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

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Abstract

Since 1998, the New York City Metropolitan Transportation Authority (MTA) system has used prepaid cards (MetroCards) to collect subway and bus fares. In 2013, the MTA imposed a $1 card fee (surcharge) on new MetroCard purchases. After the card fee was imposed, riders started to put more money on new MetroCard purchases. The response to the card fee was greater in low-income neighborhoods and among riders who used cash or debit cards rather than credit cards. As a result, the net monthly outstanding balance from 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 in the first year were never redeemed and escheated to the MTA when these cards expired. I document these changes using a novel dataset with transaction-level deposit and card use information. The leading explanation highlights the importance of the cost of effort to remember to carry the same card for future periods. I pose a structural model to calibrate the effect of a new card fee. Counterfactual simulation predicts that the optimal new card fee is $4.35 to maximize the MTA’s profit. These findings have implications for fiscal policy designs and fee structures of prepaid card industry.

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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, most metropolitan areas in US and abroad use prepaid cards to collect fares for public transit systems. 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). 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 the 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.

Since 1998, the New York City Metropolitan Transportation Authority (MTA) system has used prepaid cards to collect subway and bus fares. Riders load plastic cards (MetroCards) with amounts that they choose and swipe these cards when they ride subways or buses. In March 2013, the 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\footnote{Mathematically, the net outstanding balance for a specific month is calculated as $Balance = \sum deposits \times (1 + bonus(\%)) - \sum rides \times basefare}$ 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.
Moreover, over $20 million of the increased balances in the first year were never redeemed and escheated to the MTA when these cards expired. Each MetroCard is valid for 18 months after the initial 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.

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 importance of the cost of effort to remember to bring the same MetroCard for future rides, the fixed cost of making deposits to MetroCards, and consumer uncertainty about future rides. When MetroCards were free, riders with a low fixed cost of making deposits to MetroCards chose not to incur the cost of effort to remember to bring the same card for future days. They deposited only a small amount of money on cards and purchased a new MetroCard each period if needed. After the new card fee was imposed, many riders switched to refilling existing cards since their cost of effort to remember to carry the same card was smaller than the new card fee. They started making larger deposits to save on the fixed cost of making deposits to cards. Because consumers 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 usage that makes use of detailed MetroCard data from the years 2013 to 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 an exact number of rides. Holding prices fixed, my simulations predict an increase in expired fare revenue of $19.76 million (39.52%) after the $1 card fee was imposed on new MetroCard purchases, as opposed to $25 million. I then 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 every subway ride fixed. The model predicts that the optimal amount of new card fee is $4.35.

The importance of the cost of effort to remember to carry the same card and the fixed cost to make deposits to cards 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’ fixed cost to make payments converges to zero. As a result, cash flow from prepaid services will drop significantly as consumers switch from prepaying for future consumption to pay only for consumption this 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 deposits.

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).

Finally, these findings 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.

**Related Literature**

This paper contributes to the existing literature in several distinct ways. First, these findings have implications for fare designs of public transportation systems. The exploration of optimal pricing for public transit system started in the 1950s when [Vickrey](1955) wrote about revising New York’s subway fare structure. Since then, scholars have conducted many theoretical studies on transport...
pricing (Vickrey 1963; De Palma and Lindsey 2007; Small and Verhoef 2007; Tirachinia and Henshera 2012). Empirical analysis on the effects of these varied pricing policies has been limited, with most studies focusing on the demand elasticity of rides in response to fare increases (De Jong and Gunn 2001; Litman 2004; Chen et al. 2011; Miao and Gao 2013). 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 expired.

Second, these findings 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 push consumers to prepay more for future consumption.

Third, this paper contributes to literature on regressive fees. Prior studies have shown that many fees are regressive and impose a heavier burden on low-income people (Dorfman 1977; Gertler et al. 1987; Grainger and Kolstad 2010 and Leape 2006). Grainger and Kolstad (2010) found that a policy targeting CO$_2$ from energy consumption is more regressive than a price on all emissions. Furthermore, on a per-capita basis a carbon price is much more regressive than calculations at the household level. Leape (2006) showed that a congestion charge, as a flat-rate charge, imposes a heavier burden on low-income drivers. With a rich data set, I show that, even if the burden of a fee itself is not regressive, it could induce behavior with regressive consequences.

Fourth, these findings have implications for consumer behavior changes in response to the introduction of financial incentives such as a penalty or a bonus. Studies suggest that financial incentives will be effective if the costs an individual associates with changing her behavior are smaller than the incentive provided for doing so. For example, small fees on residential trash collection have been shown to increase recycling (Fullerton and Kinnaman 1996). Homonoff (2015) found that a five-cent shopping bag tax imposed in the Washington metropolitan area decreased the proportion of customers using disposable bags by a substantial amount. Consistent with findings in prior studies, a $1 new transit card fee pushed a lot of riders to refill and keep using their existing cards rather than purchasing new ones.

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 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. It is a thin plastic card on which a rider electronically loads fares. The MTA introduced the card to enhance the technology of the transit system and eliminate the burden of carrying and collecting tokens. The MTA discontinued the use of tokens in the subway on May 3, 2003, and on buses on December 31, 2003.

Types of MetroCard

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 pay-per-ride MetroCard is a thin plastic card on which riders can electronically load fares. The new pay-per-ride MetroCard minimum purchase is the fare of a round trip (currently $5.50). No minimum purchase is required for refill transactions. Riders can buy as many trips as they want. When a ride swipes a pay-per-ride MetroCard at a turnstile, the base fare is deducted from the card balance.

A single-ride ticket is a paper card with a magnetic strip on the front and the date and time of purchase stamped on the back. Each ticket is for one subway or one local bus ride with one free bus-to-bus transfer. Single-ride tickets expire two hours from the time of purchase. A 7-day-unlimited MetroCard is good for unlimited subway and local bus rides until midnight of the seventh day following the first usage. A 30-day-unlimited MetroCard is good for unlimited subway and local bus rides until midnight of the thirtieth day following the first usage.
Purchase Venues

A rider can purchase new or refill existing MetroCards at a subway station MetroCard vending machine (MVM) (Figure 11a) or at a station’s manned booth (teller) (Figure 11b). Manned booths sell all cards, except single-ride tickets, and they accept only cash payments. Station MetroCard vending machines sell all cards, including single-ride tickets. The screen asks what type of MetroCard a rider wants and takes the rider through the steps to buy it. For cash payments, vending machines accept different types of coins and bills in denomination of $1, $5, $10, $20, and $50. Machines can return no more than $9 in change and the change is given only in coins (quarters, dimes, nickels, and dollar coins). An illustration showing this process is located at www.antennadesign.com/transit.

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 12). When a rider uses a credit card at a vending machine, the rider is prompted to enter a zip code for verification. However, if the credit card account has a billing address outside of the United States, the rider is not subject to the zip code verification requirement. Instead, the rider should type in “99999” when prompted for a zip code. This will indicate to the machine that the rider is using an international credit card, and the regular transaction authorization process will still take place. More information is available on MTA’s website: www.mta.info.

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). Currently, the bonus value for pay-per-ride MetroCards is 11% of the purchase amount for purchases of $5.50 or more (Table 1 row 6).

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2MetroCards 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).

3Quarters, dimes, nickels, and dollar coins, except pennies and half-dollar coins.
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.

Table 1: Recent History of MTA Policy Changes

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<tr>
<td>Base fare ($)</td>
<td>2.25</td>
<td>2.25</td>
<td>2.50</td>
<td>2.75</td>
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<tr>
<td>7-day-unlimited ($)</td>
<td>27</td>
<td>29</td>
<td>30</td>
<td>31</td>
</tr>
<tr>
<td>30-day-unlimited ($)</td>
<td>89</td>
<td>104</td>
<td>112</td>
<td>116.50</td>
</tr>
<tr>
<td>Single-ride tickets ($)</td>
<td>2.25</td>
<td>2.50</td>
<td>2.75</td>
<td>3.00</td>
</tr>
<tr>
<td>$1 Card Fee on new MetroCard purchase</td>
<td>No</td>
<td>No</td>
<td>Yes*</td>
<td>Yes</td>
</tr>
<tr>
<td>Bonus for Pay-Per-Ride, % (threshold)</td>
<td>15%($8)</td>
<td>7%($10)</td>
<td>5%($5)</td>
<td>11%($5.50)</td>
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* The main policy change for this paper is the imposition of $1 card fee on new MetroCard purchases.
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 customers (seniors and customers with disabilities).

2.3 Environmental Impact

The transportation authority justified the new policy of 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.

On average, it costs the agency $20 million a year to print and clean up discarded cards from subway stations. According to MTA, after the imposition of the new card fee, printing fewer MetroCards and trimming cleanup costs was expected to save about $2 million a year. Compared to the annual total cost, the saving from the imposition of the new card fee is relatively small. It is not unreasonable since MetroCard printing likely requires a huge fixed-cost to set up printing facilities and experience economies of scale.

3 Data

In this section, I present the main features of the datasets 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.

3.1 MetroCard Deposit Data

The MetroCard deposit data includes detailed information on deposit transactions made to MetroCards. These data allow me to calculate daily sales of different types of MetroCards as well as to track changes in the deposit amounts on MetroCards. Therefore, I can compare purchases of new MetroCards before and after the imposition of the new card fee. I can also check the changes in deposit amounts to MetroCards before and after the implementation of the new card fee.

Monthly-Aggregate Deposit Data

The MetroCard monthly revenue data from January 2009 to June 2015 includes 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.

Transaction-level Deposit Data

The transaction-level MetroCard deposit data covers all deposit transactions for the following periods: 1) May 1, 2009 - September 30, 2009; 2) January 1, 2013 - May 1, 2013; and 3) September 1, 2014 - 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 MetroCard before the transaction. The data also include information on whether the transaction took place at a booth station or at a vending machine.

3.2 MetroCard Swipe Data

The swipe data includes detailed information on MetroCard swipes made by riders. I use the swipe data to investigate whether the differences in behavior I observed in deposit amounts and sales of new MetroCards suggest that riders reuse their existing MetroCards more after the imposition of

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7 Pay-per-ride, 7-day-unlimited, 30-day-unlimited Express, single-ride, reduced-fare seniors and disabled, etc.
8 This dataset included 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
the new card fee or have decreased their use of the subway system because of the new card fee and/or fare hikes. Also, these data, in combination with the deposit data and card trade-in and trade-out data, allow me to track changes in the card balance. I can then compare changes in foregone balance on MetroCards initially purchased before and after the implementation of the new card fee.

Transaction-level Swipe Data

The transaction-level swipe data\footnote{This dataset included 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} covers all MetroCard swipe transactions for the time period 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 MetroCard before the transaction.

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 June 2015, 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 have. 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 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 4. Additional findings are listed in Table 5 as robustness checks. In particular, riders purchased MetroCards with much larger deposits after
the imposition of the new card fee. Consequently, the monthly outstanding balance of deposits and forgone balances on expired cards jumped up significantly.

### 4.1 Purchases of New MetroCards Dropped After the New Card Fee was Introduced

Table 6 shows the monthly purchase of new MetroCards from January 2009 to June 2015. After the implementation of the new card fee, the total monthly new MetroCard sales dropped from over 7 million to about 2 million and stayed low, which is very robust across different sub-groups: 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 about 0.15 million; and the monthly sales of new 7-day-unlimited cards decreased by over 1.2 million to 0.34 million.

Figure 13 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 6. I replicated this analysis using transaction-level deposit data in Figure 14. This figure plots the daily new MetroCard sales from January 1, 2013 to April 30, 2013. The MTA sold about 0.2 million new MetroCards daily before the new card fee was introduced. This estimate dropped immediately to about 0.13 million 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 15-17).

#### Regression-Discontinuity Approach

Since there was no significant sorting of MetroCard purchases around the date when the MTA implemented the new card fee, I estimated the effect of the new card fee with a sharp 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:

\[
Y_t = \beta + \gamma \mathbb{I}\{t \geq t_0\} + a(t) + X_t + u_t,
\]

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 changes in 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 used local quadratic regression (a local polynomial of order two) for \( \alpha(.) \). Across specifications, the estimated effect of the new card fee from both local linear and local quadratic regressions corroborate the visual evidence.

Table 7 presents the results for the effects of the new card fee on changes in daily new MetroCard sales from January 1, 2013 to April 30, 2013, using different control variables in each specification. The model in column 2 controls for day of week. The results show that the implementation of the new card fee caused a significant decrease of 125,000 in daily new MetroCard purchases. To account for the possibility of variations in MetroCard sales across different months, my preferred specification in column 3 included month-of-year fixed effects. As with the other controls, the addition of month-of-year fixed effects has little impact on the estimated effects of the new card fee.

Using this preferred specification, Table 8 includes measures of changes in daily new card sales for 7-day-unlimited and 30-day-unlimited cards as well as 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 in daily new pay-per-ride MetroCard sales, a decrease of 23,000 in daily new 7-day-unlimited MetroCard sales, and a decrease of 24,000 in daily new 30-day-unlimited MetroCard sales.

### 4.1.1 Minor Decrease in Ridership

Besides the anticipated drop in new MetroCard sales, there was a minor decrease in ridership since the imposition of the new card fee when looking at weekly ridership (Figure 20).

### 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 22a and Figure 23a). I checked 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 22b and 23b). As a result, monthly revenue jumps up by 9.4%, from around $160 million to $175 million after the implementation of the new card fee (Figure 21a). This increase in monthly
revenue becomes more noticeable when looking at year-by-year monthly revenue (Figure 21b).

I then used a regression framework to evaluate the effects of the new card fee on the amounts of deposits. Table 9 presents the results for the effects of the new card fee on changes in 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 implementation of the new card fee caused a significant increase of $1.64 in deposit amounts on new pay-per-ride purchases. Riders, on average, made 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 included station fixed effects. The addition of station fixed effects causes the estimated effects of the new card fee to be smaller, which indicates that there is heterogeneity in deposit amounts across different stations.

4.3 Changes in the Outstanding Balance of Deposits

Because of the minor decrease in ridership and 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 18). The aggregate monthly outstanding balance that riders carried on their MetroCard is defined as the difference between the total amount loaded on the cards and the reductions caused by swipes at turnstiles. This additional outstanding balance translates to riders lending, on an annual basis, an extra $150 million to the MTA. In contrast, the net 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 was not likely driven primarily by the $0.25 increase of base fare.

Mathematically, the net outstanding balance for month $i$ is calculated as:

$$ \text{Balance}_{ni} = \sum \text{deposits} \times (1 + \text{bonus}(\%)) - \sum \text{rides} \times \text{base fare} $$

where base fare is $2.0 for months before February 2008, $2.25 for months from March 2008 to February 2013; $2.5 for months from March 2013 to February 2015.

Theoretically, the net outstanding balance for month $i$ should be calculated as:

$$ \text{Balance}_{ni} = \sum \text{deposits} + \sum \text{bonus} - \sum \text{rides} \times \text{base fare} $$

However, I only have aggregate monthly deposit amounts 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 from the imposition of the new card fee should be even larger.
4.4 Increases in Forgone Balances on Expired MetroCards

Moreover, over $20 million of the increased balances on MetroCards that were purchased in the first year after the new card fee was imposed were never redeemed and escheated to the MTA when these cards expired. Each MetroCard is valid for 18 months after the initial 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.

Figure 19 plots the aggregate leftover 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 leftover balances on expired MetroCards.

### 4.5 Deposits to MetroCards Show Different Changes: New MetroCards That Would be Held for Different Lengths of Time

In order to further explore the change in deposit patterns, I examined the deposit pattern in MetroCards held for different lengths of time. Deposits on new pay-per-ride purchases increased tremendously for MetroCards without subsequent refill activities\(^\text{11}\) (Figure 24a). Before the new card fee, about 60% of deposits were $5 or less for pay-per-ride MetroCards 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 the initial deposit amount for MetroCards that showed subsequent refill activities (Figure 24b).

### 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 examined the changes in deposit amounts and forgone balances on cards purchased using different payment methods (cash, debit card, versus credit card). The main changes came from cash or debit card payments rather than from credit card payments. Consistent with the pattern of deposit changes, there was higher forgone fare on MetroCards initially purchased by cash or debit cards rather than by credit cards (Figure 26b).

\(^{11}\)To minimize measurement errors, I only focused on cards purchased before April 1, 2013 and give each card at least one month to demonstrate refill activities.
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 26e and 27c). 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 26a and 27a). 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 26c and 27b).

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); Klee (2006); Feudner (2011)). To test whether this is true in the case of MetroCards, I linked the deposit amounts in different subway stations to local census tract income data. As shown in Figure 28, 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 (Bricker et al. (2014); Kennickell and Kwast (1997); Klee (2006); Feudner (2011)).

Since the increase in the outstanding balance mainly came from cash or debit-card payments, the new card fee may cause a stronger tendency to load more onto their cards among low-income communities. Controlling for station-level covariates, I used a regression framework to evaluate the effects of new card fee on deposit amounts across different neighborhoods. The empirical model takes the following forms:

\[ Y = \theta_0 + \theta_1 \text{Surcharge} + \theta_2 \text{Income} + \theta_3 \text{Surcharge} \times \text{Income} + \lambda X + \epsilon \]

where \( Y \) is the deposit amount for pay-per-ride MetroCards, and \( \text{Surcharge} \) is an indicator for observations after the implementation of the new card fee. \( \text{Income} \) 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 \( \text{Surcharge} \) and \( \text{Income} \), which measures the effect of income level on changes in deposit amounts after the new card fee relative to changes in deposit amounts before the new card fee.

Table 10 presents the results for the effect of the new card fee on deposit amounts. After the implementation of the new card fee, the change in deposit amounts was larger in poorer neighborhoods. On the other hand, there are no significant changes in ridership across different neighborhoods before and after the new card fee (Table 11). 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, which is not surprising because riders from richer neighborhoods already made large deposits on their MetroCards before the new card fee was imposed.

### 4.7 Cash Payments on New Pay-per-ride Purchases: Vending Machines versus Manned Booths

Since riders can purchase MetroCards at both manned booths (tellers) and vending machines, I checked whether there was any difference in changes in deposit patterns and forgone balances at manned booths versus at vending machines. As manned booths only accept cash payments, Figure 29 plots the cumulative distribution function for deposits and forgone balances on new pay-per-ride MetroCards purchased by cash before and after the new card fee went into effect.

Cash deposits made at vending machines for new MetroCard purchases grew in size while cash deposits made at booths for new MetroCard purchases increased only slightly. Consistent with the pattern of deposit changes, there was higher forgone fare on MetroCards initially purchased by cash at manned booths than at vending machines (Figure 29b and 29d). At vending machines, the percentage of riders who made cash deposits of approximately $10 or $20 almost doubled after the imposition of the new card fee. The percentage of riders who made cash deposits of approximately $5 dropped by about one-third (Figure 29c and 30b). At booths, the percentage of riders who made deposits of approximately $10 or $20 only increased from 20% to 30%, while the percentage of riders who made deposits of approximately $5 dropped from 80% to 70% (Figure 29a and 30a).

What is also interesting to note is that most cash deposits (net of new card fee) are in amounts of $5, $10, or $20 at manned booths, which means that riders pay $6, $11, or $21 in total, respectively. In contrast, most cash deposits (net of new card fee) are in amounts of $5, $9, or $19 at vending machines, indicating that riders pay $6, $10, or $20 in total, respectively (Figure 29 and 30).

I then used a regression framework to evaluate the effects of the new card fee on cash deposit amounts at vending machines versus at manned booths for new pay-per-ride purchases. The OLS empirical model takes the following form:

$$ Y = \theta_0 + \theta_1 \text{Surcharge} + \theta_2 \text{Machine} + \theta_3 \text{Surcharge*Machine} + \lambda X + \epsilon, $$

where $Y$ is the cash deposit amounts on new pay-per-ride purchases, and $\text{Surcharge}$ is an indicator for observations after the implementation of the new card fee. $\text{Machine}$ is an indicator for observations at vending machines. $X$ is a set of controls such as day-of-week and station fixed effects. The coefficient of interest is $\theta_3$, the coefficient on the interaction of $\text{Surcharge}$ and $\text{Machine}$, which measure the effect of the new card fee on changes in deposit amounts at vending machines relative to changes in deposit amounts at manned booths.
Table 12 presents the results for the effects of the new card fee on changes in cash 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 significant increase of $1.687 in cash deposit amounts on new pay-per-ride purchases. On top of that, the increase of cash deposit amounts is much larger at vending machines than at manned booths. The cash deposit amounts, on average, increased $0.74 more at vending machines than at manned booths, almost half of the size of the increase in deposit amounts from the imposition of the new card fee.

To account for the possibility of variations in deposit amounts across different neighborhoods, my preferred specification in column 4 included station fixed effects. The addition of station fixed effects causes the estimated effects of the new card fee to be smaller, which indicates that there is heterogeneity in deposit amounts across different stations. However, the increase of cash deposit amounts is still much larger at vending machines than at manned booths.

4.7.1 Cash Deposits to MetroCards in Stations Without Booths or Without Vending Machines

A concern that may arise is whether riders who make cash deposits at booth are different from riders who make cash deposits at vending machines. To investigate this issue, I looked at stations without booths or without vending machines. In these stations, riders who make cash deposits have no choice but to use only vending machines or use only booths. In Figure 29a and 29c, similar cash deposit patterns at vending machines are observable among different stations with or without booths. Similar cash deposit patterns are also observed at booths among stations with or without vending machines (Figure 29b and 29f). If there was selection bias in riders who made cash deposits at booths versus at vending machines, cash deposit patterns at booth-only stations or vending-machine-only stations should have looked like the total cash deposit patterns in stations with both manned booths and vending machines.

I performed robustness tests on booth-only stations and the station right before and right after the booth-only station along the same subway line. For instance, the Seneca Avenue station is a booth-only station that serves subway line M. It is located in Queens, New York, and shares the same neighborhood with the next station, Forest Avenue, which also serves subway line M and has both a manned booth and several vending machines. The cash deposit patterns in these two stations are very different from each other (Figure 32). Another example is from the vending-machine-only 74th-Broadway station which serves subway line 7. It is located in Jackson Heights, Queens, and shares the same station complex with the express station Jackson Heights – Roosevelt Avenue, which serves subway lines E, F, M, and R and has both a manned booth and vending machines.
Again, the cash deposit patterns at vending machines in these two stations are very similar to each other, but cash deposit patterns at the manned booth are very different from those at vending machines (Figure 33). Even in neighborhoods with few tourists such as Riverdale and South Bronx, similar differences in cash deposits are observable at booths versus at vending machines.

Yet another concern is that riders who use booth-only stations or vending-machine-only stations are different from riders using stations with both booths and vending machines. To investigate possible selection effects in station usage, I compared MetroCard transactions that occurred in subway stations that were booth-only stations but later became stations with both booths and vending-machines. For instance, the Seneca station was a booth-only station in early 2013, but vending machines were installed later at this station. There was no change in the total number of deposit transactions (new and refills) in this station (Figure 34), but riders who switched from booths to vending machines began to make larger deposits (Figure 35). These findings suggest that endogenous selection in using booths versus vending machines is not likely to account for the observed differences in deposit amounts.

5 Model

I present a simple model that highlights card carrying cost 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 ($n \in (0, \infty)$). 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 fixed 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 $c_i$. 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 for the next day. Among riders, latent $e_i$ is normally distributed censored at zero among riders: $N_e \sim (\mu_e, \sigma_e)$. (Throughout the paper, I will 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 $c_i$ depends on rider $i$’s opportunity cost of time while $e_i$ depends on rider $i$’s mental cost to be well-organized.

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. For now, I assume that $q_i$ is independent of the price of a subway ride. This is a reasonable approximation for the changes I study. In the appendix, I show how the results can
be extended to the general case where $q_i$ depends on the price of a subway ride. $N_i$ 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 $i$ makes choice of deposit amount $D_{it} \in [0, 2np]$ to her MetroCard. 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 on day $t$. Rider $i$ incurs utility cost $e_i$ if she exerts effort (i.e., $E_{it} = 1$). Every day $t$, rider $i$ decides whether or not to incur cost $C_{it}$ to make a deposit on her card. 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 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:

$$U_{it} = q_i(r_{it} - D_{it} - E_{it}e_i - C_{it}c_i - T(1 - E_{i,t-1}))$$  \hfill (3)

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

$$E[\min_{\{D_{it}, E_{it}, C_{it}\}} (D_{i,1} + E_{i,1}e_i + C_{i,1}c_i + T + \sum_{t=2}^{n} q_i(D_{it} + E_{it}e_i + C_{it}c_i + T(1 - E_{i,t-1})))]$$  \hfill (4)

## 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)? The table below outlines the conditions under which a rider would choose to bring the same MetroCard under different policies when the card balance is zero. If no card fee is imposed, riders will discard their MetroCards when the card balance is zero if $e_i > 0$, i.e., if they have to incur a utility cost to remember to carry the same card to the next day. If riders are charged a fee for purchasing a new MetroCard, they will keep the same card for the next period when the card balance is zero if the decrease in utility they suffer from having to pay the new card fee is larger than the cost to remember to carry the same card for the next period.
<table>
<thead>
<tr>
<th>Cost Function</th>
<th>Decision Variables</th>
<th>Condition to Prepay for Rides in the Second Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>With Card Fee</td>
<td>(4p + e_i + c_i)</td>
<td>(E_{i,1} = C_{i,1} = 1) and (C_{i,2} = 1)</td>
</tr>
<tr>
<td></td>
<td>((1 + q_i)2p + e_i + (1 + q_i)c_i)</td>
<td>(D_{i,1} = 4p) and (D_{i,2} = 0)</td>
</tr>
<tr>
<td></td>
<td>((1 + q_i)2p + (1 + q_i)c_i)</td>
<td>(E_{i,1} = 0) and (C_{i,1} = C_{i,2} = 1)</td>
</tr>
<tr>
<td>With Card Fee</td>
<td>(4p + e_i + c_i + T)</td>
<td>(E_{i,1} = C_{i,1} = 1) and (C_{i,2} = 1)</td>
</tr>
<tr>
<td></td>
<td>((1 + q_i)2p + e_i + (1 + q_i)c_i + T)</td>
<td>(E_{i,1} = C_{i,1} = C_{i,2} = 1)</td>
</tr>
<tr>
<td></td>
<td>((1 + q_i)2p + (1 + q_i)c_i + (1 + q_i)T)</td>
<td>(E_{i,1} = 0) and (C_{i,1} = C_{i,2} = 1)</td>
</tr>
</tbody>
</table>

### 5.2 Optimal Strategy: Prepay versus No Prepay

To begin the analysis, I look at the case of \(n = 2\). When \(n = 2\), the rider’s only decision is whether to prepay for rides in the second day. The table below outlines the conditions under which a rider would choose to prepay for rides. When no card fee is imposed, riders will prepay for future rides only if the fixed cost to make deposits is larger than the cost to remember to carry the same card for the next day and the risk of losing the deposit. If riders are charged a fee for purchasing a new MetroCard, riders will prepay for future rides only if the fixed cost to make deposits and pay the new card fee is larger than the cost to remember to carry the same card for the next day and the risk of losing the deposit.

Figure 1 shows the threshold of prepaying for rides in the second day when no card fee is imposed (Figure 1a) and when a card fee is imposed (Figure 1b), respectively. Before the new card fee was imposed, riders in region \(C\) only deposited the fare of the first day’s rides since the decrease in utility they suffer from having to incur the fixed 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 deposit. After the new card fee was imposed, these riders switched to prepaying for rides in the second day as the fixed cost to make deposits and pay the new card fee is larger than the cost to remember to carry the same card for the next period and the risk of losing the deposit. As a result, they risk losing \(2p\) on expired MetroCards if they do not actually take rides in the second day (Table 2).
Figure 1: Threshold of Prepaying for Rides in the Second Day For $n = 2$ Case

(a) No Card Fee

(b) With Card Fee

(c) With Card Fee (Changes)

Figure 1 shows the threshold of prepaying for rides in the second day for $n = 2$ case when no card fee is imposed (1a) and when a card fee is imposed (1c), respectively. Before the new card fee was imposed, riders in region $C$ only deposited the fare of the first day’s rides since the fixed 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 deposit. After the new card fee was imposed, these riders switched to prepaying for rides in the second day as the fixed cost to make deposits and pay the new card fee is larger than the cost to remember to carry the same card for the next period and the risk of losing the deposit. As a result, they risk losing $2p$ on expired MetroCards if they do not actually take rides in the second day (Table 2).
Table 2: Welfare Analysis: Cost of Rides for \( n = 2 \) Case

<table>
<thead>
<tr>
<th></th>
<th>No Card Fee</th>
<th>With Card Fee</th>
<th>Changes in Utility</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>(-(c_i + 2p) - q_i(c_i + 2p))</td>
<td>(-(c_i + 2p) - e_i - q_i(c_i + 2p))</td>
<td>(-e_i)</td>
</tr>
<tr>
<td>B</td>
<td>(-(c_i + 2p) - q_i(c_i + 2p))</td>
<td>(-(c_i + 2p) - q_i(c_i + 2p + T))</td>
<td>(-q_iT)</td>
</tr>
<tr>
<td>C</td>
<td>(-(c_i + 2p) - q_i(c_i + 2p))</td>
<td>(-(c_i + 4p) - e_i)</td>
<td>(-e_i - (1 - q_i)2p + q_i c_i)</td>
</tr>
<tr>
<td>D</td>
<td>(-(c_i + 4p) - e_i)</td>
<td>(-(c_i + 4p) - e_i)</td>
<td>No change</td>
</tr>
</tbody>
</table>

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 by tourists. Visitors are likely to have low probability of taking a round-trip in the second day (i.e., small \( q_i \)). Also, visitors may have low fixed cost to make deposits to a MetroCard (i.e., small \( c_i \)) since they may not understand they are missing a train or they are on vacation so their time is not very valuable. The fixed cost to make deposits and pay the new card fee is smaller than the cost to remember to carry the same card for the next period and the risk of losing the deposit. As a results, visitors were not likely to increase their deposits after the new card fee was imposed.

Local residents, in contrast, are likely to have high probability of taking a round-trip in the second day (i.e., large \( q_i \)). Also, their fixed cost 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. The fixed cost to make deposits and pay the new card fee is larger than the cost to remember to carry the same card for the next period and the risk to lose rides fare if they do not actually take rides in the second day. As a results, local residents are more likely to increase their deposits after the new card fee was imposed.

5.2.2 \( n=3 \) Case

In line with the \( n = 2 \) case, when \( n = 3 \), riders in region \( D \) switched from only depositing the fare of the first day’s rides to prepaying for rides in the second day after the new card fee \( T \) was introduced. Riders in region \( E \) switched from prepaying for rides in the second day to prepaying for rides in the second and third day after the new card fee was imposed (Figure 2b). Leftover balances on expired cards will increase accordingly.
Figure 2 shows the threshold of prepaying for rides in the second and third day for $n = 3$ case when no card fee is imposed (2a) and when a card fee is imposed (2b), respectively. Before the new card fee was imposed, riders in region $D$ only deposited the fare of the first day’s rides since the fixed 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 deposit. After the new card fee was imposed, these riders switched to prepaying for rides in the second day as the fixed cost to make deposits and pay the new card fee is larger than the cost to remember to carry the same card for the next period and the risk of losing the deposit. As a result, they risk losing $2p$ 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 and third day after the new card fee was imposed.
Figure 3: 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-one regions ranging from no prepay for future rides (region A) to prepay for rides in the next 30 days (region Z) when no card fee is charged for new MetroCard purchases.

5.3 \( n=30 \) Case

When \( n = 30 \), according to the model, there should be thirty-one regions ranging from no prepay for future rides to prepay for rides in the next 30 days (Figure 3). 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 4a and 4c). Therefore, there should be four regions as in Figure 5a and Figure 5b 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 take two rides in day 1, rider \( i \)'s objective is to choose a fare deposit policy \( \{D_{it}, E_{it}, C_{it}\} \) that minimizes expected total cost:

\[
E[\min_{D_{it} \in \{5,10,20,40\}, E_{it}, C_{it}} (D_{i,1} + E_{i,1}e_i + C_{i,1}c_i + T + \sum_{t=2}^{n} q_{it}(D_{it} + E_{it}e_i + C_{it}c_i + T(1 - E_{i,t-1})))]
\]

(5)

When riders are charged a fee for purchasing a new MetroCard, riders in region \( A' \) switched from choosing "other amount" choice to the first suggested deposit amount ($10); riders in region \( B' \) switched from the first suggested deposit amount to the second suggested deposit amount ($20); while riders in region \( C' \) switched from the second suggested deposit amount ($20) to the third suggested deposit amount ($40) (Figure 5c). Consistent with the predictions of the model, the number of deposits in suggested amounts jumped up significantly after the new card fee was
Figure 4: 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 4a and 4c show the suggested deposit amounts on vending machine screen before and after the new card fee went into effect, respectively. Figure 4b and 4d 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 5: Default Choices of Deposit Amounts For $n = 30$ Case

(a) No Card Fee

(b) With Card Fee

(c) With Card Fee (Changes)

Figure 5 shows the threshold of choosing different deposit amounts for $n = 30$ case when no card fee is imposed (5a) and when a card fee is imposed (5b), 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 6: Daily Total Number of Pay-per-ride MetroCard Purchases From January 1, 2013 To April 30, 2013 By Deposit Amounts

(a) $\sim5$

(b) $\sim10$

(c) $\sim20$

(d) $40\sim50$

Note: Figure 6a plots daily total number of MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 6b 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 7: 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 7a and 7b 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 8: 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 8a and 8b 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.
Table 3: Parameter Estimates

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \beta )</td>
<td>Price Sensitivity</td>
</tr>
<tr>
<td>( E[q_i] )</td>
<td>Mean of Probability</td>
</tr>
<tr>
<td>( \sigma[q_i] )</td>
<td>Standard Error of Probability</td>
</tr>
<tr>
<td>( E[c_i] )</td>
<td>Mean of Fixed Cost</td>
</tr>
<tr>
<td>( \sigma[c_i] )</td>
<td>Standard Error of Fixed Cost</td>
</tr>
<tr>
<td>( E[e_i] )</td>
<td>Mean of Carrying Cost</td>
</tr>
<tr>
<td>( \sigma[e_i] )</td>
<td>Standard Error of Carrying Cost</td>
</tr>
</tbody>
</table>

### 5.4 Parameter Estimates

This subsection summarizes the construction of the likelihood function and the estimation procedure; complete details are in Appendix D. I use changes of deposits in suggested amounts 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.

The estimates for the 7 parameters discussed in the main text are shown in Table 3. Recall that the parameters of the pre-censoring distributions are used to describe the censored distributions. The price coefficient \( \beta \) is 0.12, which indicates that a price increase from $0.00 to $2.50 per ride decreases usage by 25 percent. The next six parameters characterize the normal distribution of riders’ riding probability \( q_i \), fixed cost to purchase MetroCards \( c_i \), and card carrying cost \( e_i \). The average rider’s riding probability \( q_i \) is estimated to be 0.62. The average riders’ fixed cost \( c_i \) is estimated to be $1.45, while the average rider’s 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 having payment prompts (i.e., default choices of deposit amounts) on TouchScreen of MetroCard vending machines that do not give an exact number of rides: If a
rider chooses one of the payment prompts on the Touchscreen, she will end up with a card that has leftover change because none of those 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 every subway ride.

Some people have proposed a software change as shown in Figure 9. Now all the payment prompts on Touchscreen give an 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 this new payment prompts on Touchscreen while holding base fare for every subway ride fixed. 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 give an exact number of rides, expired fare revenue will still increase by 39.52% ($19.76 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 every subway ride fixed. 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 importance of the cost of effort to remember to bring the same MetroCard for future rides, the fixed cost of making deposits to MetroCards, and consumer uncertainty about future rides. However, transaction cost is not the only possible explanation for the observed increase in deposit amounts and the 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 payment amounts ($10, $20, $40), along with bonuses. This could potentially push riders to make higher deposits. However, the screen displayed 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 4a and 4c). Since the main changes in deposit amounts were switching from $5 to $10 and $20 with no changes of the $10 and $20 suggested amounts, persuasion, solely, is not likely to account for the observed changes in new purchases.

6.2 Avoidance of Coins

When riders make deposits to MetroCards using cash at vending machines, they may receive as many as 20 quarters (i.e., $4) as change if they purchase new MetroCards 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 making $10 or $20 cash deposits during new pay-per-ride card purchases 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 26c). 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 26c).
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 refill transactions 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 should decrease their deposit amounts back to the pre-fee level. It has been three years since the introduction of the new card fee. I did not observe decrease in deposit amounts or forgone balances over time.

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. It has been three years since the the introduction of the new card fee. No decrease in deposit amounts or forgone balances was observed.

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 whether 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).
Cross-type switch in purchases of MetroCards

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 to unlimited-ride cards or single-ride tickets due to the variations in fare hike across different types of MetroCards.

Table 16 lists monthly revenue before and after the new card fee. There was no significant change in the percent of revenue from pay-per-ride versus that from time-based cards. Table 13 and Table 14 show that the threshold for switching from pay-per-ride 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 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 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.

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

Table 13 compares the 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 implementation. Before the new card fee, a rider would only save more money buying a 7-day-unlimited than buying a pay-per-ride card if he takes more than 14 trips within one week. After the new card fee, this threshold was 13, only decreasing by one trip.

Table 14 compares the 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 for switching from pay-per-ride to 30-day-unlimited cards only slightly changed after the fare hikes in March 2013.
There may be some concern that changes in deposit patterns are solely due to the fare hike in 2013. Figure 38 and 39 plots the histogram for deposits on pay-per-ride MetroCard purchases 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 increase of base fare.

8 Implications of the Model

In this section, I discuss implications of the model 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 importance of the cost of effort to remember to carry the same card ($e_i$) and the fixed cost to make deposits 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, consumers’ fixed cost to make payments $c_i$ converges to zero. As a result, consumers switch from prepaying for future consumption to pay 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 deposits. For skype credit, the minimum purchase amount is $10 (Figure 10a) 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 the forgone balance on expired cards. After the introduction of a $1 new card fee, the net monthly outstanding balance from 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 in the first year 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 that would not have 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 importance of the cost of effort to remember to bring the same MetroCard for future rides, the fixed cost of making deposits to MetroCards, and consumer uncertainty about future rides. When MetroCards were free, riders with a low fixed cost of making deposits to MetroCards chose not to incur the cost of effort to remember to bring the same card for future days. They deposited only a small amount of money on cards and purchased a new MetroCard each period if needed. After the new card fee was imposed, many riders switched to refilling existing cards since their cost of effort to remember to carry the same card was smaller than the new card fee. They started making larger deposits to save on the fixed cost of making deposits to cards. Because consumers are uncertain about future rides, these riders on average had higher leftover 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’ fixed cost to make payments 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 consumption to pay only for consumption this period (pay-as-you-go). A natural follow-up works is to conduct field experiments to examine the effects of mobile payments on riders’ deposit amounts.

References


Figure 11: MetroCard Purchase Venues

(a) Vending Machine

(b) Manned Booth

Source: Figure 11a [www.fastcompany.com](http://www.fastcompany.com); Figure 11b [Benjamin Kabak on Flickr](https://www.flickr.com)

Figure 12: First Screen Snapshot on Vending Machine Purchases Before and After the New Card Fee

(a) Before

(b) After

*Note:* Figure 12 shows the first screen snapshot of the vending machines before (12b) and after (12b) the new card fee went into effect, respectively.
Table 4: Main Empirical Findings

<table>
<thead>
<tr>
<th>Finding 1</th>
<th>A large drop in number of new MetroCard sold (Figure 13 - 17)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finding 2</td>
<td>Monthly outstanding balance from pay-per-ride MetroCard deposits jumped by one-third (Figure 18 - 21)</td>
</tr>
<tr>
<td>Finding 3</td>
<td>Expired fare revenue substantially increased</td>
</tr>
<tr>
<td>Finding 4</td>
<td>Larger increase in deposits on new purchases (Figure 22 - 23)</td>
</tr>
<tr>
<td>Finding 5</td>
<td>Larger increase in deposits on cash or debit-card payments (Figure 26 - 27)</td>
</tr>
<tr>
<td></td>
<td>Riders from low-income neighborhoods make larger increase in deposits on new pay-per-ride card purchases (Figure 28 and Table 10)</td>
</tr>
<tr>
<td>Finding 6</td>
<td>Larger changes in deposits on cash payments at machines than at manned booths (tellers) (Figure 29 - 30)</td>
</tr>
<tr>
<td>Finding 7</td>
<td>Most cash deposits (net of new card fee) in amounts of $5, $10, or $20 at manned booths (Figure 29a and 30a); Most cash deposits (net of new card fee) in amounts of $5, $9, or $19 at vending machines (Figure 29b and 30b).</td>
</tr>
<tr>
<td>Finding 8-1</td>
<td>Larger increase in deposits on cards with no subsequent refill activities (Figure 24 - 25)</td>
</tr>
<tr>
<td></td>
<td>Trivial change in deposit amount on cards with subsequent refill activities (Figure 24 - 25)</td>
</tr>
</tbody>
</table>
Table 5: Robustness Findings

Finding 9
No significant changes in ridership (Figure 20)

Finding 10
No significant increase in demand for single-ride tickets (Figure 31)

Finding 11
No significant changes in purchase amounts before versus after the fare hike in 2009 or 2015 (Figure 38 and 39)

Finding 12
No significant cross-type changes (unlimited-type versus pay-per-ride) (Figure 36)

Table 6: Monthly Demand for New Cards Before And After the new card fee (In millions)

<table>
<thead>
<tr>
<th></th>
<th>Before (Jan 2009 to Feb 2013)</th>
<th></th>
<th>After (Mar 2013 to Jun 2015)</th>
<th></th>
<th>p-value (5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number (1)</td>
<td>Percent (2)</td>
<td>Number (3)</td>
<td>Percent (4)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>7.70</td>
<td>1</td>
<td>2.32</td>
<td>1</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>(0.55)</td>
<td></td>
<td></td>
<td>(0.39)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pay-per-ride</td>
<td>5.84 (0.47)</td>
<td>0.758 (0.011)</td>
<td>1.826 (0.28)</td>
<td>0.791 (0.01)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>30-day-unlimited</td>
<td>0.58 (0.055)</td>
<td>0.076 (0.01)</td>
<td>0.15 (0.042)</td>
<td>0.063 (0.01)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>7-day-unlimited</td>
<td>1.26 (0.079)</td>
<td>0.163 (0.005)</td>
<td>0.339 (0.076)</td>
<td>0.144 (0.01)</td>
<td>&lt;0.0001*</td>
</tr>
</tbody>
</table>

N 104 112

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 7: Effect of New Card Fee on Daily Total New MetroCard Sales

<table>
<thead>
<tr>
<th></th>
<th>(1) Sales</th>
<th>(2) Sales</th>
<th>(3) Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card Fee</td>
<td>-125286***</td>
<td>-124822***</td>
<td>-163102***</td>
</tr>
<tr>
<td></td>
<td>(6634)</td>
<td>(4975)</td>
<td>(19695)</td>
</tr>
<tr>
<td>Day of Week FE</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Month Fixed Effects (FE)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>120</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.751</td>
<td>0.868</td>
<td>0.879</td>
</tr>
</tbody>
</table>

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

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

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 9: Effect of New Card Fee on Deposit Amounts: RD Regressions

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card Fee</td>
<td>1.614***</td>
<td>1.644***</td>
<td>0.933***</td>
</tr>
<tr>
<td></td>
<td>(0.062)</td>
<td>(0.058)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>AM Early Hrs (0:01-6:29am)</td>
<td>–0.697***</td>
<td>–0.755***</td>
<td>–0.235***</td>
</tr>
<tr>
<td></td>
<td>(0.120)</td>
<td>(0.118)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>AM Rush Hrs (6:30-10:00am)</td>
<td>0.736***</td>
<td>0.574***</td>
<td>1.078***</td>
</tr>
<tr>
<td></td>
<td>(0.102)</td>
<td>(0.095)</td>
<td>(0.008)</td>
</tr>
<tr>
<td>AM Late Hrs (10:00-1:00pm)</td>
<td>–0.147***</td>
<td>–0.170***</td>
<td>–0.051***</td>
</tr>
<tr>
<td></td>
<td>(0.031)</td>
<td>(0.031)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>PM Rush Hrs (4:30-8:00pm)</td>
<td>1.174***</td>
<td>1.149***</td>
<td>0.741***</td>
</tr>
<tr>
<td></td>
<td>(0.060)</td>
<td>(0.057)</td>
<td>(0.009)</td>
</tr>
<tr>
<td>PM Late Hrs (8:00-11:59pm)</td>
<td>–0.293***</td>
<td>–0.246***</td>
<td>–0.486***</td>
</tr>
<tr>
<td></td>
<td>(0.055)</td>
<td>(0.054)</td>
<td>(0.011)</td>
</tr>
<tr>
<td>Card Fee * AM Early Hrs</td>
<td>0.494***</td>
<td>0.491***</td>
<td>0.661***</td>
</tr>
<tr>
<td></td>
<td>(0.067)</td>
<td>(0.068)</td>
<td>(0.029)</td>
</tr>
<tr>
<td>Card Fee * AM Rush Hrs</td>
<td>0.379***</td>
<td>0.318***</td>
<td>0.347***</td>
</tr>
<tr>
<td></td>
<td>(0.034)</td>
<td>(0.033)</td>
<td>(0.015)</td>
</tr>
<tr>
<td>Card Fee * AM Late Hrs</td>
<td>0.240***</td>
<td>0.232***</td>
<td>0.117***</td>
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<tr>
<td></td>
<td>(0.024)</td>
<td>(0.025)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Card Fee * PM Rush Hrs</td>
<td>–0.310***</td>
<td>–0.333***</td>
<td>–0.265***</td>
</tr>
<tr>
<td></td>
<td>(0.048)</td>
<td>(0.049)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Card Fee * PM Late Hrs</td>
<td>–0.058</td>
<td>–0.072*</td>
<td>0.107***</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
<td>(0.035)</td>
<td>(0.021)</td>
</tr>
</tbody>
</table>

Day of Week FE: No, Yes, Yes
Station Fixed Effects (FE): No, No, Yes

Observations: 13260141, 13260141, 13260141
R²: 0.011, 0.015, 0.011

Dependent variable: deposit amount 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 April 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 10: Median Neighborhood Income and Pay-per-ride Deposit Amounts

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>New</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
<td></td>
</tr>
<tr>
<td>Income(log)</td>
<td>0.221***</td>
<td>0.220***</td>
<td>0.245***</td>
<td>0.242***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001 )</td>
<td>(0.001 )</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>Card Fee</td>
<td>0.129***</td>
<td>0.123***</td>
<td>0.411***</td>
<td>0.404***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.012 )</td>
<td>(0.011 )</td>
<td>(0.014)</td>
<td>(0.014)</td>
<td></td>
</tr>
<tr>
<td>Card Fee*Income(log)</td>
<td>–0.006***</td>
<td>–0.005***</td>
<td>–0.030***</td>
<td>–0.030***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.001 )</td>
<td>(0.001 )</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td>Day of Week FE</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
<td>68632976</td>
<td>68632976</td>
<td>13659758</td>
<td>13659758</td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.015</td>
<td>0.020</td>
<td>0.015</td>
<td>0.020</td>
<td></td>
</tr>
</tbody>
</table>

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

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

Table 11: Median Neighborhood Income and Ridership At Station-level

<table>
<thead>
<tr>
<th></th>
<th>Pay-per-ride</th>
<th>7-day</th>
<th>30-day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td>Income(log)</td>
<td>0.293*</td>
<td>0.293*</td>
<td>–0.155</td>
</tr>
<tr>
<td></td>
<td>(0.115 )</td>
<td>(0.115 )</td>
<td>(0.125 )</td>
</tr>
<tr>
<td>Card Fee</td>
<td>–0.184</td>
<td>–0.186</td>
<td>0.347</td>
</tr>
<tr>
<td></td>
<td>(0.240 )</td>
<td>(0.239 )</td>
<td>(0.279 )</td>
</tr>
<tr>
<td>Card Fee*Income(log)</td>
<td>0.014</td>
<td>0.014</td>
<td>–0.003</td>
</tr>
<tr>
<td></td>
<td>(0.024 )</td>
<td>(0.024 )</td>
<td>(0.029 )</td>
</tr>
<tr>
<td>Month of year FE</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Observations</td>
<td>34132</td>
<td>34132</td>
<td>34087</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.040</td>
<td>0.041</td>
<td>0.051</td>
</tr>
</tbody>
</table>

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 12: Effect of New Card Fee on Deposit Amounts at New Pay-per-ride MetroCard Purchases: Cash Payments Only

<table>
<thead>
<tr>
<th></th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Card Fee</td>
<td>1.695***</td>
<td>1.687***</td>
<td>1.327***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>Machine</td>
<td>1.912***</td>
<td>1.914***</td>
<td>1.506***</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Card Fee*Machine</td>
<td>0.740***</td>
<td>0.741***</td>
<td>0.778***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Day of Week FE</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Station Fixed Effects (FE)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Observations</td>
<td>4689119</td>
<td>4689119</td>
<td>4689119</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.052</td>
<td>0.053</td>
<td>0.083</td>
</tr>
</tbody>
</table>

Dependent variable: deposit amount at new pay-per-ride MetroCards (cash). Standard Deviation in parentheses and clustered at station level. The sample is limited to deposit transactions to new pay-per-ride MetroCards (cash payments only) from January 1, 2013 to April 30, 2013.

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

Table 13: Comparison of ridership cost Pay-per-ride versus 7-day-unlimited

<table>
<thead>
<tr>
<th>Rides</th>
<th>Dec 30, 2010 to Mar 2, 2013 7% bonus for every $10</th>
<th>Mar 3, 2013 to Mar 21, 2015 5% bonus for every $5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pay-per-ride</td>
<td>7-day-unlimited</td>
</tr>
<tr>
<td>1</td>
<td>2.25</td>
<td>29</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>29</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>12</td>
<td>25.23</td>
<td>29</td>
</tr>
<tr>
<td>13</td>
<td>27.34</td>
<td>29</td>
</tr>
<tr>
<td>14</td>
<td>29.44</td>
<td>29</td>
</tr>
</tbody>
</table>

Table 13 compares the 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 14: Comparison of ridership cost Pay-per-ride versus 30-day-unlimited

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7% bonus for every $10</td>
<td>5% bonus for every $5</td>
</tr>
<tr>
<td></td>
<td>Pay-per-ride</td>
<td>30-day-unlimited</td>
</tr>
<tr>
<td>1</td>
<td>2.25</td>
<td>104</td>
</tr>
<tr>
<td>2</td>
<td>4.5</td>
<td>104</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>47</td>
<td>98.83</td>
<td>104</td>
</tr>
<tr>
<td>48</td>
<td>100.93</td>
<td>104</td>
</tr>
<tr>
<td>49</td>
<td>103.04</td>
<td>104</td>
</tr>
<tr>
<td>50</td>
<td>105.14</td>
<td>104</td>
</tr>
</tbody>
</table>

Table 14 compares the 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>
<thead>
<tr>
<th>Finding</th>
<th>After the new card fee</th>
<th>Persuasion of Machine</th>
<th>Avoidance of Coins</th>
<th>Quick Fix</th>
<th>Commitment Device</th>
<th>Transaction Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A large drop in number of new MetroCard sold</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Monthly outstanding balance from pay-per-ride deposits jumped by 1/3</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>3</td>
<td>Increased expired fare revenue</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4</td>
<td>No decrease in deposit amounts or forgone balances over time</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Increase in deposit amount on new purchases</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>6</td>
<td>Larger increase in deposits on cash or debit card payments</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>7</td>
<td>Larger changes in deposits on cash payments at machines than at booths</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>8</td>
<td>Most cash deposits in amounts of $5, $10, or $20 at manned booths (net of new card fee)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>9</td>
<td>Larger increase in deposits on cards with no subsequent refill activities</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Trivial change in deposit amount on cards with refill activities</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
Table 16: Monthly Revenue Before and After the New Card Fee (In Millions $)

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

Standard deviations in parentheses
Table reports mean values of each variable
Table shows the monthly revenue from sales of different types of Metro-Cards before and after the new card fee. There was no significant change in the percent of revenue from pay-per-ride versus that from time-based cards.
Figure 13: 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 13 plots monthly sales of new MetroCards 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 14: Daily Sales of New MetroCards (All Types) from January 1, 2013 to April 30, 2013

(a) Raw
(b) Adjusted

Figure 14a plots daily sales of new MetroCards (all types) from January 1, 2013 to April 30, 2013. Figure 14b plots residual of daily sales from day of week fixed effect. The vertical line marks the day when the new card fee was implemented.

Figure 15: Daily Sales of New Pay-per-ride MetroCards from January 1, 2013 to April 30, 2013

(a) Raw
(b) Adjusted

Note: Figure 15a plots daily sales of new pay-per-ride MetroCards from January 1, 2013 to April 30, 2013. Figure 15b 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 16: Daily Sales of New 7-day-unlimited MetroCards from January 1, 2013 to April 30, 2013

(a) Raw  
(b) Adjusted

Note: Figure 16a plots daily sales of new 7-day-unlimited MetroCards from January 1, 2013 to April 30, 2013. Figure 16b 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 17: Daily Sales of New 30-day-unlimited MetroCards from January 1, 2013 to April 30, 2013

(a) Raw  
(b) Adjusted

Note: Figure 17a plots daily sales of new 30-day-unlimited MetroCards from January 1, 2013 to April 30, 2013. Figure 17b 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 18: Monthly Outstanding balance from Pay-per-ride Deposits from January 2008 to April 2015

Note: Figure 18 plots monthly outstanding balance from pay-per-ride deposits from January 2008 to April 2015. The aggregate monthly outstanding balance that riders carried on their MetroCard 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 first imposed (also the month when the 2013 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 19: Aggregate Forgone Balances on Pay-per-ride MetroCards Initially Purchased Between January 1, 2013 and April 30, 2013

Note: Figure 19 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 20: Weekly Total Number of MetroCard Swipes from January 2011 to May 2015

*Note:* Figure 20 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 21: Monthly Revenue from Pay-per-ride Deposits from January 1, 2011 to April 30, 2015

(a) Figure 21a 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. (b) Figure 21b plots year-to-year monthly revenue of pay-per-ride deposits from January 2012 to December 2014.
Figure 22: 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 22 plots the cumulative distribution function (CDF) for deposit amounts on new pay-per-ride MetroCard purchases before versus after the new card fee. Figure 22a used all the deposit transactions from January 1, 2013 to April 30, 2013. Figure 22b plots deposits of purchases within one week before and after the new card fee.

Figure 23: 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 23 plots the histogram of deposit amounts on new pay-per-ride MetroCard purchases before versus after the new card fee. Figure 23a used all the deposit transactions from January 1, 2013 to April 30, 2013. Figure 23b plots deposits of purchases within one week before and after the new card fee.
Figure 24: 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 24 plots the cumulative distribution function for deposits on new pay-per-ride purchases before and after the new card fee. Figure 24a plots the cumulative distribution function for deposits on new pay-per-ride purchases without subsequent refill activities. Figure 24b plots the cumulative distribution function for deposits on new pay-per-ride purchases with subsequent refill activities.

Figure 25: 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 25 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 25a plots the histogram for deposits on new pay-per-ride purchases without subsequent refill activities. Figure 25b plots the histogram for deposits on new pay-per-ride purchases with subsequent refill activities.
Figure 26: 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 26 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 26a-26b plot the charts for cash purchases. Figure 26c-26d plot the charts for debit card purchases. Figure 26e-26f plot the charts for credit card purchases.
Figure 27: 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 27 plots the histogram for deposits on new pay-per-ride purchases before and after the new card fee by different payment methods. Figure 27a plots the cumulative distribution function for cash deposits on new pay-per-ride purchases. Figure 27b plots the histogram for debit-card payments on new pay-per-ride purchases. Figure 27c plots the histogram for credit-card payments on new pay-per-ride purchases.
Figure 28: Percent of Cash Payments Across Different Subway Stations From January 2013 To April 2013

Note: Figure 28 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 29: Total Cash Deposit Amounts (Including the New Card Fee) 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) Deposits (Manned Booths)  
(b) Forgone Balances (Manned Booths)  
(c) Deposits (Vending Machines)  
(d) Forgone Balances (Vending Machines)  
(e) Deposits (Booth-only Stations)  
(f) Deposits (Vending-Machine-Only Stations)

Note: Figure 29 plots the cumulative distribution function for deposits and forgone balances on new pay-per-ride MetroCards purchased by cash before and after the new card fee. Figure 29a-29b plot the charts for cash purchases at manned booths. Figure 29c-29d plot the charts for cash purchases at vending machines. Figure 29e plots the CDF for cash deposits at manned booths in booth-only stations. Figure 29f plots the CDF for cash deposits at vending machines in vending-machine-only stations.
Figure 30: Cash 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) Manned Booths

(b) Vending Machines

Note: Figure 30 plots the histogram of total cash deposit amounts (including the new card fee) on new pay-per-ride MetroCard purchases before versus after the new card fee. Figure 30a plots the histogram for total cash deposit amounts (including the new card fee) on new pay-per-ride MetroCard purchases at manned booths. Figure 30b plots the histogram for total cash deposit amounts (including the new card fee) on new pay-per-ride MetroCard purchases at vending machines.

Figure 31: Monthly Sales of Single-ride Tickets From January 2011 To June 2015
Figure 32: Total Cash Deposits on New Pay-per-ride MetroCard Purchases Before and After the New Card Fee (From January 1, 2013 To April 30, 2013): Forest Avenue Station Versus Seneca Avenue Station

(a) Forest Avenue

(b) Seneca Avenue

Note: Figure 32 plots the cumulative distribution function for cash deposit amounts on new pay-per-ride MetroCard purchases after the new card fee in Forest Avenue station versus Seneca Avenue Station from January 1, 2013 to April 30, 2013. Figure 32a plots the cumulative distribution function for all cash deposit amounts on new pay-per-ride purchases at Forest Avenue station which has both a manned booth and several vending machines. Figure 32b plots the cumulative distribution function for all cash deposit amounts on new pay-per-ride purchases at Seneca Avenue Station which has only a manned booth.
Figure 33: Cash Deposits on New Pay-per-ride MetroCard Purchases After the New Card Fee (From January 1, 2013 To April 30, 2013): 74-Broadway Station versus Jackson Height-Roosevelt Avenue Station

(a) Vending Machine

(b) Within Roosevelt Avenue Station

Note: Figure 33 plots the cumulative distribution function for cash deposit amounts on new pay-per-ride MetroCard purchases after the new card fee in 74-Broadway Station versus Jackson Height-Roosevelt Avenue Station from January 1, 2013 to April 30, 2013. Figure 33a plots the cumulative distribution function for cash deposit amounts on new pay-per-ride MetroCard purchases at vending machines in 74-Broadway station versus in Jackson Height-Roosevelt Avenue Station. Figure 33b plots the cumulative distribution function for cash deposit amounts on new pay-per-ride MetroCard purchases at manned booth versus at vending machines within Jackson Height-Roosevelt Avenue Station.
Figure 34: Total Number of Daily Deposit Transactions (New and Refills) at Seneca Station: 2013 Versus 2015

(a) 2013
(b) 2015

Note: Figure 34a plots daily total number of MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013 at Seneca Station. Figure 34b plots daily total number of MetroCard purchases (new and refills) from January 1, 2015 to April 30, 2015 at Seneca Station. The vertical line (red) marks the day when the new card fee went into effect.

Figure 35: Cash Deposits at Seneca Avenue Station: 2013 Versus 2015

(a) booth cash
(b) vending machine cash

Note: Figure 35a plots the cumulative distribution function (CDF) for cash deposit amounts on new pay-per-ride MetroCard purchases at manned booths of Seneca Station. Figure 35b plots the CDF for cash deposit amounts on new pay-per-ride MetroCard purchases at manned booth versus at vending machines of Seneca Station in 2015. Seneca station was a booth-only station in early 2013. Vending machines were installed at this station in 2014.
Figure 36: 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 36a plots daily total number of 7-day-unlimited MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 36b plots residual of daily total number of 7-day-unlimited MetroCard purchases (new and refills) from day of week fixed effect. Figure 36c plots daily total number of 30-day-unlimited MetroCard purchases (new and refills) from January 1, 2013 to April 30, 2013. Figure 36d 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 37: 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 37 plots the cumulative distribution function for deposits on pay-per-ride MetroCard purchases before and after the 2009 fare hike. Figure 37a plots cumulative distribution function for deposits on new pay-per-ride MetroCard purchases from May 1, 2009 to August 30, 2009. Figure 37b plots the cumulative distribution function for deposits on pay-per-ride refills from May 1, 2009 to August 30, 2009.

Figure 38: 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 38 plots the histogram for deposits on pay-per-ride MetroCard purchases before and after the 2009 fare hike. Figure 38a plots the histogram for deposits on new pay-per-ride purchases from May 1, 2009 to August 30, 2009. Figure 38b plots the histogram for deposits on pay-per-ride refills from May 1, 2009 to August 30, 2009.
Figure 39: 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 39 plots the cumulative distribution function for deposits on pay-per-ride MetroCard purchases before and after the 2015 fare hike. Figure 39a plots cumulative distribution function for deposits on new pay-per-ride MetroCard purchases from January 1, 2015 to May 31, 2015. Figure 39b plots the cumulative distribution function for deposits on pay-per-ride refills from January 1, 2015 to May 31, 2015.
Appendices

A A General Model where $q_i$ Depends on the Base Fare of a Ride

The marginal utility of a subway or bus ride for rider $i$ on day $t$ is $r_{it}$. $\beta$ is the price sensitivity parameter that determines how sensitive riding choices are to the marginal price of an additional ride. Here marginal price is $v_i$ for rider $i$. For each rider $i$, $r_{it}$ is uniformly distributed from 0 to $\frac{1}{\beta} \sim U(0, \frac{1}{\beta})$. On day $t$, the probability of actually taking a round-trip for rider $i$ is:

$$q_i = q_i \hat{q}(v_i)$$

(6)

where $\hat{q}(v) = 1 - \beta v$ is the fraction of riding opportunities worth more than $v_i$ per ride. Over the course of an $n$-day period, actual number of rides taken by rider $i$ is:

$$\hat{N}_i = \hat{N}(v_i, q_i, N_i) = N_i \hat{q}(v_i)$$

(7)

The expected value from riding subways and buses over a $n$-day time period is:

$$V(\hat{N}_i, N_i) = \frac{1}{\beta} \hat{N}_i (1 - \frac{1}{2} \hat{q}(v_i))$$

(8)

Figure 40 shows the riding threshold $v$ and resulting riding choice in relation to a rider’s realized inverse demand curve. 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:
When purchasing a new MetroCard with card fee $T$ and take two rides in day 1, rider $i$’s objective is to choose a fare deposit policy $\{D_{it}, E_{it}, C_{it}\}$ that maximizes expected total utility:

$$U_i = E[\max_{\{D_{it}, E_{it}, C_{it}\}} (V(\hat{N}_i, N_i) - (D_{i,1} + E_{i,1}e_i + C_{i,1}c_i + T + \sum_{t=2}^{n} q_i (D_{it} + E_{it}e_i + C_{it}c_i + T(1 - E_{i,t-1}))))]$$

(10)

Alternatively, to minimize total cost:

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

(11)

## A.1 Stylized Facts Relevant to Modeling Rides Choices

Three features of the data are important to accurately model rides choices by riders. First, riders’ usage choices are price sensitive. Second, riders’ usage choices are made while riders are uncertain about the ex post marginal price. Third, riders are inattentive to the remaining balance of their MetroCards. These three stylized facts motivate my assumption that, rather than choosing a precise quantity, riders choose riding thresholds and proceed to take all rides valued above the threshold.

Rider price sensitivity is clearly illustrated by a sharp decrease in single-ride ticket riding volume when the base fare for a ride increased (Figure 31). Two pieces of evidence demonstrate rider uncertainty about ex post marginal price. First, given clear sensitivity to marginal price, we would expect to see most riders using all the money in their MetroCards. Figure 29b shows more than 82 percent MetroCards had leftover balances at expiration, which is consistent with similar findings in the contexts of cellular phone service (Grubb and Osborne 2015), electricity consumption (Borenstein 2009), and labor supply (Saez 2010). Hence the standard model (Cardon and Hendel 2001; Reiss and White 2005), which assumes perfect consumer foresight, fits the MetroCard data poorly.

Evidence for inattention comes from in-person surveys of riders I conducted as they exited subway stations. These surveys were conducted at forty-two subway stations in Manhattan, Bronx, Brooklyn, and Queens. The survey yielded a response rate of 91 percent for a total of 8,346 respondents. Riders were asked whether they knew the current balances of their MetroCards. Out of the 8,346 respondents, 99.7% riders did not give the accurate balances of their MetroCards.
B Rides Choices

In line with the approach taken by Grubb and Osborne (2015) and Borenstein (2009), I assume that riders are uncertain about the ex post marginal price when making riding choices. She chooses a riding threshold $v_i$ based on her beliefs about $q_i$. During the course of the month, rider $i$ is inattentive and does not track usage but takes all rides valued above $v_i$. Taking all rides above the constant threshold $v_i$ is the optimal strategy of an inattentive rider who does not track usage and hence cannot update her beliefs about the marginal price of the next ride. (It is analogous to an electricity consumer setting a thermostat rather than choosing a quantity of kilowatt hours.)

Conditional on choosing pay-per-ride MetroCards, rider $i$ chooses her riding threshold $v_i$ to maximize her expected utility conditional on her information about $c_i$, $e_i$, and $q_i$. Given new card fee $T$, the base fare per ride $p$, and demand in equation (8), the optimal threshold derived in Appendix B.1 is uniquely characterized by equation (12)

$$v_i = p Pr(N_i \geq 0|e_i; c_i; q_i) \frac{E[N_i|N_i \geq 0; e_i; c_i; q_i]}{E[N_i|e_i; c_i; q_i]}$$

Here the calling threshold $v_i = v = p$. Note that choosing threshold $v_i$ is equivalent to choosing a target riding quantity $\hat{N}^T_i = E[N_i]q(v_i)$, which is implemented with endogenous error $(N_i - E[N_i])q(v_i)$. Importantly, riders are aware of their inability to hit the target precisely and take this limitation into account when making their threshold/target choice.