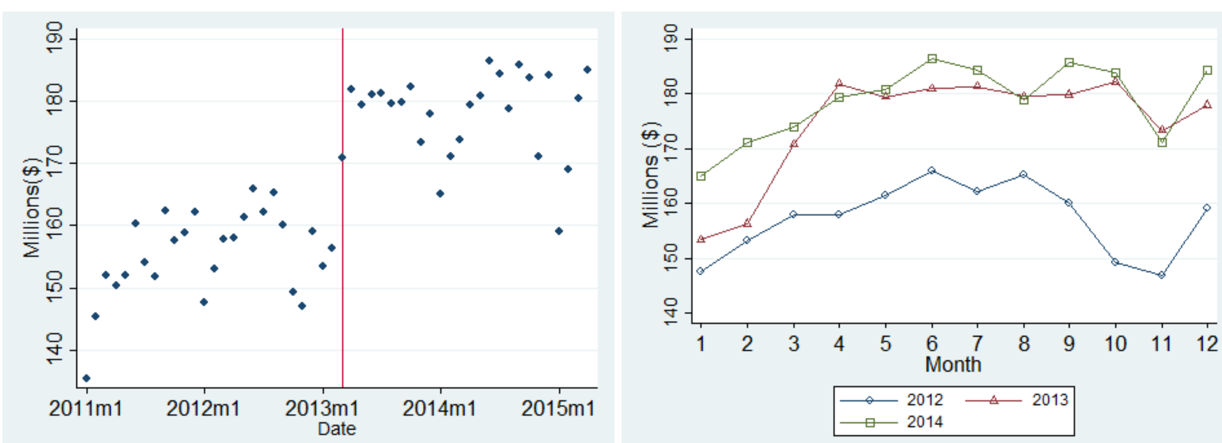
Figure 10: Weekly Total Number of MetroCard Swipes from January 2011 to May 2015




*Note*: Figure 10 plots weekly total number of MetroCard swipes from January 2011 to May 2015. The vertical line (red) marks the week when the new card fee went into effect.

Figure 11: Monthly Revenue from Pay-per-ride Deposits from January 1, 2011 to April 30, 2015

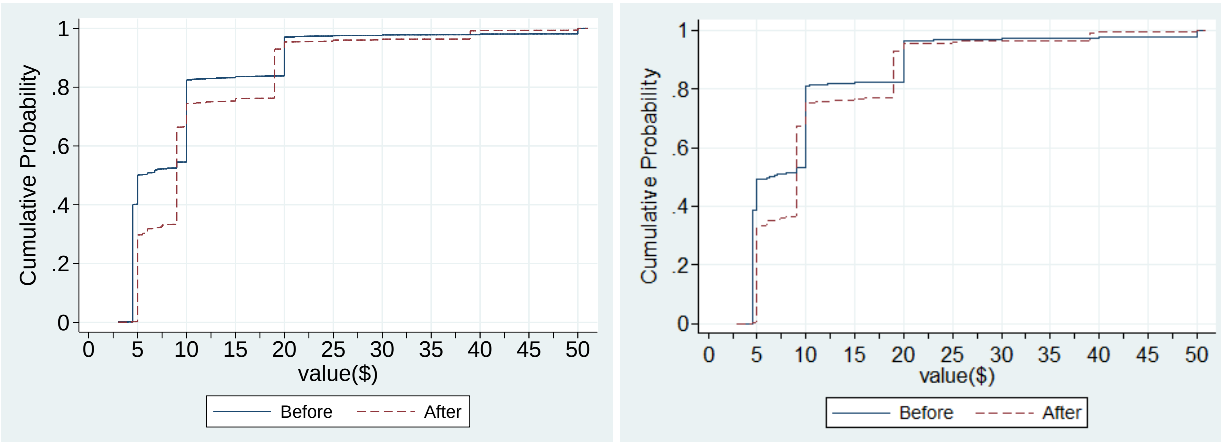
(a) (b)




*Note*: Figure 11a plots monthly revenue of pay-per-ride deposits from January 2011 to April 2015. The vertical line (red) marks the month when the new card fee went into effect. Figure 11b plots year-to-year monthly revenue of pay-per-ride deposits from January 2012 to December 2014.

Figure 12: Deposits on New Pay-per-ride MetroCard Purchases Before versus After the New Card Fee (From January 1, 2013 To April 30, 2013): Cumulative Distribution Function

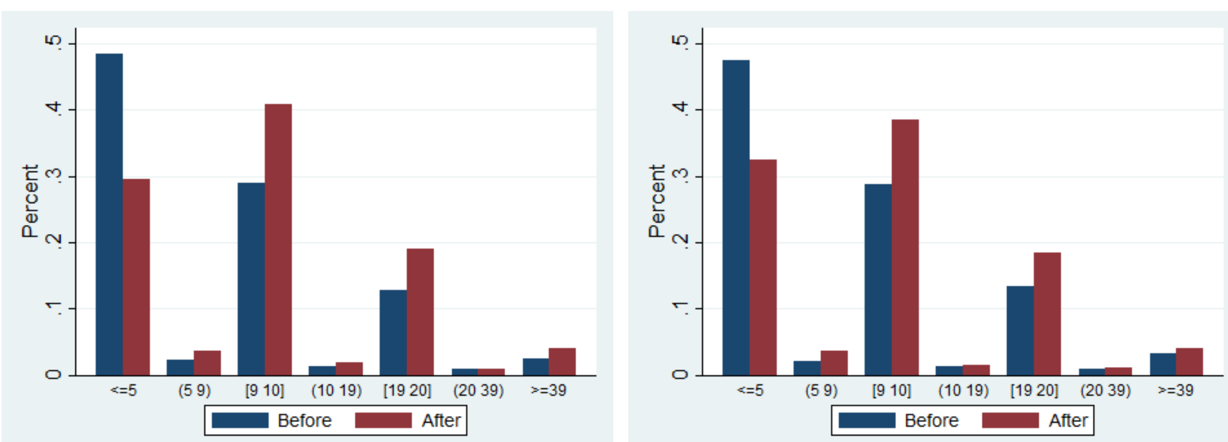
(a) Total (b) One-week




*Note*: Figure 12 plots the cumulative distribution function (CDF) for deposit amounts on new pay-per-ride MetroCard purchases before versus after the new card fee. Figure 12a used all the deposit transactions from January 1, 2013 to April 30, 2013. Figure 12b plots deposits of purchases within one week before and after the new card fee.

Figure 13: Deposits on New Pay-per-ride MetroCard Purchases Before and After the New Card Fee (From January 1, 2013 To April 30, 2013): Histogram

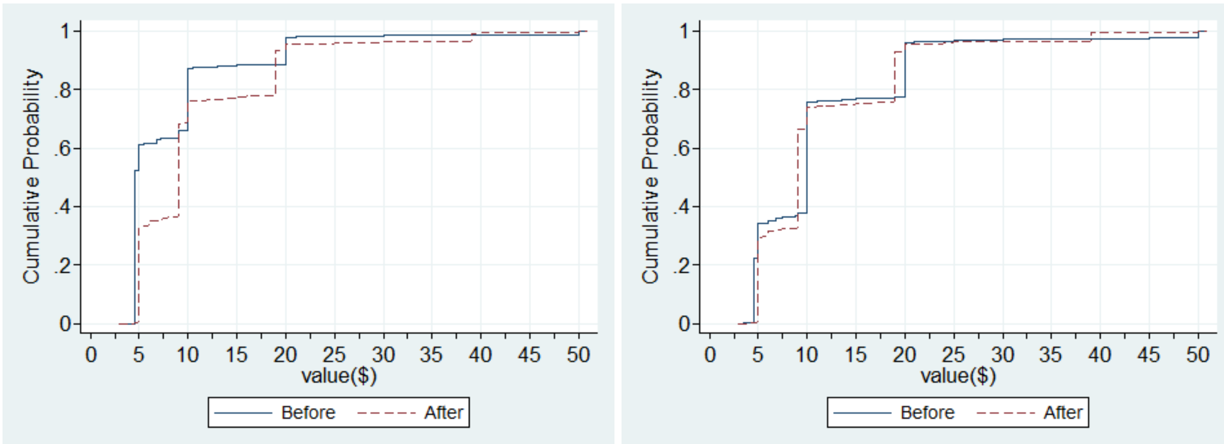
(a) Total (b) One-week




*Note*: Figure 13 plots the histogram of deposit amounts on new pay-per-ride MetroCard purchases before versus after the new card fee. Figure 13a used all the deposit transactions from January 1, 2013 to April 30, 2013. Figure 13b plots deposits of purchases within one week before and after the new card fee.

Figure 14: Deposits on New Pay-per-ride MetroCard Purchases Before and After the New Card Fee (From January 1, 2013 To April 30, 2013): Cumulative Distribution Function

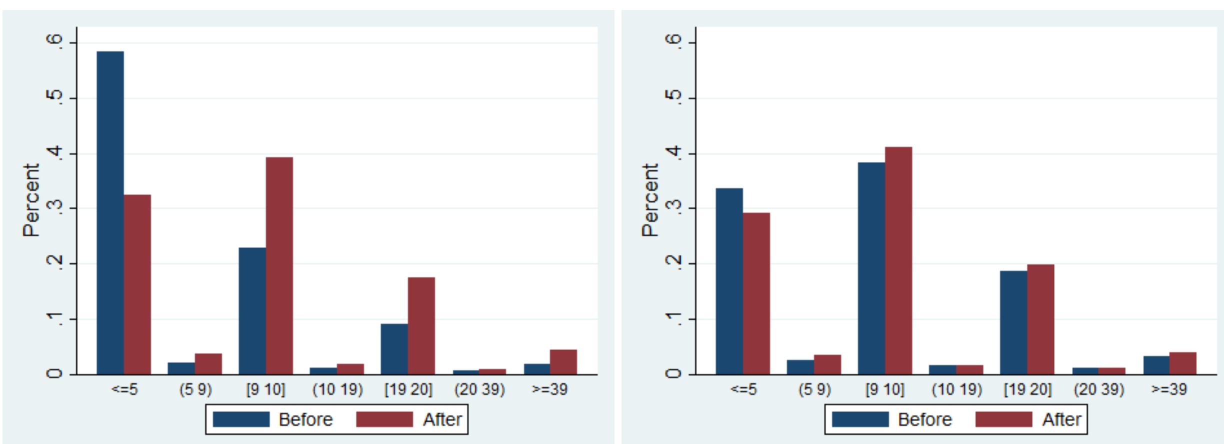
(a) No Refills (b) With Refills




*Note*: Figure 14 plots the cumulative distribution function for deposits on new pay-per-ride purchases before and after the new card fee. Figure 14a plots the cumulative distribution function for deposits on new pay-per-ride purchases without subsequent refill activities. Figure 14b plots the cumulative distribution function for deposits on new pay-per-ride purchases with subsequent refill activities.

Figure 15: Deposits on New Pay-per-ride MetroCard Purchases Before and After the New Card Fee (From January 1, 2013 To April 30, 2013): Histogram

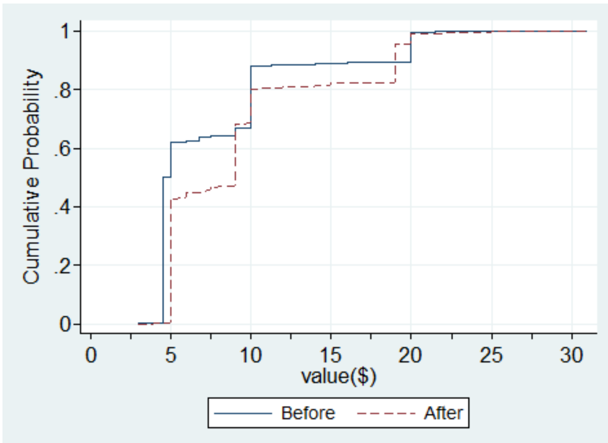
(a) No Refills (b) With refills



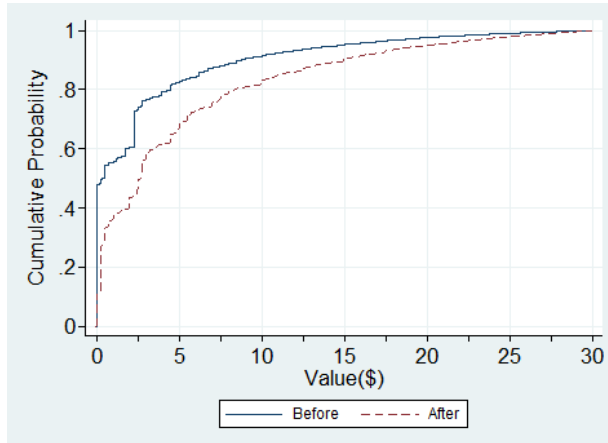

*Note*: Figure 15 plots the histogram for deposits on new pay-per-ride purchases before and after the new card fee (from January 1, 2013 to April 30, 2013). Figure 15a plots the histogram for deposits on new pay-per-ride purchases without subsequent refill activities. Figure 15b plots the histogram for deposits on new pay-per-ride purchases with subsequent refill activities.

Figure 16: Changes in Deposits and Forgone Balances on New Pay-per-ride MetroCards By Different Payment Methods (January 1, 2013 To April 30, 2013): Cumulative Distribution Function

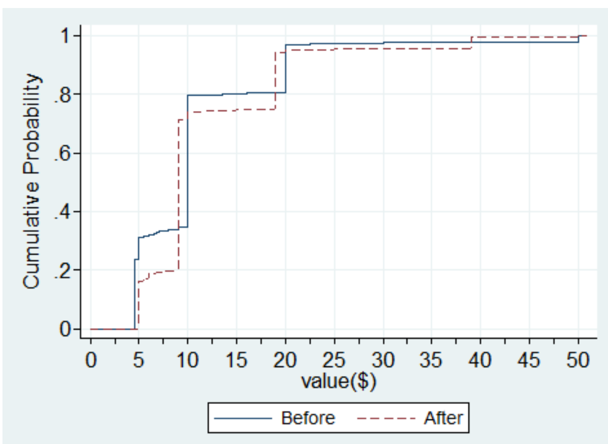
(a) Deposits (Cash)



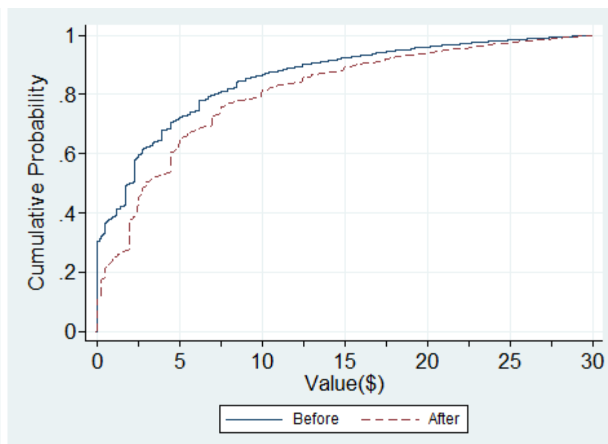

(b) Forgone Balances (Cash)



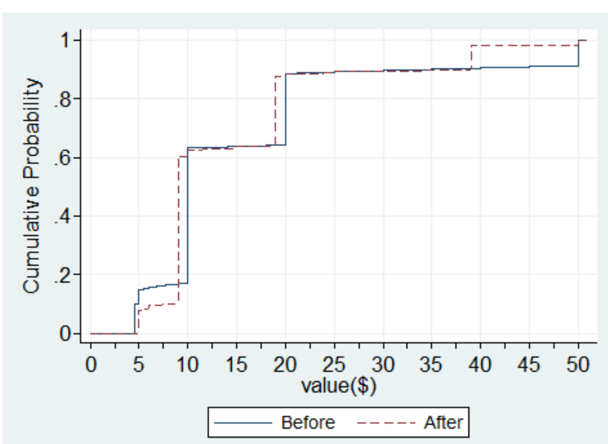

(c) Deposits (Debit)



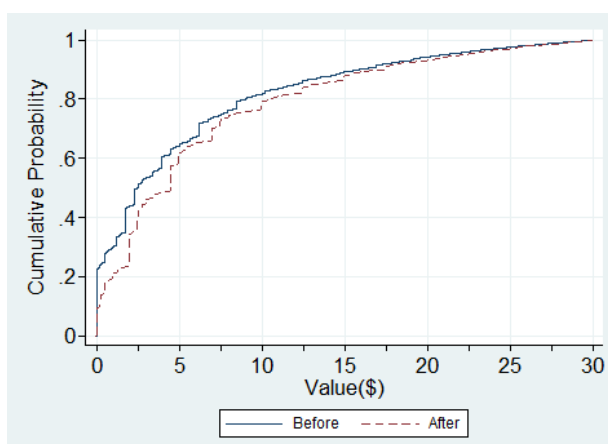

(d) Forgone Balances (Debit)




(e) Deposits (Credit)



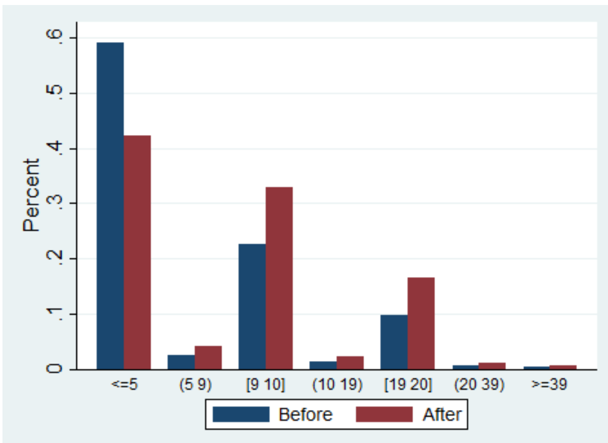

(f) Forgone Balances (Credit)



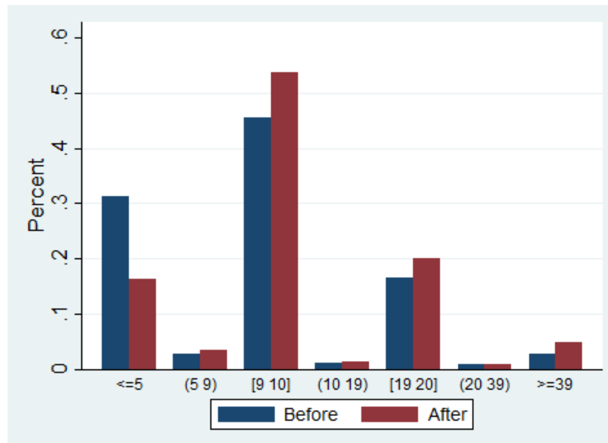

*Note*: Figure 16 plots the cumulative distribution function for deposits and forgone balances on new pay-per-ride MetroCards before and after the new card fee, broken out for different payment methods. Figure 16a-16b plot the charts for cash purchases. Figure 16c-16d plot the charts for debit card purchases. Figure 16e-16f plot the charts for credit card purchases.

Figure 17: Deposits on New Pay-per-ride MetroCard Purchases Before and After the New Card Fee by Payment Methods (From January 1, 2013 To April 30, 2013): Histogram

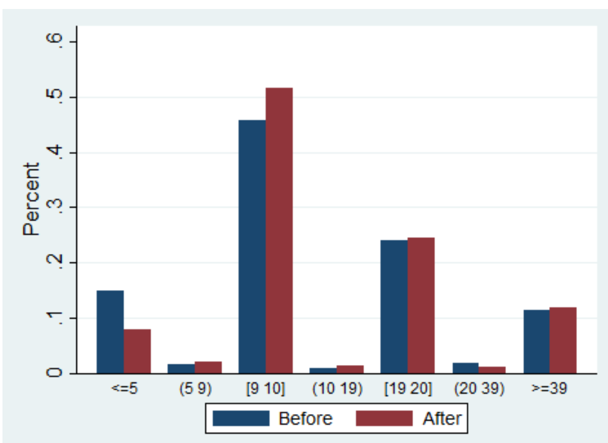
(a) Cash




(b) Debit

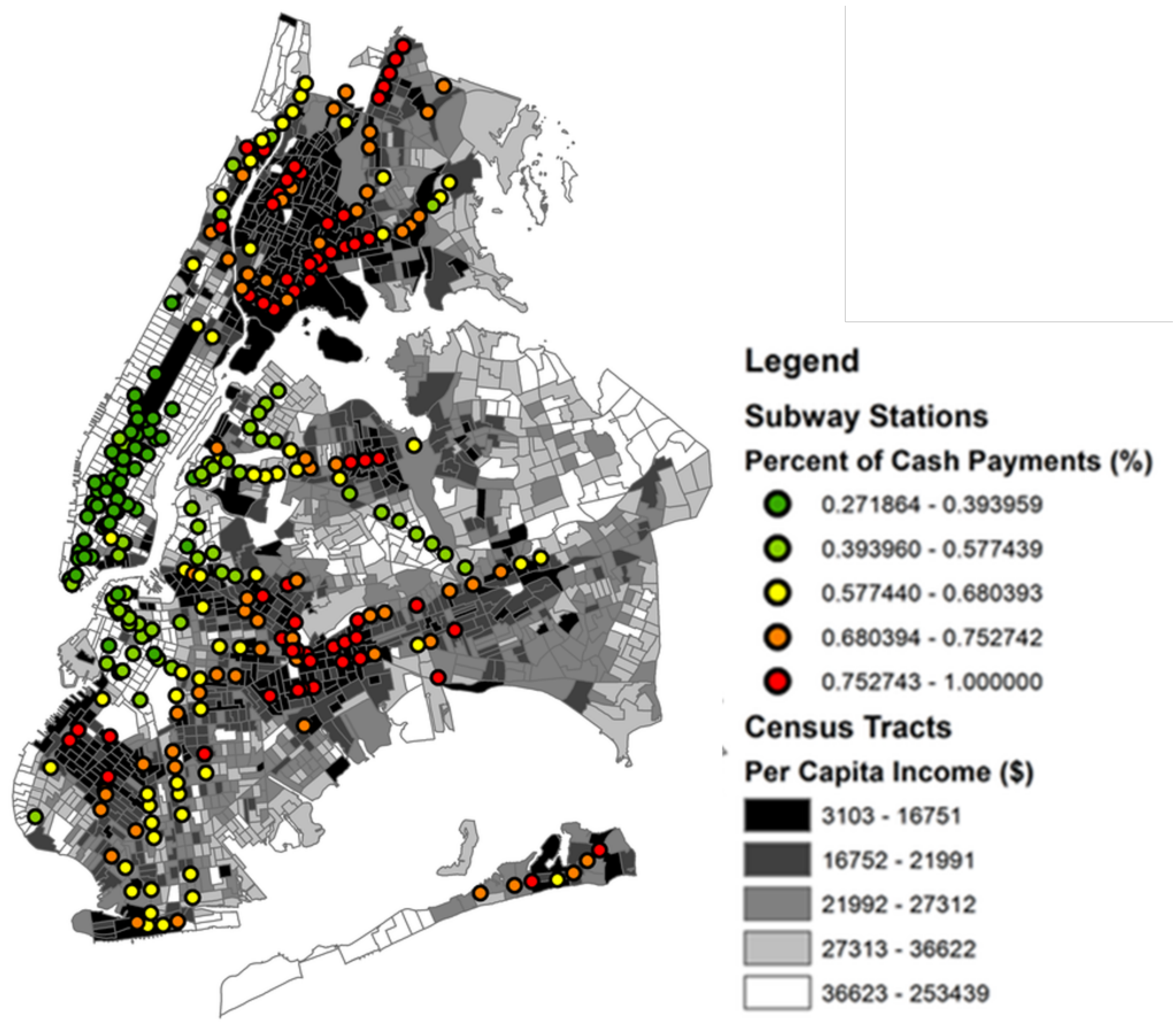



(c) Credit




*Note*: Figure 17 plots the histogram for deposits on new pay-per-ride purchases before and after the new card fee by different payment methods. Figure 17a plots the cumulative distribution function for cash deposits on new pay-per-ride purchases. Figure 17b plots the histogram for debit-card payments on new pay-per-ride purchases. Figure 17c plots the histogram for credit-card payments on new pay-per-ride purchases.

Figure 18: Percent of Cash Payments Across Different Subway Stations From January 2013 To April 2013




*Note*: Figure 18 plots the spatial differences in percent of cash payments for MetroCard purchases across different census tracts. The census-tract level per-capita income data is from American Community Survey (ACS) 2009–2013 (5-Year Estimates)

Figure 19: Threshold of Prepaying for Rides in the Second Day For $n = 2$ Case

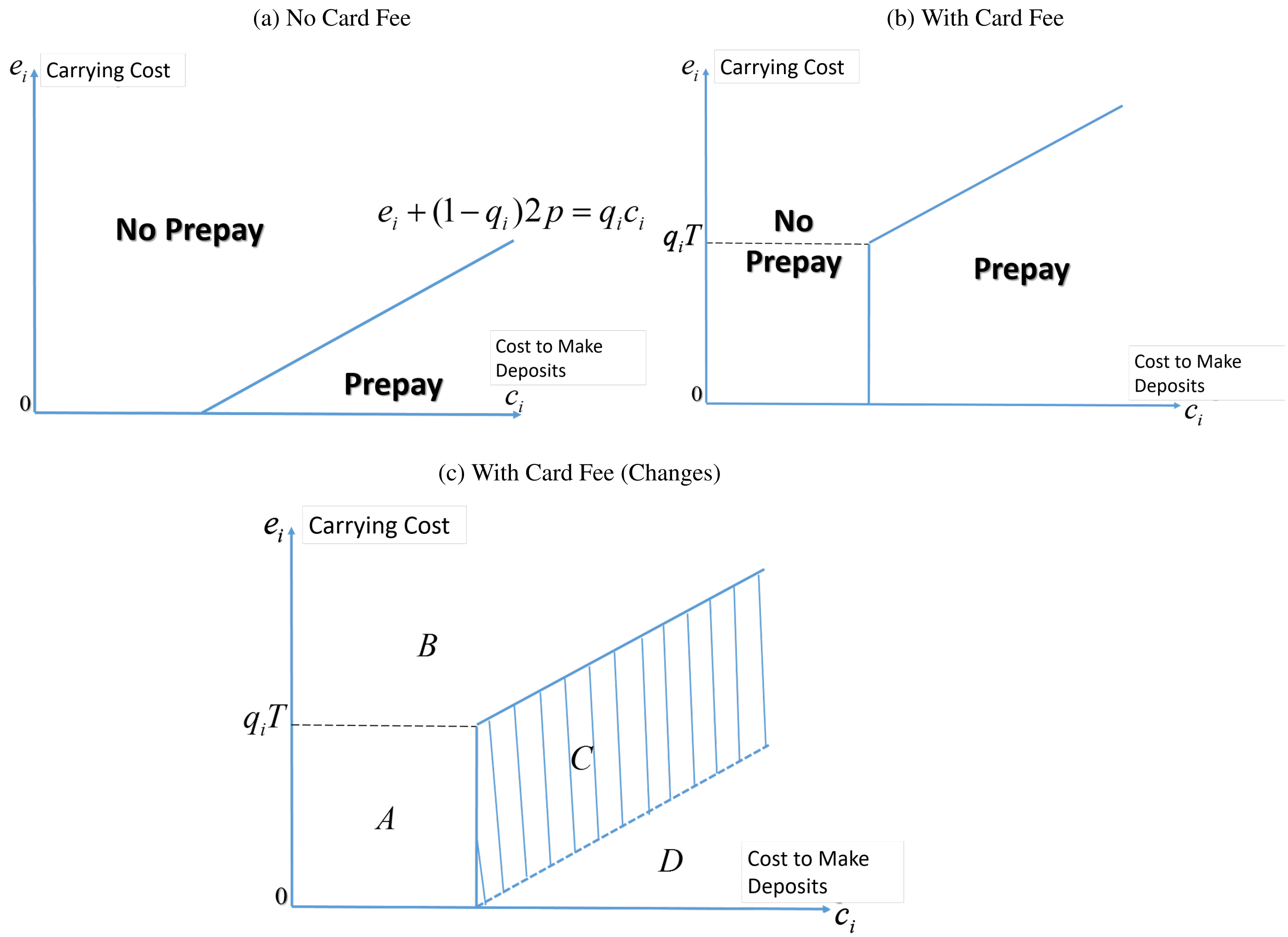



Figure 19 shows the threshold of prepaying for rides in the second day for $n = 2$ case with no new card fee (19a) and without a new card fee (19c), respectively. Before the new card fee was imposed, riders in region $C$ only deposited fare of the first day's rides since the cost to make deposits in the second day is smaller than the cost to remember to carry the same card to the second day and the risk of losing the prepaid deposit. After the new card fee was imposed, these riders switched to prepaying for rides in the second day as the cost to make deposits and the cost of the new card fee are larger than the cost to remember to carry the same card to the second day and the risk of losing the prepaid deposit. As a result, they lose $2p$ on expired MetroCards if they do not actually take rides in the second day (Table 11).

Figure 20: Threshold of Prepaying for Rides in the Second and Third Day For $n = 3$ Case

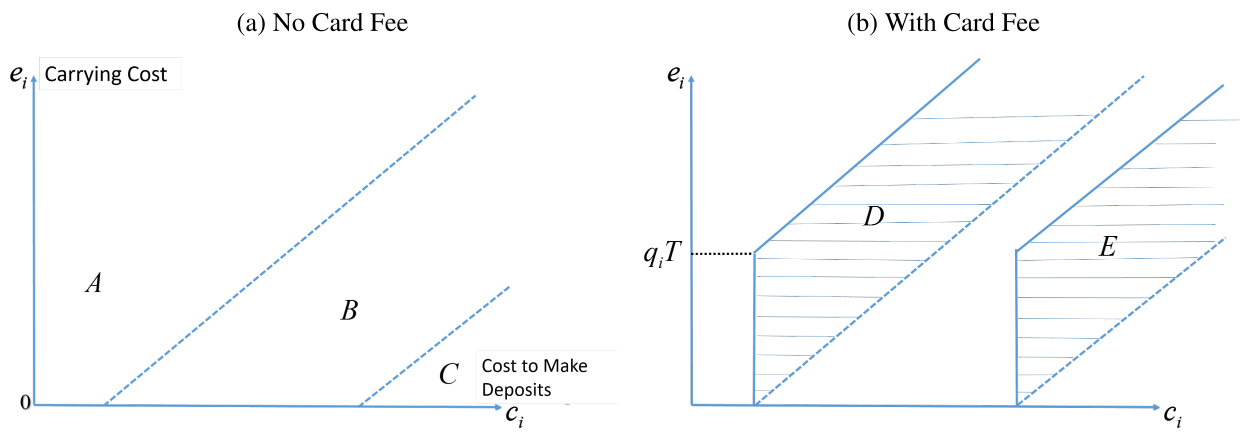
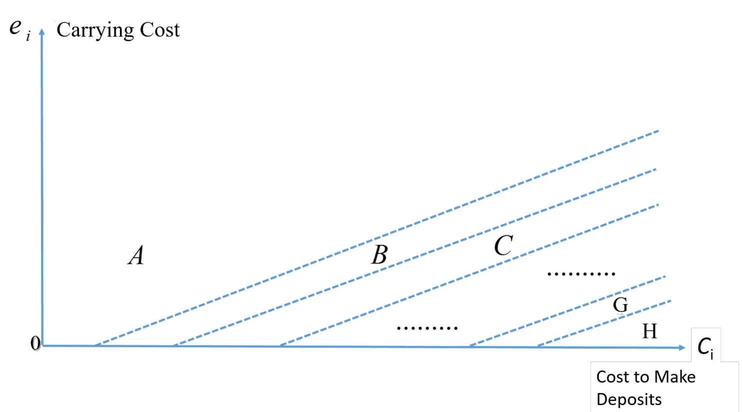



Figure 20 shows the threshold of prepaying for rides in the second and third day for $n = 3$ case when no card fee is imposed (20a) and when a card fee is imposed (20b), respectively. Before the new card fee was imposed, riders in region $D$ only deposited the fare of the first day's rides since the cost to make deposits in the second day is smaller than the cost to remember to carry the same card to the second day and the risk of losing the prepaid deposit. After the new card fee was imposed, these riders switched to prepaying for rides in the second day as the cost to make deposits and the cost of the new card fee are larger than the cost to remember to carry the same card to the next day and the risk of losing prepaid deposit. As a result, these riders lose $2p$ on expired MetroCards if they do not actually take rides in the second day. Analogously, riders in region $E$ switched from prepaying for rides in the second day to prepaying for rides in the second day and the third day after the new card fee was imposed.

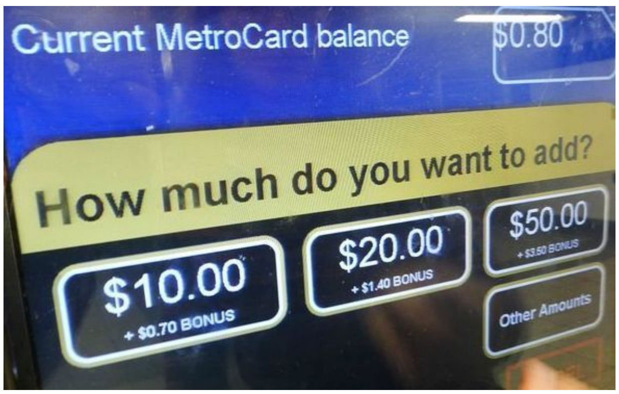
Figure 21: Threshold of Prepaying for Rides in Future Days For $n = 30$ Case (No Card Fee)



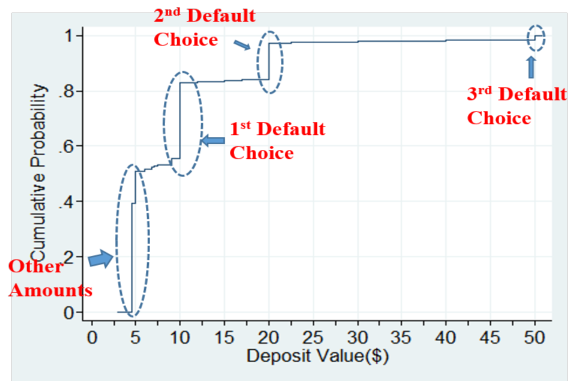

*Note*: For the $n = 30$ case, according to the model, there will be thirty regions ranging from no prepay for future rides (region A) to prepay for rides in the next 29 days (region H) when no card fee is charged for new MetroCard purchases.

Figure 22: Default Choices of Deposit Amounts on Vending Machine Screen Before and After the New Card Fee

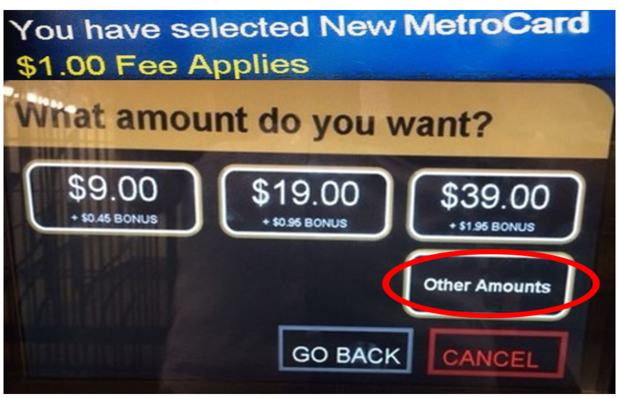
(a) Screen Before



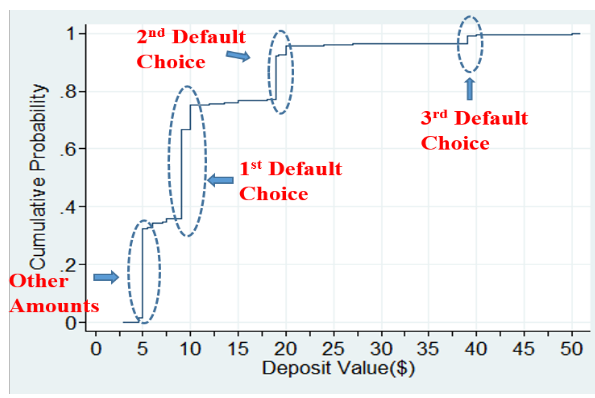

(b) Cumulative Distribution Before




(c) Screen After



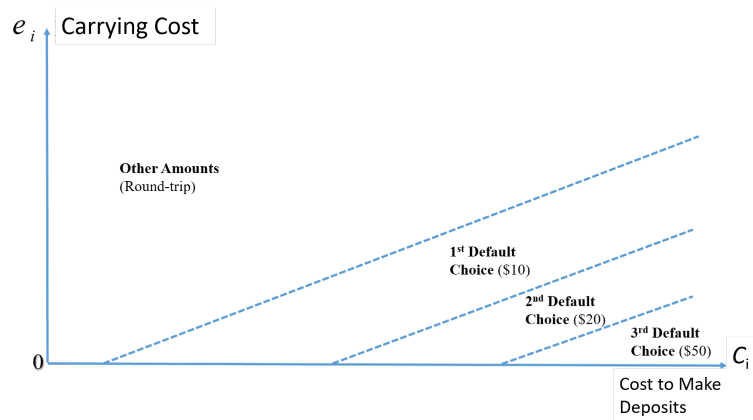

(d) Cumulative Distribution After



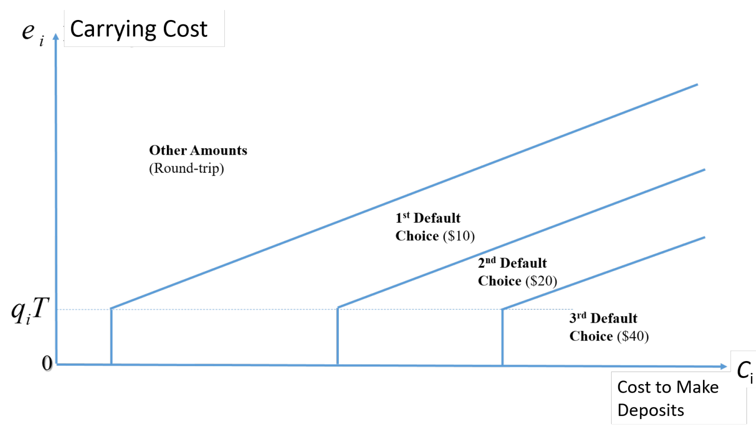

*Note*: Figure 22a and 22c show the suggested deposit amounts on vending machine screen before and after the new card fee went into effect, respectively. Figure 22b and 22d plot the cumulative distribution function (CDF) for deposit amounts on new pay-per-ride MetroCards before and after the new card fee was imposed, respectively.

Figure 23: Default Choices of Deposit Amounts For $n = 30$ Case

(a) No Card Fee




(b) With Card Fee




(c) With Card Fee (Changes)

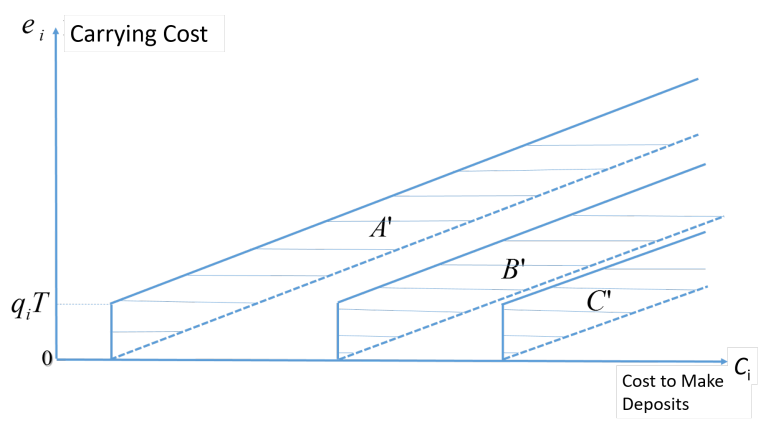
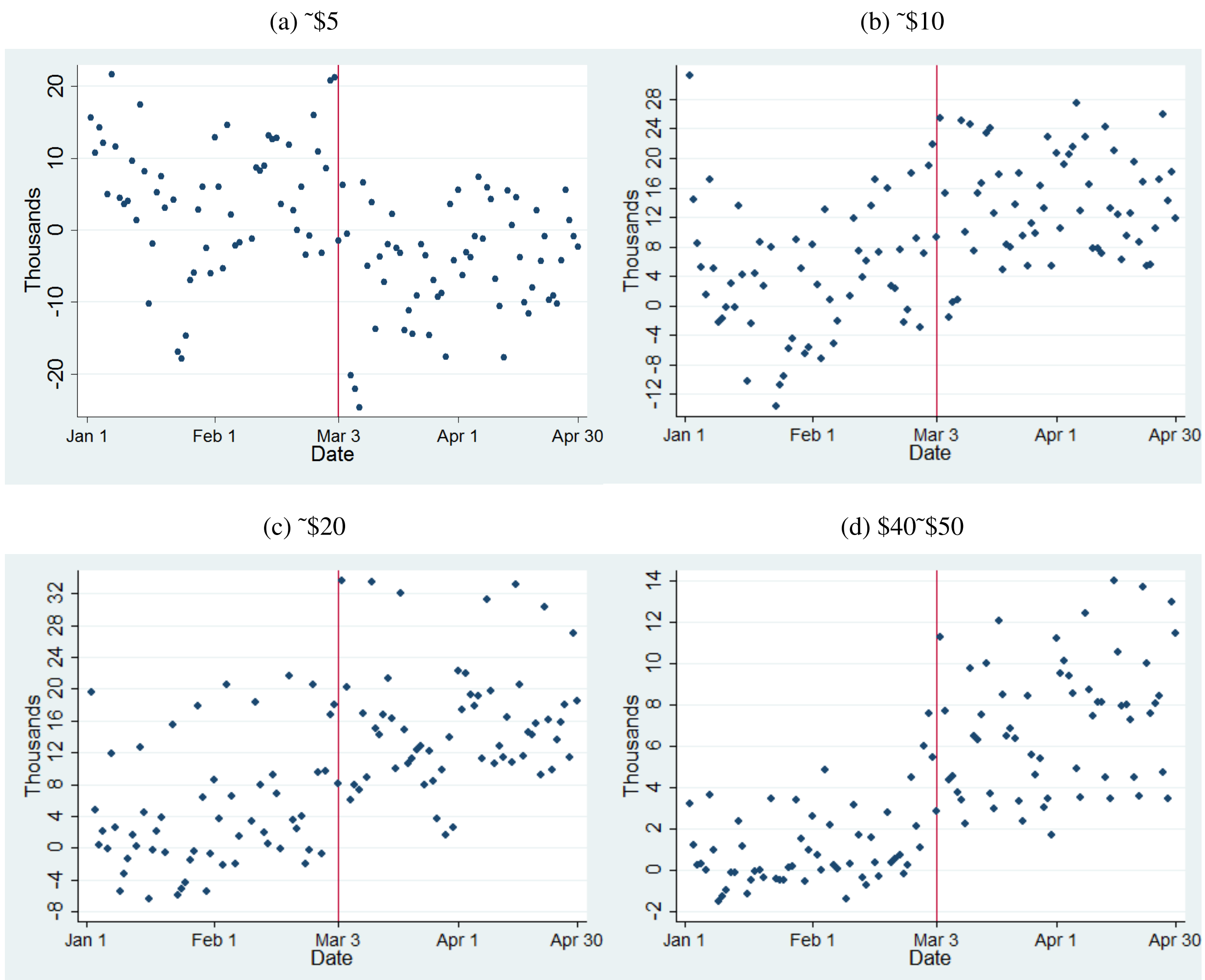



Figure 23 shows the threshold of choosing different deposit amounts for $n = 30$ case when no card fee is imposed (23a) and when a card fee is imposed (23b), respectively. Riders in region $A'$ switched from choosing "Other Amounts" to choosing "1st default choice ($10)" after the new card fee was imposed. Riders in region $B'$ switched from choosing "1st default choice ($10)" to choosing "2nd default choice ($20)" after the new card fee was imposed. Riders in region $C'$ switched from choosing "2nd default choice ($20)" to choosing "3rd default choice ($40)" after the new card fee was imposed.

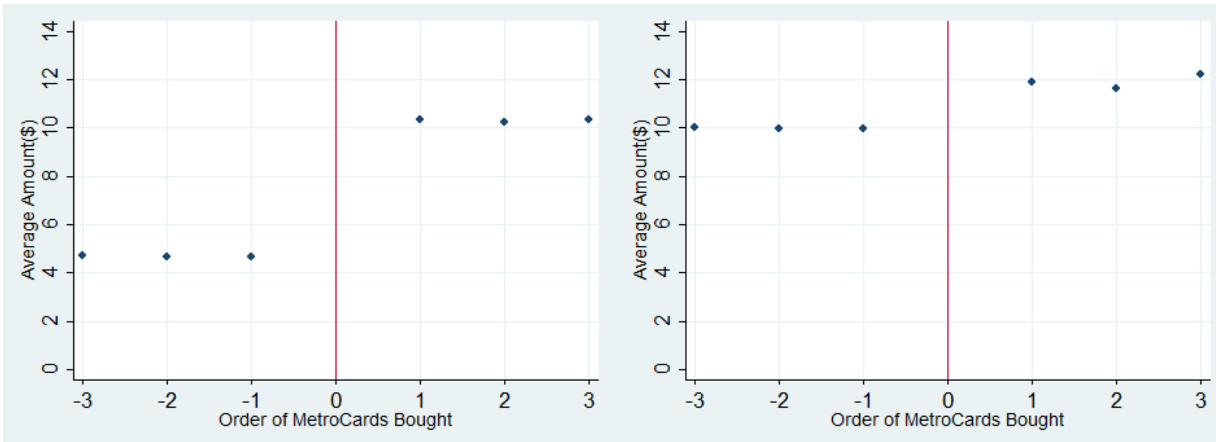
Figure 24: Daily Total Number of Pay-per-ride MetroCard Purchases From January 1, 2013 To April 30 2013 By Deposit Amounts




*Note*: Figure 24a plots daily total number of MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 24b plots residual of daily total number of MetroCard purchases (new and refills) from day of week fixed effect. The vertical line marks the day when the new card fee was implemented.

Figure 25: Changes in Average Deposit Amounts For Pay-per-ride MetroCards Linked to the Same Rider Using MetroCard Trade-in and Trade-out Data (January 1, 2013 To December 31, 2013)

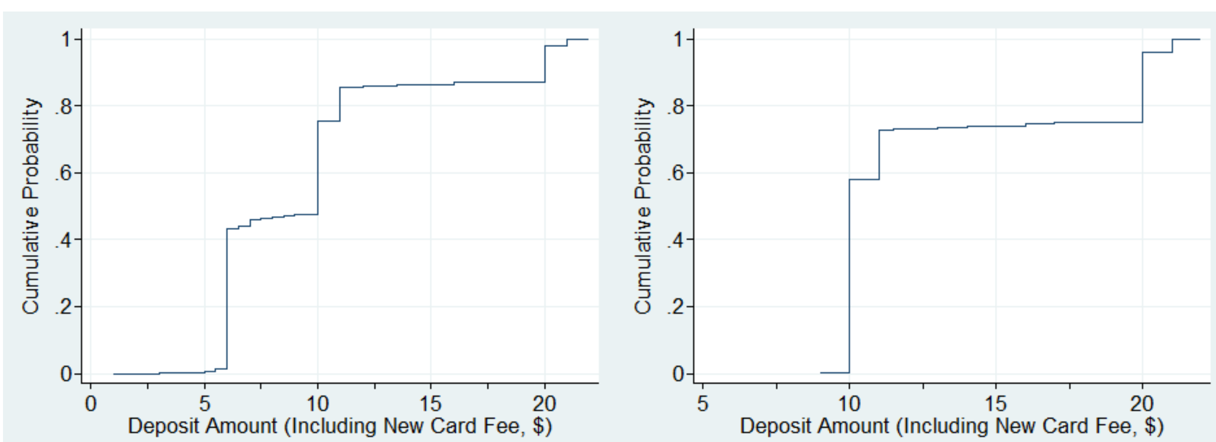
(a) ~$5 Deposit Amounts Before the New Card Fee (b) ~$10 Deposit Amounts Before the New Card Fee




*Note*: Figure 25a and 25b show average deposit amounts for pay-per-ride MetroCards linked to the same rider using MetroCard trade-in and trade-out data, by ~$5 and ~$10 average deposit amounts before the new card fee was implemented, respectively. X-axis shows the order of MetroCards purchased: the number 1 represents the first MetroCard purchased by a rider after the new card fee was introduced, the number -1 represents the last MetroCard purchased by the same rider before the new card fee was implemented, and so on.

Figure 26: Changes in Deposit Amounts After the New Card Fee For Pay-per-ride MetroCards Linked to the Same Rider Using MetroCard Trade-in and Trade-out Data (January 1, 2013 To December 31, 2013): Cumulative Distribution Function

(a) ~$5 Deposit Amounts Before the New Card Fee (b) ~$10 Deposit Amounts Before the New Card Fee




*Note*: Figure 26a and 26b show cumulative distribution function for deposit amounts after the new card fee, by ~$5 and ~$10 average deposit amounts before the new card fee was implemented, respectively.

Figure 27: Proposed Default Choices of Deposit Amounts on Touchscreen

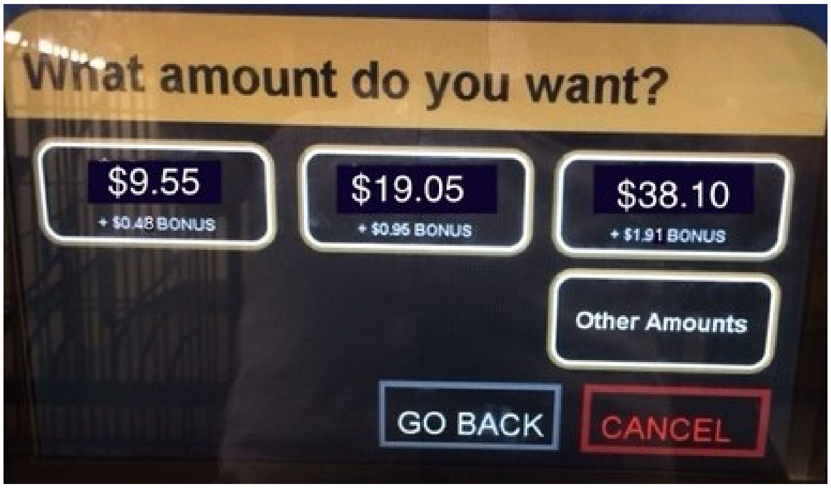



Figure 28: Monthly Sales of Single-ride Tickets From January 2011 To June 2015

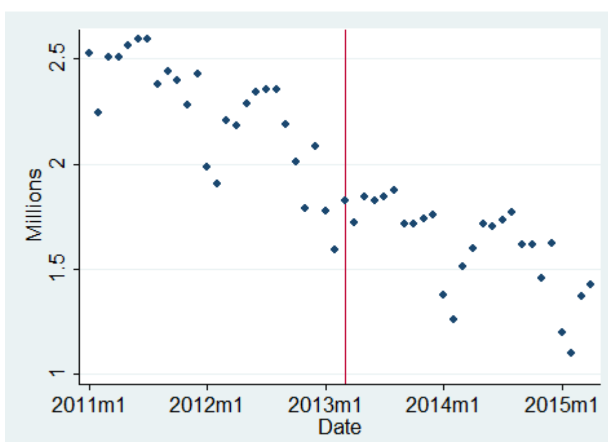
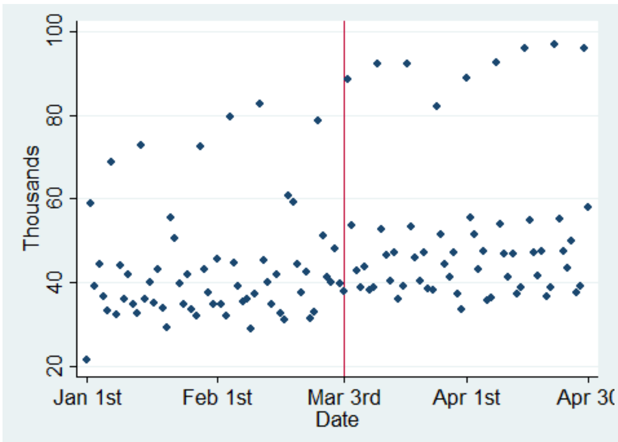
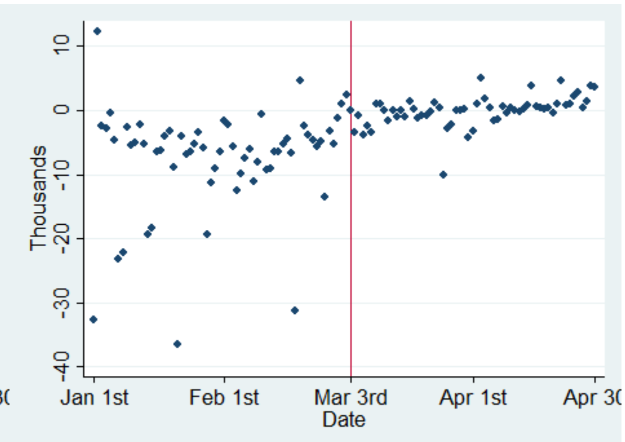


Figure 29: Daily Total Number of MetroCard Purchases From January 1, 2013 To April 30, 2013: New and Refills

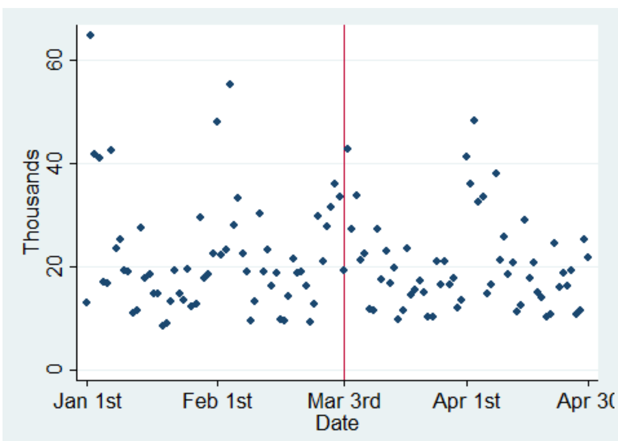
(a) 7-day-unlimited Raw



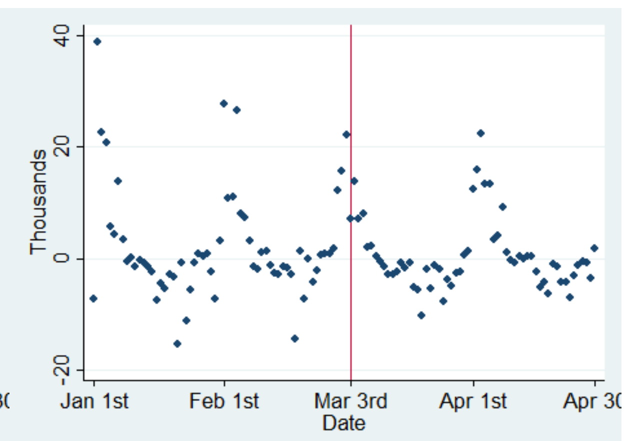

(b) 7-day-unlimited Adjusted




(c) 30-day-unlimited Raw



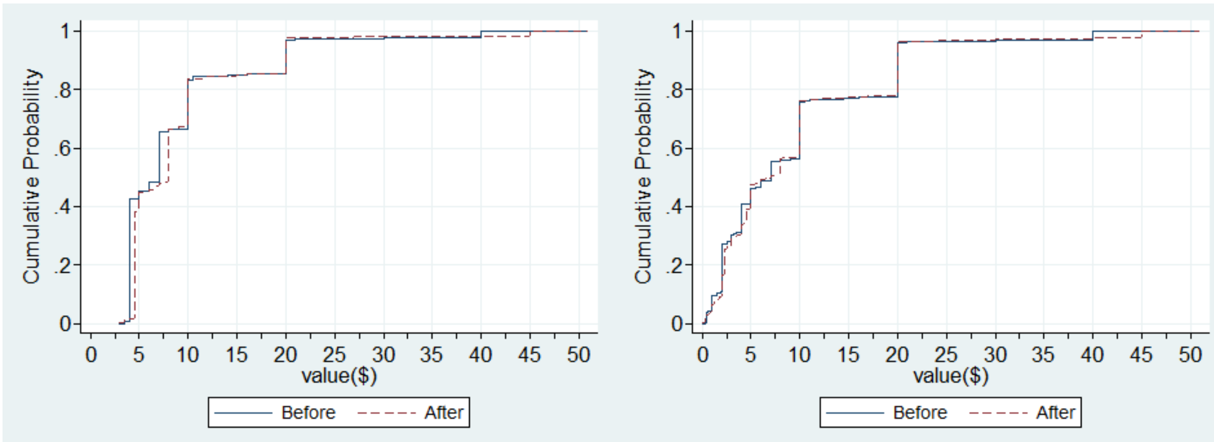

(d) 30-day-unlimited Adjusted




*Note*: Figure 29a plots daily total number of 7-day-unlimited MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 29b plots residual of daily total number of 7-day-unlimited MetroCard purchases (new and refills) from day of week fixed effect. Figure 29c plots daily total number of 30-day-unlimited MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 29d plots residual of daily total number of 30-day-unlimited MetroCard purchases (new and refills) from day of week fixed effect. The vertical line marks the day when the new card fee was implemented

Figure 30: Deposits on Pay-per-ride MetroCard Purchases Before and After the 2009 Fare Hike (From May 1, 2009 To August 30, 2009): Cumulative Distribution Function

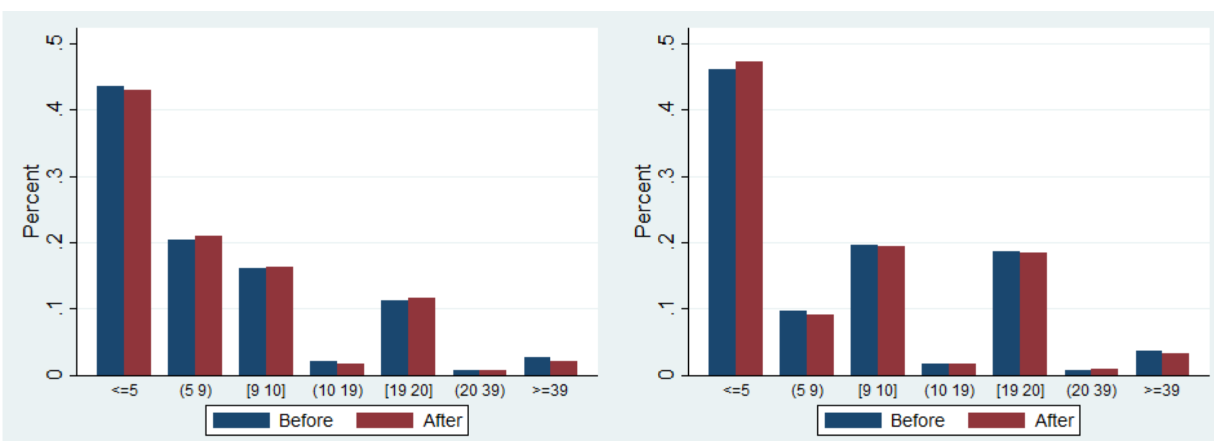
(a) New (b) Refill




*Note*: Figure 30 plots the cumulative distribution function for deposits on pay-per-ride MetroCard purchases before and after the 2009 fare hike. Figure 30a plots cumulative distribution function for deposits on new pay-per-ride MetroCard purchases from May 1, 2009 to August 30, 2009. Figure 30b plots the cumulative distribution function for deposits on pay-per-ride refills from May 1, 2009 to August 30, 2009.

Figure 31: Deposits on Pay-per-ride MetroCard Purchases Before and After the 2009 Fare Hike (From May 1, 2009 to August 30, 2009): Histogram

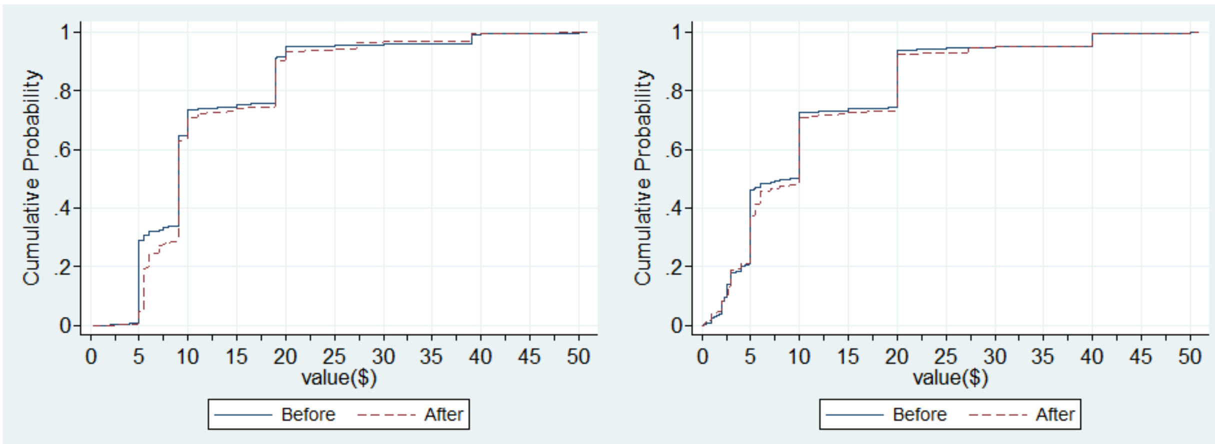
(a) New (b) Refill




*Note*: Figure 31 plots the histogram for deposits on pay-per-ride MetroCard purchases before and after the 2009 fare hike. Figure 31a plots the histogram for deposits on new pay-per-ride purchases from May 1, 2009 to August 30, 2009. Figure 31b plots the histogram for deposits on pay-per-ride refills from May 1, 2009 to August 30, 2009.

Figure 32: Deposits on Pay-per-ride MetroCard Purchases Before and After the 2015 Fare Hike (From January 1, 2015 To May 31, 2015): Cumulative Distribution Function

(a) New (b) Refill




*Note*: Figure 32 plots the cumulative distribution function for deposits on pay-per-ride MetroCard purchases before and after the 2015 fare hike. Figure 32a plots cumulative distribution function for deposits on new pay-per-ride MetroCard purchases from January 1, 2015 to May 31, 2015. Figure 32b plots the cumulative distribution function for deposits on pay-per-ride refills from January 1, 2015 to May 31, 2015.

Figure 33: Implication of the Models

(a) Skype (b) Reloadable Debit Card