Payment Network Competition

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October 17, 2022

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Abstract

How does payment network competition affect merchant fees, consumer rewards, and welfare? I use bank payment volumes and consumer surveys to estimate an industry model of network pricing, consumer payment choice, and merchant acceptance. I simulate the entry of a new fintech payment network that competes with incumbent credit card networks. In equilibrium, incumbents increase merchant fees by 8 basis points to fund 13 basis points more rewards. Retail prices rise by 16 basis points and dissipate the welfare gains of entry typical in one-sided markets. Consumer and total welfare fall by $7 and $10 billion, respectively.

*Wang: Stanford GSB, 655 Knight Way, Stanford CA 94305. Email: luluyw@stanford.edu. Job market paper. I am extremely grateful to my advisors Amit Seru, Darrell Duffie, Ali Yurukoglu, and Claudia Robles-Garcia. I thank Lanier Benkard, Greg Buchak, Jacob Conway, Liran Einav, Joseph Hall, and Ben Hebert for helpful comments. I acknowledge support from the National Science Foundation Graduate Research Fellowship under Grant Number 1656518. Researcher(s)' own analyses calculated (or derived) based in part on data from Nielsen Consumer LLC and marketing databases provided through the NielsenIQ Datasets at the Kilts Center for Marketing Data Center at The University of Chicago Booth School of Business. The conclusions drawn from the NielsenIQ data are those of the researcher and do not reflect the views of NielsenIQ. NielsenIQ is not responsible for, had no role in, and was not involved in analyzing and preparing the results reported herein.

1 Introduction

Many argue that the high fees merchants pay to accept credit and debit cards in the US reflect a lack of competition.[1] If true, then the rapid growth of fintech payment networks such as PayPal and Klarna should bring merchants relief (Berg et al., 2022). However, payment networks compete not only by charging merchant fees, but also by paying consumer rewards. The price and welfare effects of competition are ambiguous. The theoretical literature has shown that it is possible for competing networks to raise merchant fees to fund larger consumer rewards, decreasing consumer and total welfare (Rochet and Tirole, 2003; Armstrong, 2006; Edelman and Wright, 2015).

In this paper I quantify the effects of payment network competition on merchant fees, consumer rewards, and welfare. I build and estimate an industry model featuring three competing, multiproduct payment networks: Visa, Mastercard, and American Express. I use data on bank payment volumes, consumer card holdings, and merchant card acceptance to estimate networks' costs and consumer and merchant preferences over payment instruments. I identify the parameters of the model with price variation from regulatory shocks, consumer second choice data, and a conduct assumption. I use this model to simulate entry of a new fintech payment app as a new payment network.

Entry inflates merchant fees and consumer rewards, exacerbates regressive transfers, and reduces consumer and total surplus. The entrant charges high merchant fees to fund consumer rewards. Incumbent credit card networks respond in kind. Welfare falls because some consumers who find debit more convenient than credit decide to switch from debit to credit to take advantage of higher rewards. By sacrificing convenience to chase rewards, these consumers incur social costs to chase transfers. Merchants pass on the higher transaction fees into higher retail prices, shifting the burden of the higher merchant fees onto cash and debit consumers. Scaling the overall loss in surplus to the roughly \$10 trillion in annual consumer-to-business payments translates to consumer losses of around \$7 billion a year. Payment networks' profits, inclusive of the entrant, fall. Total surplus falls by \$10 billion.

Payment markets are inefficient because of externalities, not market power. The central friction is that merchants charge consumers the same price no matter how they pay (Stavins, 2018). Consumers do not internalize the effect of their payment choice on the

[1] Many public sector commentators argue that new competition from government payment networks would drive down the cost of card acceptance (Shin, 2021; Usher et al., 2021; Federal Reserve, 2022) In 2020, the Department of Justice (DOJ) challenged Visa's acquisition of a nascent payment network, Plaid, on the grounds that competition "would drive down prices for online debit transactions" (Read et al., 2020).

level of retail prices. Consumers are locked into a prisoner's dilemma. While they collectively prefer a world with lower credit card use and lower retail prices, they individually choose to use credit cards to earn rewards. Networks exploit this coordination failure to charge merchants high fees that fund consumers' rewards. Whereas market power in traditional markets results in too little output, externalities in payment markets cause too much card adoption.

My reduced-form analysis suggests that a two-sided model is necessary to predict how competing networks behave. I identify four facts that suggest networks face strong incentives to give consumers large rewards but weak incentives to cut merchant fees. First, a regulatory shock to debit interchange, the Durbin Amendment, had a small effect on debit rewards but caused a large shift in payment volumes from debit to credit. Second, secondary card data indicates consumers are more willing to substitute between credit cards of different networks than between credit and debit. Third, merchants' gains in additional sales from accepting consumers' preferred payment methods dwarf the costs of high fees. Fourth, not all consumers carry cards from multiple networks. The first two facts suggest that consumers are willing to change payment methods to chase rewards, especially when the payment methods have similar characteristics (e.g. two credit cards). The third and fourth facts show that merchants who try to reject cards from high fee networks risk large declines in sales. Thus, payment networks are likely better substitutes for consumers than merchants. Competing networks are likely to charge high merchant fees to fund rewards. A two-sided model of competing payment networks is necessary to capture the connection between fees and rewards.

I build and estimate a structural model of payment network competition. The model has three kinds of players: consumers, merchants, and payment networks. Consumers choose which cards to put in their wallets and where to shop. Consumers prefer cards that pay high rewards and that are widely accepted. Consumers buy more from merchants that set low prices and that accept the consumers' cards. Merchants choose the subset of payment methods to accept and set retail prices. Networks maximize profits by adjusting consumer rewards and merchant fees, accounting for the effects on subsequent adoption decisions.

I estimate the model with the generalized method of moments (GMM). I assume that the observed data reflect an equilibrium of the structural model. Consumer preference parameters are identified by aggregate shares, reduced-form facts on the Durbin Amendment, and consumer card co-holding data. I invert the consumer demand system to recover networks' costs. By comparing the marginal costs and equilibrium merchant fees, I recover the elasticity of merchant demand. Combining the elasticity and expenditure data from consumer payment surveys then yields merchants' margins and the distribution of merchants' benefits from card acceptance. This procedure enables me to estimate consumer and merchant demand curves with only consumer price variation and a conduct assumption.

The model fits important patterns in the data. For example, I match the fact that American Express consumers are unlikely to use a debit card for their secondary card. I am also able to match out-of-sample predictions for how credit card volumes change after a shock to debit rewards. The estimated network marginal cost parameters are consistent with accounting data.

Introducing a fintech payment app that competes for credit card consumers inflates merchant fees and consumer rewards. I model the app as a new network competing for credit card consumers, but consumers who use the app do not treat credit card acceptance as an adequate substitute for accepting the app.[2] The entrant charges high merchant fees and pays large rewards. Its fees are 39 basis points higher than American Express' fees in the baseline equilibrium, and its rewards are 28 basis points larger than American Express' baseline rewards. In response, incumbent credit card networks raise merchant fees by 8 basis points to fund 13 basis points more rewards.

Entry hurts cash and debit users more than credit card users. The combination of higher credit card fees and more consumers using credit cards causes merchants to raise prices by 16 basis points. Among the consumers who do not switch, cash and debit users' welfare falls by 16 and 11 basis points, respectively. In contrast, credit card consumers' welfare falls by only 6 basis points as the increase in rewards cushions the rise in prices.

Competition reduces consumer and total welfare by \$7 and \$10 billion, respectively. The key mechanism comes from consumers' non-pecuniary preferences over payment methods. Before entry, many consumers turn down rewards credit cards to use no-rewards debit cards instead.[3] By revealed preference, these consumers value the non-price characteristics of debit, which I summarize as "convenience".[4] Higher credit card rewards after entry cause some debit consumers to switch to credit. In sacrificing convenience to earn rewards, they incur a social cost to capture transfers. Total surplus falls.

[2]This is consistent with the evidence in Berg et al. (2022) that PayPal users will shop less at a store if it does not accept PayPal, even if the store accepts debit and credit cards. I discuss this further in Section 8.

[3]In the US, cash and debit cards by and large do not pay rewards.

[4]The same logic applies for cash and debit users, but I focus on debit for exposition. One possibility why cash and debit card users do not use credit is because they do not have access to credit cards. In section 3 I show that most cash and debit consumers have access to credit cards. Even if some consumers are constrained, my argument applies to anybody who is not constrained. I discuss in section 8.5.2 why the presence of constrained consumers does not affect my welfare results. I discuss more examples of "convenience" in section 4.

After merchants pass on transaction fees into higher prices, much of consumers' gains from more rewards are washed out by higher retail prices. In equilibrium, consumers' \$20-billion gain from higher rewards is approximately cancelled out by the \$16-billion loss from higher retail prices. Consumers use payment methods with \$10 billion lower convenience. This loss of convenience drives the decline in consumer welfare and is equal to the decline in total welfare.

I explore three additional counterfactuals that illustrate credit card adoption is excessive in the current equilibrium. These counterfactuals show that any regulation or merger that disincentivizes credit card use on the margin can raise consumer and total surplus. These counterfactuals illuminate why entry is harmful. By encouraging more credit card use, entry lowers consumer and total welfare.

In my first two counterfactuals, I show that *either* deregulating debit interchange or regulating credit interchange would both increase welfare relative to the current regulatory regime. When I relax the Durbin Amendment and let debit cards charge merchants 1%, debit rewards rise by 22 basis points. Restoring debit rewards means fewer debit card consumers choose credit cards solely for the rewards. Consumer and total welfare rise by \$5 and \$6 billion, respectively. When I cap Visa and Mastercard merchant fees at 1%, credit card rewards fall by 75 basis points. Consumers and total welfare rise by \$38 and \$28 billion, respectively, as retail prices fall and fewer consumers choose credit cards for the rewards.

In a third counterfactual, I merge Amex and Mastercard and assume that marginal costs do not change. The resulting increase in market power causes credit card rewards to fall by 11 basis points and credit card merchant fees to rise by 3 basis points. Surprisingly, consumer and total surplus rise by \$1 and \$6 billion, respectively, as consumers sacrifice less convenience to chase credit card rewards. This merger counterfactual highlights how the excess adoption of credit cards reverses many standard intuitions about competition and welfare, as mergers without marginal cost efficiencies in typical one-sided markets never raise total or consumer surplus.

Although I focus on payment networks, my empirical approach is also relevant to other two-sided markets in which network pricing can affect retail prices. Advertising platforms like Facebook or Google connect merchants with consumers. Just as in payment services, these platforms charge merchants high prices while subsidizing consumer adoption. Competition forces platforms to invest more in consumer benefits and to fund these investments with even higher ad prices. Just as in payments, higher advertising prices may be passed through to final goods prices, potentially causing consumer harm.

1.1 Related Literature

My primary contribution is to show that, in a realistic model of the US payments market, competition can raise merchant fees and reduce consumer and total surplus. The core innovation is to model how consumer and merchant preferences determine the prices that networks set in equilibrium. I can then quantify how changes in market structure affect prices and welfare.

The closest related work is Huynh, Nicholls and Shcherbakov (2022), who also estimate a structural model of consumer and merchant card adoption.[5] One important difference is that I model how retail prices respond to merchant fees. Whereas credit card rewards in their model always benefit consumers, credit card rewards in my model can hurt consumers by inflating retail prices. I also model how rewards and merchant fees are determined by network competition, rather than assuming that prices are exogenous.

Past approaches to the welfare effects of payment market regulations have not focused on changes in consumer payment behavior as the source of welfare effects. Mukharlyamov and Sarin (2022) study the effects of the Durbin Amendment on checking account fees, but do not model the implied welfare costs of changing consumer payment behavior. Felt et al. (2020) study the distributional effects of credit card rewards, but ignore how consumer and merchant adoption might respond to changes in rewards. My model allows me to quantify the welfare consequences of changes in consumer payment behavior.

My paper contributes to the literature on two-sided markets by introducing a quantitative model of network competition. Edelman and Wright (2015) argue that platform competition can lead to higher merchant fees and excess adoption. I build upon their work by incorporating merchant heterogeneity (Rochet and Tirole, 2003; Guthrie and Wright, 2007) and consumer multihoming (Armstrong, 2006; Anderson et al., 2018; Liu et al., 2021; Bakos and Halaburda, 2020), which have been shown to play important roles in shaping network competition. By introducing a quantitative model, I am able to incorporate these additional features and show that competition can hurt consumers in a realistic model of the US payments market.

My paper contributes to the finance literature on payments by providing an equilibrium model of network competition.[6] Many papers have documented the importance of

[5] Li et al. (2020) also build an equilibrium model but assume that merchants accept cards to reduce costs. As a result, in their model card users cross subsidize cash users.

[6] Berg et al. (2022) document that consumers of many new fintech products seem unwilling to substitute to traditional cards even when available. I use this fact in defining my counterfactual. Ghosh et al. (2021); Parlour et al. (2022) study how payment data complement traditional banking activities. My model provides a benchmark for how payment networks that do not bundle with other services should compete.

adoption externalities (Gowrisankaran and Stavins, 2004; Rysman, 2007; Higgins, 2020; Crouzet et al., 2020), unobserved preference heterogeneity (Koulayev et al., 2016; Huynh et al., 2020), and rewards (Arango et al., 2015; Ru and Schoar, 2020) in determining consumer payment choice. I show that by combining these forces with an equilibrium model of how networks compete predicts that more competition can hurt consumers.

More broadly, my paper echoes arguments about the dark side of competition in the presence of externalities in the banking and intermediation literatures. For example, lender competition may reduce incentives to lend to financially constrained firms (Petersen and Rajan, 1995). Competing high frequency traders over-invest in speed (Budish et al., 2015). Competing over the counter intermediaries over-invest in contact rates and bargaining ability (Farboodi et al., 2019; Farboodi and Jarosch, 2022).

2 Institutional Details

This section explains how networks influence merchant fees and rewards rates for merchants and consumers, and why networks can attract consumers by funding large consumer rewards with high merchant fees.

2.1 Payment Card Networks in the United States

Cards dominate the US retail payments market. Three companies – Visa, Mastercard (MC), and American Express (Amex) – intermediate almost all card payments. Appendix Table B.1 reports a breakdown of retail payments in the United States, derived from a payments trade journal (Nilson, 2020c,d). These payments are meant to capture consumer-to-business payments for purchases, and exclude the recurring bills that are often paid by ACH. While cash and checks are used for 20% of payments by value, the remaining payments in the US are all done by cards. Visa and MC handle around three-quarters of all card payments, while Amex covers a tenth. In comparison, the remaining firms are all quite small. Debit cards are popular. Visa and MC's total credit volumes are approximately equal to their debit card volumes. Unlike fintech payment platforms like Alipay in China or UPI in India, fintech payment platforms in the United States like Venmo or Cash App do not yet have a large market share in consumer-to-business payments.

Visa, MC, and Amex charge similar merchant fees, offer similar rewards, and have similarly broad acceptance. Appendix Table B.2 shows Nilson (2020b) data on prices and acceptance. While Visa and Mastercard charge similar prices, around 2.25% of the transaction, Amex charges 2.27%, only slightly higher. Visa and MC charge lower fees for debit cards due to regulatory limits. Rewards are similar across credit cards, whereas debit cards do not typically offer rewards. Amex's acceptance is similar to Visa and MC, with 10.6 million locations compared to 10.7 million for Visa and MC.[7]

2.2 How Visa and Mastercard Influence Merchant Fees and Consumer Rewards

Card networks shape both the prices that merchants pay to accept cards as well as the subsidies consumers receive from using cards. In doing so they affect consumers' incentives to adopt cards.

Visa and MC are known as open loop payment networks because they connect four types of players: merchants, merchants' banks (acquirers), the consumers' banks (issuers), and consumers.[8] Figure 1 illustrates the typical flow of money between these players. When a consumer uses her Chase Freedom Unlimited credit card to buy $100 of product at a large retailer, the merchant might pay a $2.25 merchant discount fee to her acquiring bank to process the transaction. The acquirer can be a bank like Wells Fargo or a fintech player like Square who works with a bank to connect the merchant to the Visa network. The acquirer will use some of that fee to cover its costs, but then must also send $1.75 to the issuing bank, Chase, in the form of interchange. The issuer and the acquirer collectively then pay around 14 cents in assessment fees to Visa. While some of the $1.75 of interchange fees goes towards covering the issuer's costs, a large part of it is also rebated back to the consumer in the form of rewards. In the case of the Chase Freedom Unlimited card, this rebate is $1.50.[9]

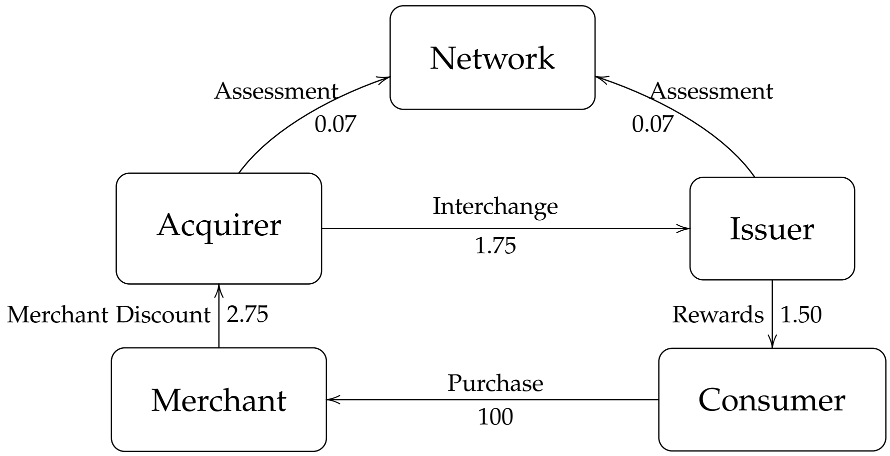
Regulatory caps highlight how interchange fees affect merchant fees. Gans (2007) shows that after Australia regulated credit interchange in 2003, the merchant discount fee fell almost one for one. Valverde et al. (2016) document that merchant discounts moved

[7]The small gap in fees and acceptance may seem surprising given general perceptions that American Express charges higher fees and is accepted less. However, in recent years, Amex has aggressively cut its fees for small businesses to close the acceptance gap (Amex, 2020). At the same time, new premium Visa and MC credit cards have pushed up the average cost of their cards (Barro, 2018).

[8]Proprietary payment networks like American Express have similar pricing structure, but can be thought of as a vertically integrated entity that combines Visa, the acquirer, and the issuer. In their case, they directly set the prices that merchants pay and the benefits consumers receive. From Amex's 2019 10k, their merchant business is responsible for "signing new merchants to accept our cards, agreeing on the discount rate (a fee charged to the merchant for accepting our cards) and handling servicing for merchants". On the consumer side they "offer a broad set of card products, rewards and services to a diverse consumer and commercial customer base".

[9]`https://creditcards.chase.com/cash-back-credit-cards/freedom/unlimited1`

Figure 1: Illustration of payment flows in a payment network.



Notes: Prices are meant to capture typical fees paid. The merchant discount fee comes from Nilson (2020b), the average assessment comes from example rate sheets from acquirers. The interchange is derived from Visa's interchange schedule for a Visa Signature card at a large retailer. The rewards are for a Chase Freedom Unlimited Card.

one for one with interchange fees over a 10-year window in Spain, when interchange fees fell due to regulation. The European Commission (2020) found a similar passthrough of European interchange caps to merchant fees.

Consumer rewards also fall when interchange falls. Large banks ended rewards debit programs after the Durbin Amendment capped debit card interchange fees (Hayashi, 2012; Schneider and Borra, 2015). After the Reserve Bank of Australia (RBA) capped interchange fees on Visa and Mastercard issued credit cards, rewards fell on those cards. Because the RBA's interchange regulations did not limit the merchant fees charged by American Express, banks started issuing American Express cards through "companion" card programs and continued to offer high rewards on those cards (Chan et al., 2012). When this regulatory loophole was closed in 2017, the same large banks substantially devalued their rewards programs and ended their companion card programs (Emmerton, 2017; Reserve Bank of Australia, 2021).

2.3 The Role of Issuers

My model abstracts from the strategic decisions of issuers. In my model, networks directly set the merchant discount fee and consumer rewards. This is accurate for proprietary networks like Amex or fintechs like PayPal, for whom there are no issuers or acquirers. In the case of Visa and MC, this abstraction can be justified under the assumption that Visa, the issuers, and acquirers can cooperate to maximize joint profits.

Joint profit maximization holds whenever parties bargain under complete information with a complete contract space. Visa pays substantial side payments to both issuers and acquirers, separate from the fees in Figure 1.[10] I interpret these payments as evidence that the contract space is approximately complete. Joint profit maximization can thus be consistent with a wide range of issuer market structures, from perfect competition to a monopoly issuer.

Treating both merchant fees and rewards as variables set at the network level is essential for understanding how entry simultaneously affects merchant fees and consumer rewards. Regulatory shocks to interchange illustrate how merchant fees play an important role in influencing rewards.[11] Competition between Chase and Bank of America shapes the rewards they offer. But to model the connection *between* merchant fees and consumer rewards, it's essential to have a player that can simultaneously influence both merchant and consumer prices.

I also abstract from issuers' choices of interest rates and credit lines. My model will assume that the subsidies paid to the consumer side of the market are passed through to rewards, not to credit card interest rates. This is a reasonable assumption given that the consumers most relevant for borrowing make up a relatively small share of purchase volume. Adams et al. (2022) show that the consumers who carry a balance every month in a 12 month window pay around 72% of the interest revenue but make up only 9% of the purchase volume.

2.4 Uniform Prices for Different Payment Methods

Merchants charge uniform prices to consumers who use different payment methods. Historically, uniform prices were the result of no-surcharge rules and laws imposed at different times by the US federal government, the payment networks, and US state governments (Blakeley and Fagan, 2015). Over time, these laws have been repealed. Despite the repeal of these laws, merchants are reluctant to pass on merchant fees to consumers (Stavins, 2018).

When merchants charge uniform prices, networks gain consumer market share by

[10] In their 2019 10k, Visa reported $6.2 billion in client incentives to issuers and acquirors on a total of $29.2 billion in gross revenues.

[11] Rewards may also be partially funded by interest payments by unsophisticated borrowers (Ru and Schoar, 2020; Agarwal et al., 2022) in a shrouding equilibrium as in Gabaix and Laibson (2006). However, this does not mean that merchant fees do not pass through to rewards. The evidence from regulatory events shows that lower merchant fees reduce consumer rewards. Even if shrouding explains some rewards programs, the large marginal effect of merchant fees on rewards shows that platforms can fund more rewards by charging merchants higher fees.

charging merchants higher fees to fund consumer rewards. If Visa raises both merchant discounts and rewards by one cent, Visa customers benefit from the one cent increase in rewards but only bear part of the cost of higher merchant fees through higher retail prices. Consumers then have stronger incentives to use Visa cards. In a frictionless world in which merchants pass on the cost of payments to the consumer on each transaction, networks have no incentive to raise merchant fees to fund rewards. Doing so would have no effect on the net prices consumers pay (Gans and King, 2003).

Theoretically, it may be boundedly rational for merchants to not pass on the cost of payments. If consumers do not change their payment method in response to a surcharge, then the reduction in profit from charging uniform prices relative to surcharging is second order in the size of the merchant fees. The typical merchant in my estimated model loses 16 bps in profit from charging a uniform price relative to charging optimal prices for each payment instrument. Although consumers are not given the option to pay a lower "cash price" in the model, no credit card consumer in the model would choose to switch even if given the choice. Potential first order costs to surcharging such as menu costs or reputational costs could then overwhelm the benefits of surcharging.[12] Even though the network-level consequences of surcharges are large, no individual merchant can influence consumers' adoption decisions. Therefore, no one merchant can realize large gains from surcharging.

3 Data

I combine bank level data from a payments trade journal, the Nilson Report, with consumer level data from the Nielsen Homescan panel and the Federal Reserve's Diaries and Surveys of Consumer Payment Choice. These data provide key moments for estimating consumer and merchant demand for payments.

3.1 Issuer Payment Volumes

I construct an imbalanced annual panel of issuer payment volumes from the Nilson Report. This panel tracks the effects of a regulatory shock to interchange fees on payment volumes. The Nilson Report publishes the dollar payment volumes of the top credit and debit card issuers every year. These issuers include both banks and large credit unions.

[12]Caddy et al. (2020) document that even though surcharging has been legal in Australia since 2003, around one-quarter of consumers report that they avoid merchants who surcharge and that surcharges are only paid on 4% of card transactions.

Table 1: Summary statistics of Nilson Report panel

	N	Mean	P25	P50	P75
Assets	309	29126.09	4207.34	9673.76	34162.04
Credit	296	1431.63	365.44	554.50	1455.00
Debit	294	4928.75	1237.25	2526.00	5435.00
Signature Debit	292	3035.46	783.75	1270.50	2715.25
Treated	309	0.48	0.00	0.00	1.00

Notes: Treated refers to whether the financial institution had more than $10 billion in assets in 2010. Assets is measured in millions. Credit, Debit, Signature Debit all refer to measures of card volumes in millions. Sig Debit Ratio is the value of signature debit transactions divided by the total value of signature debit and credit card transactions at the financial institution.

My main difference in difference analysis focuses on a subset of 39 issuers, 19 of them above the Durbin cutoff and 20 below. Table 1 reports the main summary statistics for this sample. These issuers have assets in 2011 between $2.5 billion and $200 billion. The smallest issuers are small regional credit unions like the Pennsylvania State Employees' Credit Union, while the largest of these issuers are regional banks like Suntrust Bank or Fifth Third Bank. Signature debit volumes are around twice those of credit card volumes.

3.2 Consumer Payment Surveys

I combine the Atlanta Federal Reserve's Diary of Consumer Payment Choice and Survey of Consumer Payment Choice to build a transaction level dataset on consumers' payment choices over three day windows. I use the data from the $2015-2020$ waves of both surveys for my main sample, although to study credit versus debit acceptance I also use data from the $2008-2014$ waves of the SCPC. This data is both useful in establishing basic facts about how consumers use different payment methods as well as establishing the relationship between consumer demand for payments and merchants' acceptance policies.

Appendix table B.3 reports the key summary statistics for the transactions in the dataset. I focus on non-bill, in person purchase payments in consumer retail and service sectors with ticket sizes of less than 100 dollars for my analysis. I group cash and check payments together under "cash". Around 38% of the payments are made in cash, with the remainder split relatively evenly over credit and debit. Most transactions (95%) are at a merchant who accepts cards. In the United States, merchants who accept cards typically accept all debit and credit cards from the three major networks: Visa, MC, and Amex.

Table 2: Summary statistics of the consumer types in the payment diary sample.

	Cash	Debit, Low Credit Share	Debit, High Credit Share	Credit
Share	0.25	0.31	0.11	0.34
Owns CC	0.68	0.74	1.00	1.00
Owns Rewards CC	0.45	0.45	0.80	0.85
Owns Bank Acct	0.87	1.00	1.00	0.99
Balance / Limit	0.22	0.31	0.23	0.10
HH Income	61.24	74.73	83.36	112.88

Notes: Consumers are split into four groups: those who prefer to use cash as their main non-bill payment instrument, those who prefer debit but have a below median utilization of credit cards, those who prefer debit but have an above median utilization of credit cards, and those who prefer credit cards. The share variable reports the share of the sample in each column. All other variables report averages within the group of consumers of a given payment choice.

Table 2 shows that debit is the most popular payment instrument, followed by credit and then cash. Most consumers in the sample are banked and have access to credit cards. Of those who prefer cash, around 87% have a checking account and even 68% have a credit card. Even among those who prefer debit but have a low use of credit cards, around 74% own a credit card. The consumers who prefer debit but who have above median use of credit cards look even more similar to those who prefer credit. Around 80% of these debit consumers have a rewards credit card, which is similar to the 85% of credit card consumers who own a rewards credit card.

3.3 Nielsen Homescan Panel

The Nielsen Homescan panel tracks the method of payment of around 90,000 households at large consumer packaged goods stores. I use this to build measures of primary and secondary cards at the consumer level. Appendix table B.4 reports the main summary statistics at the household-year level. I focus on households without any missing payment data. The average household is in the sample for 3 years and records 500 transactions. The typical household's average ticket size is around $50.

The main shortcoming of the Homescan panel is that it does not cover certain spending categories, such as travel or restaurants, that tend to have a high prevalence of credit card use. Appendix Table B.5 shows that Homescan overrepresents cash and debit transactions while underrepresenting American Express. This is reasonable given Nielsen's sector composition.

4 Intuition for the Results

The contribution of the paper can be understood as combining the insights from two areas of the theoretical literature on two sided markets. Rochet and Tirole (2003) and Armstrong (2006) derive the conditions under which competing platforms can cause prices for one side of the market to rise, and Edelman and Wright (2015) show how high merchant fees and consumer rewards can lower consumer surplus.

In traditional one-sided markets, firms cut prices in response to entry. This would be valid if payment platforms only charged fees to merchants. Merchants should pass on the lower fees to consumers as lower prices. The left panel of Figure 2 illustrates this case.

In reality, payment platforms are two-sided. They not only charge merchant fees, but they also pay consumer rewards. The right panel of Figure 2 illustrates the more complicated two-sided case. Networks can respond to competition by charging higher merchant fees to fund more rewards. Merchants pass on the higher fees into higher retail prices.

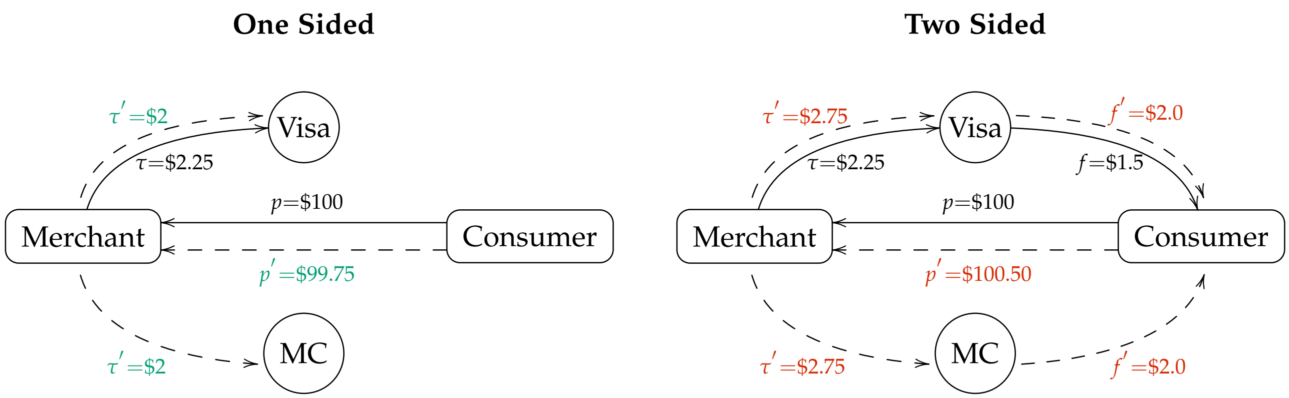
Whether or not merchant fees fall in response to competition depends on whether the networks are better substitutes for consumers or for merchants. Suppose merchants are reluctant to drop a high fee network out of a fear of losing customers, but consumers are sensitive to higher rewards. Then the platforms are poor substitutes for merchants but good substitutes for consumers. In this case, competing platforms would charge higher merchant fees to fund more consumer rewards.

The welfare losses of competition stem from consumers' non-pecuniary preferences over payment methods, which I call "convenience". Some debit consumers have access to a rewards credit card but choose to use their no-reward debit card because they find it more convenient.[13] The source of the convenience may come from the self-discipline imposed by debit cards and not having to worry about interest charges (Benson et al., 2017). Table 3 shows data from the SCPC on what consumers with different payment preferences report as the most important characteristic of their preferred payment instrument. Around 9% and 41% of debit users report that "budget control" and "convenience" are the reasons they choose to use debit cards. Only 4% and 28% of credit card users say that those are the reasons they choose credit cards. These answers motivate why I call the non-pecuniary term "convenience".

Competition can reduce total surplus by causing consumers to sacrifice convenience to chase rewards (Edelman and Wright, 2015). By revealed preference, the marginal con-

[13] See Table 2 on debit consumers' ownership of credit cards.

Figure 2: Intuition on the relationship between competition and fees



Notes: Dashed lines denote flows of money when Visa and Mastercard (MC) compete, while solid lines denote flows of money under monopoly (Visa only). τ denotes the merchant fee, f is the consumer reward, and p is the transaction price. Primes denote prices when Visa and MC compete. The two sided case illustrates one possibility for how competition affects prices. It is also possible for merchant fees and rewards to fall, depending on the parameters.

Table 3: Survey data on why consumers chose their preferred payment instrument

	Cash	Debit, Low Credit Share	Debit, High Credit Share	Credit
Why: Budget Control	0.15	0.09	0.09	0.04
Why: Convenience	0.31	0.41	0.41	0.28
Why: Rewards	0.00	0.02	0.03	0.28

Notes: Consumers are split into four groups: those who prefer to use cash as their main non-bill payment instrument, those who prefer debit but have a below median utilization of credit cards, those who prefer debit but have an above median utilization of credit cards, and those who prefer credit cards. The "Why: X" variable is equal to 1 if the consumer reports X as the "most important characteristic" of the preferred payment instrument in making purchases. All averages and shares are calculated with individual level sampling weights.

sumer deciding between credit and debit must find debit more convenient than credit.[14] Otherwise, she would use a credit card and earn rewards. If competition raises credit card rewards and causes her to switch, she sacrifices convenience to earn rewards. This decision is privately optimal. But while lower convenience is a social cost, the additional rewards are merely transfers. Society as a whole suffers a loss in payment convenience without any compensating gain, reducing total surplus. Around 28% of credit card users report "rewards" as the reason they use credit cards, whereas almost no debit card users say the same about debit cards. Therefore many people indeed use credit cards primarily to earn rewards.

The above mechanism also yields a simple back of the envelope estimate of the total welfare loss from competition. Some debit consumers choose to use debit cards instead of using credit cards, which earn around 1.3% in rewards. By revealed preference, each marginal debit consumer values the relative convenience of debit at 1.3%.[15] The approximate total surplus effect of competition can be summarized by the change in cash and debit market share multiplied by 1.3%. In my main entry counterfactual, this approximation yields a $9 billion decline in total surplus while the true number is $10 billion. While the model is necessary to predict the 7pp. change in market shares, the source of the welfare loss relies on revealed preference.[16]

If networks fund rewards with transaction fees, and if merchants pass on transaction fees into higher prices, some of the burden of increased credit card use falls on cash and debit consumers. Competition can therefore lower consumer surplus as the increase in credit card use inflates retail prices.

The effects of competition on merchant fees and consumer rewards depend on whether different payment networks are better substitutes for consumers or for merchants. If networks are better substitutes for merchants, the usual one-sided market intuition obtains and merchant fees fall with competition. If networks are better substitutes for consumers, merchant fees and consumer rewards will rise with competition. The welfare effects depend on the distribution of consumers' non-pecuniary preferences over payment instruments. If consumers have strong non-pecuniary preferences for certain payment methods that cannot pay rewards, then network competition can hurt consumers. Modeling and estimating consumer and merchant substitution patterns as well as the distribution of consumers' non-pecuniary preferences will be the focus of my estimation in the sections to follow.

[14] The same argument applies to cash versus credit, but I focus on debit for exposition here.

[15] In the US, most debit cards from large banks do not pay rewards.

[16] In section 8.5.2 I discuss how incorporating consumers who do not have access to credit cards would change the analysis.

5 Reduced Form Analysis

The reduced form analysis motivates a model of network competition in which networks simultaneously compete in merchant fees and consumer rewards. The magnitudes will discipline the parameters governing consumer and merchant demand for payments. The facts suggest consumers are willing to substitute between networks but merchants are limited in their ability to substitute. By the logic from section 4, network competition has the potential to lead to higher merchant fees and consumer rewards.

5.1 Consumer Substitution Between Credit and Debit

A regulatory shock that reduced debit interchange rates, thereby ending debit rewards, led to large reallocation of spending from debit to credit. Consumers' choice between debit and credit is thus sensitive to rewards.

Ideal variation to identify consumers' elasticity to rewards would shock rewards at some banks and then study how consumers at those banks change their payments. As an approximation to the ideal variation, I exploit the caps on debit card interchange fees introduced as part of the 2010 Dodd Frank Financial Reform Act.[17] Illinois Senator Richard Durbin inserted an amendment into the bill to cap debit interchange at large banks and credit unions[18] with more than \$10 billion in assets to 22 cents and 0.05% of the purchase value. Credit interchange was unaffected. By changing banks' income from debit card issuance, this led to a change in rewards. All large banks ended their debit reward programs, while small banks largely kept their rewards programs intact (Schneider and Borra, 2015; Orem, 2016).

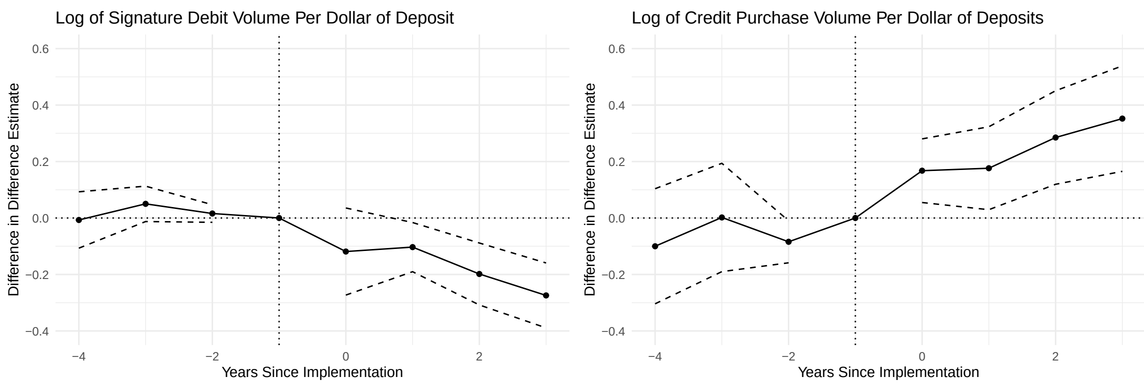
To study the effect of the Durbin Amendment on payment volumes, I employ a difference in difference approach that compares payment volumes at large banks versus small banks around the time the Durbin Amendment was implemented. I estimate the regression

$$y_{it} = \sum_{k=-3}^{3} \beta_k I\{t = k\} \times \text{Treated}_i + \delta_i + \delta_t + \epsilon_{it} \tag{1}$$

[17]While there have been a few empirical papers on the effects of interchange fee regulation (Chang et al., 2005; Valverde et al., 2016), these papers cannot identify consumer preferences because of potential merchant responses. It is important that the shock to interchange is small because the goal is to isolate consumer preferences holding fixed merchant adoption. In models of interchange, the level of the interchange fee should affect both consumer utilization and merchant adoption (Rochet and Tirole, 2002).

[18]While the regulation covered both banks and credit unions, for the rest of the discussion I will refer to these financial institutions as simply "banks".

Figure 3: The effect of the Durbin Amendment on debit card and credit card volume.



Notes: The vertical line marks the year before the policy announcement. The policy started in Q3 2011 and went into full effect in year 2012, which is at $t = 1$.

where y_{it} is the log signature debit or credit card payment volume at a bank. Treated$_i$ refers to whether the bank had more than $10 billion in assets in 2010, and δ_i and δ_t represent bank and year fixed effects, respectively. By comparing large versus small banks I am able to difference out the effects of the CARD act and the effect of the Durbin Amendment on debit routing. I define $t = 0$ as 2011 and use 2010 as my base year. Figure 3 shows that signature debit volumes fell by 27 percent whereas credit card volume rose by 35 percent. Volume largely substituted between payment forms, as overall card spending fell by a small but statistically insignificant 5 percent. Appendix table B.6 reports the exact coefficients and standard errors.

The Durbin Amendment evidence suggests that consumers are sensitive to rewards. Hayashi (2012) estimates that the average debit rewards program paid consumers around 25 bps of transaction value, yet even that small change led to a 27% decline in signature debit volumes. Consumers' high sensitivity to rewards may be a surprise given consumers' general price insensitivity in other household finance settings. Part of this may reflect that banks tend to make rewards salient in advertising (Ru and Schoar, 2020). My estimated results are also consistent with Mukharlyamov and Sarin (2022) who find that geographic areas that were more affected by the Durbin interchange caps also saw larger increases in credit card volumes.

In the appendix I include additional robustness checks. Figure C.2 shows that the two groups of banks did not suffer large relative shocks in their asset values at the same time. Figure C.3 shows that the overall debit cards, which included PIN debit cards that were not affected by the regulation, declined less.[19] The differential pattern across debit

[19]Besides signature debit, many banks offered PIN debit. PIN debit was not affected by Durbin since

cards suggests the effect I am identifying is about relative prices for credit and debit, and not just other shocks to big and small banks during this time period.

5.2 Consumer Substitution Between Networks

Data on consumers' primary and secondary cards shows that credit cards from different networks are good substitutes for each other. This fact suggests that consumers' choice between cards of similar characteristics (e.g. debit or credit) but from different networks (e.g. Visa or Mastercard) should be particularly sensitive to rewards.

I identify substitution patterns by studying co-holding data. Amex users often carry Visa credit cards as a backup card for when Amex is not accepted. I infer from this fact that primary Amex users are therefore likely to use Visa credit cards in an alternative world without Amex. Formally, I interpret data on consumers' primary and secondary cards as data on hypothetical first and second choices. Armed with first and second choices, I can then use techniques to identify how consumers substitute between cards (Berry et al., 2004).

To interpret primary and secondary cards as first and second choices, I assume that consumers ignore complementarities or substitution effects in deciding which pair of cards to put in their wallet. For example, two credit cards in different rewards categories (e.g. grocery + travel) could be complements. However, rewards do not create complementarities at the network level. Visa, MC, and Amex all offer a robust suite of rewards credit cards across various categories. Cards could also be substitutes, as a credit card user does not bother to get a second card that offers a similar service. I ignore this possibility and therefore underestimate substitution patterns, which will lead to an underestimate of the harms of competition. Appendix F derives a dynamic microfoundation that features no complementarities or substitution effects. Under the microfoundation, the stationary distribution of primary and secondary cards (viewed as a Markov Chain) corresponds exactly to the joint distribution of first and second choices among primary payment methods.

From the Homescan shopping data, I split consumers by cash and card users[20], and for card users I define their primary payment card as the card network that is used for the highest share of trips.[21] I define the secondary card as the card network used the second most often. If the consumer only uses one card, I define the secondary "card" as

the interchange rates were already low (Hayashi, 2012).

[20]I match the share of consumers who prefer cash in the DCPC as in Homescan.

[21]In Appendix table B.8, I show that the total number of trips is highly correlated with the card with the highest share of spending.

Table 4: Conditional probabilities of each secondary card given the consumer's primary card.

	Secondary Card				
Primary Card	Cash	Debit	Visa	MC	Amex
Debit	0.22		0.45	0.26	0.07
Visa	0.16	0.38		0.29	0.17
MC	0.13	0.29	0.45		0.13
Amex	0.09	0.20	0.49	0.22	
Primary Card Share	0.26	0.44	0.18	0.08	0.04

Notes: The bottom row shows the share of each column payment method among primary payment methods. If a consumer only uses one type of card, the secondary "card" is defined as cash.

cash.

Table 4 shows both the aggregate shares of each primary payment method and the conditional probability of each payment option occurring as the second choice. The bottom row of the table shows that debit cards are the most popular primary payment method, followed by cash, then Visa credit cards, MC credit cards, and lastly Amex.

If credit cards, debit cards, and cash were all equally good substitutes for each other, then we should expect Amex users' second choices to mostly be debit cards and cash with a small share of Visa and MC. In reality, Amex users are more likely to have a Visa or a MC than they are to have a debit card, even though debit cards are dramatically more popular in the general population. Similar patterns are present for Visa and MC users. In particular, primary Visa users' strong tendency to carry a secondary Amex suggests that primary Amex users' tendency to carry a secondary Visa is not solely driven by the desire of primary Amex users to have a backup card when the merchant does not accept Amex.

5.3 Merchant Benefits from Accepting All Cards

The average merchant's sales increase around 30% from card acceptance yet not all merchants choose to accept cards. The large average sales benefit combined with less than universal card acceptance motivates a model where merchants accept cards to increase sales, but merchants differ in how much their sales increase. The large benefit relative to the level of fees also suggests that merchant demand should be price insensitive.

I exploit variation in consumer payment preferences to identify how much merchants' sales increase from card acceptance. Ideal variation shocks merchant adoption of payment methods and measures the effect on sales. As an alternative, I hold fixed merchant adoption but assume that variation in payment preferences among consumers is orthogonal to consumers' baseline preferences over merchants. If card acceptance increases sales, then, relative to cash consumers, card consumers should transact more at merchants who accept cards. If card consumers travel more, and payment convenience is more important when one is traveling, then my approach will overestimate merchants' benefit from card acceptance. I try to adjust for these differences by saturating my regressions with fixed effects, but inevitably there are confounds. The main benefit is that by using the survey data I can provide an integrated view of how the US payment market works.

I use a logistic regression to measure how much sales increase from card acceptance. Index consumers by i and transactions by t. Let y_{it} be an indicator for whether the transaction t occurred at a store that accepts cards. Let X_i be an indicator of whether the consumer prefers cards. Let δ_{it} be a vector of fixed effects such as the survey respondent's income and education, the ticket size of the transaction, and the merchant category (e.g. restaurant versus retail). I run the logistic regression

$$P\left(y_{it}=1\right) \sim \phi X_i + \delta_{it} + \epsilon_{it} \tag{2}$$

The coefficient ϕ can be interpreted as the average increase in sales experienced by the merchants who accept card, netting both the positive effect from increased convenience and the negative effect of higher fees that get passed through to higher prices.

Table 5 shows the result of this regression with different options for fixed effects. My preferred estimate includes both the consumer and merchant controls, and suggests that the average consumer who prefers cards is around 30% more likely to shop at a store that accepts cards than a consumer who does not prefer to use cards. I interpret this as saying merchants are more likely to attract card consumers if they accept cards. The relative stability of the results even as I adjust the consumer and transaction fixed effects suggests there is little unobserved variation driving the result. This estimate is similar to estimates from Higgins (2020) and Berg et al. (2022) on the effects of payment acceptance on sales that instead relies on random shocks to merchant acceptance.[22]

Most but not all consumer spending is done at stores that accept cards. Therefore even though most merchants gain a large amount from accepting cards, some merchants

[22]Appendix table B.7 shows that this effect does not vary much across debit versus credit card users, those who hold one or multiple cards, or high or low income respondents.

Table 5: Logistic regressions predicting the probability that a given transaction occurs at a merchant who accepts credit cards as a function of consumer preferences.

	No Controls	Tx Controls	Consumer Controls	Both
Prefer Card	0.35***	0.34***	0.36***	0.30***
	(0.07)	(0.08)	(0.08)	(0.09)
N	29661	29661	29661	29661
Year FE	X	X	X	X
Merch Type FE		X		X
Ticket Size FE		X		X
FICO Category FE			X	X
Age Group FE			X	X
Income Category FE			X	X
Education FE			X	X
State FE		X	X	X

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

do not. From the diary data I see that consumers who prefer to use cards spend around 97% of their money at stores that accept cards. Given not all merchants accept card despite large average increases in sales, I infer that merchants must differ in their sales benefit.

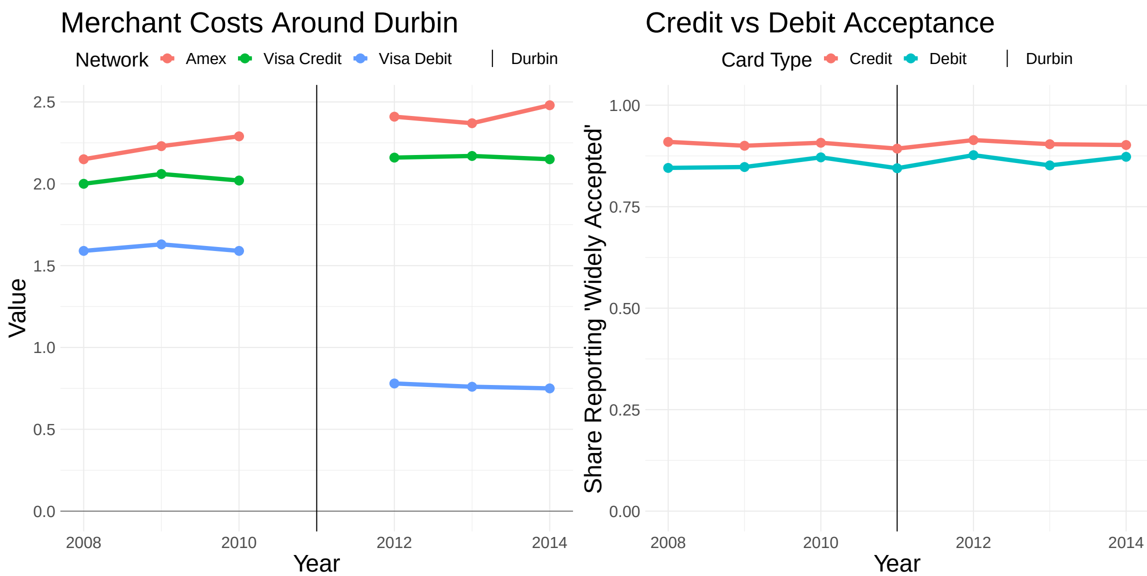
5.4 Merchant Substitution Between Networks

Merchants do not view credit card and debit card acceptance as substitutes, and consumer holding data suggests that different credit card networks are imperfect substitutes for each other.

I use a large change in the cost of debit versus credit acceptance to test merchant substitution patterns between debit and credit. Intuitively, two goods are good substitutes if changes in relative prices induce large changes in relative quantities. Yet when the Durbin Amendment cut debit card fees, there was no significant change in the number of merchants that accepted credit cards. Figure 4 plots of credit and debit card fees around the implementation of the Durbin Amendment and survey measures of credit and debit acceptance around the same time. The left graph shows that the cost of debit acceptance fell by half and the cost of credit card acceptance continued to rise. Yet the right graph shows that consumer ratings of debit and credit card acceptance were unchanged.

One reason debit acceptance may not substitute for credit acceptance is because the

Figure 4: Card fees and acceptance around Durbin



Notes: Merchant costs come from the Nilson Report. Consumer ratings of credit and debit acceptance count the proportion of consumers who rate credit and debit cards as either "usually accepted" or "almost always accepted".

consumers who use both a debit and credit card use them for different purposes.[23] For example, a consumer might use a debit card when she has money in her checking account, but then switch to a credit card when she does not. Therefore when the consumer wants to use the credit card, using a debit card is not an acceptable substitute. Table 2 shows that when compared to consumers who only pay with credit cards, consumers who use a mix are more likely to carry balances. Another reason for the lack of substitution is if merchants have to accept Visa credit and debit together. However, there is no longer any legal requirement to do so.[24] Such a theory would also counterfactually predict that Amex acceptance should drop in response to the Durbin Amendment.

Accepting one network's credit cards is an imperfect substitute for accepting a different network's credit cards because around 40% of consumers carry a card from only one of the three major networks (Visa, MC, Amex). The literature refers to consumers who carry multiple cards as multihomers and those who carry only one as singlehomers.

[23]This is the logic behind defining credit cards as a separate market from debit cards in past antitrust cases. In footnote 8 of the decision in the US v. VISA USA, Judge Jones argues for a separate credit card market based on Visa and Mastercard analysis showing that possession of debit cards did not reduce credit card spending. Jones (2001)

[24]Before a 2003 court settlement, Visa and Mastercard did have "honor all cards" rules that tied the acceptance of debit and credit cards. However, the 2003 settlement dropped these rules and in the following years Visa and Mastercard cut interchange fees on debit cards (Constantine, 2012). Therefore there was no formal requirement that prevented merchants from substituting from credit to debit acceptance.

Table 6: Number of credit cards and debit cards carried by typical consumer

	Rysman (2007)	DCPC	Homescan
Share of Credit Card Singlehomers	0.51	0.39	0.38

Notes: The number for Rysman (2007) is the conditional probability of owning only one of a Visa, MC, or Amex credit card conditional on owning at least one. This is different than the number he reports for singlehoming because I ignore Discover. The probabilities from the DCPC and Homescan are analogous

Multihomers empower merchants to reject high fee cards. If every Visa consumer owns a MC, then accepting MC also enables merchants to serve customers with a Visa card. Visa and MC would compete down merchant fees since merchants would only accept the cheapest option. In contrast, if consumers singlehome, then Visa can charge merchants high prices for exclusive access to Visa customers (Armstrong, 2006). Table 6 compares my estimates of the probability that a credit card consumer singlehomes. Across both Homescan and the DCPC I find that 40% of credit card consumers use only credit cards from one network. This is somewhat lower than the Visa Payments Panel data in Rysman (2007), but is consistent with the general growth of the card industry in the past 15 years.

5.5 Summarizing the Reduced Form Facts

The first two reduced form facts suggest that consumers are quick to switch to networks with high rewards. The last two reduced form facts suggest that merchants who try to reject cards from high fee networks risk large declines in sales. In sum, these facts point to a world where different networks are good substitutes for consumers, but poor substitutes for merchants. The theoretical literature emphasizes that, under these conditions, network competition can result in higher merchant fees and higher consumer rewards. However, the reduced form facts do not speak to exactly how good of substitutes the networks are for consumers and merchants. The model in the next section is necessary to translate the reduced form facts into precise statements about consumer and merchant substitution patterns, and to predict how competition affects prices and welfare.

6 Model

The model maps reduced form facts into predictions for how networks compete. Once I estimate the parameters, solving the game under different conditions will enable me to predict network behavior under different market structures and decompose the welfare effects of changes in competition and regulation.

6.1 Structure of the Game

I model competition between card networks as a static game with three stages with three kinds of players: networks, consumers, and merchants. I solve for a subgame perfect equilibrium of this game.

In the first stage, profit maximizing networks set per transaction fees for merchants and promised utility levels for consumers. In the second stage, consumers and merchants make adoption and pricing decisions. Consumers choose up to two cards to put in their wallet. Merchants choose which cards to accept and set prices. In the third stage, consumers decide how much to consume from each merchant and pay with the cards in their wallet. Below, I walk through the stages of the game in reverse order.

6.2 Stage 3: Consumer Payment Choice at the Point of Sale

At the point of sale, consumer payment behavior is mechanical and reflects the order of the cards in their wallet. Consumers will first try to use their primary card. If that is not possible, they will use their secondary card if it shares the same card type as their primary card. Otherwise they pay with cash. Although high reward cards are more likely to be chosen as the primary card in an earlier stage of the game, rewards have no effect on the intensive margin.

Define the set of all inside payment methods (i.e. cards) as $\mathcal{J}_1 = \{1, \ldots, J\}$, and the set of all payment methods as $\mathcal{J} = \{0\} \cup \mathcal{J}_1$, where 0 refers to cash. Although I have in mind a fintech platform entering in the counterfactual, for simplicity I will refer to all inside payment methods as cards. Each payment method has a type, $\chi^j \in \{0, D, C, A\}$ for cash, debit, credit, or a new app.

Each consumer has a wallet w with zero, one or two inside payment methods (i.e. cards[25]) that have already been chosen in the second stage of the game. Let $\mathcal{W} = \{(j,k) : j,k \in \mathcal{J}, j \neq k\}$ denote the set of all possible wallets. For a wallet $w = (w_1, w_2)$, the term w_1 is the primary payment method and w_2 is the secondary payment method.

If the merchant accepts the cards $M \subset \mathcal{J}_1$, then an indicator for whether a wallet w

[25] I refer to all inside payment methods as cards to reflect the current equilibrium. I choose two cards because two networks covers 95% of an average consumer's card spending (see table B.9).

consumer pays with payment method j can be defined as

$$I_{j,M}^{w}=\begin{cases}1 & w_1=j,j\in M\\ 1 & w_1\neq j,w_2=j,\chi^{w_1}=\chi^{w_2},j\in M\\ 0 & \text{Otherwise}\end{cases} \tag{3}$$

where $I_{j,M}^{w}=1 \iff$ a consumer with wallet w pays with j at a merchant that accepts M. Consumers only pay with their secondary card if the primary card is not accepted, the secondary card is accepted, and the secondary card is the same type as their primary card. I require consumers to only use the secondary card if it shares the same type to match the reduced form fact that lower debit card merchant fees do not reduce merchants' acceptance of credit cards (Section 5.4).

By modeling wallets, I unify cash consumers, consumers who use only one card, and consumers who use multiple cards under one framework. Diagrams of how different types of consumers pay are shown in Figure 5. A cash only consumer's primary payment method is cash, $w_1=0$. A consumer who only carries a Visa has $w_1=\text{Visa}$ but $w_2=\text{Cash}$. A consumer who carries an Amex as their primary card and a Visa as a backup has $w_1=\text{Amex}$, $w_2=\text{Visa}$. Note that the Amex + Debit consumer either pays with Amex or cash, skipping over the debit card. This occurs because Amex and debit cards are different types of payment.

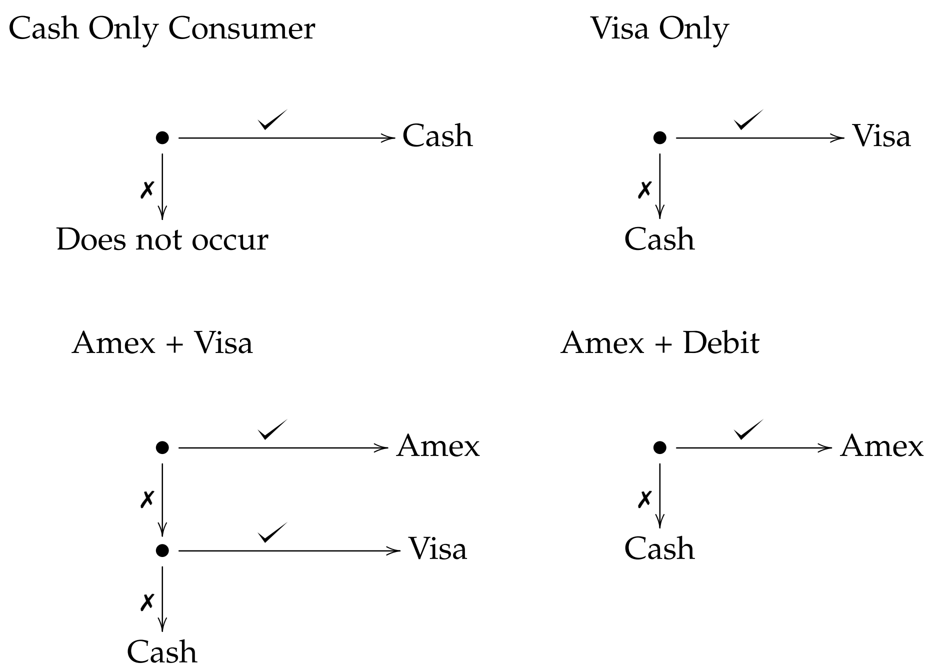
6.3 Consumer Consumption Decisions Over Merchants

Consumers value both card acceptance and low prices. Fix a consumer who has chosen a wallet w at an earlier stage. Each merchant ω has already decided to accept cards $M^{*}(\omega)\subset\mathcal{J}_1$ and has set prices $p^{*}(\omega)$. Define an indicator v_M^w for whether the consumer can pay with card. It can be defined as $v_M^w=I_{w_1,M}^{w}+\left(1-I_{w_1,M}^{w}\right)I_{w_2,M}^{w}$ and is thus equal to one for a consumer with two cards of the same type provided that one of their cards is accepted.

The consumer has symmetric CES preferences over merchants, where payment acceptance enters into quality. Each merchant is characterized by a type $\gamma(\omega)\geq 0$ that determines the importance of payment availability for consumer shopping behavior at the merchant. Let the elasticity of substitution be σ. The consumer has income y^w. The consumer chooses a consumption vector $q^w(\omega)$ to maximize utility subject to a budget constraint:

$$U^w=\max_{q^w}\left(\int_0^1\left(1+\gamma(\omega)\,v_{M^*(\omega)}^{w}\right)^{\frac{1}{\sigma}}q^w(\omega)^{\frac{\sigma-1}{\sigma}}\,\mathrm{d}\omega\right)^{\frac{\sigma}{\sigma-1}}$$

Figure 5: Illustration of how consumers choose payment methods at the point of sale.



Notes: The Amex/Debit consumer does not spend on her debit card because it is not the same type as her primary card.

$$\text{s.t.} \int_0^1 q^w(\omega)\, p^*(\omega)\ \mathrm{d}\omega \leq y^w$$

The inclusion of $v^w_{M^*(\omega)}$ in the integral means that a consumer derives higher utility from consuming at a merchant that accepts a card the consumer wants to use.

Standard CES results imply that the quantity consumed at a merchant ω depends on the type γ, the price p, the payments accepted M, income y^w, and an aggregate price index P^w that summarizes the impact of the pricing and adoption decisions of all other merchants. The demand from a consumer with wallet w for a merchant of type γ is:

$$q^w(\gamma, p, M, y^w, P^w) = (1 + \gamma v^w_M)\, p^{-\sigma} \frac{y^w}{(P^w)^{1-\sigma}} \tag{4}$$

$$(P^w)^{1-\sigma} = \int \left(1 + \gamma(\omega)\, v^w_{M^*(\omega)}\right) p^*(\omega)^{1-\sigma}\ \mathrm{d}\omega$$

In this demand curve, only γ, v^w_M, and p vary across merchants. The price index P^w and the income y^w are not affected by any one merchant's actions.[26]

The merchant's γ parameter determines the percentage increase in sales from a card consumer who originally had to pay in cash, but who can now pay with a card. A low γ firm might be a small business with a loyal customer base, for whom the method of payment is not important. A high γ firm could be an e-commerce firm, who can benefit from significantly higher sales if the online checkout process is convenient (Berg et al., 2022).

I assume consumers only care about *whether* they use a card from their wallet and not about which card is used. This allows me to use the share of credit card consumers in the data who only carry cards from one network to discipline how much merchant demand depends on card acceptance.

The CES assumption underpins my welfare analysis. I infer from card consumers' higher consumption at merchants who accept card as indicating consumer utility goes up from card acceptance. CES provides a disciplined framework for adding up the utility benefits across merchants to arrive at an aggregate change in consumer welfare.

Two merchants with the same γ will choose the same price and acceptance policy. Therefore the merchant variety ω can be dropped from the analysis. I can describe the equilibrium in terms of a equilibrium price schedule $p^*(\gamma)$ and a set valued adoption schedule $M^*(\gamma)$. This reparameterization means that the price index can now be

[26]This simplifies the strategic interaction between merchants, who only need to care about other merchants' pricing and adoption decisions through the effect on the price index.

expressed as

$$\left(P^{w}\right)^{1-\sigma}=\int\left(1+\gamma v^{w}\left(M^{*}\left(\gamma\right)\right)\right)p^{*}\left(\gamma\right)^{1-\sigma}\,\mathrm{d}G\left(\gamma\right) \tag{5}$$

where $G\left(\gamma\right)$ is the distribution of the γ parameter across merchants.

In equilibrium, consumers will consume according to a consumption schedule $q^{w*}\left(\gamma\right)$ for each merchant type γ that is optimal given all merchants' equilibrium pricing p^{*} and adoption M^{*} decisions.

$$q^{w*}\left(\gamma\right)=q^{w}\left(\gamma,p^{*}\left(\gamma\right),M^{*}\left(\gamma\right),y^{w},P^{w}\right) \tag{6}$$

6.4 Merchant Pricing

Merchants are single product firms that maximize profits by setting prices and choosing the subset of payments to accept.

I first solve for optimal pricing conditional on a given acceptance decision M. Collapse the wallet specific price indices from the consumer problem to $P=\left(P^{w}\right)_{w\in\mathcal{W}}$. Let the merchant fee for payment method j equal τ_j of sales. Let the share of consumers with wallet w be $\tilde{\mu}^{w}$ and collapse the vector of shares as $\tilde{\mu}$. These shares should be thought of as the share of dollars in the economy in a wallet of type w. Normalize the firm's marginal costs to 1.

The profit function as a function of that one merchant's price is

$$\Pi\left(p,\gamma,M,P,\tau,\tilde{\mu}\right)=\sum_{w\in\mathcal{W}}\tilde{\mu}^{w}\left[\underbrace{q^{w}p\left(1-\tau_{M}^{w}\right)}_{\text{Net Revenue}}-\underbrace{q^{w}}_{\text{Costs}}\right] \tag{7}$$

Where the fee τ_{M}^{w} for wallet $w=\left(w_1,w_2\right)$ is the fee of the payment method that is finally used. Formally it is $\tau_{M}^{w}=\sum_{j\in\mathcal{J}}I_{j,M}^{w}\tau_j$, where the indicators $I_{j,M}^{w}$ were defined in equation 3 and pick up whether payment method j was used.

The expression for profit in equation 7 is a wallet weighted average of revenues less costs. The first term is revenue net of card fees. The second captures the costs of production, which have been normalized to 1. The merchant's optimal pricing problem is

$$\hat{p}\left(\gamma,M^{*}\left(\gamma\right),P,\tau,\tilde{\mu}\right)=\underset{p}{\operatorname{argmax}}\,\Pi\left(p,\gamma,M,P,\tau,\tilde{\mu}\right) \tag{8}$$

The optimal price passes on the average transaction fee to the consumer.

$$\implies \hat{p}\left(\gamma, M^*\left(\gamma\right), P, \tau, \tilde{\mu}\right) = \frac{\sigma}{\sigma - 1} \times \frac{1}{1 - \hat{\tau}} \tag{9}$$

$$\hat{\tau}\left(\gamma, M, P^*, \tau, \tilde{\mu}\right) = \frac{\sum_{w \in \mathcal{W}} \tilde{\mu}^w \frac{y^w}{\left(P^w\right)^{1-\sigma}} \left(1 + \gamma v_M^w\right) \tau^w}{\sum_{w \in \mathcal{W}} \tilde{\mu}^w \frac{y^w}{\left(P^w\right)^{1-\sigma}} \left(1 + \gamma v_M^w\right)} \tag{10}$$

When payment methods have no fees, the above formula becomes the standard CES optimal pricing equation where prices are equal to $\frac{\sigma}{\sigma-1}$ times marginal costs. When transaction fees τ_j are positive, prices are inflated relative to the standard CES benchmark by $\left(1 - \hat{\tau}\right)^{-1}$. The realized transaction fee $\hat{\tau}$ captures the average transaction fee the merchant pays, averaging across all the consumers it serves.[27]

In equilibrium, merchants set optimal prices given the optimal pricing and adoption strategies of other merchants.

$$\hat{p}\left(\gamma, M^*\left(\gamma\right), P, \tau, \tilde{\mu}\right) = p^*\left(\gamma\right) \tag{11}$$

6.5 Merchant Acceptance

Merchants also choose the profit maximizing bundle of payments to accept. Define the profit function for a particular bundle of payments $M \in 2^{\mathcal{J}_1}$, taking into account the merchant's optimal pricing policy, as

$$\widehat{\Pi}\left(\gamma, M, P, \tau\right) = \Pi\left(\hat{p}, \gamma, M, P, \tau\right)$$

Merchants then solve the profit maximization problem

$$\widehat{M}\left(\gamma, P, \tau\right) = \underset{M \in 2^{\mathcal{J}_1}}{\operatorname{argmax}}\, \hat{\Pi}\left(\gamma, M, P, \tau\right) \tag{12}$$

Where the price index P already depends on the equilibrium pricing p^* and adoption decisions M^*. In equilibrium, merchants adopt optimal bundles holding fixed the optimal

[27] The pricing formula 9 states that fees are passed through to prices more than one for one. The high rate of pass through reflects a combination of market power and log-convex demand (Weyl and Fabinger, 2013; Pless and van Benthem, 2019).. Empirical work on the pass-through of card transaction fees suggests that merchants tend not to change prices in response to transaction fees in the short run (Higgins, 2020). A model with high passthrough is reasonable for long run analysis since menu costs might prevent short run adjustment while allowing for long run passthrough. This issue is also unlikely to be resolved empirically, as tests of the long run response of prices to transaction fees lack power.

adoption and pricing behavior of other merchants.

$$\widehat{M}(\gamma, P, \tau) = M^*(\gamma) \tag{13}$$

Merchants are able to accept any subset of cards, including subsets that are not played on the equilibrium path. This is essential to discipline networks' incentives to raise merchant fees. In the current US market, almost all merchants who accept Visa credit cards also accept MC credit cards. That is rational in the current equilibrium where both networks charge similar fees. However, it's essential that merchants are able to drop Visa credit while still accepting MC credit in an alternative world where Visa were more expensive than MC. Otherwise, Visa would face strong incentives to raise merchant fees since doing so would not have a large effect on merchant acceptance.

6.6 Consumer Adoption

Consumers choose the two payment instruments that offer the highest payment utility to put in their wallet. If a consumers top two options are cards, the consumer will also carry cash.

I define the log payment utility V_i^j from a single payment method $j \in \mathcal{J}$ as

$$\log V_i^j = \underbrace{\log U^j}_{\text{CES}} + \underbrace{\Xi^j}_{\text{Intercepts}} + \frac{1}{\alpha}\left(\underbrace{\eta_i^j}_{\text{Unobs Char}} + \underbrace{\beta_i X^j}_{\text{R.C.}}\right) \tag{14}$$

Each component of payment utility plays an important role. The first term is the CES utility, U^j. This combines the consumer's utility from rewards with the gains from card acceptance. If the network pays consumers who singlehome on card j a reward f^j, then the consumer's log optimal utility from solving her consumption problem is U^j where

$$U^j = \frac{1 + f^j}{P^j} \implies \log U^j \approx f^j - \log P^j \tag{15}$$

where P^j is the CES price index associated with a customer who only uses j. The utility from the CES system increases for a payment method that earns a large reward (which increases f^j) and also increases for a payment method that is widely accepted (which decreases P^j).[28] The variables Ξ^j represent unobserved characteristics that rationalize market shares. I normalize the unobserved characteristic of cash as $\Xi^0 = 0$. The pa-

[28] A more widely accepted payment instrument will have a lower price index by equation 5.

rameter α is a measure of how elastic consumers are to increases in the reward. A large value of α will mean that a small increase in rewards f^j leads to a large increase in j's market share. The shocks η_{ij} represent unobserved characteristics of payment methods. The characteristics X^j are indicators for whether a payment method is a card or cash and whether it has a credit function. The random coefficients are distributed $\beta_i \sim N(0, \Sigma)$ for some covariance matrix Σ. This unobserved heterogeneity across consumers generates rich substitution patterns between credit and debit cards and between cards and cash.

The share of demand at each merchant from consumers of each kind of wallet is pinned down by the joint distribution of the largest and second largest values of V_i^j. The payment method with the highest utility becomes the primary payment and the second highest utility becomes the secondary payment in the wallet. I define *insulated* market shares for the wallet $w = (w_1, w_2)$ as

$$\mu^w = P\left(\left(V_i^{w_1} = \max_{j \in \mathcal{J}} V_i^j\right) \cap \left(V_i^{w_2} = \max_{j \in \mathcal{J} \setminus \{l\}} V_i^j\right)\right) \tag{16}$$

These shares add up to 1 and represent the share of demand for a cash only merchant from consumers of each wallet type.

Market shares $\tilde{\mu}$ are constructed so that each merchant's decision on which cards to accept will only depend on the insulated shares μ, and not on the underlying price index P^w or the rewards f^w. Actual market shares among consumers for different wallets are derived from the insulated shares as

$$\tilde{\mu}^{(l,k)} = \frac{1}{C} \frac{\mu^{(l,k)} \left(P^{(l,k)}\right)^{1-\sigma}}{1 + f^{(l,k)}} \tag{17}$$

$$C \equiv \sum_{w \in \mathcal{W}} \frac{\mu^w \left(P^w\right)^{1-\sigma}}{1 + f^w} \tag{18}$$

where f^w is the total rewards paid[29] to a consumer with wallet w. The constant C has been defined in a way to make the market shares add up to 1. If one alternatively defined the market shares $\tilde{\mu}$ in terms of the joint distributions of the payment methods delivering the top two highest V_i^j, that would create a strategic substitutability where merchants are less likely to adopt payment methods if other merchants have already adopted. A

[29]The rewards f^w for consumers who only hold one card will be set by the networks, and the rewards for the consumers who multihome will be based off of the singlehoming rewards under the assumption that the reward from a card is proportional to the amount of spending done on that card. I discuss the calculation of these rewards in the next subsection.

pure strategy equiliubrium for consumer and merchant adoption may no longer exist in the alternative setting.

6.7 Network Profits

Network profits come from transaction fees charged to merchants, less the rewards paid to consumers. A useful quantity for computing profits is the total dollar amount $\tilde{d}_j^w$ consumers with wallet w spend on card j. This is

$$\tilde{d}_j^w = \tilde{\mu}^w \int I_{M(\gamma),j}^w q^w(\gamma)\, p(\gamma)\ \mathrm{d}G(\gamma)$$

where the indicator $I_{M,j}^w$ picks up whether payment method j was used if the merchant accepts M and the consumer has a wallet w defined in equation 3.

Total profits from the merchant side of the market for card j is

$$T_j = \left(\tau_j - c_j\right) \sum_{w \in \mathcal{W}} \tilde{d}_j^w$$

where c_j is the cost of processing one dollar on method j. This expression multiplies the networks' profit per transaction by the total dollar value of transactions. The total cost of rewards is

$$S_j = \sum_{w \in \mathcal{W}} \tilde{\mu} f_j^w$$

where f_j^w is the amount of rewards that need to be paid to consumer w for her use of j.

In the model, networks own multiple cards. For a network n that owns cards $\mathcal{O}_n \subset \mathcal{J}_1$, the profit is

$$\Psi_n = \sum_{j \in \mathcal{O}_n} \left(T_j - S_j\right) \tag{19}$$

I describe how to calculate each of the terms below. First, note that the total dollars can also be expressed in terms of insulated shares μ^w and a new expression for insulated dollars, d_j^w, that does not depend on the normalizing constant C.

$$\tilde{d}_j^w = \frac{\mu^w}{C} \underbrace{\int I_{M(\gamma),j}^w \left(1 + \gamma v_M^w\right) p(\gamma)^{1-\sigma}\ \mathrm{d}G(\gamma)}_{d_j^w}$$

The profits networks earn from merchants can then be re-expressed as a sum involving insulated dollars

$$T_j = \frac{1}{C} \times \left(\tau_j - c_j\right) \sum_{w \in \mathcal{W}} d_j^w \tag{20}$$

To calculate the cost of consumer rewards, I assume that consumers receive rewards according to a fixed percent of their equilibrium spending. This assumption is only relevant in the off equilibrium path where different networks that are substitutes for merchants charge different fees. If a singlehoming American Express user spends 50 cents on American Express and earns 2 cents in rewards, and a singlehoming Visa user spends $1 on Visa and earns 2 cents in rewards, a multihoming consumer who spends 50 cents on Visa and 50 cents on American Express should earn 3 cents of rewards. This assumption is equivalent to assuming networks pay all consumers the same rewards per transaction, but pay these rewards in a lump sum fashion with knowledge of equilibrium payment volumes.

To implement the above assumption, I calculate the total rewards the card j pays out as

$$S_j = f^j \tilde{\mu}^j \left(\frac{\sum_{k \neq j} d_j^{(j,k)} + d_j^{(k,j)}}{d_j^{(j,0)}} \right) \tag{21}$$

where $\tilde{\mu}^j \equiv \mu^{(j,0)}$ is the share of consumers who singlehome on j. Intuitively, the network must pay out $f^j \tilde{\mu}^j$ to the singlehoming agents. To compute how much needs to be paid out to the multihoming agents, I compute how many dollars the multihoming agents spend on j relative to the amount of dollars the singlehoming agents spend on j. It is possible for multihoming agents to spend on j only when j is in the wallet, and therefore the sum iterates over both kinds of wallets (j,k) and (k,j). The amount of the reward is then inflated by the ratio of the total dollars spent on j by all agents compared to the total dollars spent on j only by the singlehoming agents.

There is one last fixed point between the normalizing constant C, the actual market shares $\tilde{\mu}$, and the rewards paid to each type of multihoming agent. To get around this issue, I make a simplifying assumption that, for the purpose of calculating network profits, the the multihoming agents can be assumed to receive the reward of their primary card. This is a small adjustment since it reflects a second order effect of differences in rewards causing consumers to have differences in income, changing spending, and thus affecting transaction fee income. Thus I approximate the profits from merchants $\tilde{T}_j$ and the reward bill $\tilde{S}_j$ as

$$\begin{aligned}\tilde{T}_j &= \frac{1}{\tilde{C}} \times \left(\tau_j - c_j\right) \sum_{w \in \mathcal{W}} d_j^w \\ \tilde{S}_j &= \frac{1}{\tilde{C}} f^j \frac{\mu^{(j,0)} \left(P^j\right)^{1-\sigma}}{1+f^j} \left(\frac{\sum_{k \neq j} d_j^{(j,k)} + d_j^{(k,j)}}{d_j^{(j,0)}}\right) \\ \tilde{C} &= \sum_{w=(w_1,w_2) \in \mathcal{W}} \frac{\mu^w \left(P^w\right)^{1-\sigma}}{1+f^{w_1}}\end{aligned} \tag{22}$$

6.8 Solving the Merchant Adoption Subgame

While the profit maximization problem in equation 12 is conceptually clean, it will be both computationally easier and yield more economic intuition to have merchants adopt bundles M that maximize a linear approximation of the profit function $\widehat{\Pi}$, which I will call quasiprofits $\overline{\Pi}$. As long as fees are small, true profits $\widehat{\Pi}$ will be approximately equal to a linear function of γ with weights and slopes that have an intuitive meaning. I formalize this in the theorem below.

Theorem 1. *True profits are approximately linear in γ. For any γ, M, P, τ,*

$$\widehat{\Pi} - \overline{\Pi} = O\left((1+\gamma)\left(\tau^{\max}\right)^2\right)$$

where

$$\overline{\Pi}(\gamma, M, P, \tau) \equiv \frac{1}{C}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}\left\{-a_M + b_M \gamma + \frac{1}{\sigma}\right\} \tag{23}$$

$$\begin{aligned}a_M &= \sum_{w \in \mathcal{W}} \mu^w \tau_M^w \\ b_M &= \frac{1}{\sigma} \sum_{w \in \mathcal{W}} \mu^w v_M^w \left(1 - \sigma \tau_M^w\right) \\ \tau^{\max} &= \max_j \tau_j\end{aligned} \tag{24}$$

Proof. See Appendix A □

The linear form of quasiprofits means the adoption equilibrium among merchants can be computed by solving for the upper envelope of a collection of linear functions. Payment bundles with a high fee have a low intercept and a flatter slope. Payment bundles that serve a large share of consumers have a steeper slope. The linear form of quasiprofits can be used to illustrate the similarities between my model of merchant adoption and that of Rochet and Tirole (2003). I elaborate on these issues in Appendix E.

6.9 Network Conduct and Equilibrium Determinacy

Networks maximize profits by adjusting promised CES utility levels for consumers U^j and transaction fees for merchants τ_j, holding fixed the utility levels and transaction fees from other networks. This conduct assumption is in line with the insulating tariffs framework of Weyl (2010) and guarantees that for every vector of network choice variables, the merchant and consumer subgame is unique.

One central challenge in modeling network competition is dealing with a potential multiplicity of equilibria due to a "chicken or egg" problem (Caillaud and Jullien, 2003; Chan, 2021). Consumers only adopt cards if they are widely accepted, and merchants only accept cards if there are enough consumers who want to use them. In monopoly settings, a common approach is to select the Pareto undominated equilibrium. However, Pareto dominance would not be able to select between competing networks.

To deal with the "chicken or egg" problem, I instead assume that networks promise CES utility levels for consumers. This is in line with the insulating tariffs outlined in Weyl (2010) and White and Weyl (2016). Networks promise consumers if merchants do not adopt, the networks will compensate the consumers with higher rewards. Consumers then each have a dominant strategy, and merchant actions are determined as soon as consumer actions are determined. Weyl (2010) argues that this is a reduced form way of capturing penetration pricing where networks subsidize consumer adoption when the network is small.

I am able to solve for the unique merchant and consumer subgame[30] and network profits given the promised utility levels U^j and merchant fees τ. At a high level, network profits are calculated by first assuming the promised utility levels are satisfied, and then by calculating the reward levels f^j that are required to satisfy the promises. The utility levels give insulated shares μ^w by equation 16. Merchant adoption then follows from solving for the upper envelope of quasiprofit functions from equation 23. The merchant adoption strategy yields the CES price indices P^w according to equation 5. The CES price indices combined with the CES utility levels U^j give implied reward levels f^j from equation 15. Equations 19, 21, and 20 then yield the network profits.

[30]There is a separate question of whether networks will play the same fees and utility in every equilibrium that I do not consider here.

I employ a refinement to deal with the non-differentiability of network profits with respect to the merchant fees. Non-differentiability predicts a continuum of equilibria. The source of this non-differentiability comes from the Bertrand like assumption that merchants always accept the bundle of payments that delivers the highest profit. Rochet and Tirole (2003) do not encounter this issue in their symmetric, two network model, but subsequent work has shown that transaction volumes are generally non-differentiable in transaction fees when consumers can multihome[31] (Liu et al., 2021). I assume that when each network chooses utility levels and transaction fees, it maximizes expected profits while assuming small trembles in the choice variables. Appendix D explains why this makes the profit function differentiable and how to efficiently calculate the derivative of the expectation.

I now have the tools to formally state the conduct assumption. For each network $n = 1, \ldots, N$, networks set promised utility levels U^{j*} and transaction fees τ_j^* for the cards that they own $\mathcal{O}_n$ such that

$$\left(U^{j*}, \tau_j^*\right)_{j \in \mathcal{O}_n} = \underset{\left(U^j, \tau_j\right)_{j \in \mathcal{O}_n}}{\operatorname{argmax}} \mathbb{E}\left[\Psi_n\left(\tilde{U}^j, \tilde{\tau}_j, \tilde{U}^{-j}, \tilde{\tau}_{-j}\right)\right] \tag{25}$$

$$\tilde{U}^j \sim N\left(U^j, \sigma^2\right) \text{iid}$$

$$\tilde{\tau}_j \sim N\left(\tau_j, \sigma^2\right) \text{iid} \tag{26}$$

where σ^2 is a small variance that I set to 10^{-10}, and U^{-j}, τ_{-j} capture all the singlehoming utilities and fees set by the other networks. I model cash as a network who sets fees to the cost of cash $\tau_j = c_0$ and sets a utility level U^0 equal to $1/P^0$ so as to not pay any rewards.

I assume networks do not price discriminate. I rule out price discrimination by assuming that consumer variation in preferences over payment methods and merchant variation in benefits $G(\gamma)$ are unobservable to the network.

6.10 Equilibrium

A full equilibrium is characterized by fees τ^*, CES utility levels U^*, insulated shares μ, a merchant pricing schedule $p^*(\gamma)$, a merchant adoption schedule $M^*(\gamma)$, and wallet specific consumer demand schedules $q^{w*}(\gamma)$ that satisfy five conditions.

[31] Starting from the symmetric equilibrium, a network that raises its merchant fee is now competing with the option to accept all other card networks. A network that cuts its merchant fee is now competing with cash. In these two regions, the marginal revenue from raising fees is very different, and therefore profits are not differentiable in the neighborhood of the original symmetric fee.

1. The demand schedule $q^{w*}(\gamma)$ is optimal given each consumer's wallet choice, the network's choice of reward, and merchants' acceptance and pricing policies (Eqn 6).

2. For each merchant of type γ, she maximizes quasiprofits by accepting $M^*(\gamma)$ and sets the price $p^*(\gamma)$ (Eqn 11 + 13), holding fixed the adoption and pricing decisions of all other merchants, consumers' choices of wallets, and networks' choices.

3. The insulated shares μ reflect consumers' optimal wallet choices, holding fixed the networks' promised utility levels (Eqn 16).

4. Networks are maximizing profits at the fees τ^* and promised utility levels U^*, holding fixed the promised utility levels and fees of other networks (Eqn 25)

5. Cash pays no reward and charges a fee τ_0 equal to the cost of cash c_0.

7 Estimation

The key primitives to recover are (1) consumers' demand parameters over the different payment options, (2) the distribution of merchant types describing how much merchants benefit from payment acceptance, and (3) the networks' marginal cost parameters. I assume the aggregate shares and prices are the equilibrium of the model with three multiproduct payment networks – Visa, MC, and Amex. Both Visa and MC each own two cards (debit and credit) while Amex only owns their credit card network.

7.1 Consumer Substitution Patterns

I first estimate how consumers substitute between payment methods of different characteristics and how consumers respond to changes in rewards. The distribution of random coefficients summarized in Σ governs substitution patterns while the parameter α governs price sensitivity. These parameters are identified by the reduced form facts on consumers' primary and secondary cards (section 5.2) and the effects of Durbin on payment volumes (section 5.1).

I allow consumers in different data samples to have different mean valuations over payment options and different choice sets, but assume that the distribution of random coefficients Σ, the price sensitivity α, and the characteristics X^j of payment methods are the same across samples. This assumption is natural because I hold these variables constant across counterfactual simulations in which I introduce new products.

I estimate substitution patterns without solving the full model. I derive a simplified representation of consumer preferences over cards that is valid when merchant adoption is held fixed. From equations 14 and 16, the insulated shares μ of each payment option can be generated by a discrete choice model where the utility for payment method j is

$$\begin{aligned} u_j &= \delta_j + \alpha f^j + \beta_i X^j + \eta_i^j \\ \beta_i &\sim N(0, \Sigma) \\ \eta_i^j &\sim \text{T1EV} \end{aligned} \tag{27}$$

where the new intercept δ_j absorbs the intercepts Ξ^j and the CES price indices $\log P^j$. This simplified model generates the same first and second choice probabilities as the full model. I estimate consumer substitution patterns by matching these insulated shares to observed market shares.[32]

The distribution of random coefficients Σ matches the Homescan data on primary and secondary cards. Let cash be the outside option, and order the choice set in Homescan as debit, Visa credit, MC credit, and Amex. For each possible wallet (j, k) where j is not cash, let s_{jk} be the estimated probability that a Homescan consumer is a primary j user and a secondary k user. Stack these shares as s. I use the simplified representation in equation 27 to calculate model implied probabilities. Since there is no price variation in Homescan I normalize $f^j \equiv 0$. The probability of a given combination of primary and secondary card is

$$\hat{s}_{jk}(\Sigma, \delta) = \int \frac{\exp\left(\delta_j + \beta_i X^j\right)}{\sum_l \exp\left(\delta_l + \beta_i X^j\right)} \times \frac{\exp\left(\delta_k + \beta_i X^j\right)}{\sum_{l \neq j} \exp\left(\delta_l + \beta_i X^j\right)} \, \mathrm{d}H(\beta_i) \tag{28}$$

where H is the joint distribution of β_i (Berry et al., 2004). I compute this with Monte Carlo integration. Intuitively, if the random coefficient on the credit characteristic has a high volatility, then primary credit card users' second choice is likely to also be a credit card. Stack the model implied shares as $\hat{s}$.

The price sensitivity coefficient α is important for matching the effects of Durbin. From the Nilson panel, I estimate two micro-moments: the effect of the Durbin Amendment on signature debit volumes (Figure 3), and the share of signature debit card volumes of total signature debit and credit volumes (Table 1). I impose a third aggregate moment that 20% of overall transactions by value are done by cash (Table B.1). Combine

[32] Although there is a wedge between insulated shares and market shares defined by equation 17, these wedges do not vary across consumers. The wedges can therefore be absorbed in the mean utility levels δ_j and do not pose a problem for the estimation of Σ and α.

these moments as m.

Next I simulate Durbin in my model. I order the choice set of payment methods as cash, signature debit, and credit cards to match the data provided.[33] Let the mean utilities in this model be $\tilde{\delta}$ to distinguish from the mean utilities used in the Homescan data. Let $\Delta f = 25$ bps, which is the change in debit rewards as a result of Durbin. The model implied moments are

$$\hat{m}\left(\Sigma,\alpha,\phi\right) = \begin{pmatrix} \log\int \frac{\exp\left(\tilde{\delta}_1-\alpha\Delta f+\beta_i X^1\right)}{\sum_k \exp\left(\tilde{\delta}_k-\alpha\Delta f I\{k=1\}+\beta_i X^k\right)} - \log\int \frac{\exp\left(\tilde{\delta}_1+\beta_i X^1\right)}{\sum_k \exp\left(\tilde{\delta}_k+\beta_i X^k\right)} \\ \int \frac{\exp\left(\tilde{\delta}_1+\beta_i X^1\right)}{\sum_k \exp\left(\tilde{\delta}_k+\beta_i X^k\right)} \times \left(\int \frac{\exp\left(\tilde{\delta}_1+\beta_i X^1\right)}{\sum_k \exp\left(\tilde{\delta}_k+\beta_i X^k\right)} + \int \frac{\exp\left(\tilde{\delta}_2+\beta_i X^2\right)}{\sum_k \exp\left(\tilde{\delta}_k+\beta_i X^k\right)}\right)^{-1} \\ \int \frac{1}{\sum_k \exp\left(\tilde{\delta}_k+\beta_i X^k\right)} \end{pmatrix}$$

where all integrals are against the distribution H of random coefficients β_i. When α is large, a small change in rewards leads to a large change in market shares.

I estimate the parameters with GMM with the optimal weight matrix. I estimate the covariance matrices of the micro-moments in s, m with the Bayesian bootstrap. I assume that the aggregate cash moment is independent of the other moments and is observed with only a small 1 bps standard error. Denote the estimated covariances as $\hat{S}_1, \hat{S}_2$ respectively. Since the empirical moments are from different datasets, the optimal weight matrix W is block diagonal with $\hat{S}_1^{-1}$ and $\hat{S}_2^{-1}$. Stack the moments as $\hat{g}\left(\Sigma,\alpha,\delta,\phi\right) = \begin{pmatrix} \hat{s}\left(\Sigma,\delta\right) & \hat{m}\left(\Sigma,\alpha,\tilde{\delta}\right) \end{pmatrix}^T$ and $g = \begin{pmatrix} s & m \end{pmatrix}^T$. Stack the parameters as $\theta_1 = \begin{pmatrix} \Sigma & \alpha & \delta & \tilde{\delta} \end{pmatrix}^T$. I estimate θ_1 by solving

$$\hat{\theta}_1 = \underset{\theta_1}{\operatorname{argmin}} \left(\hat{g}\left(\theta_1\right) - g\right)^T W \left(\hat{g}\left(\theta_1\right) - g\right)$$

I extract both $\hat{\Sigma}, \hat{\alpha}$ and the associated covariance matrix of the estimates.

7.2 Merchant Benefits, Network Costs, and Consumer Intercepts

I estimate the remaining parameters by matching the estimated effect of card acceptance on sales, matching the share of card consumers's spending at card merchants (both from section 5.3), and inverting the networks' first order conditions at the observed aggregate prices and shares.

I make two assumptions on fees and the cost of cash. First, I assume that the aggre-

[33] The crucial assumption is that the customers of these small regional banks consider only cash, their bank's debit card, and their bank's credit cards in their choice set.

gate fees are observed with error because my model cannot rationalize three credit card networks of different sizes charging identical fees. Instead of matching the surveyed fees in table B.2, I instead assume that MC credit charges a fee $\tau_{\text{Visa Credit}} + \Delta\tau_{\text{MC}}$ and that Amex charges a fee $\tau_{\text{Visa Credit}} + \Delta\tau_{\text{MC}} + \Delta\tau_{\text{Amex}}$, where $\Delta\tau_{\text{MC}}$ and $\Delta\tau_{\text{Amex}}$ are fee adjustment parameters to be estimated. I set the cost of cash $c_0 = \tau_0 = 0.003$ to match past studies (European Commission, 2015; Felt et al., 2020).[34]

I parameterize the distribution of merchant benefits G as a Gamma distribution with a mean $\overline{\gamma}$ and a standard deviation of σ_γ and adjust the mean and standard deviations to match the facts from the payment surveys. Let the first data moment $\hat{\phi}_1$ be the share of card consumers' spending at card stores (97%). Let the second data moment $\hat{\phi}_2$ be the logistic regression coefficient of how consumers' card preference relates to whether a transaction is done at a card merchant (30). Stack these data moments as $\hat{\phi}$.

To calculate the analogous model moments, define expenditure at all merchants with types $\gamma \geq \gamma'$ for a consumer with wallet w as $e^w\left(\gamma'\right)$. This is an integral of expenditure at each type of merchant:

$$e^w\left(\gamma'\right) = \int_{\gamma > \gamma'} q^{w*}(\gamma)\, p^*(\gamma)\ \mathrm{d}G(\gamma)$$

Let $\mathcal{M} = \{w \in \mathcal{W} : w_1 \in \{\text{Visa Credit}, \text{MC Credit}, \text{Amex}\}\}$ be the set of wallets that are primary credit card consumers. Let $\mathcal{C} = \{w \in \mathcal{W} : w_1 = \text{Cash}\}$ be the set of wallets of primary cash users. Let γ^* be the lowest merchant type that accepts all credit cards. The two model moments are

$$\begin{aligned}
\phi_1 &= \frac{\sum_{w\in\mathcal{M}} e^w(\gamma^*)}{\sum_{w\in\mathcal{M}} e^w(0)} \\
\phi_2 &= \ell(\phi_1) - \ell\left(\frac{\sum_{w\in\mathcal{C}} e^w(\gamma^*)}{\sum_{w\in\mathcal{C}} e^w(0)}\right) \\
\ell(p) &= \log\frac{p}{1-p}
\end{aligned}$$

The first moment is the expenditure share of credit card consumers at card stores. The second moment is the difference in the logits of two expenditure shares: the share of credit consumers' spending at card stores and the share of cash consumers' spending at card stores. Stack these two model moments as ϕ. When the mean $\overline{\gamma}$ is large, the difference ϕ_2 between card and cash consumers' expenditure shares at card stores increases. As the standard deviation σ_γ increases, the share of merchants who do not benefit from

[34] I also checked the cash deposit fees for business checking accounts at Bank of America, Chase, PNC, and Wells Fargo on October 9, 2022. These average to be 28 bps.

card acceptance also increases. Fewer merchants accept cards, and so card consumers' expenditure share at card stores ϕ_1 declines.

I jointly estimate the parameters by finding the 15 parameters to match 2 moment conditions $\hat{\phi} = \phi$, 8 first order conditions, and 5 share constraints. The fifteen parameters are the average $\overline{\gamma}$ and standard deviation σ_γ of merchant benefits, the 5 marginal cost parameters c for each card, the 5 utility intercepts Ξ for each card, the two fee adjustments $\Delta\tau_{\text{MC}}, \Delta\tau_{\text{Amex}}$, and the CES substitution parameter σ. The 8 first order conditions are the 3 first order conditions of each credit card network with respect to its merchant fee and the 5 first order conditions of each card with respect to the promised utility U^j to the consumer. Debit card fees are not at a first order condition due to Durbin. The 5 share constraints require that at the profit maximizing promised utility for each card, the resulting aggregate shares $\tilde{\mu}$ from equation 17 match the data.[35] I solve the moment conditions and the first order conditions jointly because the distribution of merchant types affects the networks' first order conditions.

I calculate the standard errors through the Delta Method. Denote all the parameters to be estimated in this step as θ_2. Stack all the first order conditions and moment conditions into a function F. The estimate $\hat{\theta}_2$ solves the equation

$$F\left(\hat{\theta}_2, \hat{\theta}_1, \hat{\phi}\right) = 0$$

The implicit function theorem gives a representation of $\hat{\theta}_2$ as $\hat{\theta}_2\left(\hat{\theta}_1, \hat{\phi}\right)$ with a known Jacobian. I calculate the covariance matrix of $\left(\hat{\theta}_1, \hat{\phi}\right)$ by assuming that the two are independent and by using the Bayesian bootstrap for the distribution of $\hat{\phi}$. The delta method converts the covariance matrix and the Jacobian into a full covariance matrix for $\hat{\theta}_2$.

One way to understand this step is that, given consumer demand, I can recover networks' marginal costs c_k by the networks' first order conditions with respect to consumer rewards. Raising rewards increases transaction volume at the cost of paying out more rewards to inframarginal consumers. The fact that networks are willing to pay large rewards to consumers must mean that they are making large margins on the merchant side of the market, which pins down the marginal cost parameters.

The fact that observed merchant fees are much higher than marginal costs then reveals that merchant demand must be inelastic. One challenge with estimating the merchant demand curve for payments is that there is little exogenous variation in merchant fees to identify demand. I avoid this issue by inferring this elasticity from networks'

[35] Here I use true market shares rather than insulated shares because the wedge between the two depends on the CES price index, which can change across parameter specifications.

optimal pricing.

Three parameters – CES substitution σ, the average merchant benefit $\overline{\gamma}$, and the standard deviation of benefits σ_γ then govern the elasticity of the merchant demand curve. I then find the three parameters that deliver the correct elasticity while also matching the payment survey moments.

7.3 Identification and the Model Intuition

The estimated parameters are closely related to how willing consumers and merchants are to substitute between networks. As discussed in section 4, if consumers are more willing to substitute between networks, competition is likely to lead to higher merchant fees and higher consumer rewards.

Consumer substitutability is governed both by the price sensitivity α and the distribution of random coefficients Σ. Price sensitivity comes from the Durbin evidence. Because the change in debit volumes in response to a small change in rewards is large, sensitivity is high. The distribution of random coefficients comes from the co-holding data. The fact that primary credit card consumers often carry secondary credit cards from different networks means different networks' credit cards are good substitutes for each other.

Merchant substitutability is partially governed by the distribution $G(\gamma)$ of merchant benefits and the CES substitution parameter σ. The average benefit $\mathbb{E}[\gamma]$ is identified by the large estimate of the benefit of card acceptance on sales from the payment surveys. Most merchants accept cards, as revealed by card consumers' high expenditure share at card stores. Thus the dispersion in merchant benefits σ_γ must be small. The CES substitution parameter σ is then adjusted to match the low estimated elasticity of merchant demand. If σ is large, then merchant margins are low and therefore merchants are more price sensitive.

The share of consumers who carry multiple cards of the same type χ will also shape merchant substitution. For example, if every Visa credit consumer carries a MC credit card and vice-versa, then merchants would only ever the cheaper of the two. Accepting either would let the merchant serve every Visa and MC credit card consumer. However, if many Visa credit consumers carry Mastercard debit cards, merchants would still not be able to substitute Visa credit acceptance with Mastercard debit acceptance since credit and debit are different payment types.

7.4 Results

I estimate precise consumer elasticities, merchant elasticities, and network marginal costs. Table 7 contains all of the parameter estimates, and below I walk through the interpretation of the parameters.

The consumer parameters indicate that consumers are highly willing to substitute between payment methods, especially between payment methods with similar characteristics (e.g. credit vs debit). I transform the consumer parameters into their implications for semi-elasticities in table 8. Each column shocks the reward for a different payment method by one basis point. Each row then records how the market share of that payment method changes in response to the shock.

The first column of table 8 shows that a one basis point shock to Visa debit rewards, holding all else equal, increases the share of Visa debit primary card users by 2.4% with a standard error of 0.4%. The new consumers mostly come from MC debit, which declines by -2.5%. In contrast, MC credit only declines by -0.6%. The difference reflects the fact that debit and credit consumers are partially segmented, and so debit cards are good substitutes for each other. Cash use only declines by -0.3%. The small change reflects the heterogeneity in consumers' valuation of cash versus cards. The third column shows a similar pattern for Visa credit. A shock to rewards steals consumers from MC credit and Amex, while having a relatively muted effect on cash and debit users.

I estimate that merchants are price insensitive. Starting from an equilibrium where three symmetric credit card networks charge the same price, a one basis point increase in the fees to one credit card network leads to only a 0.16% decrease in the number of merchants who accept that card with a standard error of only 0.01%. This is roughly one tenth of the sensitivities I estimate for consumers.

To calculate the merchant elasticity while holding consumer demand fixed, I use a fact proven in Appendix E.3. If all other credit card networks charge a fee of τ^* and one network deviates to a fee of τ, the lowest merchant type that accepts the deviating network is $\gamma^{'}$ where

$$\gamma^{'}(\tau) = \begin{cases} \frac{\sigma\tau}{1-\sigma\tau} & \tau < \tau^* \\ \frac{\sigma\rho\tau+\sigma(1-\rho)(\tau-\tau^*)}{\rho(1-\sigma\tau)-\sigma(1-\rho)(\tau-\tau^*)} & \tau \geq \tau^* \end{cases}$$

and ρ is the share of credit card holders that only carry one card. This expression is continuous but not differentiable at τ^*. To be consistent with the equilibrium refinement I use to solve the model I calculate the percentage change in acceptance by averaging the effects of deviations to higher and lower fees. Formally, I calculate the percentage

Table 7: Estimated parameters

Panel A: Consumer Parameters

Parameter	Estimate	SE
SD of Credit RC	2.0	0.0
SD of Card RC	4.9	0.1
Correlation of RC	-0.3	0.0
Price Sensitivity α	483.7	87.3
Visa Debit Intercept $\times 100$	-4.6	0.2
Visa Credit Intercept $\times 100$	-5.7	0.2
MC Debit Intercept $\times 100$	-4.8	0.2
MC Credit Intercept $\times 100$	-5.8	0.2
Amex Intercept $\times 100$	-5.9	0.2

Panel B: Merchant Parameters

Parameter	Estimate	SE
CES σ	7.2	1.9
Average γ	0.3	0.1
Log Ratio of $\frac{\sigma_\gamma}{\overline{\gamma}}$	-1.1	0.1

Panel C: Network Parameters (bps)

Parameter	Estimate	SE
Visa Debit Cost	43.3	0.2
Visa Credit Cost	13.7	0.4
MC Debit Cost	52.3	0.1
MC Credit Cost	56.1	0.3
Amex Cost	57.7	0.4
MC Fee Adj	0.1	0.0
Amex Fee Adj	0.0	0.0

Table 8: Estimated consumer own price and cross price semi-elasticities.

Payment	V Debit	MC Debit	V Credit	MC Credit	Amex
Cash	$-0.3\,(0.1)$	$-0.1\,(0.0)$	$-0.6\,(0.1)$	$-0.2\,(0.0)$	$-0.2\,(0.0)$
V Debit	$+2.4\,(0.4)$	$-1.0\,(0.2)$	$-0.7\,(0.1)$	$-0.3\,(0.0)$	$-0.2\,(0.0)$
MC Debit	$-2.5\,(0.4)$	$+3.9\,(0.7)$	$-0.7\,(0.1)$	$-0.3\,(0.0)$	$-0.2\,(0.0)$
V Credit	$-0.6\,(0.1)$	$-0.2\,(0.0)$	$+2.8\,(0.5)$	$-0.8\,(0.1)$	$-0.7\,(0.1)$
MC Credit	$-0.6\,(0.1)$	$-0.2\,(0.0)$	$-2.0\,(0.4)$	$+4.0\,(0.7)$	$-0.7\,(0.1)$
Amex	$-0.6\,(0.1)$	$-0.2\,(0.0)$	$-2.0\,(0.4)$	$-0.8\,(0.1)$	$+4.1\,(0.7)$

Notes: Each entry shows the effect of a one basis point change in the rewards of the column payment method on the market share of the row payment method. The change is measured as a percentage of the row payment method's market share.

change as

$$\frac{1}{2} \times \frac{G\left(\gamma'\left(\tau^* - 10^{-4}\right)\right) - G\left(\gamma'\left(\tau^* + 10^{-4}\right)\right)}{1 - G\left(\gamma'\left(\tau^*\right)\right)}$$

where G is the CDF of merchant types. I calculate the standard error of this change with the delta method.

The network supply parameters are also precisely estimated. I estimate marginal cost parameters that average around 45 bps with a standard error of 0.3 bps. This is reasonable given accounting estimates of issuer costs around $20-40$ bps, acquiror costs of around $5-10$ bps, and network costs of around 5 basis points.[36]

The merchant elasticity is estimated more precisely than the underlying parameters governing merchant types because different combinations of primitives deliver the same merchant elasticity. Merchants have high willingness to pay for payments both when card acceptance has a small effect on sales but merchant markups are high (low $\overline{\gamma}$, low σ), or the sales effect is large but markups are low (high $\overline{\gamma}$, high σ). Both cases deliver similar implications for merchants price elasticity with respect to fees. So even though the CES substitution parameter of 7.2 and the average sales benefit of 34% have standard errors roughly one third of the estimate, the standard error of the percentage change is much smaller relative to the size of the estimate.

The estimated CES substitution parameter of 7.2 is higher than typical estimates using

[36]For issuer costs, Mukharlyamov and Sarin (2022) note that Durbin was crafted to target an interchange fee "reasonable and proportional" to the costs of debit cards. Initial rules considered a 30 bps interchange fee (12 cents / average ticket size of \$40), which was ultimately raised to 60 bps. In Australia, credit and debit card interchange fees were also regulated by a cost based benchmark, which led to credit interchange of around 50 bps and debit interchange of 20 bps. Analyses from NACHA suggest acquirors take around 5% of the fees of credit card acceptance, such that their costs are likely between $5-10$ bps (NACHA, 2017). Visa's operating profits are around two-thirds of revenue, and so at most has a marginal cost of around 5 bps.

product data (DellaVigna and Gentzkow, 2019; Hottman et al., 2016), but ultimately delivers similar markups as macro studies on aggregate markups (Edmond et al., 2021). The estimated fee adjustments $\Delta\tau_{\text{MC}}$ and $\Delta\tau_{\text{Amex}}$ are less than one tenth of a basis point. Thus the model estimates that Visa, MC, and Amex charge essentially the same fees in equilibrium.

7.5 Goodness of Fit

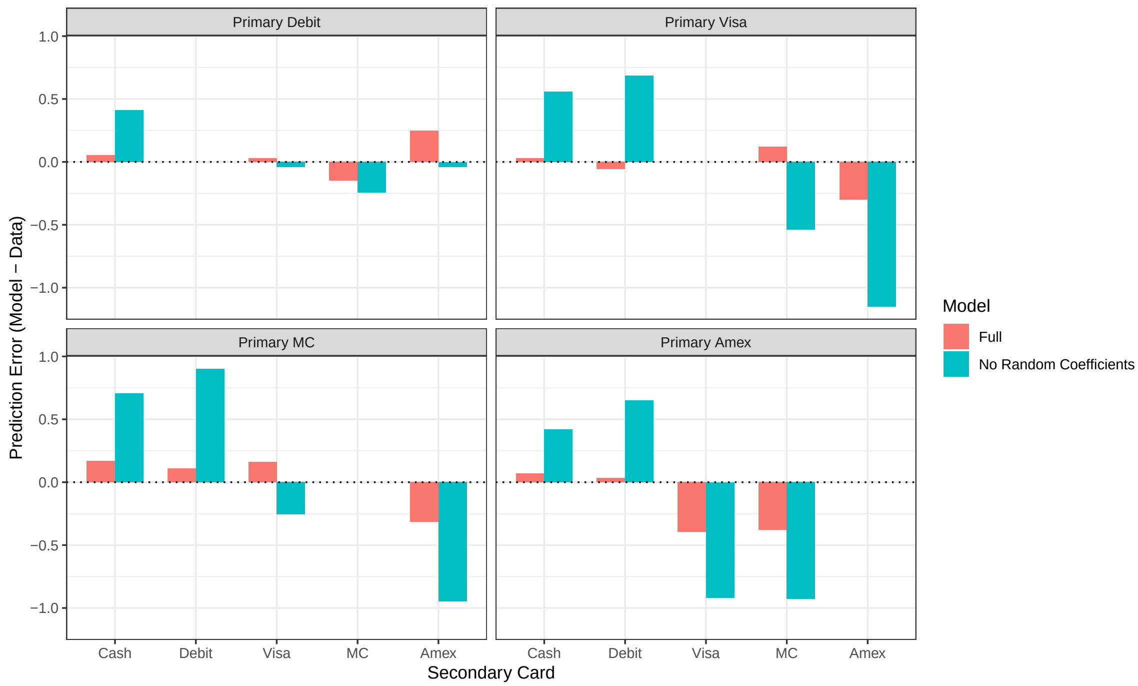
The model matches the co-holding data and the effects of Durbin on credit and overall card volumes. The model slightly underestimates Amex's equilibrium fee, but otherwise matches prices and shares well.

I show the fit of the Homescan co-holding data in figure 6. Each panel shows how well the model predicts consumers' secondary cards for the consumers described in the title of the panel. Each bar shows the log prediction error of the probability of seeing a certain combination of primary and secondary cards in the model versus in the data. The red bars show the prediction errors from my estimated model. Most red bars are close to zero, reflecting a good fit. With 7 parameters, I am able to fit the shares for all 16 combinations.

The same figure shows the random coefficients play an important role in matching the secondary card data. The blue bars show the prediction errors without random coefficients. Turning off random coefficients removes the rich substitution patterns between different payment methods. The model without random coefficients fails on three dimensions for primary credit card consumers: it overpredicts the share with a secondary debit card, it overpredicts the share whose secondary payment is cash (i.e. someone who only carries one card), and underpredicts the share who carry a secondary credit card. This is evident in the blue bars in the Visa panel. The debit and cash bars are above zero, whereas Amex and MC are below zero.

Table 9 shows how the model performs on an out of sample test: matching the facts on Durbin. The model exactly matches the percentage change in debit volumes since it was a target moment in the estimation. However, the percentage changes in credit and overall card volumes serve as out of sample tests. This is an out of sample test because the random coefficients that govern substitution patterns were estimated on co-holding data from Homescan, whereas the substitution patterns revealed by the changes in credit and total card volume use exogenous price variation. The model moments are within a standard error of the truth for both tests. This also provides evidence that co-holding data provides realistic estimates of substitution patterns in payments.

Figure 6: Comparison of estimated model's fit of the co-holding data and the fit of a model without random coefficients



Notes: Each bar is the difference between the log predicted probability of a given (Primary, Secondary) card combination less the log probability of the same combination in the Homescan data. A positive value means the model overpredicts the probability. The primary card is in the facet title while the secondary card is on the x-axis.

Table 9: Fit of Durbin facts

Effect On	Data	Model	Standard Error
Debit	-0.27	-0.27	0.06
Credit	0.35	0.30	0.09
All Card	-0.05	-0.04	0.05

Notes: The table compares the estimated effect of the Durbin Amendment on debit, credit, and overall card volumes against the simulated effects.

Table 10: Baseline Equilibrium Prices and Quantities

Variable (%)	Cash	Visa Debit	Visa Credit	MC Debit	MC Credit	Amex
Merchant Fee	0.3	0.72	2.25	0.72	2.25	2.25
Rewards	0.0	0.00	1.30	0.00	1.30	1.36
Market Share	20.0	23.88	26.27	9.55	10.75	9.55

Table 10 shows the baseline prices and quantities in my estimated model. The shares are slightly different than in table B.2 because I have scaled Visa, Mastercard, and Amex up to the entire card sector. The merchant prices are similar, although I slightly under predict American Express' merchant fee. To implement Durbin, I cap debit card merchant fees at the observed equilibrium fees.

8 Counterfactuals

In my main counterfactual I study the effects of network entry on consumers, merchants, and the networks. I show that more competition increases merchants' cost of payments as payment methods with high merchant fees and high rewards take a larger share of the market. Consumers sacrifice convenience to chase rewards and are worse off in aggregate.

I find that relaxing the Durbin Amendment's restrictions on debit card interchange fees, regulated credit interchange, and merging Mastercard and American Express would all be good for consumers. I use these counterfactuals to propose a principle for payment market regulation centered around reducing differences in rewards rates across payment options.

8.1 Credit Fintech Payment Entry

I first model the entry of a new fintech payment app that competes for credit card consumers.

8.1.1 Characteristics of the Entrant

Introducing a new product requires specifying the characteristics X^j, Ξ^j that enter consumer utility, the type χ^j of the payment method, and network costs. I give the app consumer characteristics X^j that are the same as a credit card and the same utility intercept Ξ^j as Amex. Consumers who like cards and who like credit cards in particular will prefer the new product. I assume the new app is a new payment type $\chi^j = A$, so that at the point of sale the new app does not substitute with credit and debit cards. Given these characteristics and costs, I can solve for the new equilibrium after the fintech platform enters.

The assumption that the merchant does not treat card acceptance and app acceptance as substitutes is consistent with studies of e-commerce that consumers who prefer alternative payment methods are unwilling to substitute to cards when their preferred method is not available (Berg et al., 2022). The assumption can also be justified by the way new platforms are combining commerce and other financial services with payments, so that not accepting the app would reduce demand from consumers who use the app even if those consumers own credit and debit cards.[37]

8.1.2 Effects on Prices and Shares

The new entrant pursues a high merchant fee, high rewards strategy. It charges merchant fees of 2.64% and pays rewards of 1.64%. These are 39 bps and 28 bps higher than American Express' fees and rewards. In response, incumbent credit card networks raise their fees by 8 bps and drive credit card adoption by paying out 13 bps more subsidies. Incumbent debit cards raise rewards by only around 6 bps. Incumbent debit cards are unable to raise their merchant fees due to the Durbin Amendment. After equilibrium price responses, incumbent credit networks lose 3 percentage points (pp) of market share, incumbent debit networks lose 3 pp of market share, and the market share of cash falls by 4 pp.

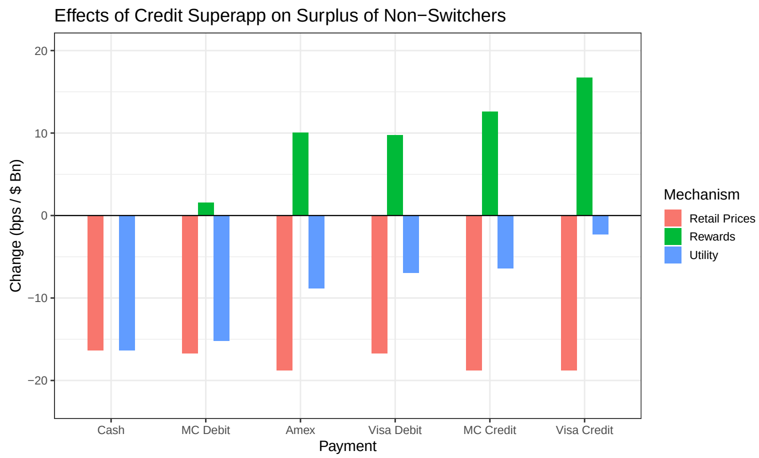
8.1.3 Distributional Effects

Entry exacerbates regressive transfers from cash and debit consumers to credit consumers and hurts all consumers who do not switch to the new platform. Merchants' cost of payments increases both because fees have risen and because more consumers are using the high cost payment options. On average, merchant prices rise by 16 bps. For consumers who do not switch, the change in welfare is simply the change in subsidies less the change in the price index. Panel A of Figure 7 illustrates the welfare effects for these consumers. The welfare of cash users who do not switch falls the most. Their

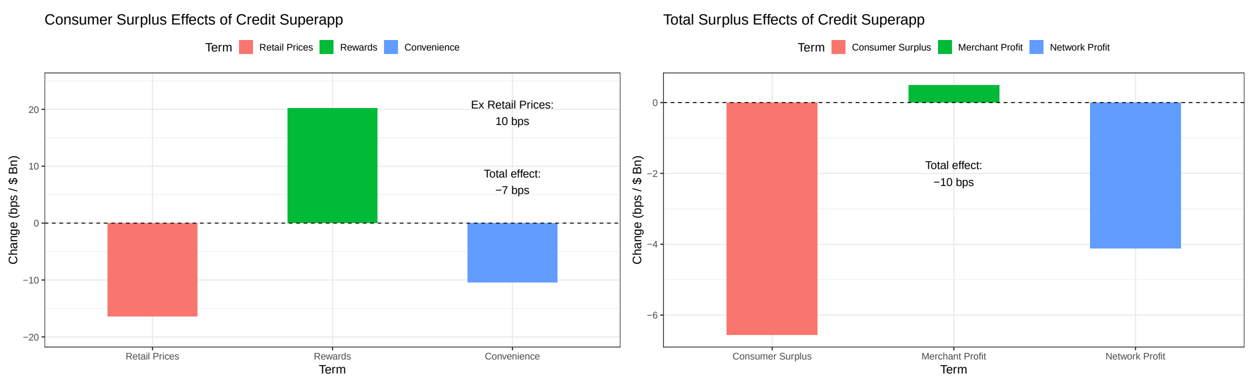
[37]For example, in their 2021 financial results buy now pay later platform Klarna argues "the Klarna app is now the single largest driver of GMV across the Klarna ecosystem, fuelling growth for Klarna and its retail partners through consumer acquisition and referrals...our app is becoming a central place in our consumers' financial lives."

Figure 7: Welfare effects of entry of a credit fintech payment platform

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Surplus and Total Surplus Effects



consumption falls by 16 bps due to higher retail prices. Debit card users lose 11 bps of consumption, and incumbent credit card users lose 6 bps.

8.1.4 Consumer Surplus Effects

To study the effects of entry on all consumers and the sources of welfare changes, I decompose consumer surplus into three terms – retail prices, the average subsidy paid, and the non-pecuniary utility which I call convenience.[38] Let E_i^k be an indicator that

[38]Debit users report liking debit because of the convenience and the fact that debit cards help consumers control their budget. See the survey evidence in section 4 on the sources of this non-pecuniary utility.

consumer i chooses payment method k. I decompose consumer surplus[39] as:

$$
\begin{aligned}
W &= \mathbb{E}_i\left[\max_k \log V_i^k\right] \\
&\approx -\log P^0 + \mathbb{E}_i\left[\max_k f^k - \log\frac{P^k}{P^0} + \Xi^k + \frac{1}{\alpha}\left(\eta_{ij} + \beta_i X^k\right)\right] \\
&= \underbrace{-\log P^0}_{\text{Retail Prices}} + \underbrace{\sum_k \mu^k f^k}_{\text{Rewards}} + \underbrace{\mathbb{E}_i\left[\sum_k E_i^k\left(-\log\frac{P^k}{P^0} + \Xi^k + \frac{1}{\alpha}\left(\eta_{ij} + \beta_i X^k\right)\right)\right]}_{\text{Convenience}}
\end{aligned}
\tag{29}
$$

where μ^k is the (insulated) market share of instrument k among all primary payment methods.

The first term captures the loss to all consumers from higher retail prices. In contrast to a standard model that normalizes the value of the outside option to zero, I set the value of the outside option to the welfare of a cash consumer. The second term captures the average level of subsidies paid to consumers, weighted by the market share of each payment instrument. The third term is then the residual, and captures the extent to which consumers choose payment methods that offer high convenience. Any gains from variety are in this term. In practice, since α is large this term mostly reflects whether consumers choose payment methods with high unobserved characteristics Ξ^k.

Aggregate consumer surplus falls by 7 bps. Scaled up to the \$10 trillion in consumer to business payments, this represents \$7 billion (bn) in lost consumption. The decline in consumer surplus is surprising because entry typically raises consumer surplus by reducing markups and increasing variety (Petrin, 2002). However, because consumer adoption of credit cards and the entrants' app raises retail prices, consumers are worse off in equilibrium. Panel B in Figure 7 shows how the three terms contribute to consumer surplus. Higher retail prices reduce surplus by 16 bps, higher subsidies increase surplus by 20 bps, but the shift to payment instuments with lower convenience hurts consumers by 10 bps. The ultimate loss is \$7 bn of consumption.

The retail price externality creates a wedge between private and social incentives to switch. Consumers who switch are privately better off because the higher rewards offsets the decline in convenience. However, higher rewards create no social gains. The associated higher merchant fees inflate retail prices for other consumers. The above

[39] Aggregating consumer surplus requires a strong assumption that the planner puts equal welfare weights on credit and debit users, which is unlikely given that credit card consumers are much higher income. Given that we already saw entry exacerbates the regressive transfers, my calculation should be considered a lower bound on the harms to consumers.

analysis highlights how the market failure in payments is not market power, but rather externalities. After entry, margins fall. Nonetheless, consumer surplus declines.

The retail price externality changes the sign of welfare calculations. If one ignored the equilibrium effect of retail prices, a standard discrete choice analysis based on observed market shares would lead to a $10 bn increase in consumer surplus from entry. But after including the retail price externalities we arrive at a loss of $7 bn in consumer surplus.

8.1.5 Total Surplus Effects

Total surplus declines because network profits fall as well. To measure total surplus, I assume all of the profits from either merchants or the networks are rebated to consumers equally. Even though different consumers face different CES price indices, the change in log CES utility can still be calculated by just adding the dollar value of the profits. Panel B in figure 7 decomposes the total welfare effects. Merchant profits rise by a negligible amount because consumers have higher incomes from higher network subsidies that offset higher transaction fees. Total network profits, including the entrant, fall by $4 bn or 12% of industry profits. Profits fall because networks are now competing harder to attract consumers and merchants. The net result is that total surplus falls by $10 bn.

These total surplus effects are close to the approximation based on revealed preference from section 4. In the counterfactual, the market share of cash and debit fall by 7 pp. Each switcher sacrifices around 1.3% of consumption in convenience. Scaled up to the total volume of payments, the revealed preference argument yields an estimated total surplus loss of $9 bn.

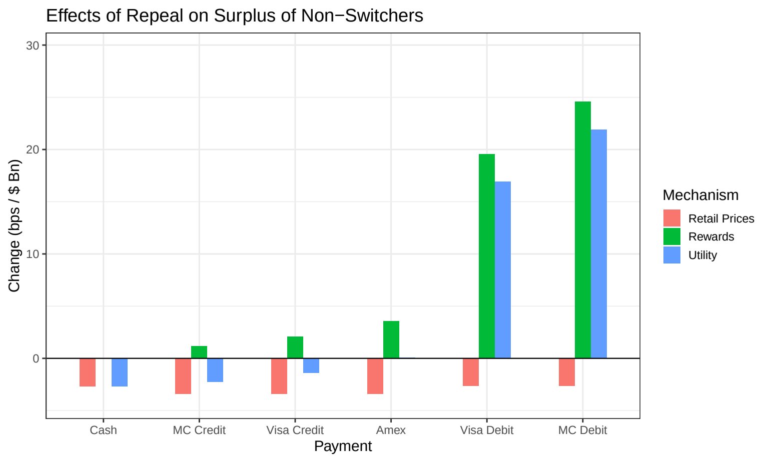
8.2 Relaxing Durbin

Relaxing the Durbin Amendment would create a progressive transfer from credit to debit consumers and increase consumer surplus. I relax the Durbin Amendment in the model by raising the cap on debit card fees to 1% from their current level around 0.72%. As a result, merchant fees for debit cards rise by 28 bps and debit subsidies rise by 22 bps. Consumers switch to debit cards. The market share of debit cards rises by 10 percentage points (pp) and the market share of credit cards falls by 8 pp.

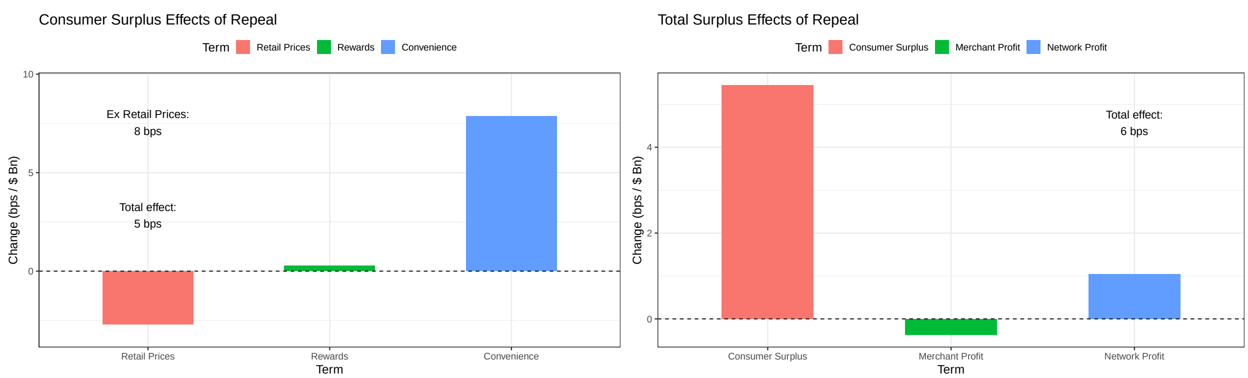
I illustrate the welfare effects in figure 8. Relaxing Durbin increases consumption of debit card users by 19 bps but reduces consumption of credit card and cash users by 1 and 3 bps, respectively. Since cash is a relatively small share of the population, on balance this is a progressive transfer from credit to debit users. Consumers as a whole gain $5 bn of consumption. Although higher retail prices cost consumers $3 bn

Figure 8: Welfare effects of relaxing the Durbin Amendment cap on debit card fees

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Surplus and Total Surplus Effects



of consumption, slightly higher subsidies and $8 bn of higher convenience more than compensate. Total surplus thus rises by $6 bn as networks enjoy higher profits from stealing market share from cash.

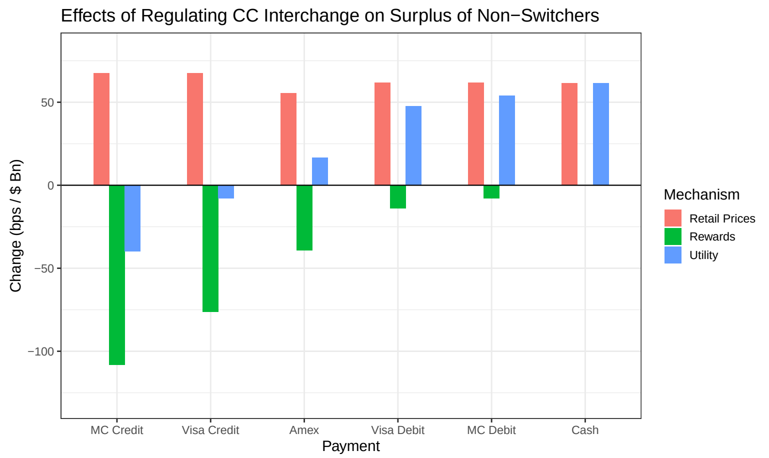
8.3 Regulating Credit Card Interchange

Regulating credit card interchange would create a progressive transfer from credit consumers to cash and debit consumers, and increases consumer surplus. I cap merchant fees for Visa and MC credit cards at 1%. I do not regulate Amex to be consistent with interchange regulations in practice. As a result, credit card rewards fall by 75 bps. Consumers switch to debit cards. The market share of debit cards rises by 18 pp and the market share of credit cards falls by 29 pp.

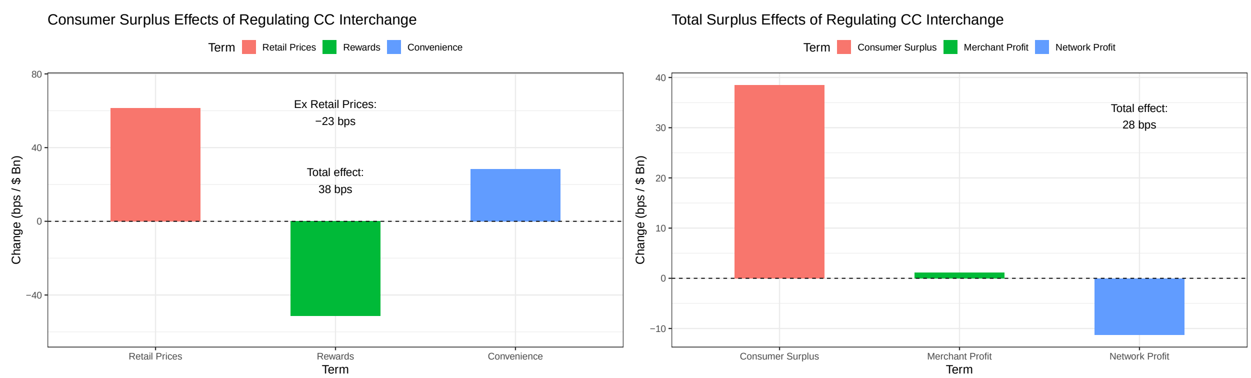
I illustrate the welfare effects in figure 9. Regulating credit interchange increases

Figure 9: Welfare effects of regulating Visa + MC merchant fees to 1%

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Surplus and Total Surplus Effects



consumption of cash and debit card users by 62 and 51 bps, respectively. Consumption of credit card users falls by 10. Consumers as a whole gain $38 bn of consumption. Although the fall in rewards costs $51 billion in consumption, lower retail prices generate $62 bn of gains and higher convenience is valued at $28 bn. Total surplus rises by $28 bn as network profits fall as the networks are no longer able to tax cash users to fund rewards.

8.4 Merger Counterfactual

Merging Amex and Mastercard without any efficiencies would generate a small increase in consumer and total surplus. This result illustrates how the effects of competition in two sided markets differ starkly from one sided markets. Whereas mergers without efficiencies in one sided markets always create deadweight loss, merging two payment platforms can increase consumer and total surplus. Credit card networks create a retail price externality when they raise subsidy rates to induce consumers to use more credit cards. Adoption is excessive. A merger can reduce output, reduce the externality, and thereby raise welfare.

When Amex and MC merge, merchant fees for credit cards rise by 3 bps but more importantly credit card rewards fall by 11 bps. Consumers switch to cash and debit cards. The market share of cash rises by 2 pp and the market share of debit cards rises by 2 pp.

I illustrate the welfare effects in figure 10. The merger creates progressive transfers. Cash and debit consumers gain 7 and 4 bps of consumption, whereas credit users lose 5 bps. All consumers benefit from lower retail prices, but only the credit card users are hurt by a large decline in rewards. Consumers as a whole gain $1 bn of consumption. Although lower subsidies cost consumers $11 bn of consumption, higher convenience and lower retail prices more than compensate. Total surplus rises by $6 bn as networks enjoy higher profits from the reduction in competition.

8.5 Discussion of Assumptions

8.5.1 Merchant Substitution Between the Entrant and Credit Cards

In my baseline entry counterfactual I assume that consumers do not treat credit card acceptance as an adequate substitute for the app. When I relax this assumption, I obtain qualitatively similar welfare results. The main difference is that credit card merchant fees fall slightly. However, credit card subsidies still increase by 4 bps and debit card subsidies rise by a smaller 2 bps. The entrant still causes more consumers to adopt high cost payment methods, which generates similar welfare results.

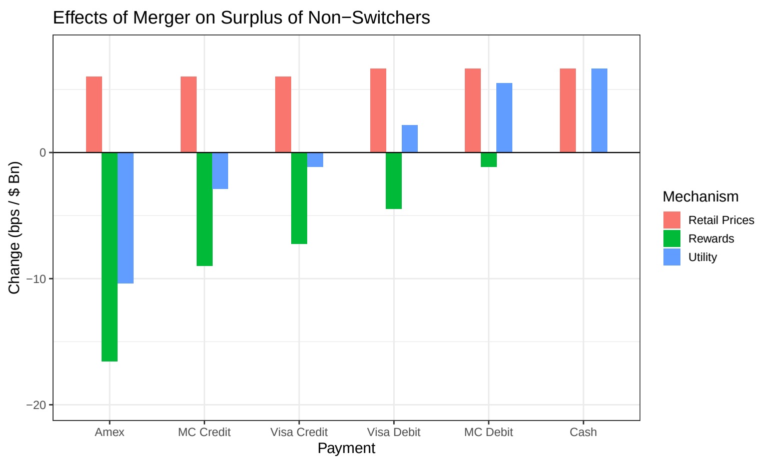
I illustrate the welfare effects in figure 11. Entry still exacerbates regressive transfers. The higher cost of payments causes the retail price level to rise by 6 bps. Cash users therefore lose 6 bps of consumption, debit users lose 4 bps, and credit users on average lose 2 bps.

Consumer and total surplus still fall. Consumers as a whole lose $2 bn of consumption. Although the net effect of higher subsidies and higher prices still puts consumers $2 bn ahead, the $4 bn decline in convenience means that consumer surplus is still lower after entry. Total surplus falls by $4 bn as networks compete down profits.

The case with substitution shows that prices are not a sufficient guide to understanding welfare effects in two sided markets. Merchant fees fall, consumers subsidies rise, and so both sides of the market face more favorable prices. Nonetheless, consumer surplus falls as consumers use payment methods with lower convenience in the coun-

Figure 10: Welfare effects of merging Amex and Mastercard

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Surplus and Total Surplus Effects

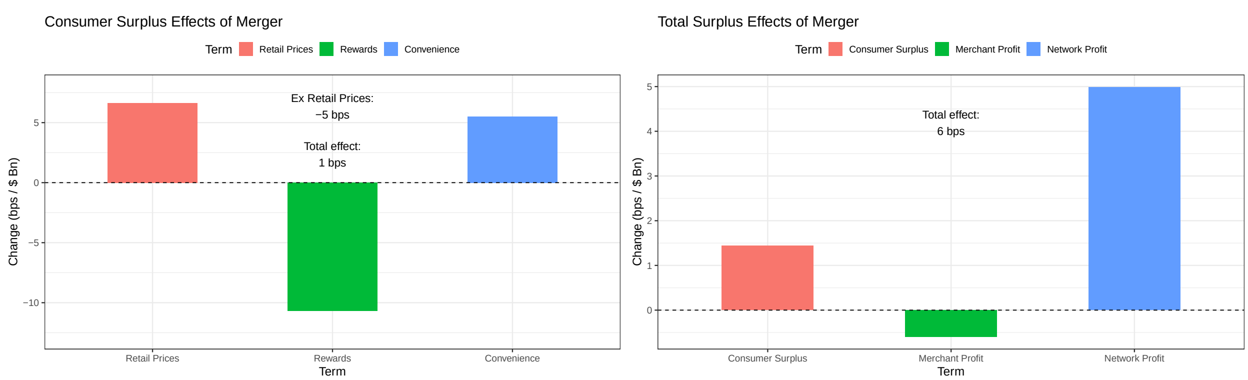
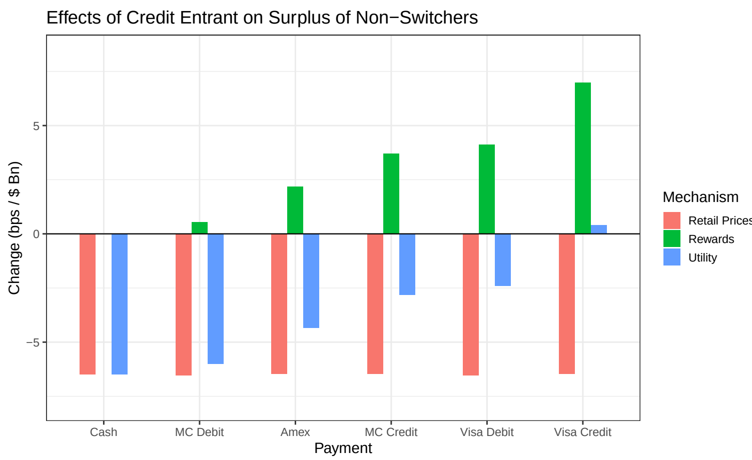
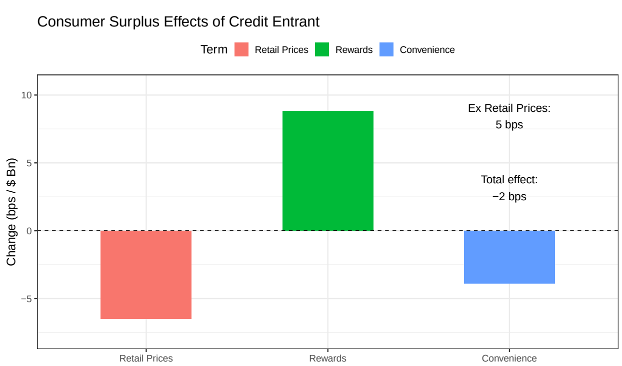


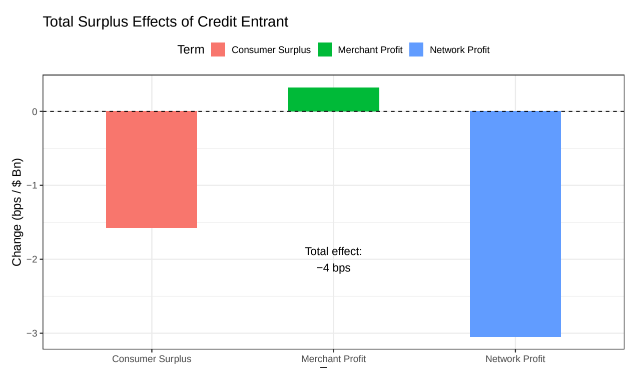
Figure 11: Welfare effects of a new platform that serves as a substitute to credit cards at the point of sale

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Surplus and Total Surplus Effects





terfactual.

8.5.2 Choice Sets

My model assumes each consumer has access to cash, debit cards, and credit cards that all earn the same rewards. My welfare results are robust to the possibility that not all consumers can get credit cards, but are sensitive to whether all consumers have access to credit cards with the same rewards.

Incorporating constraints has little effect on the welfare results because the predicted number of consumers who switch from cash and debit to credit in response to entry is not sensitive to the modeling of constraints. Holding fixed the model parameters, constraints reduce the number of consumers that switch to credit. But holding fixed the reduced form fact on the number of consumers who switch to cash and credit in response to a negative shock to debit rewards, models with constraints and models without constraints predict similar changes in market shares. If some debit consumers are constrained and cannot get credit cards, then to rationalize the reduced form fact on the Durbin Amendment I would have estimated an even larger consumer price sensitivity to rewards. Either model would predict the same number of debit consumers who switch to credit in response to rewards. Because the revealed preference argument from section 8.1.5 still applies for each person who switches, incorporating constraints would not change the total welfare loss from debit consumers switching to credit in the counterfactual. A similar argument applies to cash use since in my out of sample tests my model provides accurate predictions for the response of overall card volume (credit + debit) in response to the Durbin Amendment.

A more serious problem is if debit and cash users cannot earn the same 1.3% of rewards. This would change the revealed preference argument in section 8.1.5 by reducing the inferred value of convenience of debit cards and cash. I do not address this and leave it for future work.

8.6 Principles for Regulation

A key principle that emerges is that regulatory policy should seek to reduce differences in rewards across payment methods. Entry exacerbates the gap in credit and debit rewards, causes consumers to sacrifice convenience to chase high credit card rewards, and lowers consumer surplus. Either relaxing the Durbin Amendment or capping credit card merchant fees reduces the gap and thus raises consumer surplus. Mergers without efficiencies in one sided markets always reduce consumer surplus. Yet because a MC and Amex merger would lower credit card rewards in equilibrium, it raises consumer surplus from payments.

9 Conclusion

In this paper, I study how a new fintech payment network would affect prices and welfare in the United States payment market. I find that a fintech payment network that competes for credit card consumers increases the total fees merchants pay to handle payments and lowers consumer and total surplus. Entry reduces consumer surplus as consumers who do not value the non-pecuniary features of credit cards switch in order to take advantage of rewards. Such switching behavior inflates the aggregate price level and generates social losses.

I find that the market failure in payments is not market power, but rather excess adoption and retail price externalities. Unlike in standard antitrust settings in which market power creates harms through high prices and low output, the externalities in payment markets cause harm through high prices and *high* output. My counterfactual results on changing price regulations and on merging Amex and Visa point to a new principle that regulatory and competitive changes that equalize rewards rates across payment options should be encouraged.

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A Proofs

Proof of Theorem 1. I first prove the theorem for $\gamma = 0$, and when $\tau = 0$. I then usethe envelope theorem to extrapolate to positive values of τ. From the definition in equation 7, profits in general are

$$\begin{aligned}\hat{\Pi}(\tau) &= \left(\sum_{w \in \mathcal{W}} \tilde{\mu}^w q^w(\gamma, \hat{p}, M, P, y^w)\right) \times (\hat{p}(1 - \tau_M^w) - 1) \\ &= \frac{1}{C} \sum_{w \in \mathcal{W}} \mu^w (1 + \gamma v_M^w) \hat{p}^{-\sigma} (\hat{p}(1 - \tau_M^w) - 1)\end{aligned}$$

Suppress the $\mathcal{W}$ and leave out the $\frac{1}{C}$ normalizing factor. When $\gamma = 0$, profit simplifies to

$$\begin{aligned}\hat{\Pi} &= \sum_w \mu^w \hat{p}^{-\sigma} (\hat{p}(1 - \tau_M^w) - 1) \\ \hat{p} &= \frac{\sigma}{\sigma - 1} \frac{1}{1 - \hat{\tau}}\end{aligned}$$

At a fee of zero, $\hat{\tau} = 0$. Hence profits are

$$\begin{aligned}\hat{\Pi}(0) &= \frac{1}{\sigma - 1} \times \hat{p}^{-\sigma} \left(\sum_w \mu^w\right) \\ &= \left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} \frac{1}{\sigma} \left(\sum_w \mu^w\right)\end{aligned}$$

We next establish the result for small τ. By the envelope theorem, the derivative of the optimized profit for a $\gamma = 0$ firm with respect to the transaction fees τ at zero is

$$\begin{aligned}\left.\frac{\partial \hat{\Pi}}{\partial \tau_j}\right|_{\tau_j = 0} &= \sum_w \mu^w \hat{p}^{-\sigma} \left(-\hat{p} I_{j,M}^w\right) \\ &= -\left(\frac{\sigma}{\sigma - 1}\right)^{1-\sigma} \sum_w \mu^w I_{j,M}^w\end{aligned}$$

where the indicator $I_{j,M}^w$ is an indicator capturing whether payment method j is used by the wallet w when the merchant accepts M. Crucially, we have that the indicators multiplied by the fees gives the card fee that the consumer will cause the merchant to pay $\sum_{j=1}^{J} I_{j,M}^w \tau_j = \tau_M^w$. We can then compute profits at a generic level of fees with a Taylor approximation. Up to second order terms in τ, this should equal

$$
\begin{aligned}
\hat{\Pi}(\tau) &= \hat{\Pi}(0) + \sum_{j=1}^{J} \frac{\partial \hat{\Pi}}{\partial \tau_j} \tau_j + O\left((\tau^{\max})^2\right) \\
&\approx \sum_{w} \mu^{w} \left[\left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \frac{1}{\sigma} - \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \tau_M^{w} \right] \\
&= \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \left[-\sum_{w} \mu^{w} \tau_M^{w} + \frac{1}{\sigma} \right]
\end{aligned}
$$

This establishes the theorem for $\gamma = 0$ and small τ.

Next we prove the result for generic γ. Recall that $\hat{\tau}$ is the realized average card fee that the merchant incurs, and enters into optimal pricing. Drop terms that are of order $O\left(\tau^2\right)$. By the envelope theorem we can ignore the effect of changing γ on the optimal price. Hence the derivative of optimized profit with respect to γ is

$$
\begin{aligned}
\frac{\partial \hat{\Pi}}{\partial \gamma} &= \sum_{w} \mu^{w} v_M^{w} \hat{p}^{-\sigma} \left(\hat{p} \left(1 - \tau^{w}\right) - 1 \right) \\
&\approx \sum_{w} \mu^{w} v_M^{w} \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \left(1 - \sigma \hat{\tau}\right) \left(\frac{\sigma}{\sigma-1} \left(1 + \hat{\tau}\right) \left(1 - \tau^{w}\right) - 1 \right) \\
&\approx \left(\frac{\sigma}{\sigma-1} \right)^{-\sigma} \frac{1}{\sigma-1} \times \sum_{w} \mu^{w} v_M^{w} \left(1 - \sigma \hat{\tau}\right) \left(1 + \sigma \hat{\tau} - \sigma \tau^{k}\right) \\
&\approx \left(\frac{\sigma}{\sigma-1} \right)^{1-\sigma} \frac{1}{\sigma} \sum_{w} \mu^{w} v_M^{w} \left(1 - \sigma \tau^{k}\right)
\end{aligned}
$$

Integrating the derivative from 0 to γ gives the desired result. □

B Additional Tables

Table B.1: Aggregate shares and cost of card acceptance derived from the Nilson Report

Payment Method	Volume in 2019 (Tr)	Share of Total
Total	9.6	
Cash + Check	1.9	20%
Cards	7.7	80%
Credit	4.0	42%
Visa	2.1	22%
MC	0.9	9%
Amex	0.8	8%
Discover	0.1	1%
Debit	3.3	34%
Visa	1.9	20%
MC	0.8	8%
Other	0.6	6%
o/w Other Cards	0.4	4%

Notes: The data in this table combines both aggregate payment data from Nilson (2020c) and data on individual networks from Nilson (2020d,b). "Other Cards" captures private label credit cards, SNAP EBT cards, and prepaid cards

Table B.2: Aggregate prices for merchants and consumers and estimates of acceptance locations.

Card	Average Merchant Discount	Rewards	Number of Acceptance Locations (Mln)
Visa + MC Credit	2.25%	1.30%	10.7
Amex	2.27%	1.36%	10.6
Visa + MC Debit	0.72%	0%	

Notes: I calculate rewards for Visa + MC Credit from Agarwal et al. (2018), who report that typical consumer banks pay out around 1.4% of purchase volume for rewards and fraud expense. In the US, banks typically pay around 10 bps of fraud expense (Nilson, 2020a). Therefore rewards are around 1.3%. From American Express's 2019 10k, I calculate that American Express earned around $26 billion in gross discount revenue but paid out around $15.7 billion in net rewards. This yields a rewards rate of 1.36%. Debit cards no longer offer rewards checking in the wake of Durbin (Hayashi, 2012). Hence a rewards rate of 0%. Merchant discount fees are calculated from a survey of acquirers. Acceptance locations are also estimates obtained from the Nilson Report (Nilson, 2020d).

Table B.3: Average of transaction characteristics in the payment diary sample

	Ticket Size	Use Cash	Use Debit	Use Credit	Merchant Accepts Card
Mean	21.86	0.38	0.34	0.28	0.95

Table B.4: Summary statistics of the Homescan sample

	N	Mean	P25	Median	P75
Years per Household	92107	3.06	1.00	2.00	5.00
Transactions	92107	500.49	134.00	306.00	669.00
Average Tx Size	92107	56.62	35.41	49.56	69.43

Table B.5: Comparing Homescan payment shares to aggregate shares

Payment Method	Homescan	Nilson
Amex	0.04	0.10
Cash	0.24	0.20
Debit	0.37	0.33
MC	0.11	0.11
Visa	0.24	0.26

Notes: Homescan payment shares are calculated by summing all the dollars spent on each payment method and dividing by the total spending.

Table B.6: Event study estimates for the effect of the Durbin Amendment on signature credit, debit card, and total volume

	Interchange	Signature Debit	Credit	All Cards
Treat, t=-4	-0.034	-0.007	-0.100	-0.111+
	(0.086)	(0.051)	(0.104)	(0.060)
Treat, t=-3	0.103	0.050	0.002	-0.006
	(0.084)	(0.032)	(0.098)	(0.050)
Treat, t=-2	-0.104	0.016	-0.084*	-0.016
	(0.073)	(0.016)	(0.038)	(0.027)
Treat, t=0	0.005	-0.119	0.168**	-0.006
	(0.055)	(0.079)	(0.057)	(0.056)
Treat, t=1	-0.449***	-0.103*	0.176*	0.020
	(0.101)	(0.044)	(0.075)	(0.048)
Treat, t=2	-0.363**	-0.198**	0.285**	0.002
	(0.116)	(0.056)	(0.085)	(0.057)
Treat, t=3	-0.358**	-0.274***	0.352***	-0.048
	(0.105)	(0.059)	(0.095)	(0.057)
N	292	292	296	281
Bank FE	X	X	X	X
Year FE	X	X	X	X
Cluster N	39	39	39	39

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

Table B.7: Subgroup analysis for the effect of card preference on the likelihood the consumer shops at a store that accepts card

	Credit vs Debit	Singlehome	Singlehome CC	Income Group
Prefer Credit	0.25*			
	(0.11)			
Prefer Debit	0.33***			
	(0.09)			
Singlehome X Prefer Card		0.11	0.06	
		(0.13)	(0.09)	
Prefer Card		0.27**	0.28**	0.45***
		(0.09)	(0.09)	(0.13)
High Income X Prefer Card				-0.26
				(0.17)
N	29661	29101	29253	29661
Year FE	X	X	X	X
Merch Type FE	X	X	X	X
Ticket Size FE	X	X	X	X
FICO Category FE	X	X	X	X
Age Group FE	X	X	X	X
Income Category FE	X	X	X	X
Education FE	X	X	X	X
State FE	X	X	X	X

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

Table B.8: Correlation between being the card with the top number of trips and the card with the top share of spending.

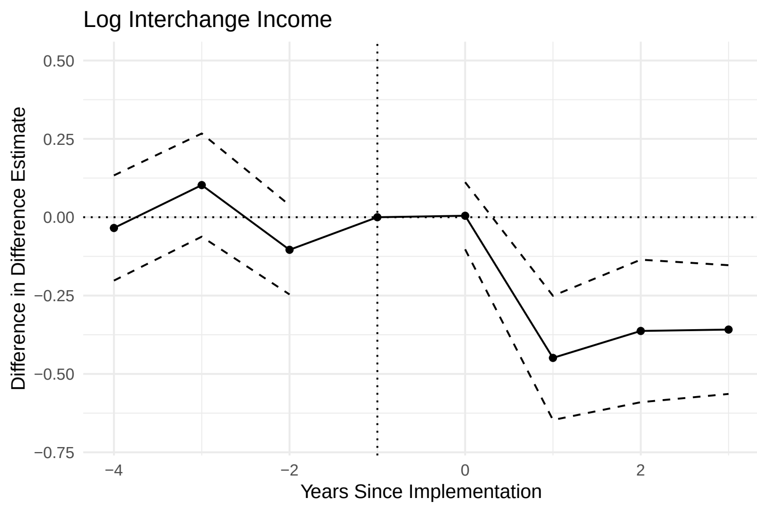
		Top Card by Spend			
Top Card by Trips		Amex	Debit	MC	Visa
Amex	N	11568	111	142	527
	% row	93.7	0.9	1.1	4.3
Debit	N	639	132097	1422	2670
	% row	0.5	96.5	1.0	2.0
MC	N	444	426	26806	1057
	% row	1.5	1.5	93.3	3.7
Visa	N	871	910	1079	61791
	% row	1.3	1.4	1.7	95.6

Table B.9: The average share of total card spending on consumers' top two cards split by the primary card of each consumer

Primary Card	Primary Share	Secondary Share	Top Two Total
Amex	0.76	0.18	0.94
Visa	0.81	0.15	0.97
MC	0.77	0.18	0.95
Debit	0.86	0.11	0.97

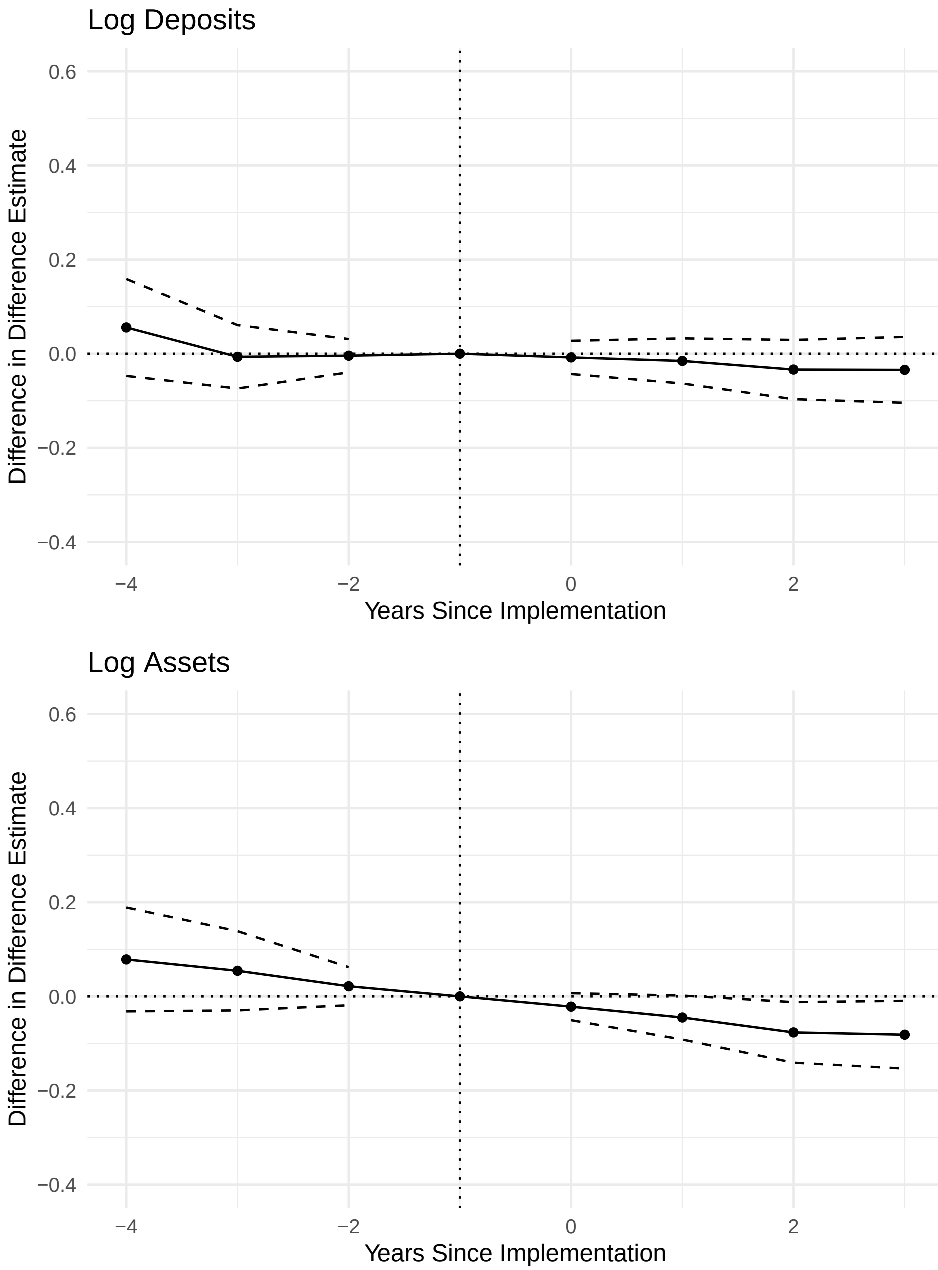
C Additional Figures

Figure C.1: The effect of the Durbin Amendment on interchange revenue.



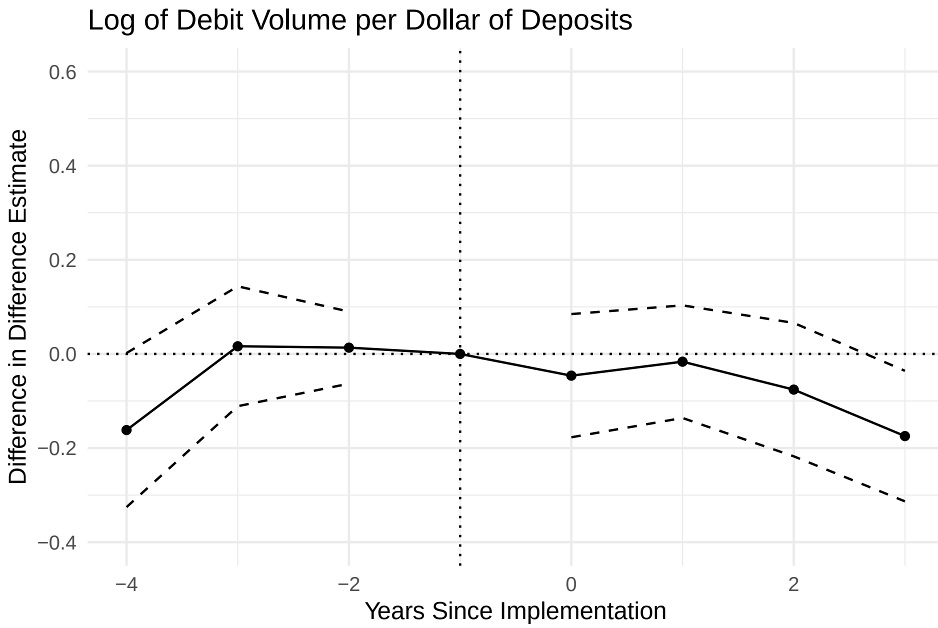
Notes: The vertical line marks the year before the policy announcement. The policy went into full effect in year 2012, which is at $t = 1$.

Figure C.2: The effect of the Durbin Amendment on deposits and assets



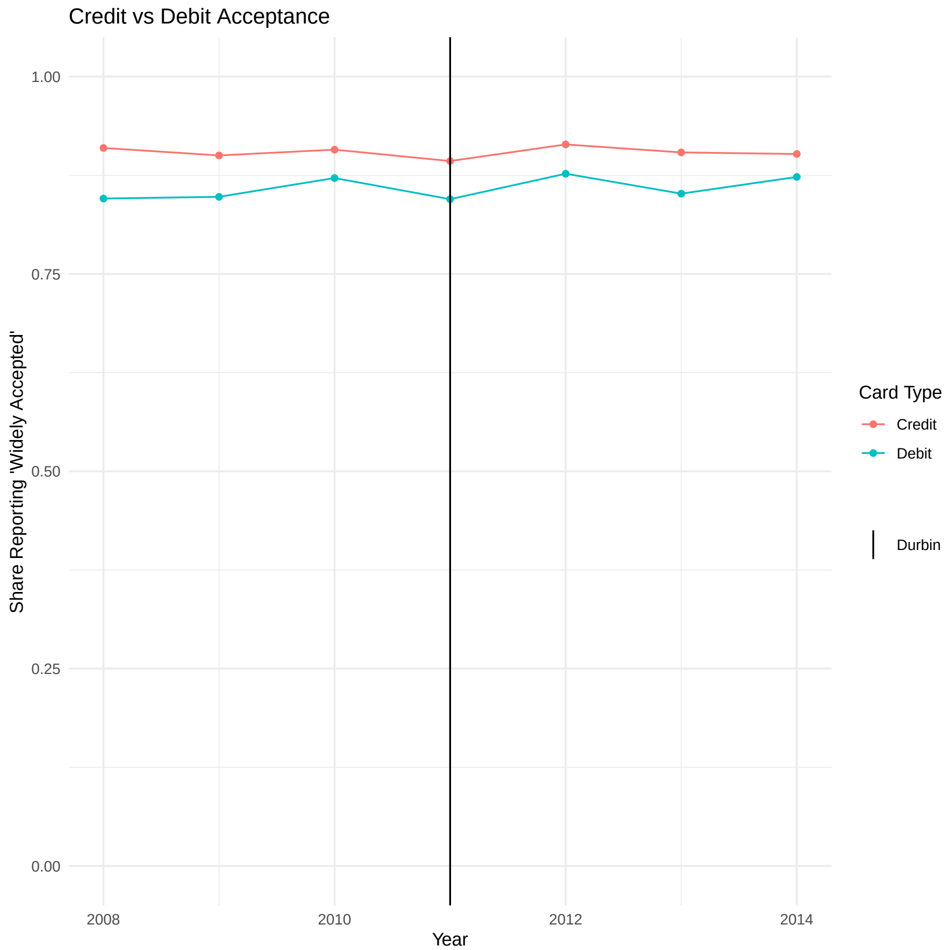
Notes: The vertical line marks the year before the policy announcement. The policy went into full effect in year 2012, which is at $t = 1$.

Figure C.3: The effect of the Durbin Amendment on overall debit volumes



Notes: The vertical line marks the year before the policy announcement. The policy went into full effect in year 2012, which is at $t = 1$.

Figure C.4: Consumer ratings of acceptance of credit and debit cards around Durbin



D A Method for Calculating Derivatives of Expectations of Nondifferentiable Functions

Suppose $f:\mathbb{R}^N \to \mathbb{R}$ is continuous but non-differentiable. Then by a standard convolution theorem

$$\begin{aligned} h : \mathbb{R}^N &\to \mathbb{R} \\ \mu &\mapsto \mathbb{E}\left[f\left(X\right)\right], X \sim N\left(\mu,\sigma^2 I\right) \end{aligned}$$

is differentiable. This note explains how to efficiently compute an approximation to the partial derivatives of h. This is non-trivial because the standard monte carlo technique to approximate h as $\hat{h} = N^{-1}\sum_{i=1}^{N} f\left(X_i\right)$ where $X_i \sim N\left(\mu,\sigma^2 I\right)$ does not generate a differentiable function in μ.

The key trick is to use the fact that convolution and differentiation commute. Let $g\left(x\right) = \mathbb{E}\left[f\left(X_1,\ldots,X_N\right)|X_1 = x\right]$. Then by the law of iterated expectations,

$$\mathbb{E}\left[f\left(X\right)\right] = \mathbb{E}\left[g\left(X_1\right)\right]$$

By the law of iterated expectations, we have that

$$\begin{aligned} \mathbb{E}\left[f\left(X\right)\right] &= \mathbb{E}\left[g\left(X_1\right)\right] \\ &= \frac{1}{\sqrt{2\pi\sigma^2}} \int_{\mathbb{R}} g\left(z\right) \exp\left(-\frac{1}{2\sigma^2}\left(z-\mu_1\right)^2\right) \mathrm{d}z \end{aligned} \tag{30}$$

where μ_1 is the first term in μ. Interchanging differentiation and integration yields

$$\frac{\partial}{\partial \mu_1}\mathbb{E}\left[f\left(X\right)\right] = \frac{1}{\sqrt{2\pi\sigma^2}} \int_{\mathbb{R}} g\left(z\right) \frac{z-\mu_1}{\sigma^2} \exp\left(-\frac{1}{2\sigma^2}\left(z-\mu_1\right)^2\right) \tag{31}$$

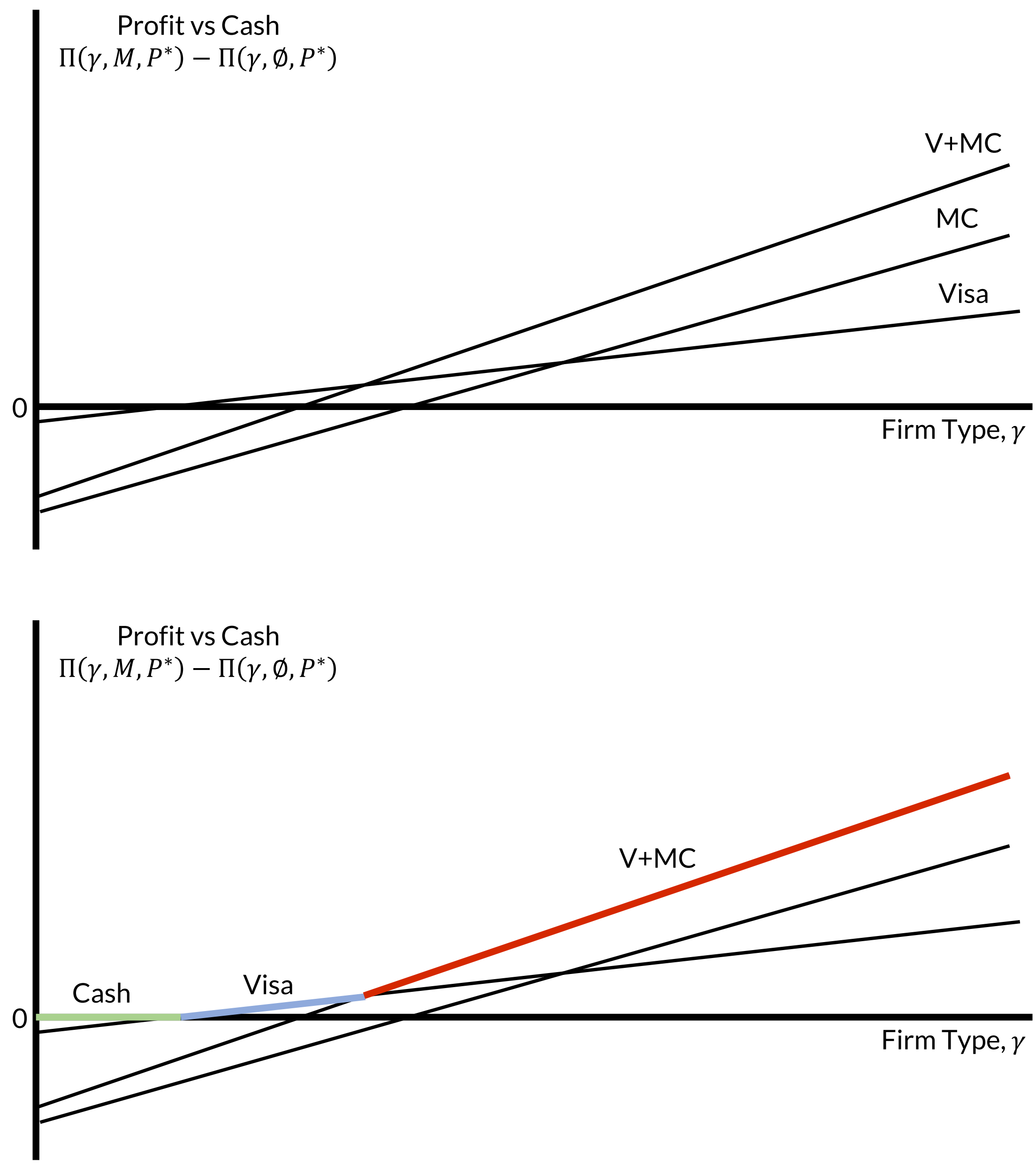
Equations 30 and 31 provide integral expressions for the expectation and the derivative of the expectation. To approximate these expectations, one can simulate g with standard monte carlo techniques as $\hat{g}$. While $\hat{g}$ will not be differentiable, by the convolution theorem expressions 30 and 31 will both be differentiable even if g is replaced by $\hat{g}$. The remaining integral can then be calculated efficiently by Gauss-Hermite quadrature.

E Quasiprofits

E.1 Example of Calculating the Equilibrium

Figure E.1 shows an example of computing an equilibrium when Visa charges merchants low fees but has a low market share among consumers, MC charges high fees and has a high market share, and cash is free. At $\gamma = 0$, because cards cost more than cash, all of the quasiprofit functions for bundles M that include cards are less than the quasiprofit for cash. Therefore merchants with low benefit parameters γ choose to only accept cash. However, because Visa's fee is lower, its y-intercept is closer to zero and its quasiprofit function crosses zero first. The crossing point marks the start of a region of merchants who only accept Visa. When the quasiprofit function for the combination of Visa plus MC exceeds the quasiprofit function for Visa, all merchants of that type or higher will then accept both.

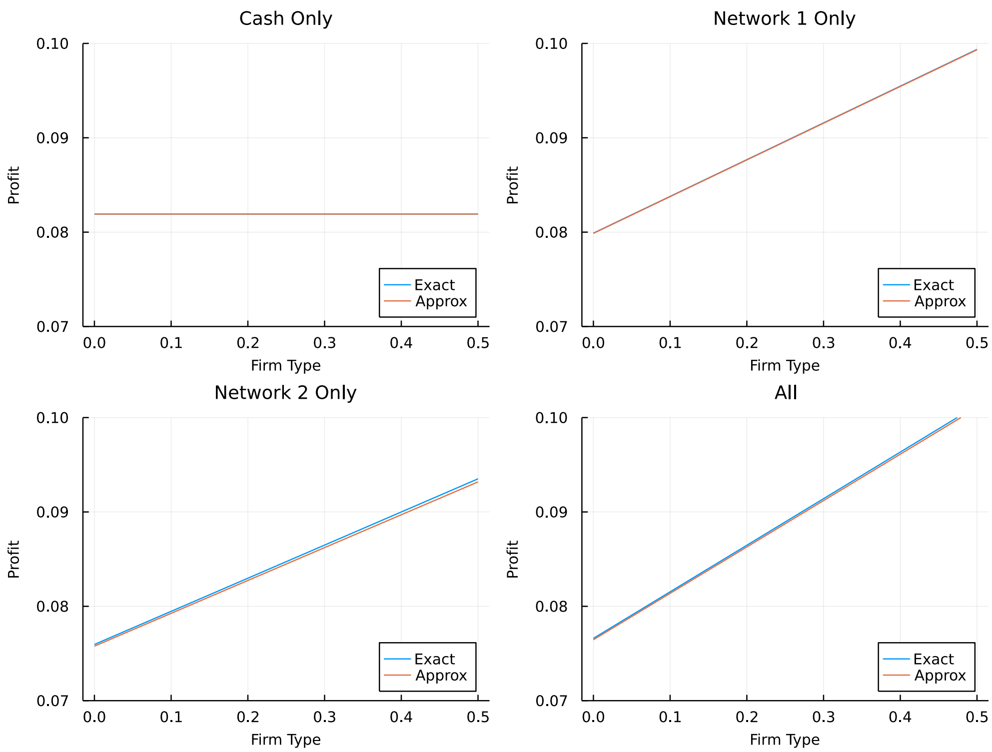
Figure E.1: Illustration of how to compute the merchant adoption subgame.



E.2 Quality of Approximation

A natural question is whether the quasiprofit functions are a good approximation of true profits. Figure E.2 compares exact and approximate profits in a case with two networks with symmetric market shares, differentiated only by the two networks charge different fees. The fit is very close for all values of the merchant type γ.

Figure E.2: Numerical example of how quasiprofit functions approximate true profit functions for a case of two networks with symmetric consumer parameters but who set merchant fees of $\tau_1 = 0.02$ and $\tau_2 = 0.04$



E.3 Comparison with Rochet and Tirole (2003)

The linearity of quasiprofits also reveals how the extent to which consumers hold one card or two will shape merchants willingness to substitute between accepting different cards, as in (Rochet and Tirole, 2003).

Consider a simplified economy in which consumers pay with cash and two cards, Visa (v) and American Express (a). Visa and American Express charge merchant fees of $0 < \tau_v < \tau_a$. Let the insulated shares be μ. Then the merchant adoption equilibrium will feature three regions:

1. Merchants of types $\gamma \in \left[0, \frac{\sigma\tau_v}{1-\sigma\tau_v}\right]$ accept only cash

2. Merchants of type $\gamma \in \left[\frac{\sigma\tau_v}{1-\sigma\tau_v}, \frac{\mu^{a,v}(\tau_a-\tau_v)+\mu^{a,0}\tau_a}{-\sigma\mu^{a,v}(\tau_a-\tau_v)+\mu^{a,0}(1-\sigma\tau_a)}\right]$ accept Visa only, where $\mu^{a,v}$ is the insulated share of consumers who primarily use American Express but who also have a Visa, and $\mu^{a,0}$ is the insulated share of consumers who only have an American Express and do not have a Visa.

3. Merchants of type $\gamma > \frac{\mu^{a,v}(\tau_a-\tau_v)+\mu^{a,0}\tau_a}{-\sigma\mu^{a,v}(\tau_a-\tau_v)+\mu^{a,0}(1-\sigma\tau_a)}$ accept both

When many American Express holders carry Visa, then $\mu^{a,v}$ is large and fewer merchants will accept American Express if Visa charges a low fee. Merchants become unwilling to accept American Express because doing so would force the merchant to raise higher prices, lowering demand, while getting few additional sales. When fewer merchants accept American Express, Visa is better off and so Visa has strong incentives to compete for merchants if most American Express consumers hold Visa cards. In contrast, if no American Express users carry a Visa, then $\mu^{a,v}$ is zero and the lowest type merchant who accepts American Express is $\frac{\sigma\tau_a}{1-\sigma\tau_a}$. In this case, the set of merchants that accepts American Express no longer depends on the fees that Visa charges. This would dramatically weaken Visa's incentives to compete for merchants.

F A Microfoundation for Interpreting Co-holding Data as Hypothetical First and Second Choices

This note outlines a microfoundation by which consumers' secondary cards can be used to identify hypothetical second choices for primary card. I assume consumers have wallets with two cards: a primary card and a secondary card. The consumer usually uses the primary card and with some small probability uses the secondary card. Periodically, consumers re-assess their primary card and choose primary cards of different brands with some probabilities. If the brand of the primary card changes, the consumer then downgrades the existing primary card to secondary status, and the new card becomes the primary card. The conditional distribution of the secondary card conditional on the brand of the primary card will then have the same distribution as second choices for primary cards conditional on the primary card. In other words, the fact that Visa cards are often found in wallets of primary Amex users will mean that Visa is a close substitute for Amex.

F.1 Environment and Proof

Let time be discrete $t = 1,2,\ldots$. For consumer i at time t, suppose that the utility from choosing a card $j \in \{1,\ldots,n\} \equiv J$ is

$$u_{ijt} = \delta_i + \epsilon_{ijt}$$

Suppose her wallet at time t contains two cards, $w_t = (p_t, s_t)$, where $p_t \in J$ is the primary card and s_t is the secondary card. Then at time $t+1$, the consumer draws new utilities and chooses a new primary card $p_{t+1} \in J$ that yields the highest utility. If $p_{t+1} = p_t$, then the wallet does not change and $w_{t+1} = w_t$. Otherwise, the new primary card changes, and then the new secondary card $s_{t+1} = p_t$, and so $w_{t+1} = (p_{t+1}, s_{t+1})$.

Theorem 2. *The joint stationary distribution of w_t is the same as the joint distribution of first and second choices, that is*

$$P\left(\left(u_{ijt} = \max_{l \in J} u_{ikt}\right) \cap \left(u_{ikt} = \max_{l \in J \setminus \{j\}} u_{ilt}\right)\right) = P(p = j, s = k)$$

Proof. Fix i. The probability of choosing j is

$$q_i(j) = \frac{\exp(\delta_i)}{\sum_{l \in J} \exp(\delta_l)}$$

The joint distribution of first and second choices comes from a standard result on logit choice probabilities:

$$P\left(\left(u_{ijt}=\max_{l\in J}u_{ikt}\right)\cap\left(u_{ikt}=\max_{l\in J\backslash\{j\}}u_{ilt}\right)\right)=q_i\left(j\right)\times\frac{q_i\left(k\right)}{\sum_{l\neq j}q_i\left(l\right)} \tag{32}$$

Next we calculate the joint stationary distribution of the wallets w_t. Denote this stationary distribution with P_i. Fix the wallet $w_{t+1}=(p_{t+1},s_{t+1})$ at time $t+1$. For this to have occured, there are two possibilities for the wallet at time t. In the first case, the wallet did not change and $w_{t+1}=w_t$. This happens with probability $q_i\left(p_{t+1}\right)P_i\left(w_{t+1}\right)$. In the second case, a new primary card was chosen at time $t+1$ such that the primary card is p_{t+1} and the secondary card was s_{t+1}. This happens with probability

$$\begin{aligned}
q_i\left(p_{t+1}\right)\sum_{k=1}^{n}P\left(w_t=\left(s_{t+1},k\right)\right)&=q_i\left(p_{t+1}\right)q_i\left(s_{t+1}\right)\sum_{w_{t-1}\in S^2}P_i\left(w_{t-1}\right)\\
&=q_i\left(p_{t+1}\right)q_i\left(s_{t+1}\right)
\end{aligned}$$

We can then drop time subscripts, and the stationary distribution P_i must then be determined by

$$\begin{aligned}
P_i\left(w\right)&=q_i\left(p\right)P_i\left(w\right)+q_i\left(p\right)q_i\left(s\right)\\
P_i\left(w\right)&=\frac{q_i\left(p\right)q_i\left(s\right)}{1-q_i\left(p\right)}\\
&=q_i\left(p\right)\times\frac{q_i\left(s\right)}{\sum_{l\neq p}q_i\left(l\right)}
\end{aligned}$$

Which is the same as 32. Conditioning down on i then gives the desired result. □

F.2 Discussion

This works because an IIA assumption holds conditional on i. For a given i, if a particular card p is the primary card, then the probability a different card is the second choice is determined by just dividing the probabilities.

The assumption that the primary card changes only if the new primary card is a different brand helps to map the thought experiment to my empirical work. In my empirical work, the secondary card counts any card brand with any amount of positive spending. Therefore if a Visa/Mastercard multihomer decides to add a new Visa card to her wallet, as long as she puts some positive spending on Mastercard I will count her secondary card as Mastercard. Therefore adding a new card does not change primary/secondary status if the new card has the same brand as the old primary card.

A key behavioral assumption is that the consumer does not choose the new primary card based on the characteristics of the secondary card. This is reasonable at the brand level. This is primarily because variation in merchant adoption of payments is primarily vertical, rather than horizontal. While different cards might offer different rewards, Visa, Mastercard, and American Express all offer rewards programs across major sectors. Therefore I'm assuming that if a consumer has a travel card, and is looking to get a card with grocery rewards, then her preferences over brands would be the same as if she already had a grocery card and is looking to get a travel card.

The microfoundation means that if a consumer has a primary Visa credit card card and a secondary Mastercard credit card as a secondary card, then in an alternative world where Visa did not exist the consumer would have chosen to use a Mastercard credit card as their primary card. This is only a reasonable assumption if Visa and Mastercard credit cards offer similar services. For example, if one thought that Visa and American Express were primarily accepted on the west coast and that Mastercard was primarily accepted on the east coast, then a west coast person who travels occasionally to the east coast might choose to have a primary Visa card and a secondary Mastercard card to cover their needs. If Visa did not exist, such a person would likely choose American Express as the primary card to cover their west coast needs.