Payment Network Competition

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Abstract

Consumer payment markets are inefficient because of excessive credit card adoption, not insufficient competition. I use bank payment volumes and consumer surveys to estimate a model of payment network competition, consumer payment choice, and merchant acceptance. I simulate the entry of a new network that competes for credit card consumers. In equilibrium, networks raise merchant fees to fund more consumer rewards. Merchants raise retail prices, dissipating consumer gains from rewards. Credit averse consumers who switch to credit cards incur social costs to earn transfers, lowering total welfare. Annual consumer and total welfare fall by $7 billion 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 blame Visa and Mastercard's market dominance for merchants' high credit and debit card acceptance fees.[1] If true, then the rapid growth of new fintech payment networks such as PayPal or Klarna should reduce merchant fees, benefitting merchants directly and consumers indirectly through lower retail prices. However, payment network competition has ambiguous effects on prices and welfare (Rochet and Tirole, 2003; Armstrong, 2006; Edelman and Wright, 2015). Networks compete not only by charging merchant fees but also by paying consumer rewards. It is theoretically possible for competing networks to raise merchant fees to fund more rewards, reducing consumer and total welfare.

In this paper I quantify the effects of payment network competition on merchant fees, consumer rewards, and welfare. I build and estimate a structural model of multiproduct payment networks that compete in both merchant fees and consumer rewards. I use data on bank payment volumes, consumer card holdings, and merchant card acceptance to estimate networks' costs and consumer and merchant preferences. I identify the parameters of the model with price variation from interchange fee regulations, consumer second choice data, and the assumption that networks maximize their own profits. I use this model to simulate entry of a new payment network that primarily competes for credit card consumers.

I start by showing that different payment networks are highly substitutable for consumers, but poor substitutes for merchants. First, the Durbin Amendment, a regulatory shock to debit interchange, caused a small reduction in debit rewards but a large shift in payment volumes from debit to credit. Second, primary credit card consumers use debit cards less than would be expected based on the general popularity of debit cards. I interpret this as indicating consumers are more willing to substitute between credit cards of different networks than between credit and debit. These two facts suggest that consumers are willing to change payment methods to earn rewards, especially when the payment methods have similar characteristics (e.g. two credit cards). Third, merchants' gains in additional sales from accepting consumers' preferred payment methods dwarf

[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, chipping away at Visa's monopoly and resulting in substantial savings to merchants and consumers." (Read et al., 2020). A US retailers trade association argued that "the absence of competition in the payments ecosystem allows Visa and MasterCard to get away with highway robbery when it comes to swipe fees." (Jensen, 2022). A recent Economist article wrote "After a long wait, new entrants now look like they could shake up America's market. That would be good news for consumers and retailers." (Economist, 2022).

the costs of merchant fees. Fourth, not all consumers carry cards from multiple networks. Thus merchants have limited ability to substitute away from accepting expensive payment methods without risking large declines in sales.

The reduced-form facts indicate that a two-sided model is likely to give different predictions for how networks compete compared to a traditional approach. A traditional one-sided analysis focuses on network competition in merchant fees, and would predict that competition lowers merchant fees. However, a two-sided model recognizes that when networks are better substitutes for merchants than for consumers, competing networks may instead raise merchant fees to fund more rewards (Rochet and Tirole, 2003; Armstrong, 2006).

I build 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. Consumers vary unobservably in their preferences over payment instruments, and merchants vary unobservably in their benefits of card acceptance.

I estimate the model by matching the reduced form facts, aggregate prices, and aggregate shares. The large effect of rewards on payment volumes identifies a consumer demand system in which consumers are willing to substitute to high rewards payment methods. I invert the consumer demand system to recover networks' costs. By comparing marginal costs and equilibrium merchant fees, I recover the elasticity of merchant demand at the observed equilibrium. I then recover merchants' margins and the distribution of merchants' benefits from card acceptance by matching the required demand elasticity and facts from consumer payment surveys. This procedure estimates consumer and merchant demand curves with only exogenous variation in rewards and the assumption that networks maximize their own profits.

I estimate that consumers are price sensitive while merchants are not. A one-basis-point increase in Visa credit rewards increases Visa credit's market share among consumers by 2.8%. In contrast, a one-basis-point increase in merchant fees for Visa credit causes only a 0.16% decrease in the share of merchants that accept Visa credit.

The model fits important patterns in the data. I match market share data on consumers' primary and secondary cards. I 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.

In my main counterfactual, I simulate network entry. I model the new network to resemble new fintech payment platforms. I assume the new app competes for credit card consumers, but consumers who use the app do not shop more at merchants that accept credit cards but not the app.[2]

I find that entry inflates merchant fees and consumer rewards. The entrant charges high merchant fees and pays large rewards. Its merchant 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 higher rewards cushion the rise in prices.

Entry reduces annual consumer and total welfare by $7 and $10 billion, respectively. Welfare falls with entry because each marginal consumer who switches to credit cards in response to the higher rewards destroys social value. Empirically, many cash and debit consumers who could pay with credit cards choose to pay with cash or debit cards. [3] By revealed preference, the marginal consumer deciding between debit and credit must be credit averse. When the marginal consumer switches to credit cards to earn the higher rewards in the new equilibrium, she suffers a non-pecuniary loss arising from her credit aversion. Total welfare falls because the non-pecuniary loss is a social cost, whereas rewards are transfers paid for by consumers in the form of higher retail prices. I estimate losses of $10 billion from credit averse consumers' increased use of credit cards. This is approximately equal to the decline in total welfare. Consumer welfare falls by a smaller amount because payment networks' transfer some profits to consumers through competition.

Entry has counterintuitive effects because credit card adoption is already too high. In

[2]The substitution assumption matches evidence from 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]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 8.4 why the presence of constrained consumers does not affect my welfare results. I discuss potential sources of this aversion in Section 4.

standard models of one-sided markets, market power always results in inefficiently low output. But in consumer payment markets, credit card adoption can be too high because merchants charge consumers the same price for all payment methods (Stavins, 2018). Under uniform pricing, consumers do not internalize the effect of their payment choice on merchants' costs and the level of retail prices. Consumers face a prisoner's dilemma. Even if consumers collectively prefer a world with lower credit card use and lower retail prices, individuals choose to use credit cards to earn rewards (Edelman and Wright, 2015). Entry reduces payment networks' markups, but nonetheless lowers welfare by pushing credit card use farther above the efficient level. Increased credit card use also inflates retail prices, negating consumers' gains from rewards.

I explore four 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 reduces credit averse consumers' credit card use, raising consumer and total welfare. In two counterfactuals, I show that *either* deregulating debit interchange by repealing the Durbin Amendment or regulating credit interchange increase welfare by discouraging credit card use. In a third counterfactual, I show that merging Amex and Mastercard without cost efficiciencies reduces credit card use and raises consumer and total welfare. In a fourth counterfactual, I modify the network entry counterfactual to allow merchants to substitute between the entrant and incumbent credit card networks. Credit card adoption increases, thereby reducing consumer and total welfare.

Although I focus on payment networks, my empirical approach is relevant to other two-sided markets in which platforms affect retail prices, and merchants charge the same price to consumers on and off the platform. Advertising platforms like Facebook or Google connect merchants with consumers. Ad platforms charge merchants high prices while subsidizing consumer adoption. Competition can force platforms to invest more in consumer benefits and to fund these investments with even higher ad prices. Just as in payments, higher ad prices may inflate retail prices, dissipating consumer gains from competition. I show how variation on one side of the market can help identify demand on both sides, enabling an empirical study of platform competition in other contexts.

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 welfare. 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.[4] 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. Thus the distributional effects of credit card rewards studied by Felt et al. (2020) play an important role in generating my welfare losses. I also model how rewards and merchant fees are determined by network competition, rather than assuming that prices are exogenous.

My paper contributes to the finance literature on payments by providing an equilibrium model of network competition. Many papers have documented forces that influence consumer payment choice, such as 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). I show that combining these forces with an equilibrium model of how networks compete can help quantify the harms of network competition for consumers.

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 certain forms of competition hurt consumers in a realistic model of the US payment market.

More broadly, my paper echoes arguments from the banking and intermediation literatures about the dark side of competition in the presence of externalities. 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).

[4] 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.

2 Institutional Details

In the model, networks compete by paying consumer rewards and charging merchant fees. This section explains how networks influence merchant fees and rewards rates in practice, and why networks can attract consumers by funding consumer rewards with merchant fees. I also discuss why I ignore the role of credit cards as a borrowing instrument.

2.1 Payment Card Networks in the United States

Credit and debit 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 merchant fees, around 2.25% of the transaction, Amex charges 2.27%, only slightly higher. Visa and MC charge lower merchant 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.[5]

[5] 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).

2.2 How Networks Influence Merchant Fees and Consumer Rewards

Networks influence the fees that merchants pay to accept cards as well as the rewards consumers receive from using cards. Proprietary networks like Amex set merchant and consumer prices directly. Open loop networks like Visa and MC influence merchant and consumer prices by adjusting the *interchange fee* and the *network fee*.

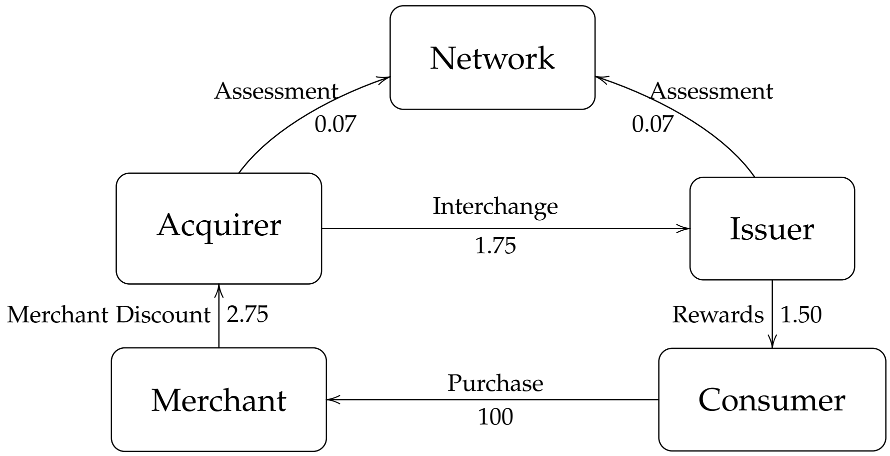
Visa and MC connect four types of players: merchants, merchants' banks (acquirers), the consumers' banks (issuers), and consumers.[6] Figure 1 illustrates the typical flow of money between these players. When a consumer uses her Chase Freedom Unlimited credit card to buy $100 of product at a large retailer, 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.[7]

Visa and MC influence merchant fees and consumer rewards primarily by adjusting the *interchange fee.* Regulatory caps on interchange highlight how interchange fees affect merchant fees. After Australia, Spain, and the EU regulated interchange fees, merchant fees fell around one-for-one (Gans, 2007; Valverde et al., 2016; European Commission, 2020). These same regulatory shocks highlight the role of interchange in funding consumer rewards. Large US banks ended rewards debit programs after the Durbin Amendment capped their 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 in 2003, 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 and continued to offer high rewards on those cards (Chan et al., 2012). When the RBA closed this regulatory loophole in 2017, the same large banks substantially devalued their rewards programs and

[6] 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".

[7] `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.

stopped issuing American Express cards (Emmerton, 2017; Reserve Bank of Australia, 2021).

2.3 The Role of Issuers

My model abstracts from the influence issuers have in setting rewards. 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.[8] 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 impor-

[8] 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.

tant role in influencing rewards. 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.

2.4 Uniform Prices for Different Payment Methods and Incentives to Fund Consumer Rewards with Merchant Fees

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 charging merchants higher fees to fund consumer rewards. If Visa raises both merchant fees and consumer 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).

Merchants may charge uniform prices because the benefits of surcharging are small. 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.[9] 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.

[9]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.

2.5 Credit Cards as a Borrowing Instrument

I do not model the borrowing features of credit cards. I thus assume that merchant fees flow through to rewards, not lower interest rates. I do this because the consumers most relevant for borrowing make up a 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. Data from Agarwal et al. (2018) show that consumers with credit scores above 720 make up around two thirds of purchase volume but only around one-quarter of interest and fee payments. Agarwal et al. (2022) show that while around 80% of the income from a consumer with an 800 FICO score comes from interchange, this drops to 20% for a consumer with a 650 FICO score. Anecdotally, issuers also segment credit card users to offer different cards to those who use credit cards as a spending instrument versus a borrowing instrument (Fiorio et al., 2014).

My model is consistent with rewards being partially funded by interest payments by unsophisticated borrowers (Ru and Schoar, 2020; Agarwal et al., 2022). My model only relies on the importance of merchant fees in funding rewards, which is confirmed by the response of consumer rewards to interchange fee regulations. To the extent profits from interest charges fund rewards, the profits would show up as lower marginal cost estimates for credit card payments.

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.

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

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.

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 shows that debit is the most popular payment instrument, followed by credit and then cash. When consumers report preferring a given payment method, they tend to use that payment method more.

Most consumers in the sample are banked and have access to credit cards. Of those who prefer cash, 87% have a checking account and 68% have a credit card. I split

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	0.20	0.21	0.34
Owns CC	0.68	0.61	1.00	1.00
Owns Rewards CC	0.45	0.32	0.76	0.85
Owns Bank Acct	0.87	1.00	1.00	0.99
Balance / Limit	0.22	0.32	0.26	0.10
HH Income	61.24	67.48	86.05	112.88
Debit Share	0.29	0.73	0.55	0.14
Credit Share	0.17	0.01	0.26	0.66

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 (relative to all debit card users), 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.

debit card users into two segments with above and below median usage of credit cards. Among those who prefer debit but have a low use of credit cards, 61% own a credit card. Consumers who prefer debit but who have above median use of credit cards own rewards credit cards at a similar rate as primary credit card consumers (76% versus 85%). These debit consumers nonetheless use their debit card in 55% of their transactions, despite often owning a rewards credit card. Although cash and debit users have lower incomes than credit users, neither the cash nor debit users have low average household incomes.

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

My paper combines 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 networks 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 welfare.

In traditional one-sided markets, firms cut prices in response to entry. This would be valid if payment networks only charged fees to merchants. In that case, the entry of a new network would reduce merchant fees. Merchants would 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 this 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.

When credit card networks compete and raise consumer rewards, cash and debit card users suffer relative to credit card users. Higher rewards cause more consumers to use credit cards. Because credit cards charge higher merchant fees than other payment methods, higher credit card use causes merchants to raise prices. Cash and debit card users are hurt by the higher prices, whereas credit card users benefit from the higher rewards.

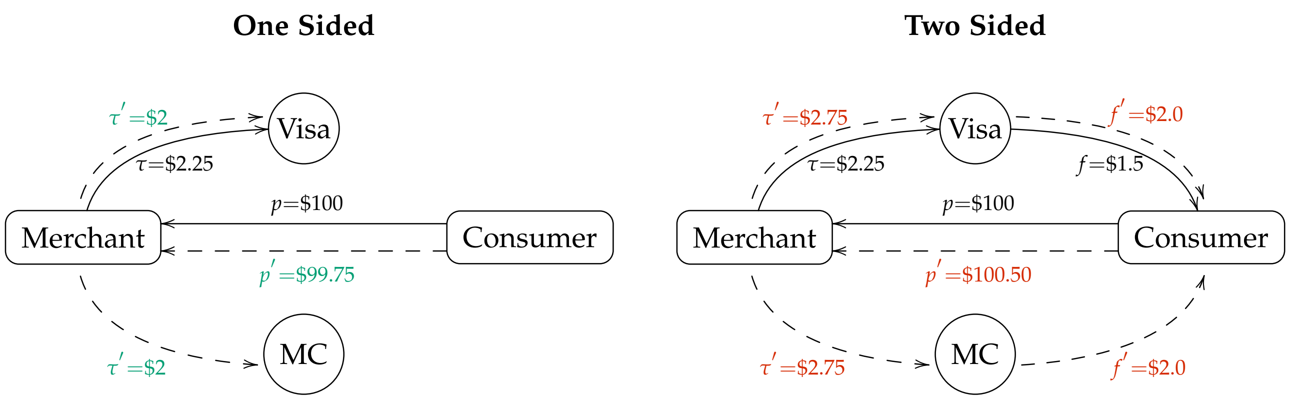
Competition can reduce total and consumer welfare by changing consumers' payment choices (Edelman and Wright, 2015).[10] The marginal consumer deciding between paying with debit or credit owns a rewards debit card but does not use it.[11] By revealed preference, this marginal consumer must be credit averse.[12] If network competition

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

[11]Table 2 shows that, among debit consumers with an above median usage rate of credit, 76% own a rewards credit card.

[12]Credit aversion could reflect a fear of overspending on a credit card, perceived costs of using a more

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.

raises credit card rewards and the marginal debit consumer switches to credit, total welfare falls. The switcher chooses to bear a non-pecuniary cost from using credit cards because she is compensated by high rewards. But while the non-pecuniary cost of a credit averse consumer using a credit card is a social loss, the additional rewards are merely transfers. When this loss from credit aversion is combined with higher retail prices, consumer welfare can fall.

The price effects of network competition depend on consumer and merchant substitution patterns, whereas the welfare effects depend on the distribution of consumer preferences. If networks are better substitutes for merchants than for consumers, 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. If consumers are credit averse, then network competition that induces more consumers to adopt credit cards hurts consumers. Modeling and estimating consumer and merchant substitution patterns as well as the distribution of consumers'

complicated payment instrument, or a general aversion to debt. Appendix Table B.6 summarizes data from the SCPC on the reasons consumers choose their primary payment method. Around 15% and 9% of primary cash and debit card users do so because it helps them control their budget, compared to 4% of credit card users. Table B.6 shows that debit card consumers are around 10 percentage points more likely than credit card consumers to choose their primary payment method based on convenience. Issa (2017) finds that a quarter of consumers report feeling "impulsive", "anxious", or "overwhelmed" when using a credit card, twice the rates from debit card use. Behavioral marketing research finds that some consumers prefer to time payments with consumption so that the pain of payment occurs before enjoying the purchase (Prelec and Loewenstein, 1998).

preferences will be the focus of my estimation in the sections to follow.

5 Reduced Form Analysis

The reduced-form facts show that consumers are willing to substitute to high reward networks, but merchants are limited in their ability to substitute to low fee networks. By the logic from Section 4, network competition has the potential to generate higher merchant fees and consumer rewards.

5.1 Consumer Substitution Between Credit and Debit

The Durbin Amendment reduced debit interchange rates, ended debit rewards, and led to large reallocation of spending from debit to credit. Consumers' choice between debit and credit is thus sensitive to rewards.

The Durbin Amendment was a part of the 2010 Dodd Frank Financial Reform Act and reduced debit interchange fees at large banks and credit unions with more than \$10 billion in assets from roughly 1.3% of purchase value to 22 cents and 0.05% of the purchase value.[13] Credit interchange was unaffected. By reducing banks' income from debit card spending, this law led to the end of debit rewards at large banks (Hayashi, 2012; Schneider and Borra, 2015). In contrast, small banks largely kept their rewards programs intact (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

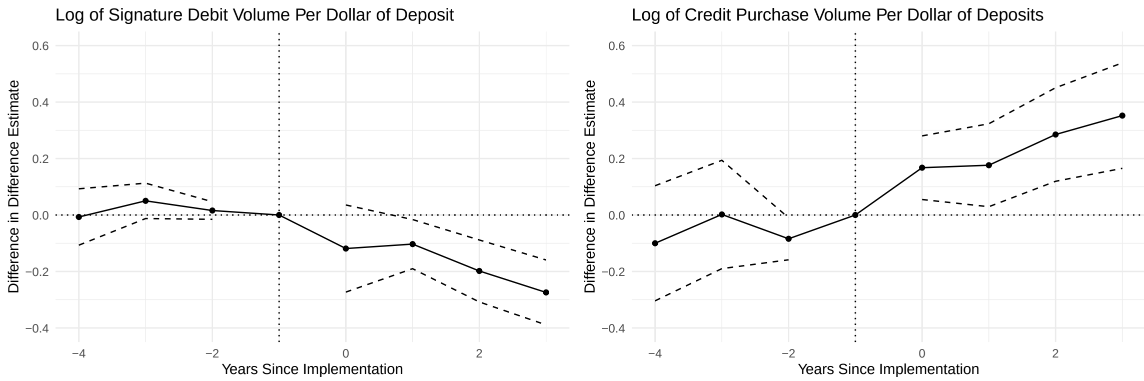
$$y_{it} = \sum_{k=-3}^{3} \beta_k I\{t = k\} \times \text{Treated}_i + \delta_i + \delta_t + \epsilon_{it}, \tag{1}$$

where y_{it} is the logarithm of signature debit or credit card payment volumes at bank i. Treated_i refers to whether bank i 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 banks to small banks, I can difference out the effects of the Durbin routing requirements, the CARD act, or changes in merchant acceptance on debit and credit card use.[14] I define

[13] 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".

[14] 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

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 $t = 1$. Standard errors are clustered at the issuer level.

$t = 0$ as 2011. I use 2010 as my base year. Figure 3 shows that signature debit volumes fell by 27 percent whereas credit card volumes rose by 35 percent. Volume was largely substituted between payment forms, as I estimate overall card spending fell by a small but statistically insignificant 5 percent. Appendix Table B.7 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 estimates are also consistent with Mukharlyamov and Sarin (2022), who find that geographic areas that were more affected by the Durbin interchange caps experienced 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 respond to the $10 billion cap by changing the growth trajectories. Figure C.3 shows that the overall debit cards, which included PIN debit cards that were not affected by the regulation, declined less. Besides signature debit, many banks offered PIN debit, which was not affected by Durbin since the interchange rates were already low (Hayashi, 2012). The differential pattern across debit cards suggests the effect I am identifying is about relative prices for credit and debit, and not just other

merchant responses. In models of interchange, the level of the interchange fee should affect both consumer utilization and merchant adoption (Rochet and Tirole, 2002).

shocks to big and small banks during this time period.

5.2 Consumer Substitution Between Networks

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

I use the Homescan shopping data to construct primary and secondary cards. I split consumers by cash and card users.[15] I define card users' primary payment card as the card network that is used for the highest share of trips.[16] 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" to be cash. Appendix Table B.10 shows that two card networks covers around 95% of card spending for the typical Homescan consumer who carries cards from two networks. The primary network typically covers around 80% of the card spending while the remainder is on a second network.

I identify substitution patterns by studying patterns in primary and secondary card holdings. Primary Amex users often carry a secondary Visa credit card 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 over primary cards. I apply techniques from Berry et al. (2004) for studying second choice data to identify how willing consumers are to substitute between credit cards from different networks.

Interpreting primary and secondary cards as first and second choices requires that consumers ignore the effects of complementarity and substitution in deciding which pair of cards to put in their wallet. For example, two credit cards in different rewards categories (e.g. grocery and travel) could be complements. However, rewards do not create complementarities at the network level. Visa, MC, and Amex all offer credit cards with rewards in categories such as travel, grocery, restaurants, or gas. 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 how willing consumers are to substitute between credit cards of different networks. Because the welfare losses from competition are increasing in the number of consumers who switch

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

[16] In Appendix table B.9, I show that the total number of trips is highly correlated with the card with the highest share of spending.

Table 3: 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.

between cards, my estimate leads to an underestimate of the harms from competition. Appendix F derives a dynamic microfoundation in which consumers periodically update their primary card in a way that features no effects from complementarity or substitution. Under this 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.

The primary and secondary card data indicate that if a primary credit card consumer were to have her primary card taken away, she is more likely to substitute to a credit card from a different network rather than a debit card. Table 3 shows both the aggregate shares of each primary payment method and the conditional probability of each payment option occurring as the second choice. In the Homescan panel, 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 equally good substitutes for each other, then we would 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.[17]

[17] One may be concerned that Amex card users have a particularly strong incentive to carry Visa credit cards because some stores do not accept Amex. While this may be true, it does not appear to be driving the entire correlation between having a secondary Visa credit card given a primary Amex card. In particular, primary Visa credit card users also have a strong tendency to carry a secondary Amex card.

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 sales 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. Studies that use this ideal variation find that accepting consumers' preferred payment methods can raise sales from those consumers by $10-40\%$ (Higgins, 2020; Berg et al., 2022). As an alternative identification approach, 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 cash is less convenient when 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. The survey data's main benefit is that it allows me to use US data.

I use a logistic regression to measure the extent to which sales are increased by card acceptance. Index consumers by i and transactions by t. Let y_{it} be the indicator for whether the transaction t occurred at a store that accepts cards. Let X_i be the 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 estimate the logistic regression

$$\log \frac{P(y_{it}=1)}{1-P(y_{it}=1)} = \phi X_i + \delta_{it} + \epsilon_{it}. \tag{2}$$

Because most merchants accept cards, the coefficient ϕ can be interpreted as the average increase in sales experienced by the merchants who accept cards. This increase in sales nets the positive effect from increased convenience against the negative effect of higher fees that may be passed through to higher prices.

Table 4 shows the results of this regression with different options for fixed effects. My preferred model 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 prefers cash. I interpret this as saying that merchants are significantly more likely to attract card consumers if they accept cards.

Table 4: 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

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

Notes: Standard errors are clustered at the consumer level

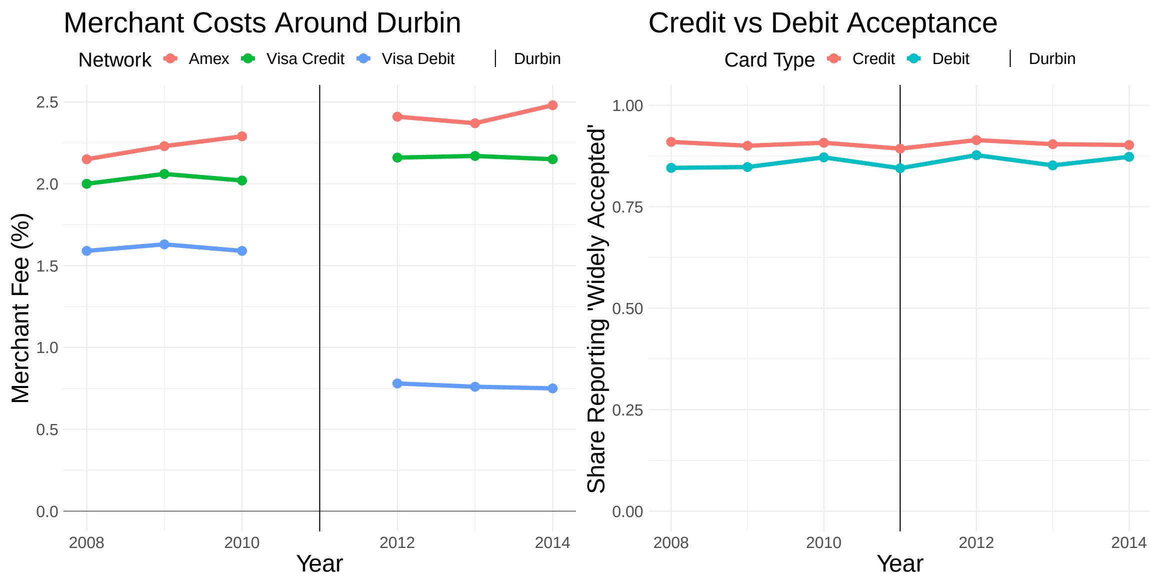
The relative stability of the results, even as I adjust the consumer and merchant fixed effects, suggests there is little unobserved variation driving the result. Appendix Table B.8 shows that this effect does not vary much across debit versus credit card users, those who hold one or multiple cards, or high or low income respondents.

5.4 Merchant Substitution Between Networks

Merchants do not view credit card and debit card acceptance as substitutes. 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 their relative prices induce large changes in relative quantities. Yet when the Durbin Amendment cut debit card merchant fees, there was no significant decline in the number of merchants that accepted credit cards. Figure 4 plots 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.

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".

One reason that debit acceptance may not substitute for credit acceptance is the fact that the consumers who use both debit cards and credit cards use them for different purposes.[18] 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 pay only with credit cards, debit card consumers carry larger balances.[19]

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). Consumers who carry cards from multiple networks empower merchants to reject high fee cards. If every Visa consumer owns

[18]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)

[19]There is no longer any legal requirement to accept Visa credit cards with Visa debit cards. 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. Such a theory would also counterfactually predict that Amex acceptance should drop in response to the Durbin Amendment.

Table 5: 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

a MC, then accepting MC also enables merchants to serve customers with a Visa card. Visa and MC would generate competition that reduces merchant fees since merchants would only accept the cheapest option. In contrast, if consumers only carry cards from one network, then Visa can charge merchants high prices for exclusive access to Visa customers (Armstrong, 2006). Table 5 shows that across both Homescan and the DCPC, around 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. These numbers suggest that refusing to accept a network may lose sales from a sizeable fraction of the holders of that network's cards.

5.5 Summarizing the Reduced Form Facts

The large change in debit volumes in response to the Durbin Amendment and primary credit card consumers' willingness to substitute between credit card networks suggest that consumers are quick to switch to networks with high rewards (Facts 1 and 2). Merchants' large sales benefits from card acceptance and the presence of consumers with cards from only one network suggest that merchants who try to reject cards from high-fee networks risk large declines in sales (Facts 3 and 4).

These facts suggest different networks are good substitutes for consumers, but poor substitutes for merchants. Under these conditions, network competition can result in higher merchant fees and higher consumer rewards (Rochet and Tirole, 2003; Armstrong, 2006). However, the reduced-form facts do not quantify how substitutable the networks are for consumers and merchants. The model in the next section translates the reduced-form facts into quantitative statements about consumer and merchant substitution patterns, and predicts how competition affects prices and welfare.

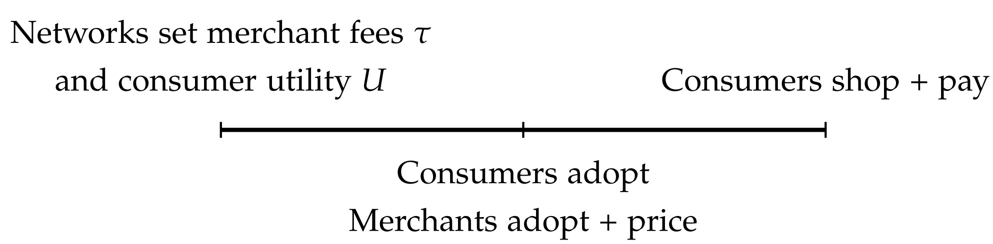
6 Model

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, a unit continuum of 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. Consumers vary in their preferences over payment methods. Merchants vary in how much their sales increase from card acceptance. 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 cards that have already been chosen in the second stage of the game.[20] 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 consumer pays with payment method j can be defined as

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

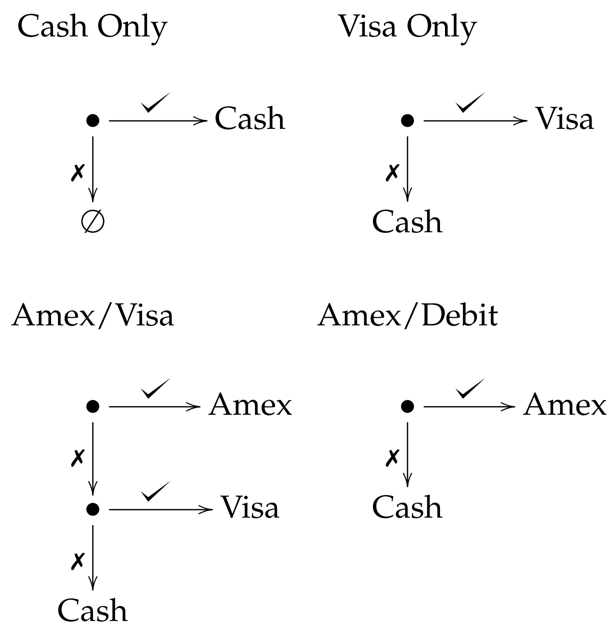
where $I^w_{j,M} = 1 \iff$ a consumer with wallet w pays with j at a merchant that accepts M. Consumers only pay with their secondary card if the primary card is not accepted, the secondary card is accepted, and the secondary card is the same type as their primary card. I require consumers to only use 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. Figure 5 shows how different types of consumers pay. A cash only consumer's primary payment method is cash, $w_1 = 0$. A consumer who only carries a Visa has $w_1 =$ Visa but $w_2 =$ Cash. A consumer who carries an Amex as their primary card and a Visa as a backup has $w_1 =$ Amex, $w_2 =$ 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.

Consumer payment choices only reflect the order of cards in their wallet and not the identity of the merchant. I do not model "store cards" that give different rewards based on the store. In practice, consumers tend to not adjust their card based on the merchant. When the Amex-Costco exclusivity agreement ended, it was revealed that 70% of the spending on the Costco Amex card was not at Costco (Sidel, 2015).

[20] I choose two cards because two networks covers 95% of an average consumer's card spending (see table B.10).

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. All merchants accept cash in equilibrium, and so the cash only consumer can always pay with cash. In this diagram Visa refers to Visa credit cards.

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 will pay with a card in their wallet. It equals $v_M^w = I_{w_1,M}^w + \left(1 - I_{w_1,M}^w\right) I_{w_2,M}^w$, and equal to one for a consumer with two cards of the same type provided that one of the cards is accepted.

Each 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:

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

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

The presence of $v_{M^*(\omega)}^w$ means that a consumer derives higher utility from consuming at a merchant that accepts a card the consumer wants to use. I assume consumers only care about *whether* they use a card from their wallet and not about which card is used.

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 pricing and adoption decisions of all other merchants. The demand from a consumer with wallet w for a merchant of type γ is:

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

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

In this demand curve, only γ, v_M^w, and p vary across merchants. The price index P^w and the income y^w are not affected by any one merchant's actions.[21]

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 which the method of

[21]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.

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).

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 value of card acceptance.

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 expressed as

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

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

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

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

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 $P = (P^w)_{w\in\mathcal{W}}$. 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

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

Where the fee τ_M^w for wallet $w = (w_1, w_2)$ 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 $I_{j,M}^w$ are defined in equation 3 and detect if payment method j is used.

The expression for profit in equation 7 is a wallet weighted average of revenues, net of transaction fees, less production costs, 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.

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

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

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 $(1 - \hat{\tau})^{-1}$. The realized transaction fee $\hat{\tau}$ captures the average transaction fee the merchant pays, which depends on the composition of its consumer base.[22]

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 choose the subset 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

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

[22] 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.

Merchants then solve the profit maximization problem

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

Where the price index P captures the equilibrium pricing p^* and adoption decisions M^* of other merchants. In equilibrium, merchants adopt optimal bundles holding fixed the optimal 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. This disciplines networks' incentives to raise merchant fees. In the US, almost all merchants who accept Visa credit cards also accept MC credit cards. This makes sense given the two networks charge similar fees. But in an alternative world in which Visa charged higher fees, merchants would be able to drop Visa while still accepting 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.

Each consumers' primary card is the one with the highest payment utility from adoption. I define the log payment utility V_i^j from a single payment method $j \in \mathcal{J}$ as

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

The first component 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 standard results on CES give that the consumer's optimized utility is

$$\log U^j \approx f^j - \log P^j \tag{15}$$

, 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).[23] The variables Ξ^j represent unobserved characteristics that rationalize market shares. I normalize the unobserved characteristic of cash as $\Xi^0 = 0$. The parameter 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_i^j represent unobserved reasons different consumers might choose one payment mehod over another. 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 allows consumers to vary in their preferences over credit cards, debit cards, and cash.

The payment method with the second highest utility becomes the secondary payment method in the wallet. Consumers' primary and secondary cards therefore reveal their first and second choices. I define *insulated* market shares for the wallet $w = (w_1, w_2)$ as

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

For a merchant who decides to accept cash, a share μ^w of their demand will come from consumers who have wallet w.

Market shares $\tilde{\mu}$ are reverse engineered so that each merchant's decision on which cards to accept depends only on the insulated shares μ, and not on the underlying price index P^w or the rewards f^w. The two shares differ because consumers shop over merchants. Actual market shares $\tilde{\mu}$ among consumers for different wallets are derived from the insulated shares as

$$\tilde{\mu}^w = \frac{1}{C} \frac{\mu^w (P^w)^{1-\sigma}}{1 + f^w} \tag{17}$$

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

where f^w is the total rewards paid[24] to a consumer with wallet w. The constant C has been defined in a way to make the market shares add up to 1.[25]

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

[24] 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.

[25] If one alternatively defined the market shares $\tilde{\mu}$ in terms of the joint distributions of the payment

6.7 Network Profits

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

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

where the indicator $I^w_{M,j}$, defined in equation 3, detects if payment method j is used when the merchant accepts M and the consumer has a wallet w.

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

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

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 a consumer with wallet w for her use of j.

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

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

Below, I describe how to calculate each of the above terms. 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.

$$\tilde{d}_j^w = \frac{\mu^w}{C} d_j^w, d_j^w = \int I^w_{M^*(\gamma),j} \left(1 + \gamma v^w_{M^*(\gamma)}\right) p^*(\gamma)^{1-\sigma}\ \mathrm{d}G(\gamma)$$

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

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

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

To calculate the cost of consumer rewards, I assume that consumers receive rewards according to a fixed percent of their equilibrium spending.[26] 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. I calculate the total rewards that card j pays 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 only use card j. Intuitively, the network must pay out $f^j \tilde{\mu}^j$ to the these agents. I then scale this by the ratio of spending on j by all agents relative to the amount of spending the agents who use only j spend on j. The total spending iterates over the wallets in which j is either the primary or the secondary card.

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 agent. To get around this issue, I make a simplifying assumption that, for the purpose of calculating network profits, the agents who carry multiple cards 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

[26] 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.

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. *For any γ, M, P, τ,*

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

where

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

$$a_M = \sum_{w\in\mathcal{W}} \mu^w \tau_M^w$$

$$b_M = \frac{1}{\sigma}\sum_{w\in\mathcal{W}} \mu^w v_M^w \left(1-\sigma\tau_M^w\right)$$

$$\tau^{\max} = \max_j \tau_j \tag{24}$$

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. I use this fact 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 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 merchant acceptance depends on consumer usage. 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. Networks promise consumers that if merchants do not adopt, the networks will compensate the consumers with high 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 by which networks subsidize consumer adoption when merchant acceptance is low.

I am able to solve for the unique merchant and consumer subgame and network profits given the promised utility levels U and merchant fees τ.[27] I first assume the promised utility levels are satisfied. 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 according to equation 5. The CES price indices combined with the CES utility levels U give how much rewards f the networks need to pay from equation 15. Equations 19, 20, and 21 then yield the network profits.

I employ a refinement to deal with the non-differentiability of network profits with respect to the merchant fees. 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. 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 carry multiple cards (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

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

cards that they own $\mathcal{O}_n$ such that

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

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

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

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 that 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 β_i 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.

1. The demand schedule $q^{w*}(\gamma)$ is optimal given 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 maximize 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

By estimating the model, I translate the reduced form facts into quantitative statements about how competition affects market outcomes. The key primitives to recover are (1) consumers' preferences over the different payment options, (2) the distribution of merchants' benefits from payment acceptance, and (3) the networks' marginal cost parameters. I assume the aggregate shares and prices are an 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 Overview of Identification

Although many steps occur jointly, my identification strategy is most easily understood as a four step process. I start by estimating consumer demand with variation in rewards. Second, I recover networks' marginal costs by inverting the networks' first order conditions with respect to consumer rewards. This depends only on consumer demand, observed shares, and observed prices. Third, I infer that merchant demand must be inelastic from the fact that observed merchant fees are much higher than networks' marginal costs. Fourth, the elasticity, combined with some moments from payment surveys, identifies the CES substitution parameter and the distribution of merchants' benefits from card acceptance. 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' optimal pricing.

7.2 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 the Durbin Amendment on debit 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 unobserved characteristics 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.[28]

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 cards equals

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

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 $\hat{s}$.

I estimate the price sensitivity coefficient α by matching the effects of the Durbin Amendment on debit card volumes. 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

[28] 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.

are done by cash (Table B.1). Combine these moments as m.

Next I simulate these moments in my model. I order the choice set of payment methods as cash, signature debit, and credit cards to match the data provided.[29] 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

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

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 model moments as $\hat{g}(\Sigma, \alpha, \delta, \phi) = \begin{pmatrix} \hat{s}(\Sigma, \delta) & \hat{m}(\Sigma, \alpha, \tilde{\delta}) \end{pmatrix}^T$ and the data moments as $g = \begin{pmatrix} s & m \end{pmatrix}^T$. Stack the parameters as $\theta_1 = \begin{pmatrix} \Sigma & \alpha & \delta & \tilde{\delta} \end{pmatrix}^T$. I estimate θ_1 by solving

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

. I use the estimates $\hat{\alpha}, \hat{\Sigma}$ in the next step, but the mean utility levels $\delta, \tilde{\delta}$ are nuisance parameters.

7.3 Merchant Benefits, Network Costs, and Consumer Intercepts

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

[29] 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.

I make two assumptions on fees and the cost of cash. First, I assume that the aggregate 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 $c_0 = \tau_0 = 30$ bps to match past studies (European Commission, 2015; Felt et al., 2020).[30]

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 ϕ_1 be the share of card consumers' spending at card stores (97%). Let the second data moment ϕ_2 be the logistic regression coefficient of how consumers' card preference relates to whether a transaction is done at a card merchant (Table 4). Stack these data moments as ϕ.

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.[31] The two model moments are

$$\begin{aligned}
\hat{\phi}_1 &= \frac{\sum_{w\in\mathcal{M}} e^w(\gamma^*)}{\sum_{w\in\mathcal{M}} e^w(0)} \\
\hat{\phi}_2 &= \ell\left(\hat{\phi}_1\right) - \ell\left(\frac{\sum_{w\in\mathcal{C}} e^w(\gamma^*)}{\sum_{w\in\mathcal{C}} e^w(0)}\right) \\
\ell(p) &= \log\frac{p}{1-p}
\end{aligned}$$

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 shares of credit and cash consumers' spending at card stores. Stack these two model moments as $\hat{\phi}$. When the mean $\overline{\gamma}$ is large, the difference $\hat{\phi}_2$ between card and cash consumers'

[30] 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.

[31] I treat credit card acceptance as the sign of accepting all cards because some merchants in the model accept debit but not credit.

expenditure shares at card stores increases. As the standard deviation σ_γ increases, the share of merchants who do not benefit from card acceptance also increases. Fewer merchants accept cards, and so card consumers' expenditure share at card stores $\hat{\phi}_1$ 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 the Durbin Amendment. 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.[32] 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 using the Bayesian bootstrap for the distribution of $\hat{\phi}$ and the GMM formula for $\hat{\theta}_1$. The delta method converts the covariance matrix and the Jacobian into a full covariance matrix for $\hat{\theta}_2$.

7.4 Relating Model Parameters to Substitutability

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

[32] 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.

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 card holdings data. The fact that primary credit card consumers often carry secondary credit cards from other 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 estimated benefit of card acceptance on sales for the average merchant. 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.

7.5 Results

I estimate precise consumer elasticities, merchant elasticities, and network marginal costs. Table 6 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 7. The first column of table 7 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. 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

Table 6: 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

Panel D: External Estimates

Cost of Cash c_0 (%)	0.30	European Commission (2015); Felt et al. (2020)

Table 7: 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.

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. I leave the details of how to calculate the merchant elasticity while holding consumer demand fixed to Appendix E.3.

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.[33]

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' sensitivity 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

[33]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.

smaller relative to the size of the estimate.

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

7.6 Goodness of Fit

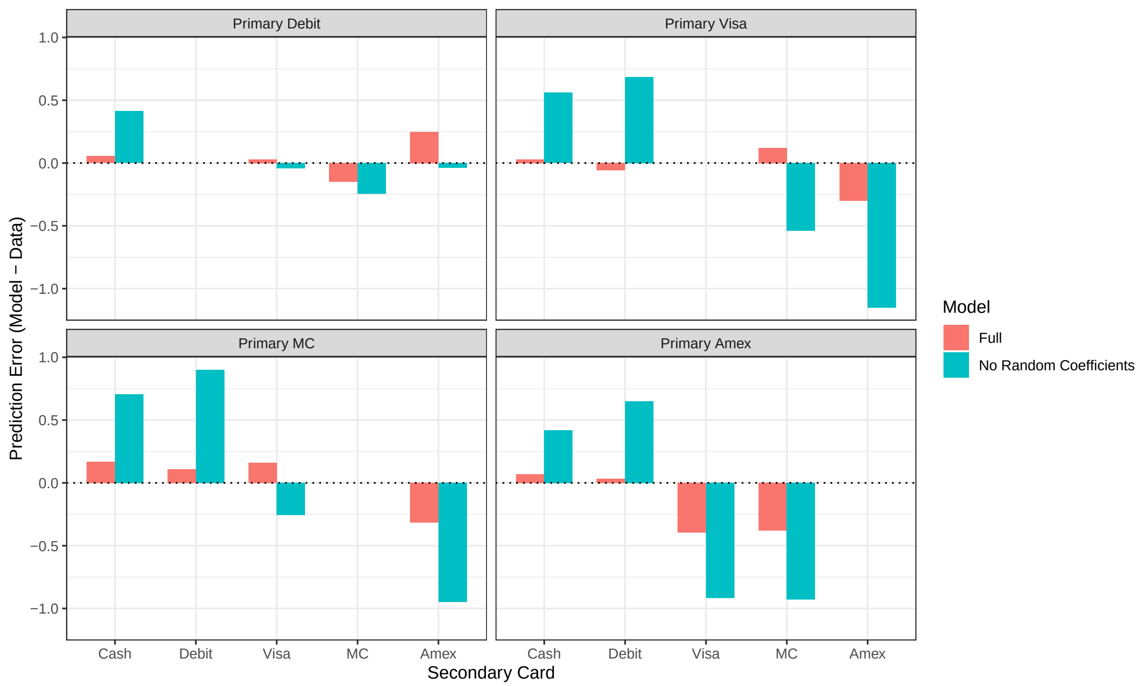
The model matches the co-holding data and the effects of Durbin on credit and overall card volumes. The model slightly underestimates Amex's equilibrium fee, and overestimates the share of stores that accept debit, but otherwise matches prices and shares well.

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 that the random coefficients play an important role in matching the secondary card data. The blue bars show the prediction errors without random coefficients. 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 8 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 is 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

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 8: 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 9: 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

standard error of the truth for both tests. This also provides evidence that co-holding data provides realistic estimates of substitution patterns in payments.

Table 9 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 in the counterfactuals, I cap debit card merchant fees at the observed 0.72%.

The model also overpredicts the gap between debit and credit card acceptance. Whereas the model predicts debit acceptance should be over 99%, only 96.7% of merchants accept credit cards. In reality there are likely fixed costs that make accepting debit cards without credit cards unprofitable in the current equilibrium, but I do not impose any additional assumptions to shrink this gap.

8 Counterfactuals

In my main counterfactual I study the effects of a new fintech payment network that competes for credit card consumers. I show that entry increases merchants' cost of payments as payment methods with high merchant fees and high rewards take a larger share of the market. Credit averse consumers switch to credit cards to chase rewards. Consumer and total welfare fall.

My additional counterfactuals suggest that my results are driven by the fact that debit cards cannot pay rewards whereas credit cards can pay rewards. Any policy change that shrinks the gap in rewards raises welfare. I find that repealing the Durbin Amendment's restrictions on debit card interchange fees, regulating credit interchange, and merging Mastercard and American Express would all be good for consumers. I also show that my welfare results on entry are not sensitive to how I model merchant substitution between the entrant and incumbent payment networks.

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 a merchant who only accepts credit cards, but not the app, loses some sales from app users. Given these characteristics and costs, I can solve for the new equilibrium after the fintech platform enters.

The assumption that the entrant is a new payment type 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. Not accepting the app would reduce demand from consumers who use the app even if those consumers own credit and debit cards.[34] In section 8.2.4, I show that this assumption is not essential.

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

[34]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."

than American Express' baseline fees and rewards. In response, incumbent credit card networks raise their fees by 8 bps to fund 13 bps more rewards. Incumbent debit cards raise rewards by only 6 bps because they 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 high merchant fee 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 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 Welfare Effects

To study the effects of entry on all consumers the gains to switchers, I decompose consumer welfare into three terms – retail prices, the average subsidy paid, and non-pecuniary utility.[35] Let E_i^k be an indicator that consumer i chooses payment method k. I decompose consumer welfare[36] as:

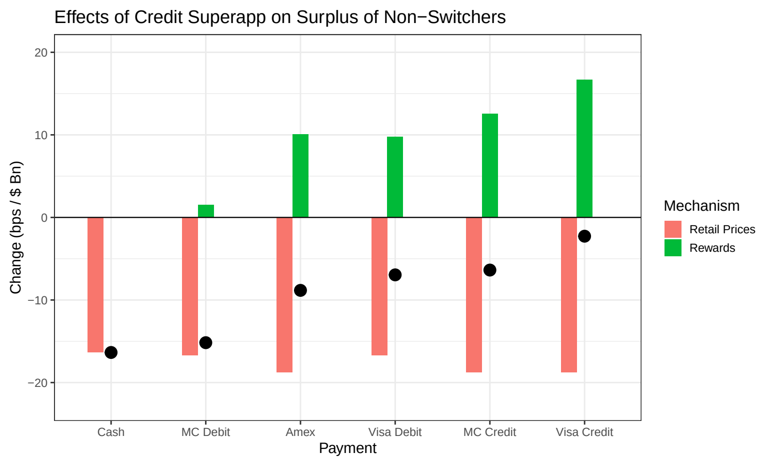
$$
\begin{aligned}
W &= \mathbb{E}_i \left[\max_k \log V_i^k \right] \\
&\approx -\log P^0 + \mathbb{E}_i \left[\max_k f^k - \log \frac{P^k}{P^0} + \Xi^k + \frac{1}{\alpha} \left(\eta_{ij} + \beta_i X^k \right) \right] \\
&= \underbrace{-\log P^0}_{\text{Retail Prices}} + \underbrace{\sum_k \mu^k f^k}_{\text{Rewards}}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

[35] See the survey evidence in section 4 on the sources of this aversion.

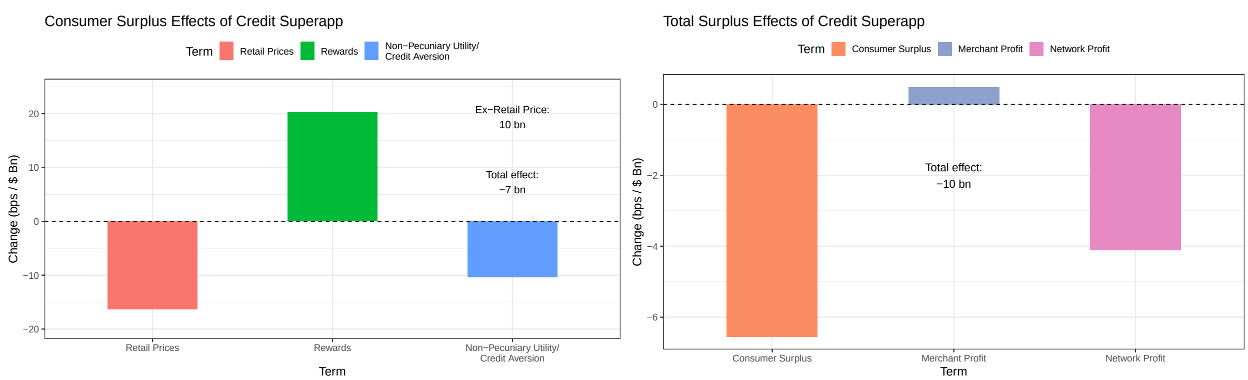
[36] Aggregating consumer welfare requires a strong assumption that the planner puts equal welfare weights on credit and debit users, which is unlikely given that credit card consumers are much higher income. Given that we already saw entry exacerbates the regressive transfers, my calculation should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

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

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Welfare and Total Welfare Effects



Notes: The black dots in Panel A show the net welfare effect from changes in retail prices and rewards

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 non-pecuniary utility. Any gains from variety are in this term. In practice, this term will increase whenever credit averse consumers decrease their use of credit cards.

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

Entry lowers welfare by inducing credit averse consumers to switch to credit cards to earn more rewards. In the baseline equilibrium, a debit card user on the margin between credit and debit must be credit averse. After entry, higher credit card rewards cause credit averse cash and debit users to switch to credit. Credit averse switchers incur non-pecuniary costs to earn rewards. But while credit aversion is a social cost, higher rewards are merely transfers. In fact, because merchants pass on transaction fees into higher prices, the switcher inflates retail prices for all consumers, dissipating gains from rewards. After entry, network margins fall. Nonetheless, consumer welfare declines due to credit aversion.

8.1.5 Total Welfare Effects

Total welfare declines because network profits fall as well. To measure total welfare, I assume all of the profits from either merchants or the networks are rebated to consumers equally. 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 welfare falls by \$10 bn.

8.2 Other Counterfactuals

8.2.1 Repealing Durbin

Repealing the Durbin Amendment would create a progressive transfer from credit to debit consumers and increase consumer welfare. I repeal the Durbin Amendment in the model by raising the cap on debit card fees to 1% from their current level at 0.72%. This generates approximately the same level of debit rewards as in the pre-Durbin data. Merchant fees for debit cards rise by 28 bps and debit rewards 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 Appendix Figure C.5. 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 of consumption, slightly higher subsidies and \$8 bn in gains from reduced debt aversion more than compensate. Total welfare thus rises by \$6 bn as networks enjoy higher profits from stealing market share from cash.

8.2.2 Regulating Credit Card Interchange

Regulating credit card interchange would create a progressive transfer from credit consumers to cash and debit consumers, and increases consumer welfare. 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 Appendix Figure C.6. Regulating credit interchange increases consumption of cash and debit card users by 62 and 51 bps, respectively. Consumption of credit card users falls by 10 bps. 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 reducing the cost of debt aversion generates \$28 bn of gains. Total welfare rises by only $28 bn as network profits fall as the networks are no longer able to tax cash users to fund rewards.

8.2.3 Merger Counterfactual

Merging Amex and Mastercard without any cost efficiencies would generate a small increase in consumer and total welfare. 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 hurt consumers, merging two payment platforms can increase consumer and total welfare (Nocke and Whinston, 2022). Credit card networks create a retail price externality when they raise rewards rates to induce consumers to use more credit cards. Adoption is excessive. A merger reduces output, reduces the externality, and thereby raises 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 Appendix Figure C.7. 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, reduced debt aversion and lower retail prices more than compensate. Total welfare rises by $6 bn as networks enjoy higher profits from the reduction in competition.

The merger counterfactual shows that prices are not sufficient for understanding welfare effects in two sided markets. Merchant fees rise, consumers rewards fall, and so both sides of the market face less favorable prices. Nonetheless, consumer and total welfare falls as fewer credit averse consumers use credit cards in the counterfactual.

8.2.4 Merchant Substitution Between the Entrant and Credit Cards

In this counterfactual I relax the assumption that consumers who use the entrant's payment network shop less at stores that only accept credit cards but not the entrant. After relaxing the assumption, the entrant can be thought of as a fourth credit card network, like Discover, becoming as large as Amex. In this case I obtain qualitatively similar welfare results. The main difference is that credit card merchant fees fall slightly. However, credit card rewards still increase by 4 bps and debit card rewards 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 Appendix Figure C.8. 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 welfare 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 cost from more debt averse consumers using credit cards results in lower consumer welfare after entry. Total welfare falls by $4 bn as networks compete down profits.

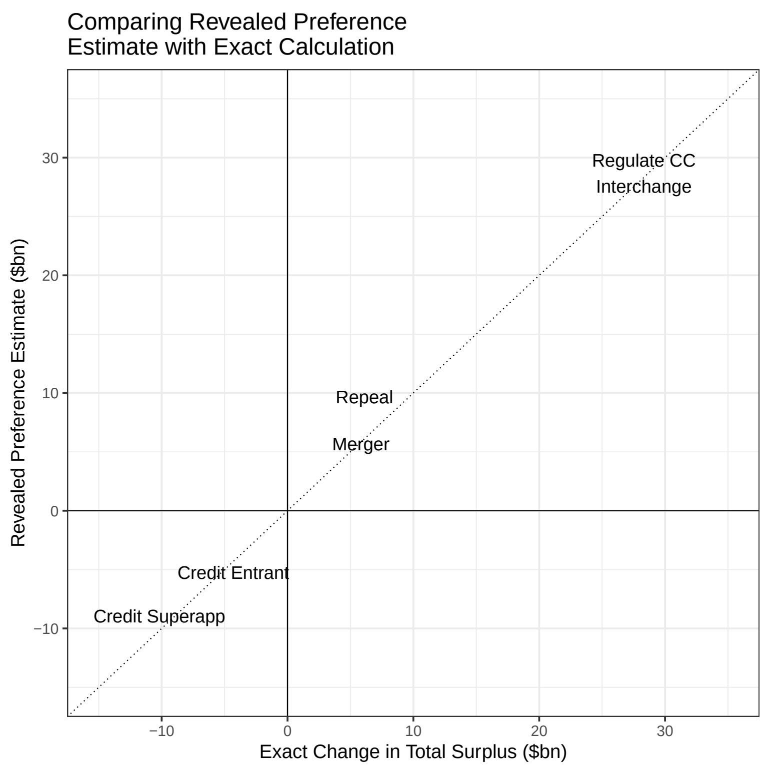
8.3 A Revealed Preference Approximation

The total welfare effects across the counterfactuals are close to a revealed preference estimate for the aggregate loss from credit aversion. This shows that changes in credit aversion drive my total welfare results. By revealed preference, the marginal cash or debit user that switches to credit cards has an aversion towards credit cards equal to the value of credit card rewards. The total welfare loss from debt aversion is then the difference between credit and debit card rewards multiplied by the share of consumers who switch from cash and debit to credit-like products (including the entrant).[37] Figure 8 compares the output of the revealed preference argument with the actual effects I calculate with the model. This approximation fits well for almost all counterfactuals. The revealed preference estimate slightly overstates the welfare benefits of repealing Durbin because the simple revealed preference argument does not incorporate some cash users' aversion to cards in general.

The revealed preference approximation highlights that the contribution of the model is primarily to offer accurate predictions of how market shares change in response to regulations or competition. Conditional on the changes in shares, the welfare effects I calculate follow from revealed preference.

[37] Since the argument only applies for small changes, I compute the rewards difference by averaging the baseline rewards difference and the rewards difference in the counterfactual.

Figure 8: Validating the revealed preference calculation of total welfare losses across counterfactuals



Notes: Each point compares the exact total welfare effects with the total welfare effects implied by the revealed preference argument for one counterfactual. Credit Superapp refers to fintech entry from Section 8.1. Credit Entrant refers to the case where the entrant is a substitute for credit cards at the point of sale (Section 8.2.4). Repeal is for repealing Durbin in Section 8.2.1, whereas Regulating Credit Interchange is from Section 8.2.2. The merger is the MC/Amex merger from Section 8.2.3.

8.4 Choice Sets

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

Incorporating constraints does not affect the welfare results because the predicted number of consumers who switch in response to entry is not sensitive to the modeling of constraints. Holding fixed the model parameters, adding constraints reduce the number of consumers that switch to credit. But because all models need to match the reduced form fact on the effect of the Durbin Amendment, models with constraints would still predict the same number of debit consumers who switch 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.

The total welfare numbers would change 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 credit aversion. The revealed preference argument would also fail if consumers are generally inattentive, but will change payment methods in response to changes in rewards. These arguments would reduce the size of the total welfare effects, but would preserve the distributional effects.

8.5 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 credit averse consumers to chase high credit card rewards, and lowers consumer welfare. Either relaxing the Durbin Amendment or capping credit card merchant fees reduces the gap and thus raises consumer welfare. Mergers without efficiencies in one sided markets always reduce consumer welfare. Yet because a MC and Amex merger would lower credit card rewards in equilibrium, it raises consumer welfare 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 process payments, increases consumer rewards, and lowers consumer and total welfare. Entry reduces consumer welfare as credit averse consumers switch in to credit cards in order to take advantage of rewards. Such switching behavior inflates the aggregate price level and generates social losses.

I find that payment markets are inefficient because of too much credit card use, not too little competition. Unlike in standard antitrust settings in which market power creates harms through high prices and low output, competition in payment markets causes 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 use the envelope theorem to extrapolate to small values of τ. From the definition in equation 7, profits in general are

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

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

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

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.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.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.6: Survey data on why consumers chose their preferred payment instrument

	Cash	Debit, Low Credit Share	Debit, High Credit Share	Credit
Budget Control	0.15	0.09	0.09	0.04
Convenience	0.31	0.40	0.41	0.28
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 (relative to all debit card users), those who prefer debit but have an above median utilization of credit cards, and those who prefer credit cards. Each 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.

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.7: 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.8: 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.9: Correlation between being the card with the top number of trips and the card with the top share of spending.

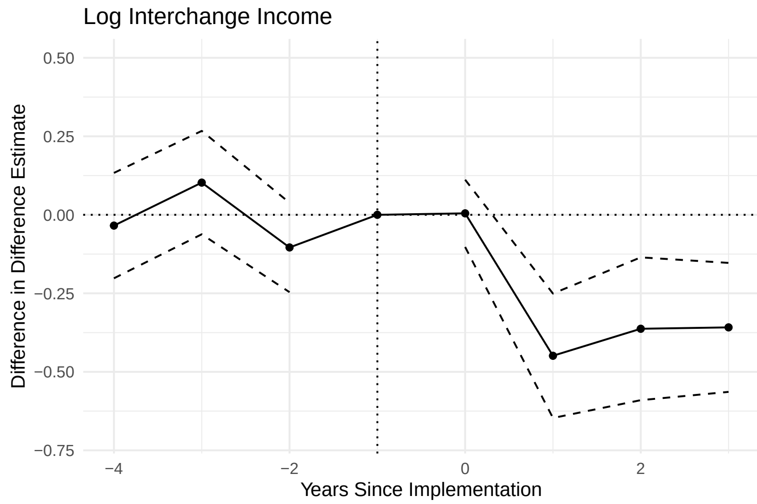
		Top Card by Spend			
Top Card by Trips		Amex	Debit	MC	Visa
Amex	N	11568	111	142	527
	% row	93.7	0.9	1.1	4.3
Debit	N	639	132097	1422	2670
	% row	0.5	96.5	1.0	2.0
MC	N	444	426	26806	1057
	% row	1.5	1.5	93.3	3.7
Visa	N	871	910	1079	61791
	% row	1.3	1.4	1.7	95.6

Table B.10: 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

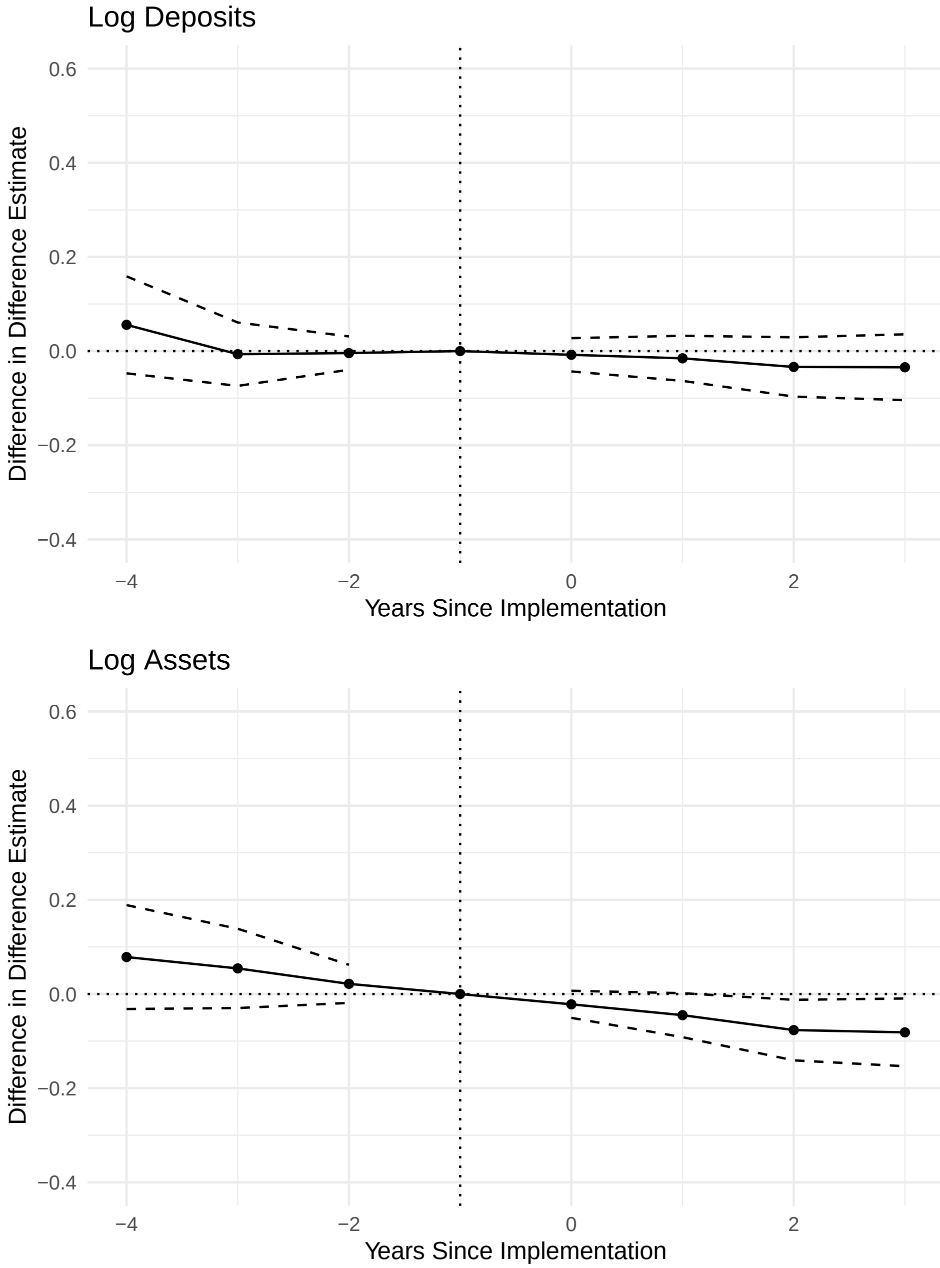
C Additional Figures

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



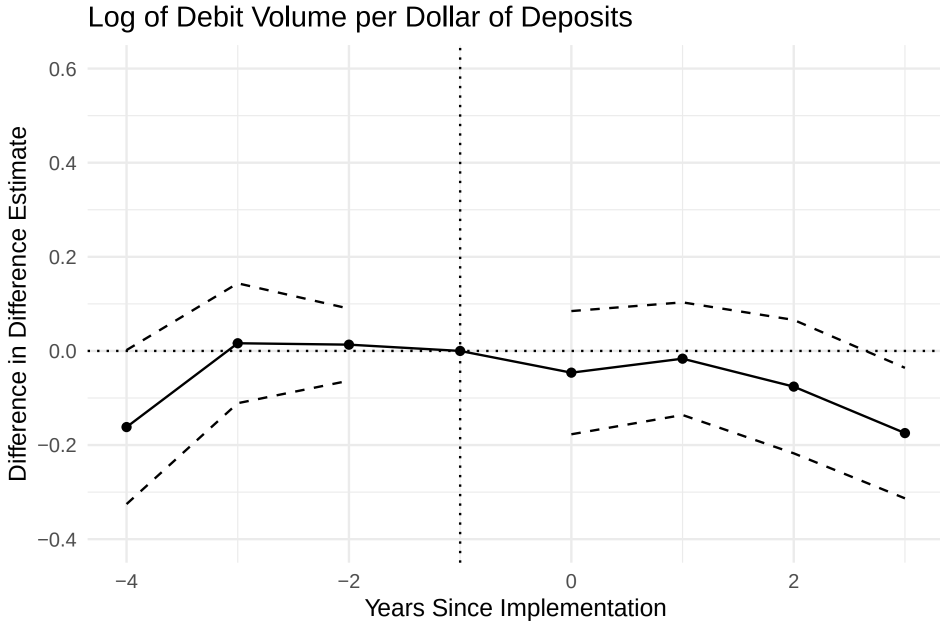
Notes: The vertical line marks the year before the policy announcement. The policy went into full effect in year 2012, which is at $t = 1$.

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

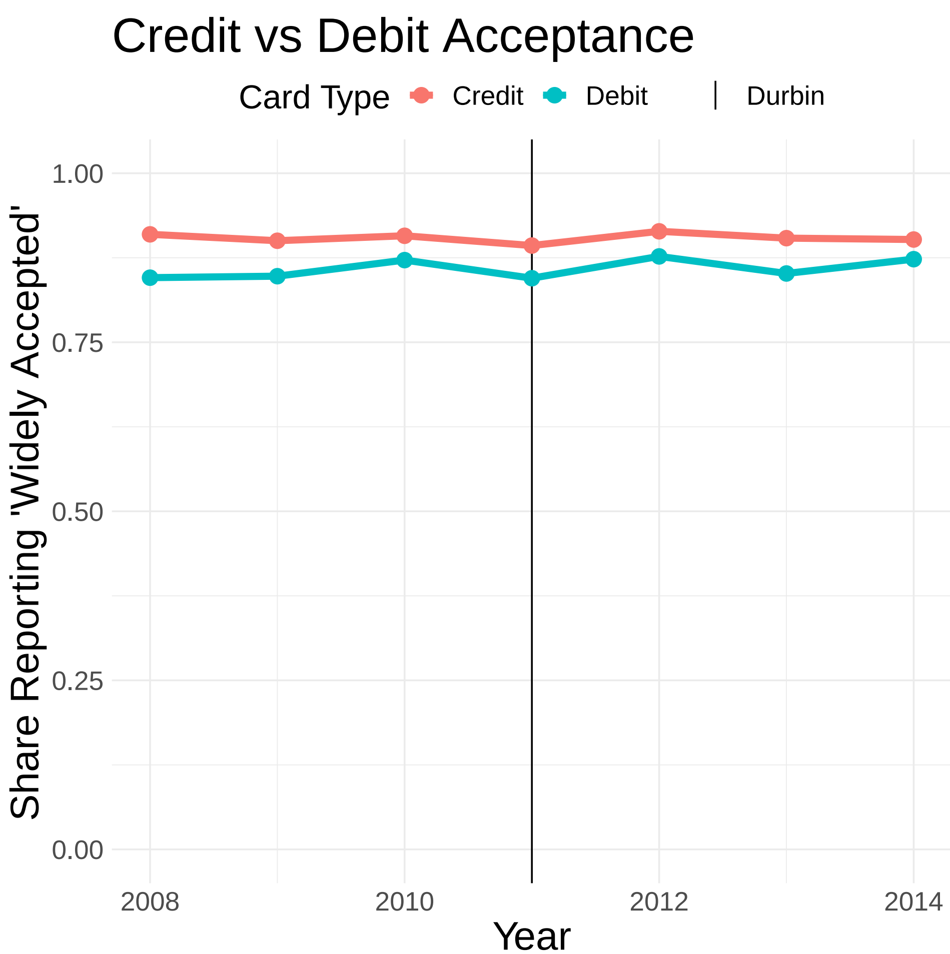
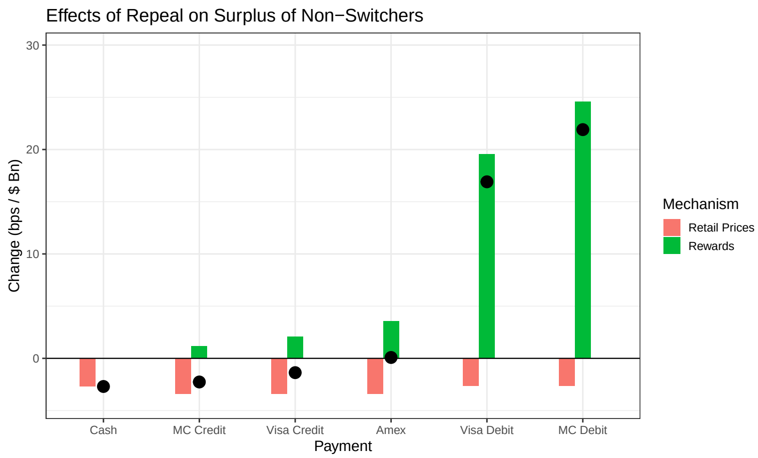
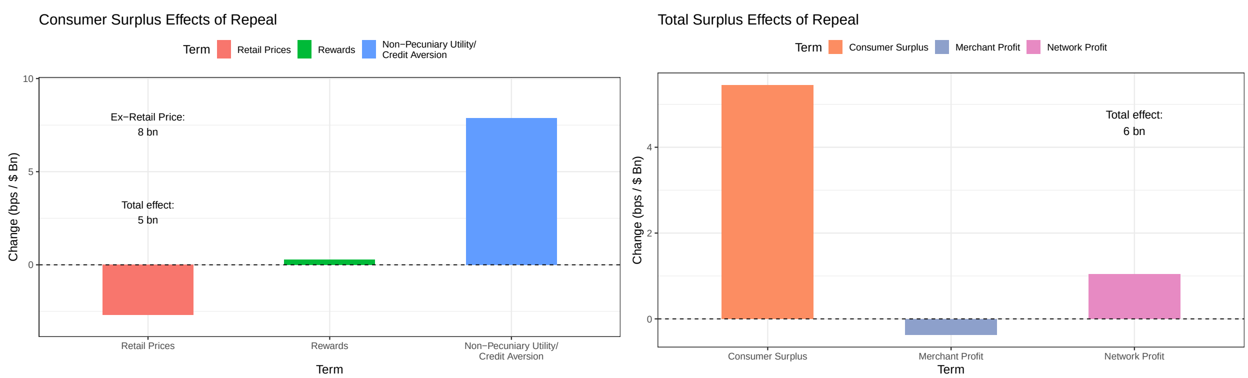


Figure C.5: Welfare effects of relaxing the Durbin Amendment cap on debit card fees

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Welfare and Total Welfare Effects



Notes: The black dots in Panel A show the net welfare effect from changes in retail prices and rewards

D A Method for Calculating Derivatives of Expectations of Nondifferentiable Functions

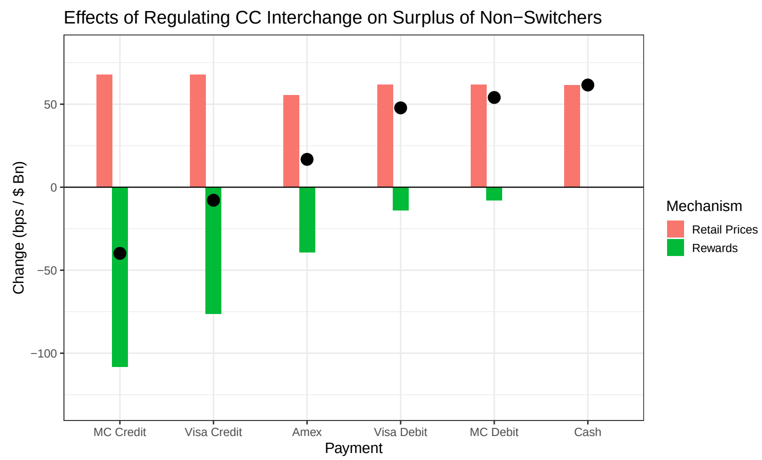
Suppose $f : \mathbb{R}^N \to \mathbb{R}$ is continuous but non-differentiable. Then by a standard convolution theorem

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

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 approxima-

Figure C.6: Welfare effects of regulating Visa + MC merchant fees to 1%

Panel A: Distributional Effects for Non-Switchers



Panel B: Decomposition of Consumer Welfare and Total Welfare Effects

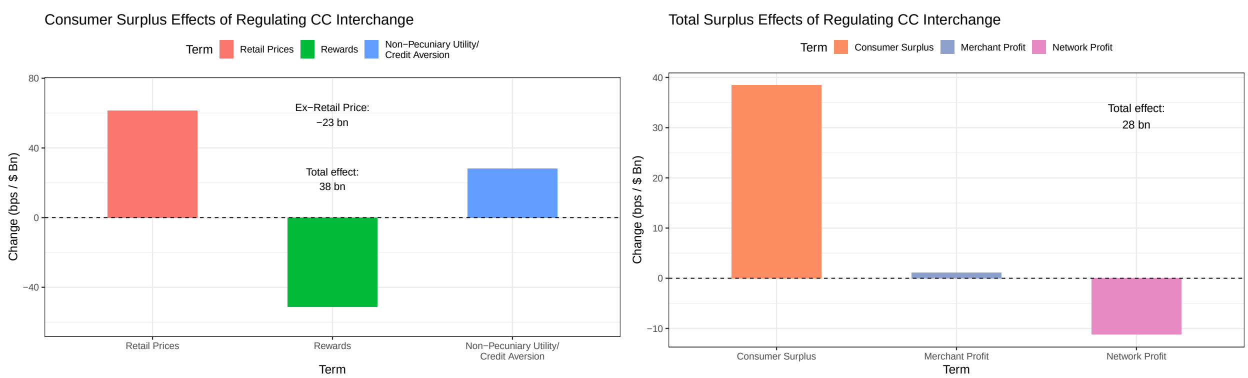
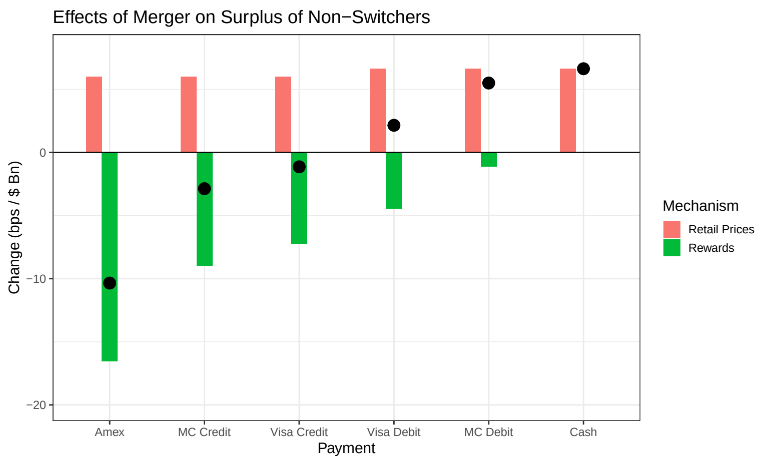
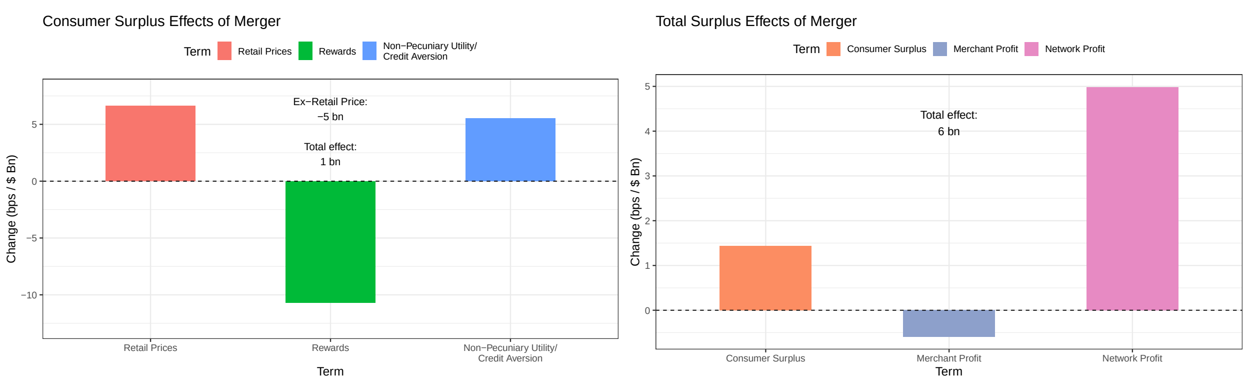


Figure C.7: Welfare effects of merging Amex and Mastercard

Panel A: Distributional Effects for Non-Switchers



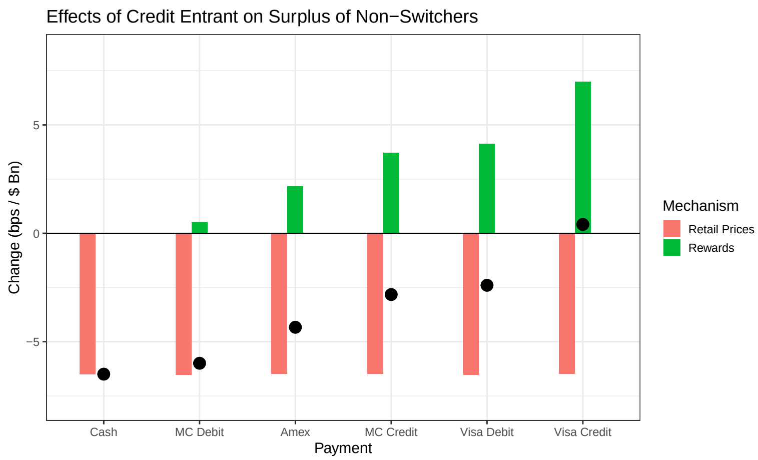
Panel B: Decomposition of Consumer Welfare and Total Welfare Effects



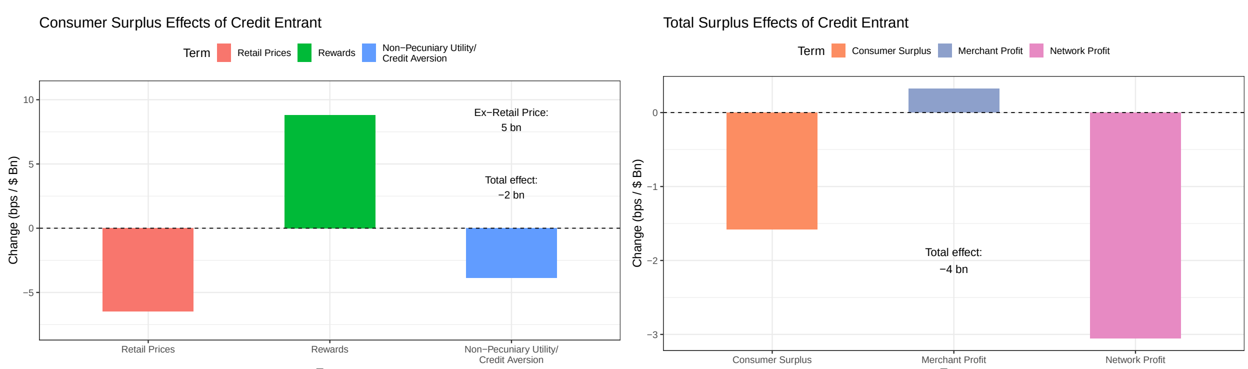
Notes: The black dots in Panel A show the net welfare effect from changes in retail prices and rewards

Figure C.8: Welcome 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 Welfare and Total Welfare Effects



Notes: The black dots in Panel A show the net welfare effect from changes in retail prices and rewards

tion of h as $\hat{h} = N^{-1} \sum_{i=1}^{N} f(X_i)$ where $X_i \sim N(\mu, \sigma^2 I)$ does not generate a differentiable function in μ.

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

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

By the law of iterated expectations, we have that

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

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

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

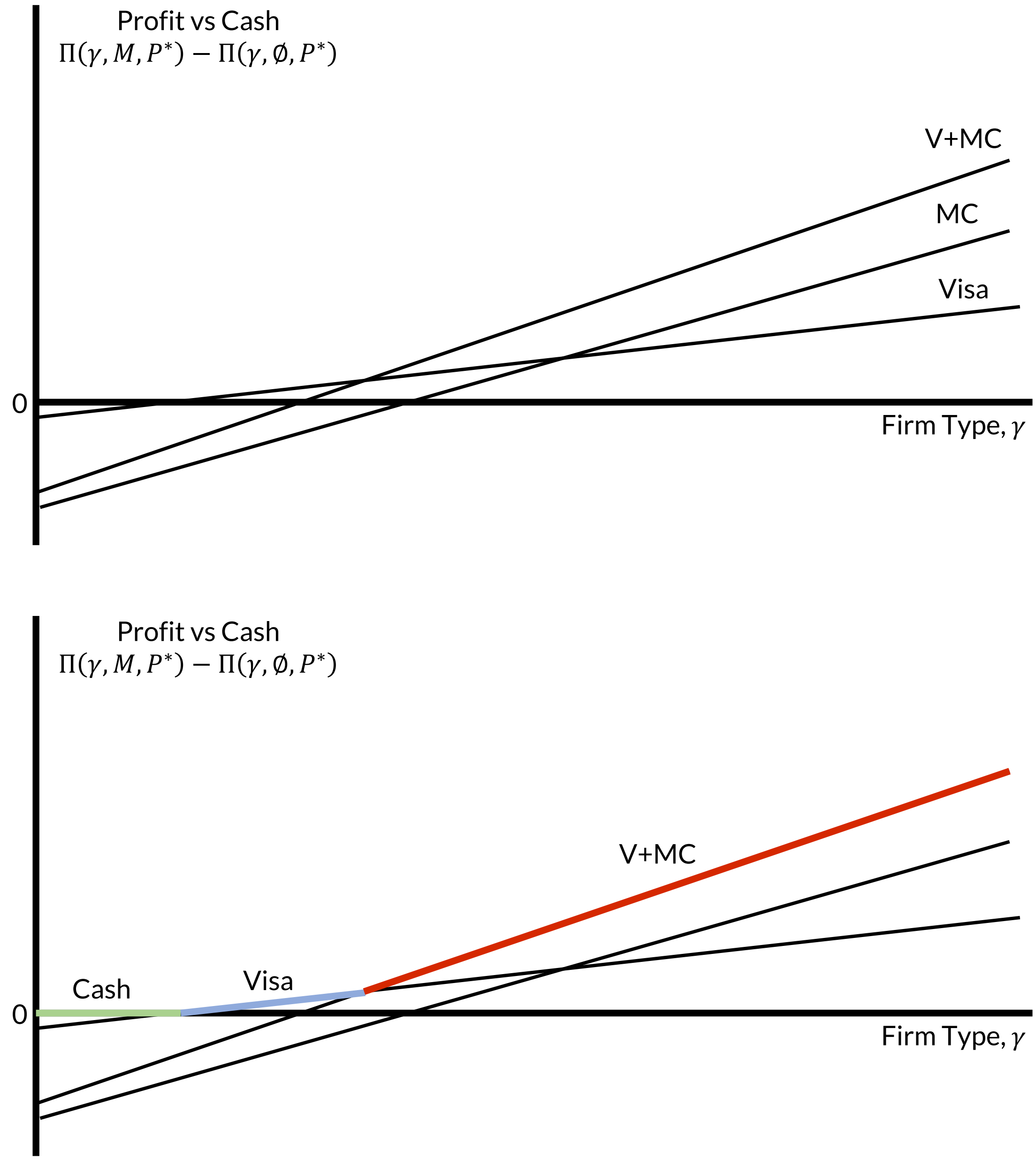
Equations 30 and 31 provide integral expressions for the expectation and the derivative of the expectation. To approximate these expectations, one can simulate g with standard monte carlo techniques as $\hat{g}$. While $\hat{g}$ will not be differentiable, by the convolution theorem expressions 30 and 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.

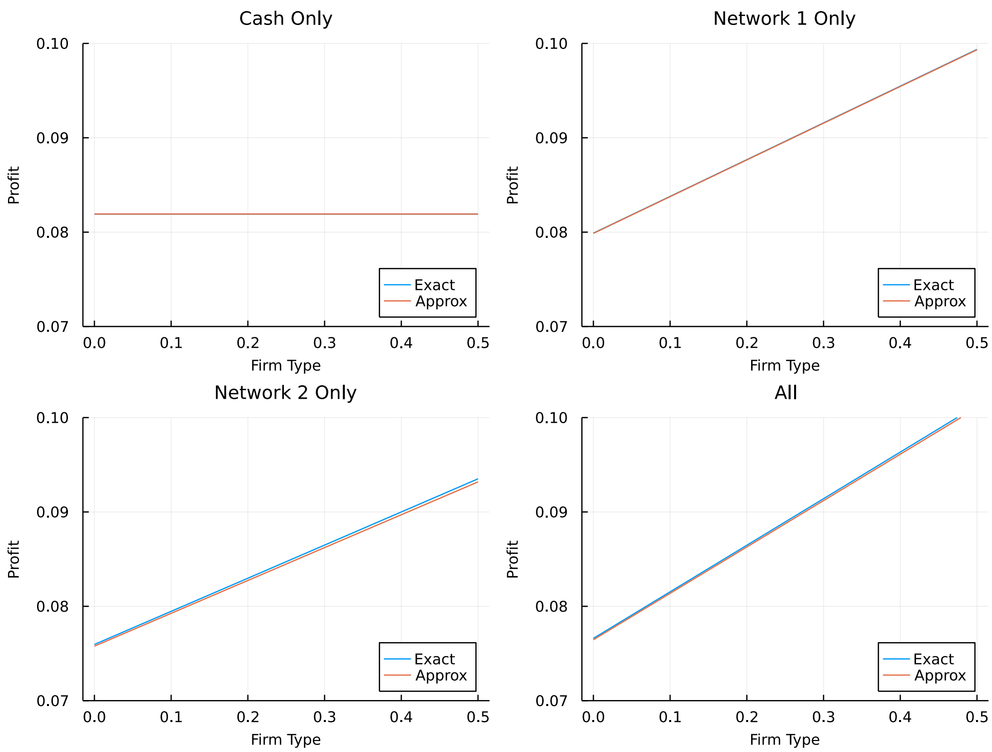
Figure E.1: Illustration of how to compute the merchant adoption subgame.



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 incremental 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.

E.4 Calculating the Deriviative of Merchant Acceptance

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 γ' 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 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.

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 $j \in \{1,\ldots,J\} \equiv \mathcal{J}$ 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 old primary card becomes the new secondary card $s_{t+1} = p_t$. Hence $w_{t+1} = (p_{t+1}, s_{t+1})$.

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

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

Proof. Fix i. The probability of choosing j is

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

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

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

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 $q_i(p_{t+1}) P_i(w_{t+1})$. 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

$$\begin{aligned} q_i(p_{t+1}) \sum_{k=1}^{J} P(w_t = (s_{t+1}, k)) &= q_i(p_{t+1}) q_i(s_{t+1}) \sum_{w_{t-1}} P_i(w_{t-1}) \\ &= q_i(p_{t+1}) q_i(s_{t+1}) \end{aligned}$$

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

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

Which is the same as equation 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 equivalent to assuming there are no complements or substitution effects that would make cards attractive or unattractive to hold together.